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A large percentage of all US degrees in mineral engineering fields are awarded by 14 institutions of higher education in 13 western states: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. But low undergraduate enrollments in the mineral engineering curricula have increased per-student costs at most of these schools. Eight of the institutions must either continue their current mineral engineering programs, find ways to increase undergraduate enrollments, or discontinue the programs. This problem was the basis for a study of these institutions in which data were gathered and processed on operating budgets, degrees awarded, and enrollment figures. The findings of the study are presented in this report, with 4 recommendations for tackling this common economic problem: (1) the 8 institutions should enter into an agreement that would permit residents of any of the states to enroll as resident students in an institution of another of the states, (2) Hawaii, California, and Oregon should consider offering scholarships for qualified residents who wish to study mineral engineering at the undergraduate level, (3) the 8 institutions should explore the possibility of a cooperative recruiting effort to attract out-of-state students, and (4) state agencies should contemplate the feasibility of federal scholarships for nonresident students who are motivated toward undergraduate programs in mineral education. (WM)

MINERAL ENGINEERING EDUCATION IN THE WEST

PREFACE

Within the western states there are 14 higher education institutions offering mineral engineering curricula. These schools produce a large percentage of all U.S. degrees in mineral engineering fields. However, small enrollments and rising costs have generated concerns.

In response to requests from several schools, WICHE identified two consultants qualified to undertake a study of the enrollment and fiscal problems shared by these institutions. The consultants were Dr. Carl W. Borgmann, Advisor on Science and Technology, the Ford Foundation, and John W. Bartram, Budget Director, University of Colorado. As a team they personally visited the schools in the West which offer mineral engineering education. They gathered and processed data on operating budgets, degrees awarded, and enrollment figures.

In June a draft of findings and recommendations was reviewed by the deans of the western schools of mines. This publication reflects consideration of their suggested revisions and capsulizes the consultants' findings. The report recommends several courses of action to remedy the problems.

WICHE acknowledges the outstanding contribution of the two consultants in conducting the study and preparing this report. WICHE also expresses appreciation to the Ford Foundation which generously donated the cost of Dr. Borgmann's time and expenses to this project.

July, 1969
Boulder, Colorado

Robert H. Kroepsch
Executive Director
Western Interstate Commission
for Higher Education

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CONCLUSIONS AND RECOMMENDATIONS

This is a report of the facts about a field of higher education as it exists in the 13 states belonging to the Western Interstate Commission for Higher Education (WICHE). It was initiated by the Commission after queries had been received from representatives of institutions in the region faced with difficult choices as to how best to meet the responsibilities of the institutions they represent and only after an assurance of interest and collaboration was received from the presidents of each of the institutions most directly involved. The field, which we have called Mineral Engineering, was arbitrarily limited to programs leading to degrees at the baccalaureate and higher levels in ceramics, fuels, geological, geophysical, metallurgical, mineral dressing, mining, and petroleum engineering. Metallurgical and mining engineering are offered at the largest number of schools, 10 and 11 respectively.

The mineral industry is of high importance to an affluent industrial society such as ours and for that matter of similar importance to any country in which greater material production is a goal. The education of men, in the present arts of mineral production and to help the development of new ones, hence is of national (and world) importance. That the brunt of this education is being carried by the less populous states of the Mountain West raises difficult questions for the university administrators and the governing bodies of those states.

As facts to aid in fiscal decision-making underlay much of the interest in having a report made, our conclusions are heavily focused on certain general facts about the economics of higher education as they apply to the institutions and curricula specifically included in this study.

This report, in consequence, could readily be described as a report of the obvious. It requires but very simple arithmetic to show that if small numbers elect to follow a particular curriculum, the costs per degree or per student credit hour are going to be larger than if the number of students is higher. The analysis of data which is provided in this report confirms these conclusions for all engineering fields, mineral or otherwise. Other studies indicate that it really matters not whether we are speaking of mining engineering, electrical engineering, Hindustani, or home economics: small numbers in classes cause high per student costs.

The common problem at all but three of the schools visited is low undergraduate enrollments in the mineral engineering curricula. To two of the three exceptions, low undergraduate enrollments are of little concern, as strong graduate programs are seen as their primary roles. In many of the state institutions, the economic problem would be even greater if an arbitrary limitation on out-of-state students were in effect. In a few institutions, foreign students provide a substantial lift to the enrollment.

For that harried and confronted mendicant, the president, this cost problem is compounded by the strong urge of many faculty members to satisfy their academic egos by offering not only the master's degree, but also the doctorate, in all fields. This is in spite of the fact that, at many of the institutions, the number of graduate students is extremely low and but half of these are U.S. citizens. It is only fair to add that this urge is supported by accrediting agencies, such as the Engineers' Council for Professional Development, and by the growing acceptance of the myth that a good researcher is, *a priori*, a good teacher. The hopes to share more fully from the federal research and development pot or to obtain more industrial support adds still another prod to this trend.

Each of the 14 institutions will face its particular set of problems as they relate to its sources of financial support and make its own decisions. For example, in some institutions, such as the University of California at Berkeley and Stanford, graduate students heavily outnumber undergraduates in these fields, and it seems quite likely that the latter will vanish soon. Mining engineering and petroleum engineering have been discontinued as degree programs (all levels) at the University of California. Mining engineering appears likely to be discontinued for lack of students or for what appears to be better use of available funds at the two Washington universities. Metallurgical and ceramic engineering in most of the institutions are trending toward a concentration on the properties of materials and away from the study of the equally important problem as to how such materials are economically produced from naturally occurring minerals.

The institutions in which the economic problem caused by small numbers of undergraduate students is most acute are the Universities of Alaska, Idaho, and Nevada. A similar, but less serious under-enrollment exists at the Universities of Arizona, Utah, and Wyoming, at the New Mexico Institute of Mining and Technology, and the Montana College of Mineral Science and Technology. All eight institutions could readily accept more undergraduate students in those fields of mineral engineering offered by each with but minor increases in departmental costs. These are all state supported institutions situated in states of low population density and in states where the mineral industry is a potent political and economic force.

The choices that each of these eight institutions face are:

(1) to continue as now;

(2) to make an added effort to increase the number of undergraduate students; or

(3) to discontinue the educational programs.

The last choice (3), is unlikely to be taken. In most, if not all, of these institutions new capital additions have been made recently or are under active planning. The real savings from program elimination will not be great and, unless the space now occupied is needed and can be readily used to relieve other educational pressures, such savings will be even less. Finally, the possibility of political reaction which might affect the total institution must be considered. As it is generally unsatisfying to choose the first alternative, it is concluded that the question of *how best to entice more undergraduate students to these institutions and to these curricula is the principal one to explore.*

It is far simpler to ask such a question than to suggest realistic answers. For whatever reasons, students are not clamoring for admission to these curricula. Certainly those reasons do not include lack of employment opportunities. It is even doubtful that more glamorous scientific and technological fields are luring prospective students away. Secondly, some states have reacted to mounting budget requests by restricting the numbers of nonresident students. *Such a reaction, in our opinion, if applied to areas of low enrollment, is economic shortsightedness, particularly if the out-of-state fee meets at least the incremental cost of accepting additional students.*

It is obvious that any major increase in undergraduate enrollments cannot be expected from resident students in any of the eight states under specific discussion. The number of eligible youths is simply too small to make such an easy answer a realistic one. Our recommendations, consequently, are made in spite of potential political and operational obstacles.

Our recommendations are that:

1. The eight states (Alaska, Arizona, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) and their respective institutions that offer undergraduate programs in mineral engineering enter into an agreement regarding acceptance of students in mineral engineering. Such an agreement would permit residents of any of these states to enroll at any class level in the appropriate institution and curriculum of another of the states as a resident student. Appendix E elaborates on the nature of such an agreement.

   It may be wise to include the states and institutions of Washington and Colorado in such an agreement, but neither is in serious need of students in the undergraduate curricula that the institutions offer. On the other hand, the University of Washington has undergraduate programs in two mineral engineering fields not offered in some of the states and Colorado provides no opportunity for its residents to study ceramic engineering. Their inclusion would appear to be optional and dependent solely on the desires of the appropriate officers of the eight states first named.

2. The states of California, Hawaii, and Oregon be urged to give serious consideration to the provision of scholarship funds for

qualified residents who wish to pursue undergraduate programs in mineral engineering. In each state such funds should provide to the student at least the amount of nonresident tuition charged at its university.

If Colorado and Washington are not included in the agreement recommended in 1 above, they too should adopt the scholarship approach.

3. The eight institutions (Alaska, Arizona, Idaho, MCMST, Nevada, NMIMT, Utah, and Wyoming) or any group of four or more of them, should seriously explore a cooperative recruiting effort aimed at enticing out-of-state undergraduate students. Such a cooperative effort should include both the seeking of industrial funds for undergraduate scholarships and the development of better communications with prospective students in the populous areas of the Midwest and the East where opportunities in mineral engineering education are limited.

4. As many appropriate state agencies as wish, either individually or collectively, should explore the possibility of federal scholarships for nonresident students motivated toward undergraduate programs in mineral education.

We have not forgotten the graduate level in our concern to point out that the crucial problem and the one to be tackled first appears to be the undergraduate effort. We have, however, only conservative and cautionary advice to offer the faculties of the less populous and affluent states of the Mountain West. It is to contain your desires for more graduate offerings until you have achieved a B.S. production of at least ten a year in each mineral engineering curriculum (and in each substantial option) that you offer.

WESTERN EDUCATIONAL INSTITUTIONS
OFFERING
MINERAL ENGINEERING PROGRAMS

University of Alaska
College, Alaska

University of Arizona
Tucson, Arizona

University of California, Berkeley
Berkeley, California

Stanford University
Stanford, California

University of Southern California
Los Angeles, California

Colorado School of Mines
Golden, Colorado

University of Idaho
Moscow, Idaho

Montana College of Mineral Science
and Technology
Butte, Montana

University of Nevada
Reno, Nevada

New Mexico Institute of Mining
and Technology
Socorro, New Mexico

University of Utah
Salt Lake City, Utah

University of Washington
Seattle, Washington

Washington State University
Pullman, Washington

University of Wyoming
Laramie, Wyoming

BACKGROUND OF STUDY

The Western Interstate Commission for Higher Education (WICHE) has had a concern with "Mineral Engineering" education dating over several years. In 1954 it sponsored a conference of educational leaders in mining engineering to assess the possibilities of interstate and regional cooperation. As a result, three subregional study groups were formed, and the matter now appears to have been dropped by all parties. Interest was reawakened in 1966 through letters to the executive director of WICHE from the academic vice-presidents of two major universities. After questioning the presidents of all the institutions involved in mineral engineering as to their willingness to cooperate, the Commission voted to undertake its own study of the field, using consultants who were knowledgeable about engineering education and its financing but who were not directly involved in the particular educational institutions to be reported upon. The consultants were appointed in October, 1968.

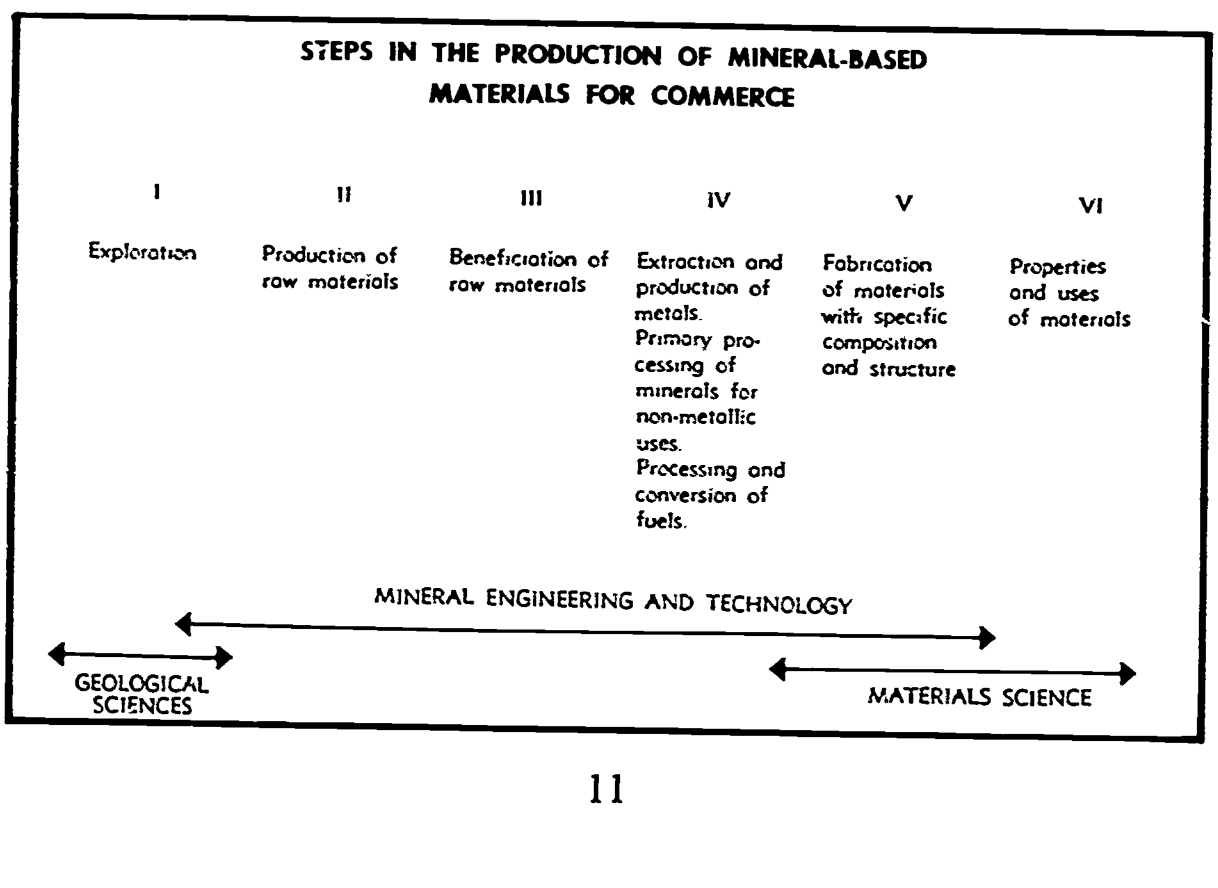
WICHE, in undertaking the study, points up a common ailment of academia—the difficulty of meeting all the variety of expectations that exist concerning it. Is its concern primarily that of aiding in the provision of a broader educational opportunity for the youth of the region? Certainly the West has provided its young people more opportunities for education in mining and the other mineral engineering fields than has any other region. Is it primarily concerned with helping to provide skilled individuals for the region? The present demand for engineers by the mineral industry is not at all similar to the needs of people for physicians which provides the base for the WICHE Student Exchange Program. Or is WICHE primarily interested in making it possible to strengthen financially educational programs by the development of interstate cooperation? The initiation of this study appears to have a bit more of the last purpose than of the other two, but there is some of all three.

If the foregoing conclusion is correct, this report charts a new field of activity for WICHE—a hard look at an undergraduate field not related to health. It is clear that there has existed a high interest by the university administrators in the facts about mineral engineering to the end that they might make better decisions as to the wise use of financial resources at their disposal. While the study has been focused on a small fraction of higher education, the fact that the basic concerns were concentrated on undergraduate education could result in findings of much wider application. From the start, it was clear that one reason help had specifically been sought in mineral engineering was the difficulty being experienced by university boards and administrators in arriving at wise decisions in dealing with the economic problems faced.

SCOPE OF STUDY

The first, and arbitrary, decision to be made concerned the educational field that should be reported upon. We decided to follow in general the definitions established in a recent national study[1] which are illustrated in Figure 1 taken from that report. We have modified the terminology somewhat by using *Mineral Engineering* instead of *Mineral Science and Technology*. Our interests, too, have tended to concentrate on the first four areas shown in Figure 1, leaving part of exploration (geology and geophysics) and all of fabrication and properties of materials out of consideration. To be specific, we have included curricula leading to B.S. degrees in ceramic engineering, fuels engineering, geological engineering, geophysical engineering, metallurgical engineering, mineral dressing engineering, mining engineering, and petroleum engineering. Chemical and petroleum refining engineering at

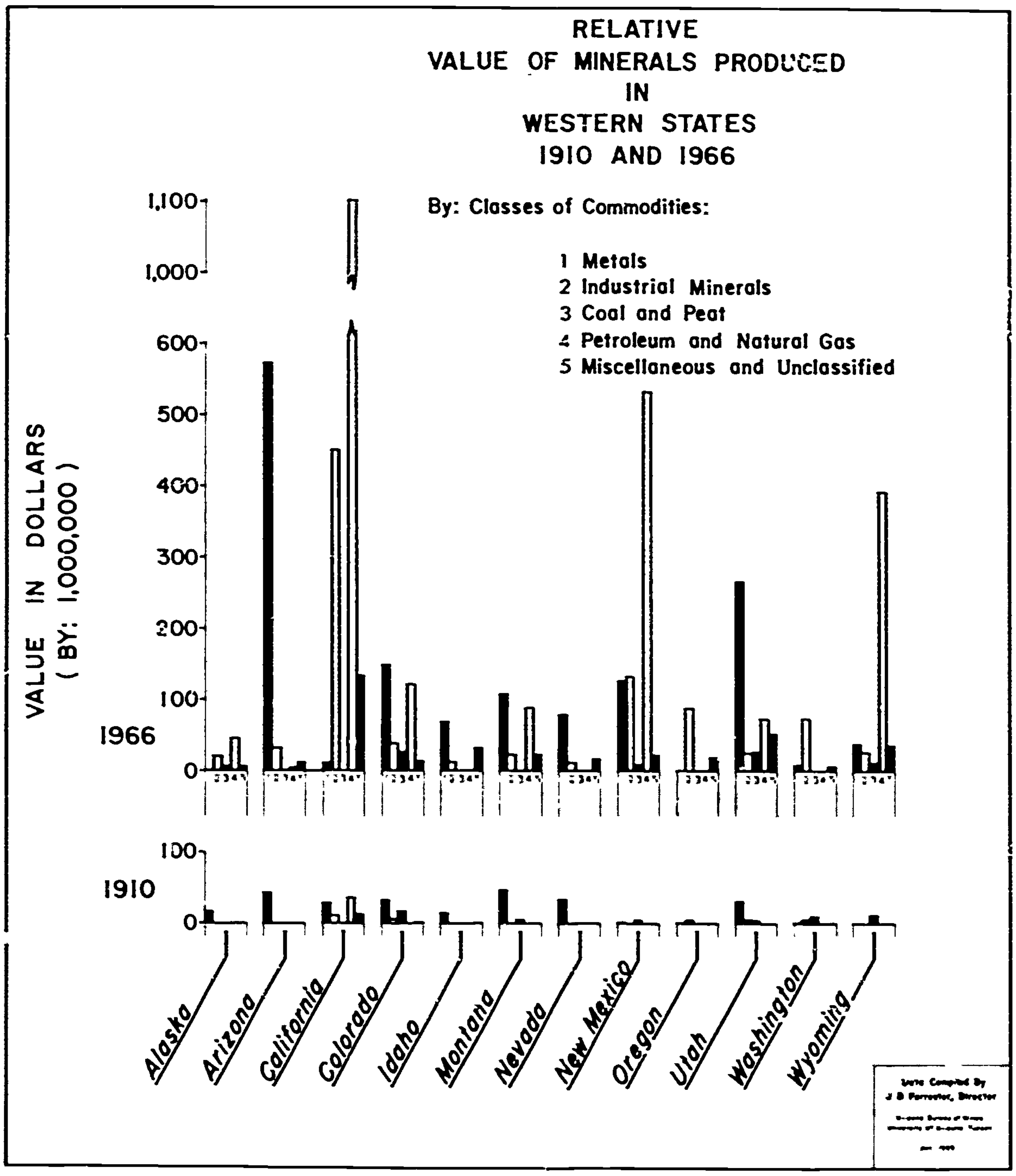
FIGURE 1



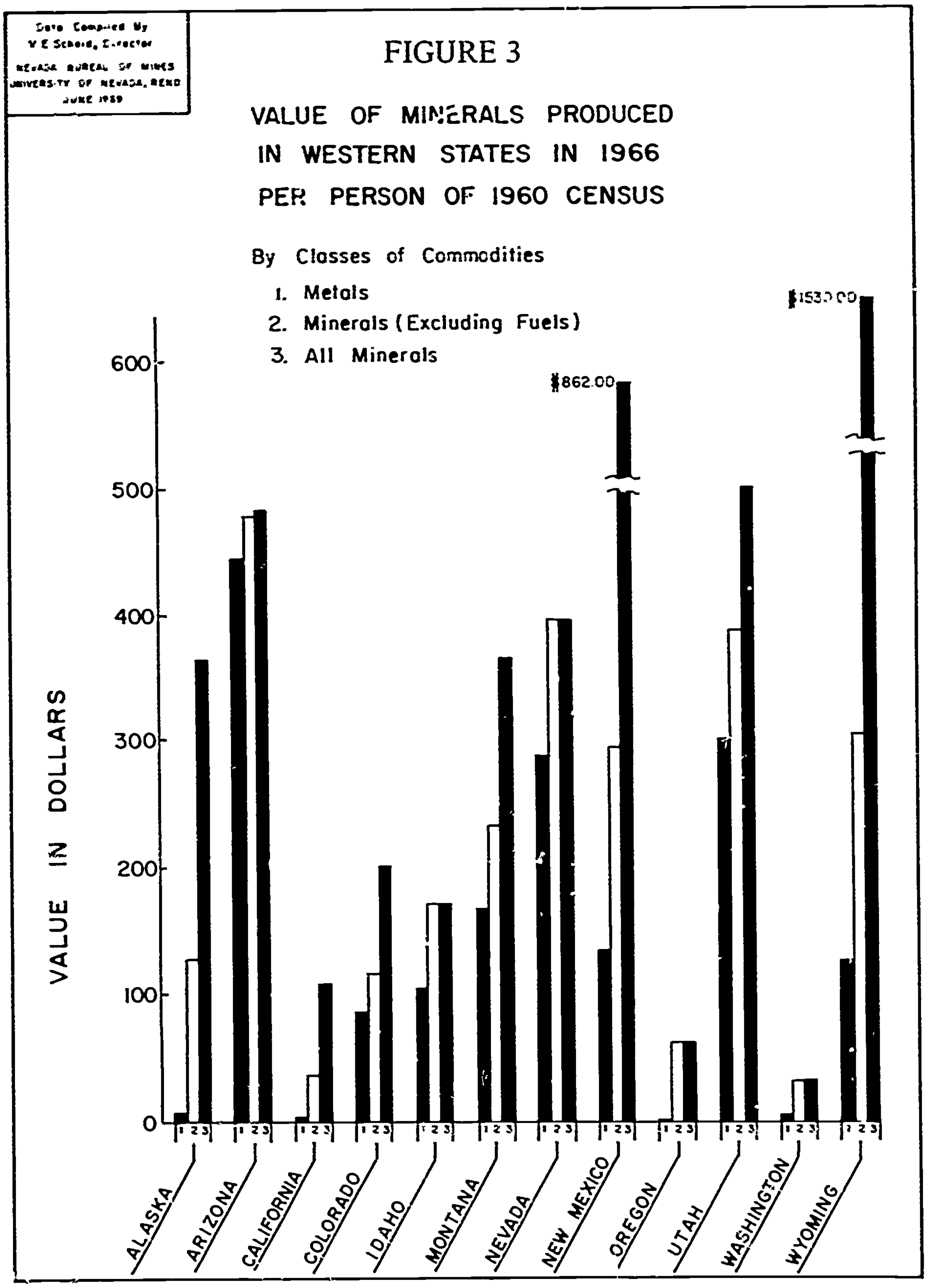
the Colorado School of Mines was excluded along with other offerings in chemical engineering.

Even with these arbitrary limitations, it has been difficult to obtain the data necessary for precise analysis. For example, metallurgical engineering is limited at some institutions to a consideration of the properties and uses of metals and alloys. At other institutions, such curricula would be labelled "physical metallurgy" or be a part of "materials science." We have arbitrarily omitted these latter curricula from our study. It is, however, almost impossible, particularly in the western institutions and at the graduate level, to separate degrees in

FIGURE 2



physical metallurgy from those in mineral processing and extractive (chemical) metallurgy. Most departments of metallurgical engineering include all aspects and the official national reports on enrollments and degrees lump all under one heading. Similar problems are to be found in the data on ceramic engineering. Hence it is clear that one must look



closely at the precise nature of these curricula rather than assume all are alike in character. One can count apples without knowing whether they are Winesaps, Jonathons, or MacIntoshes, but such tells little about how they cook, taste, or nourish.

Figure 2, adapted from a chart prepared by Dean Forrester of the University of Arizona, and Figure 3, prepared by Dean Scheid of the University of Nevada, emphasize that mineral production is still an important economic activity in most of the western states. It is difficult, however, to find any high degree of correlation between the level of such production in a state and the variety of programs and the number of students enrolled in mineral engineering in that state. It would certainly be unwarranted to assume that this mineral production is dependent on manpower trained within the state. There may have been a better correlation during the early development of the mineral industry within a state, but even that proposition would be very hard to prove. Certainly Wyoming, for example, produced much petroleum before the introduction of petroleum engineering into the offerings of its university. Hence the argument that the existence of a particular educational program will lead to industrial development is open to question.

We have defined "the West" to coincide with the 13 states belonging to the WICHE Compact. Mineral engineering programs are offered in 11 of these states (all but Hawaii and Oregon) and 14 institutions. (See Table 1. For more detail on options and graduate programs, see Appendices A 1 to A 14.)

The consultants have considered that their duties were primarily reportorial, not editorial. We certainly have not posed as accreditors of programs, nor did we consider that task to be a need. We have commented on the obvious relationships between size, educational level, and costs. Such are the facts on which any decision concerning change may be rationally made. We naturally depart from reportorial status when judgments or suggested actions are given in the recommendations.

The report is based on several sources of information. The institutions provided us with budgets and catalogs for the 1968-69 academic year, the number of degrees awarded in recent years, and the 1968 fall semester (or quarter) class enrollments. Accreditation status was obtained from the Engineers' Council for Professional Development. An

TABLE 1

MINERAL ENGINEERING OFFERINGS AT BACCALAUREATE LEVEL

Institution	Ceramics Engineering	Fuels Engineering	Geological Engineering	Geophysical Engineering	Metallurgical Engineering	Mineral Dressing Engineering	Mining Engineering	Petroleum Engineering
Colorado School of Mines	–	–	X	X	X	–	X	X
Montana College of Min. Sci. and Tech.	–	–	O	O	X	X	X	O
New Mexico Inst. of Mining and Tech.	O	–	–	–	O	–	O	O
Stanford Univ.	–	–	option	–	option	–	option	X
Univ. of Alaska	–	–	X	–	–	–	X	–
Univ. of Arizona	–	–	X	–	X	–	X	–
Univ. of Calif.(Berk)	X	–	O	–	X	–	–	–
Univ. of Idaho	–	–	X	–	X	–	X	–
Univ. of Nevada	–	–	X	–	X	–	X	–
Univ. of So. Calif.	–	–	–	–	–	–	–	X
Univ. of Utah	O	O	X	–	X	–	X	–
Univ. of Washington	X	–	–	–	X	–	O	–
Univ. of Wyoming	–	–	–	–	–	–	–	X
Washington State U.	–	–	–	–	–	–	O	–

X - curriculum presently accredited by Engineers Council for Professional Development (ECPD)

O - curriculum not listed as accredited in 1968 ECPD listing advance copy of the NAS-NAE-NEC study on Mineral Science and Technology has been made available for our use. One- or two-day visits were made by one or both consultants to all the institutions.[2] Finally, a preliminary draft was commented upon at a conference of institutional representatives.

MINERAL ENGINEERING EDUCATION: ITS PURPOSE?

There are many answers to the question of purpose of mineral engineering education. The *student* may choose the field because he is convinced that the work would be interesting, that he would have entrepreneurial opportunities, that he would live in an environment he enjoys, or that he might expect to travel widely in pursuit of his career. Perhaps he admires one or more acquaintances who have gained good livelihoods in the discovery and recovery of minerals, or he might simply have been tempted from another field by a scholarship. It is even possible that he may have chosen this field because a neighboring institution offered nothing else and family finances couldn't meet the expenses of travel and room and board involved in attending another school. One problem faced by the student is that he must make an early decision on the specific industry in which he expects to earn his livelihood.

The *people of the state*, through their elected representatives, express at least two somewhat opposing hopes when mineral engineering education is supported. On the one hand, these people, as parents, hope for a wide variety of educational opportunities for their children. On the other, the hopes that economic growth of the state will be stimulated by such a program continue to run high in the West. The more parochial desire, that of having an institution of higher education in a particular town or city, adds political support to any institution, including those with mineral engineering curricula. It would appear that the more materialistic arguments—hopes for economic development of the state and the real economic input to the town in which an institution is located—carry the most political muscle.

The *mineral industry*, particularly that component dominated by a relatively few large national and international concerns, quite naturally has had a high interest in mineral engineering education. While, not wholly dependent on the mineral engineering programs for technically trained men, the existence of such programs eases its recruiting problems. Young men studying such programs are obviously motivated toward employment within the industry. The very fact that the mineral industry has continued to thrive and to recruit its quota of new engineers during a major national decline in the numbers of men seeking degrees in mineral engineering illustrates their independence from specific educational programs. For example, men with degrees in civil and mechanical engineering or in geology can, with further training and experience, become good mining or petroleum engineers. Similarly, it is not difficult for a chemical engineer to become, with experience, a satisfactory extractive metallurgical or ceramic engineer. The costs to the industry of the specialized training and experience needed for men recruited from other technological fields are, however, materially reduced by recruiting men specifically trained. In addition, the existence of these specific programs ensures that at least some sympathetic scholarly attention will be paid to the needs and problems of the industry.

THE INSTITUTIONS

Mineral engineering curricula are offered in 12 state-supported and in two private universities at present. The undergraduate programs in the three California institutions are surprisingly few in number and small in degree production. Washington has supported programs at two state universities, but in the other states the offerings have been limited to a single institution.

There are three ways in which institutions are organized to offer mineral engineering education (see Table 2). Three of the institutions

TABLE 2

ACADEMIC ORGANIZATION TO PROVIDE EDUCATION IN MINERAL ENGINEERING

I. Part of Specialized Institutions

- A. Colorado School of Mines
- B. Montana College of Mineral Science and Technology
- C. New Mexico Institute of Mining and Technology

II. Part of Colleges other than Engineering within General Universities

- A. Stanford University–School of Earth Sciences
- B. University of Alaska–College of Earth Sciences and Mineral Industry
- C. University of Arizona–College of Mines
- D. University of Idaho–College of Mines
- E. University of Nevada–Mackay College of Mines
- F. University of Utah–State College of Mines and Mineral Industries

III. Part of Colleges of Engineering within General Universities

- A. University of California, Berkeley
- B. University of Southern California
- C. University of Washington
- D. University of Wyoming
- E. Washington State University

were established as schools of mines and originally had no other function than to train mining engineers. The mineral engineering departments are combined with geology and organized into separate colleges (or schools) of earth sciences and mineral engineering in six universities. In the five other universities, these departments are part of the college (or school) of engineering.

The three specialized institutions–Colorado School of Mines (CSM), the Montana College of Mineral Science and Technology (MCMST), and the New Mexico Institute of Mining and Technology (NMIMT) have added, over the years, not only other specialties in mineral engineering besides mining, but also other educational functions (see Appendices B 1 to B 3 for further details). While two, Colorado School of Mines and Montana College of Mineral Science and Technology, offer degrees primarily in mineral engineering, both are offering degrees in other fields of engineering and in some related sciences and would like to add still other curricula. In the third, New Mexico Institute of Mining and Technology, degrees in the sciences presently account for approximately three fourths of the baccalaureate production. At Montana College of Mineral Science and Technology, over half the students are enrolled in a two-year general academic program equivalent to that available in many junior colleges. The addition of new academic fields appears to be a common tendency at these institutions. The low student enrollments in mineral engineering fields at two (Montana College of Mineral Science and Technology and New Mexico Institute of Mining and Technology) may have given this tendency an extra push.

Six institutions, Stanford University and the Universities of Alaska, Arizona, Idaho, Nevada (Reno), and Utah, include mineral engineering departments in colleges or schools (with a variety of names) which are independent of the College of Engineering. (See Appendices B 4 and B 9 for further details.) A department of geology is usually the core of these colleges, and often there are separate departments covering geological specialties such as mineralogy and geophysics. Other departments which are sometimes included in the college are geography, meteorology, and chemical engineering. The pressures to add new baccalaureate degrees appear not to be as strong under this organizational structure as in the specialized institutions. Perhaps, if one controls the degrees, academic satisfaction is sought by adding uneconomic undergraduate options a tendency that appears strong in the catalogs of some of these institutions.

The five other institutions included in this study, the Universities of California (Berkeley), Southern California, Washington, Wyoming, and Washington State University, administer the mineral engineering departments as part of the College of Engineering (see Appendices B 10 and B 14 for further details). Only one department is represented at three of these universities, petroleum engineering at Southern California and Wyoming and mining engineering at Washington State. The latter program appears to be following the pattern set recently by the University of California, Berkeley, where degrees in mining engineering are no longer offered.

State Bureaus of Mines and/or Geological Survey are administrative parts of several of the institutions (see Table 3). It should be noted that such state bureaus are not associated with any college of engineering, but only with separate specialized institutions and with "colleges of mines" or equivalent, of universities. The geological survey function

TABLE 3

RELATED OFFICIAL STATE AGENCIES

LOCATED ON CAMPUS AND ADMINISTERED BY THE INSTITUTION

Institution	Agency
Montana College of Mineral Science and Technology	Montana Bureau of Mines and Geology
New Mexico Institute of Mining and Technology	New Mexico Bureau of Mines and Mineral Resources
University of Alaska	Alaska Division of Mines and Geology(1)
University of Arizona	Arizona Bureau of Mines
University of Idaho	Idaho Bureau of Mines and Geology(2)
University of Nevada	Nevada Bureau of Mines Nevada Mining Analytical Laboratory
University of Utah	Utah Geological and Mineralogical Survey
University of Wyoming	Geological Survey of Wyoming(3)

(1) Housed at university, but under direct administration of the State.
(2) Housed at university and administered by dean of College of Mines. The dean reports as director of the bureau, as a state official other than the president of the university.
(3) Housed at university, but affiliated with Department of Geology.

predominates in all cases and most provide a limited service of mineral identification and assay. Most bureaus are responsible for the compilation of mineral statistics. Only in two does research in mineral processing and chemical metallurgy appear to play an important role. With one minor exception, none is involved in regulatory activities.

The contribution of the state bureau to the educational process of its home institution is generally modest. Summer employment of a few faculty members or graduate students in geology is the most usual contribution. In one case, New Mexico Institute of Mining and Technology, the interplay between the bureau and the educational program is quite substantial. Sound relationships exist at both Idaho and Nevada. At other institutions, however, the relationship tends toward the minimal.

There are a number of research-oriented agencies, other than these bureaus, which have grown up in recent years and which have some relevance to mineral engineering (see Table 4). Some of these are largely administrative in character and seek to find the funds necessary to make research a more usual part of a faculty member's activity. Others, such as the Colorado School of Mines Research Foundation and the Stanford Research Institute serve as not-for-profit research and development agencies available to the mineral industry. The Research and Development Division of New Mexico Institute of Mining and Technology has only a slight impact on mineral engineering, but is highly important to the education there of scientists at both undergraduate and graduate levels. Utah's Institute for Materials Research and California's Inorganic Materials Laboratory are primarily concerned with the properties and uses of materials rather than with their recovery from natural minerals.

Finally, there are several examples of related federal agency activities housed at or near the institutions of the study. The U.S. Bureau of Mines operates Metallurgy Research Centers in Reno, Nevada, and in Salt Lake City, Utah, a Marine Mining Research Center and the Western Branch for Mineral Economics in the San Francisco area, and a Petroleum Research Center at the University of Wyoming. The U.S. Geological Survey has large regional centers near Golden, Colorado, and at Menlo Park, California. It also has offices at Fairbanks, Alaska; Tucson, Arizona; Salt Lake City, Utah; and Laramie, Wyoming. The interplay of these federal laboratories and offices with the educational process is limited but improving. They have provided graduate students with opportunities to undertake thesis problems and to derive some support in the form of fellowships. These agencies sometimes also provide the institutions with faculty members in the role of lecturers or adjunct professors.

TABLE 4

UNIVERSITY AGENCIES WITH RELEVANCE TO MINERAL ENGINEERING

Institution	Relevant Agency
Colorado School of Mines	Research Foundation CSM Foundation, Inc.*
Montana College of Mineral Science and Technology	Research and Development Foundation*
New Mexico Institute of Mining and Technology	Research and Development Division New Mexico Tech. Research Foundation*
Stanford University	Stanford Research Institute
University of Alaska	Mineral Industry Research Laboratory Proposed: Institute of Mineral Resources
University of California (Berkeley)	Inorganic Materials Laboratory Richmond Field Station Office of Research Services*
University of Idaho	Bureau of Mining Research
University of Utah	Engineering Experiment Station Institute for Materials Research
University of Washington	Office of Engineering Research*
University of Wyoming	Natural Resources Research Institute
Washington State University	Mining Experiment Station of the Office of Engineering Research

*Essentially an administrative organization–seeking funds, keeping records, reporting, etc.

EDUCATIONAL PROGRAMS

The undergraduate offerings in mineral engineering have been described previously (see Table 1). From Appendices A 1 to A 14 it can be noted that master's level graduate work is offered by most institutions and the doctor's level in many. There is some movement to add or drop undergraduate degree offerings or to make the specialty an option in a broader field. A greater tendency in most institutions is to make two or more specialty options available under each undergraduate curriculum. In many cases, this tendency appears to be fostered at low-enrollment institutions by the hopes to attract more students; these hopes appear to be ephemeral. During the past 10 or 15 years, the greatest expansion of degree offerings has been at the graduate level.

The most common faculty problem is one of small size. There are several departments with but one-to-three members. While the educational backgrounds of the faculty appear to be good and while the practical experience of most is judged to be above that in many other engineering departments, such a small size makes for the possibility of serious limitations in the educational program. For example, the loss of a senior member can markedly alter the quality and character of the program. At the graduate level, the small size limits the breadth of background courses available and the competence to direct research in all but a few areas of specialization. It is perhaps for these reasons that the engineering accrediting agency (Engineers' Council for Professional Development) generally requires a minimum of three faculty members to qualify for approval. One reaction to accreditation pressures (or to those of cost-conscious administrators) by some colleges is to combine departments. Such combinations generally have little meaning either for the educational program or its cost, if all curricular offerings and options are continued—which they appear to be.

The number of undergraduate students is likewise low in most of the institutions. None except the Colorado School of Mines has enrollments of a size which permits reasonable economy in all curricula. The Universities of Arizona and Washington approach this economy (at least 10 B.S. degrees per year) in two of the three areas offered at each. There are slight indications, however, that undergraduate enrollments are now growing in most institutions, but it is far from clear just how firm this growth may be.

The percentage of out-of-state undergraduate students is generally larger in the mineral engineering curricula of the state institutions than in those of most other academic fields. The percentage of foreign undergraduate students, while not large in most of the institutions, is likewise higher than in most other academic fields. At the graduate level, however, the percentage of foreign students at most institutions is 40 percent or higher.

TABLE 5

DEGREE PRODUCTION FOR THE 1964-68 PERIOD

Ceramics Engineering

Institution	Bachelors	Masters	Doctors
Univ. of Washington	70	26	3(1)
Univ. of Utah(2)	24	3	17
Univ. of Calif.(Berkeley)	20	28	19
New Mexico Inst. of Mining and Technology(3)	0	0	not offered
WICHE institutions Total	114	57	39

(1) First Ph. D. degree awarded in 1967.

(2) Department of Ceramic Engineering has been discontinued (1968) and the faculty transferred to the Materials Science Department of the College of Engineering, but the degree offering will be continued.

(3) Newly offered.

TABLE 6

DEGREE PRODUCTION FOR THE 1964-68 PERIOD

Fuels Engineering

Institution	Bachelors	Masters	Doctors
Univ. of Utah	2	2	10

TABLE 7

DEGREE PRODUCTION FOR THE 1964-68 PERIOD

Geological Engineering

Institution	Bachelors	Masters	Doctors
Colorado School of Mines(1)	173	37	27
Montana College of Mineral Sci. and Tech.(2)	26	8	not offered
Univ. of Arizona	20	14(3)	1(3)
Univ. of Idaho	19	3	not offered
Univ. of Nevada	16	14	2(4)
Univ. of Calif. (Berkeley)	8(5)	12(6)	4(6)
Univ. of Utah	8	2	5
Univ. of Alaska	6	not offered	not offered
WICHE institutions total	276	90	39

(1) Includes 86 B.S. degrees, 18 M.S. degrees and 11 Ph. D. degrees in Geophysical Engineering.
(2) Includes 5 B.S. degrees in Geophysical Engineering beginning in 1966.
(3) First M.S. degree in 1965 and first Ph. D. in 1967.
(4) First Ph. D. granted in 1967.
(5) B.S. degrees are in Engineering Geoscience option of Engineering Science curriculum.
(6) First M.S. and Ph. D. degrees in Engineering Geoscience awarded in 1966, hence number is for three years rather than five.

TABLE 8

DEGREE PRODUCTION FOR THE 1964-68 PERIOD

Metallurgical Engineering

Institution	Bachelors	Masters	Doctors
Colorado School of Mines	196	50	18
Montana College of Mineral Sci. and Technology(1)	53	25	not offered
Univ. of Arizona	50	17	12
Univ. of Washington	45	35(2)	3(3)
Univ. of Idaho	27	13	not offered
Univ. of Utah	23	16	24
Univ. of California (Berkeley)	22	60	40
Univ. of Nevada	21	10	not offered
New Mexico Inst. of Mining and Technology	14	8	not offered
Univ. of Alaska	2(4)	2(5)	not offered
Stanford University	1	15(6)	3
WICHE institutions total	454	251	100

(1) Includes 26 B.S. and 12 M.S. in Mineral Dressing Engineering.
(2) Includes one degree in Metallurgy.
(3) All degrees are in Metallurgy.
(4) B.S. program discontinued in 1965.
(5) "Mineral Preparation Engineering."
(6) Includes four Mineral Engineer degrees.

TABLE 9

DEGREE PRODUCTION FOR THE 1964-68 PERIOD

Mining Engineering

Institution	Bachelors	Masters	Doctors
Colorado School of Mines	165	13	3
Univ. of Arizona	50	7	*
Univ. of Utah	22	10	3
Montana College of Mineral Sci. and Technology	20	7	not offered
Univ. of Nevada	20	6	not offered
Univ. of Washington	17	8	not offered
New Mexico Inst. of Mining and Tech.	13	*	not offered
Univ. of Idaho	11	5	not offered
Univ. of Alaska	4	2(1)	not offered
Washington State Univ. (2)	4	not offered	not offered
Univ. of California (Berkeley) (3)	4	17	5
Stanford Univ.	3	24	4
WICHE institutions total	333	99	15

* Now accepting students.
(1) Mineral Industry Management.
(2) Likely to be discontinued.
(3) Discontinued all degrees in Mining as of 1966.

TABLE 10

DEGREE PRODUCTION FOR THE 1964-68 PERIOD

Petroleum Engineering

Institution	Bachelors	Masters	Doctors
Colorado School of Mines	97	16	0
Montana College of Mineral Sci. and Technology	39	1	not offered
Univ. of Wyoming	28	9	not offered
Univ. of So. California	17	51	3
Stanford Univ.	14	28(1)	8
New Mexico Inst. of Mining and Technology	8	*	not offered
Univ. of California (Berkeley) (2)	8	14	3
WICHE institutions total	211	119	14

* Now accepting students.
(1) Includes 4 Petroleum Engineer degrees.
(2) All degrees in Petroleum Engineering were eliminated in 1966.

The number of degrees awarded in mineral engineering during the most recent five-year period (1964-68) are summarized in Tables 5 through 10 (see Appendices C 1 to C 14 for details by school since 1956). The obvious giant at the B.S. level is the Colorado School of Mines except in ceramic engineering where this role is played by the University of Washington. At the other end of the academic spectrum, the Ph.D. degree, Berkeley has the major program in metallurgical engineering and shares this role with Utah in ceramic engineering. Colorado School of Mines is the major institution in geological and geophysical engineering. The Ph.D. is not a common degree in either mining or petroleum engineering insofar as the western institutions are concerned, or for that matter, in the nation as a whole.

COSTS TO STUDENTS AND STUDENT AID AVAILABLE

The 1968-69 catalogs are the sources of information on charges for tuition and fees and for room and board described in Table 11. As these are subject to change without notice, it may be that the information is not entirely up-to-date. Resident tuition and fees at the state institutions range from a low of $210.00 at the University of Idaho to $460.00 at the Colorado School of Mines. These charges for a nonresident student range from a low of $588.00 at the University of Alaska to a high of $1524.75 at Berkeley. The similar charges at the two private institutions are higher yet—$1837.00 at the University of Southern California and $1920 at Stanford. Room and board costs are highest at Alaska ($1154.00) and Stanford ($1160.00) and lowest at New Mexico Institute of Mining and Technology ($706.00).

The generally modest scholarship and somewhat more adequate loan funds available to all students at the institutions are not included in this discussion. Rather the focus is on such funds that may be earmarked for students in mineral engineering. The petroleum industry supports undergraduate scholarships in most institutions at somewhat a higher level than is true of industrial support of students in most other engineering fields and certainly better than does the metallurgical and mining industry. A number of small scholarship and loan funds have also been made available by private individuals and organizations. At many schools, however, the scholarship funds are limited to students at the junior and senior levels, and hence have little influence on choice of a field of study.

The experience at Utah is worth reporting at length. A recent bequest has provided an income sufficient to allot approximately $30,000 to scholarships in mining engineering. These are four-year awards and begin at $600 for the freshman year and increase by $100 per year

TABLE 11

BASIC STUDENT EXPENSES
1968-1969 Academic Year

Institution	Resident Tuition and/or Fees	Additional Non-Resident Tuition and Fees	Board and Room	Total Non-Resident
Colorado School of Mines	$ 460.00	$ 750.00	$ 880.00(1)	$2090.00
Montana College of Mineral Sci. and Tech.	265.50	607.50	792.00(2)	1665.00
New Mexico Inst. of Mining and Tech.	271.00	420.00	706.00	1397.00
Stanford Univ.	1920.00	–	1160.00	3080.00
U. of Alaska	288.00	300.00	1154.00	1742.00
U. of Arizona	279.00	815.00	735.00	1829.00
U. of Calif.–Berkeley	324.75	1200.00	985.00	2509.75
U. of Idaho	210.00	500.00	790.00	1500.00
U. of Nevada	366.30	600.00	900.00	1866.30
U. of So. Calif.	1837.00	–	950.00	2787.00
U. of Utah	420.00	519.00	800.00	1739.00
U. of Washington	370.00(3)	480.00	810.00	1660.00
U. of Wyoming	347.00	616.00	830.00	1793.00
Washington State U.	364.90(3)	480.00	880.00	1724.90

(1) Includes estimated cost of Sunday meals.
(2) Calculated on basis of nine months.
(3) Includes optional health insurance.

reaching $900 for the senior year. Enrollments in mining engineering have shown a healthy growth since these funds have been available. Which fields, if any, lost students as a consequence is not known, but the quality of awardees has, on the average, been well above that of students in previous classes.

The Colorado School of Mines several years ago had a National Scholarship Program in which no out-of-state fee was charged to one student a year from each of the other states in the U.S. It proved to be an excellent recruiting device until someone in the statehouse decided that there was no proper authorization for the costs of the program. An effort was made to ask industry to provide the necessary funds, but such funding has only been partially successful. In other words, the technique of the football coach in seeking a winning team by the "buying" of players appears to work. The wisdom of using these funds to provide four-year scholarship aid, beginning with the freshman year, appears to be confirmed by experience at a few other institutions and may offer an insight into ways to develop undergraduate enrollments in mineral engineering generally. Recruitment from junior colleges is of growing importance, and scholarships will be equally useful at this level.

Graduate students, particularly those studying for the doctorate, have a variety of sources of aid. Nationally-based mineral industries, and even local ones, have provided some fellowship funds at all institutions. These, however, are usually modest in size and number by comparison to the federal funds available in many other fields of engineering for fellowships, traineeships, research assistantships, and funds available for teaching assistantships. In addition, state funds appropriated to bureaus are used at a few institutions to pay graduate students to work on bureau projects. For students in geological or geophysical engineering, such work may provide the basis for a thesis. In one case, the state has reappropriated a portion of the funds received as overhead on federal grants or contracts and permitted this to be used to support institutional research which in turn may provide support of graduate students working on thesis problems.

SUPPORT OF ACADEMIC RESEARCH

The amount of research support available parallels that of graduate student support. There are modest industrial and federal grants. In addition, some of the funds appropriated to state bureaus are used for academic research support—particularly in the fields of geological and geophysical engineering and, to some extent, in extractive metallurgy. It would appear that these state funds could effectively support more of the academic research needs at some of the institutions without reducing the service to the mineral industry of the state that is the bureau's primary function.

FACILITIES: BUILDING AND MAJOR EQUIPMENT

The mineral engineering departments are well housed. While some are located in older buildings, even in the original building of the institution, the great majority are housed in buildings constructed within the past 20 years. At two of the three institutions where this is not true, Stanford and Utah, major construction is under way at present. The funds for past and present construction have in many cases, even at the state institutions, included private support by individuals and industries. Idaho provides an outstanding example of such support. The building which presently houses the College of Mines was built about eight years ago and nearly half of the needed funds came from the private sector. *It would appear that, by financing a substantial amount of fairly recent construction, the states have made political decisions concerning the permanence of mineral engineering education in their state-supported institutions.*

At one institution—Washington State—there is an illuminating example of the fact that buildings and equipment do not provide, in themselves, a viable program. Young people seeking a particular educational program and an industry wishing to support mineral engineering research on campuses appear to be the missing ingredients. The Mining Experiment Station is housed in a large building constructed with state funds for the purpose and is fully equipped with pilot-plant-size crushers, grinding mills, classifiers, flotation cells, and all the other machinery involved in mineral processing. Hardly a wheel has turned during its lifetime, and the cobwebs and dust are reminiscent of the opening scene of the movie "Great Expectations." In addition, the number of students in mining engineering, even at the undergraduate level, appears to have reached the vanishing point.

EDUCATIONAL COSTS

Attempts to make comparative costs of education are hazardous even when confined to a single institution, but they are even more properly the subject of skepticism when costs are compared between institutions. But not being angels, we have edged up to the questions of costs. We decided early in the investigation not to attempt an estimation of total costs. There were simply too many differences among the institutions in such things as subject matter, field, degree levels offered, and internal administrative organization to make such an approach realistic. We have used a much simpler approach, namely, that of determining incremental departmental and instructional costs related to the academic departments directly involved in mineral engineering curricula.

A word of caution is needed about possible misinterpretation of the data in the "cost" charts which follow. We repeat, *they do not represent total costs*, but simply that part of such costs which is incurred by the need for special courses. Thus it must be remembered that the costs per weighted degree are in addition to the costs of the other courses in a particular curriculum. Hence the doubling of small numbers of students does not result in halving the total costs. It does result, however, in halving the costs of the courses that are needed only for the specialized degree.

Figure 4 is a plot of the annual costs of each engineering department as related to the weighted number of degrees awarded in each of the mineral and other engineering programs. (Figure 4 X is the plot on an expanded scale for mineral engineering programs only.) The costs are taken from the 1968-69 departmental budgets, and the number of degrees is the average of those awarded during the years ending June 30, 1967 and 1968. Weighting factors of 2 for master's and 5 for doctor's degrees have been used. We had intended to use the 1, 1.5, and 5 weighting used in the recent Kerr study for the Carnegie Corporation, but found that most of the deans felt that 2 was a more appropriate weighting particularly in programs where a master's thesis is required. Further detail on the method involved in the calculation of the points on this chart is given in Appendix D 1.

Figure 4

Index of Departmental Cost per Weighted Degree
compared to weighted number of degrees granted in that field
at that institution (All Engineering Fields)

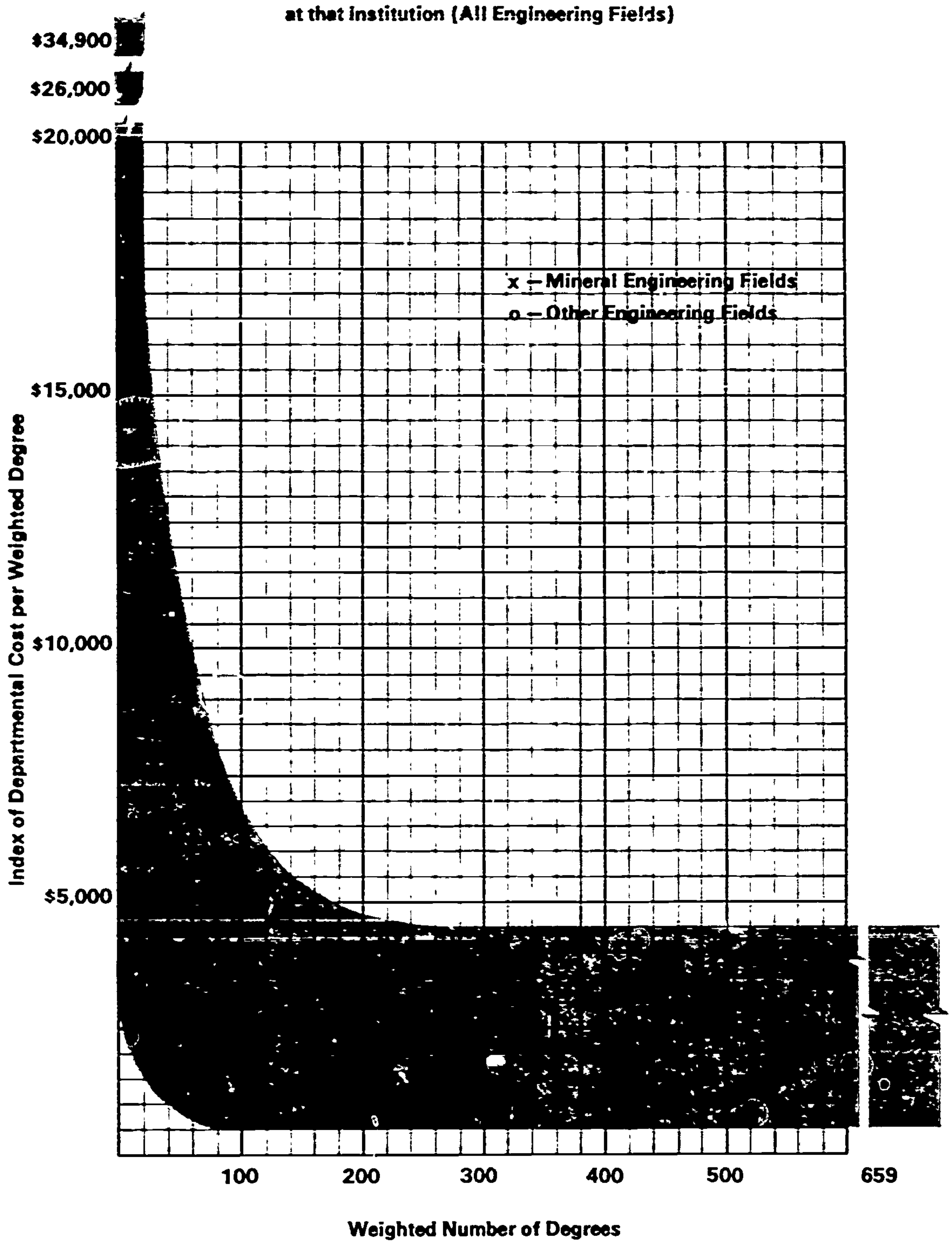
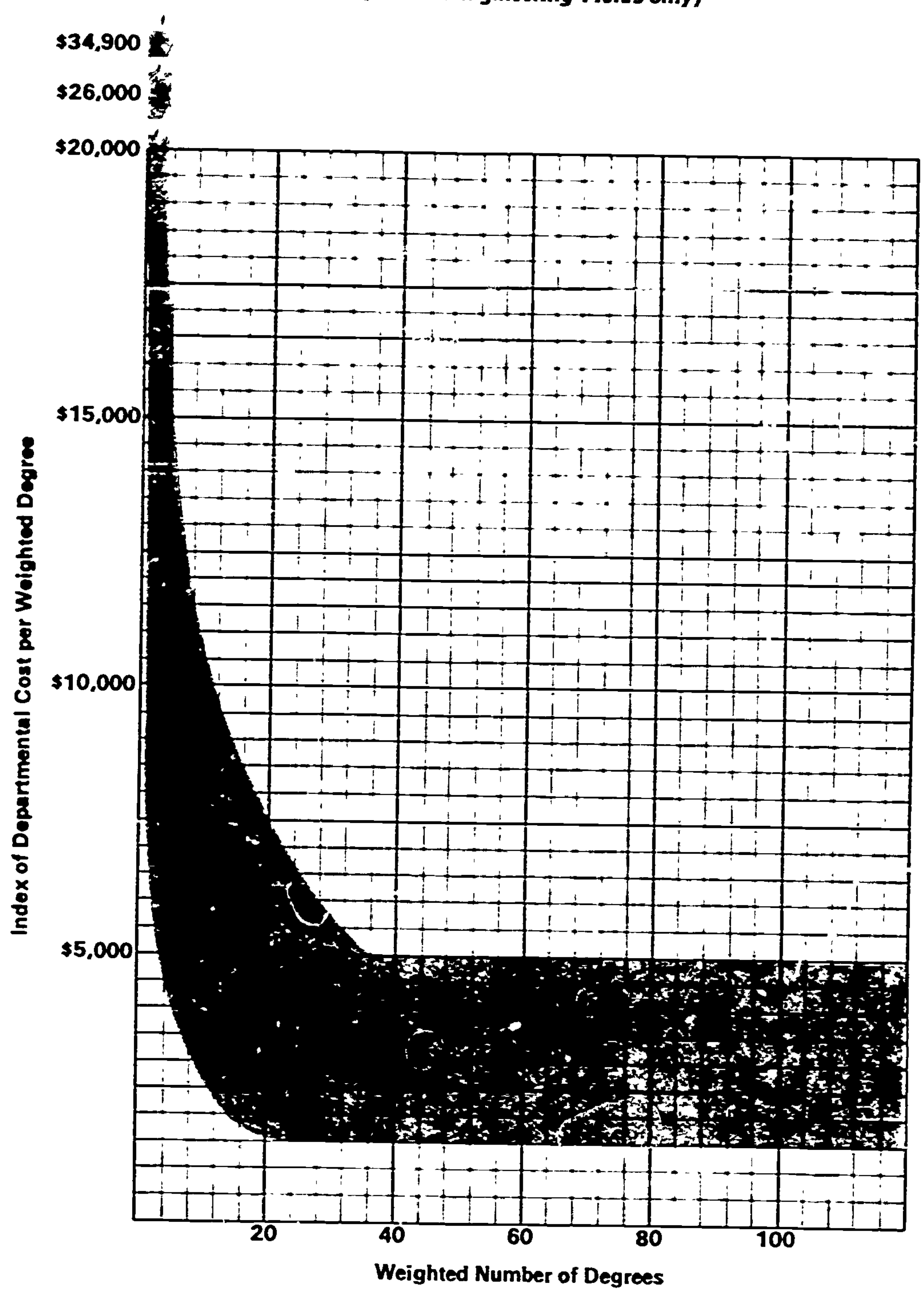


Figure 4x

Index of Departmental Cost per Weighted Degree
compared to weighted number of degrees granted in that field at that institution
(Mineral Engineering Fields only)



Another approach to presentation of educational costs results in Figure 5. In this chart, the instructional salary costs per student credit hour for each engineering department are plotted against weighted average class size. Details on the method of calculation of these two factors are described in Appendix D 2.

The obvious is made more so in these three charts. The incremental cost per degree rises sharply as the production approaches zero, and the cost per student credit hour behaves similarly as the average class size grows smaller.

Secondly, there appears to be no significant difference in cost between programs in mineral engineering and those in other engineering fields. *In fact, such incremental costs will be high in any academic field or degree level in which there are small numbers of students.* It is also obvious that such costs are increased when class sizes are reduced by adding options at the undergraduate level and by adding new areas of specialization at the graduate level.

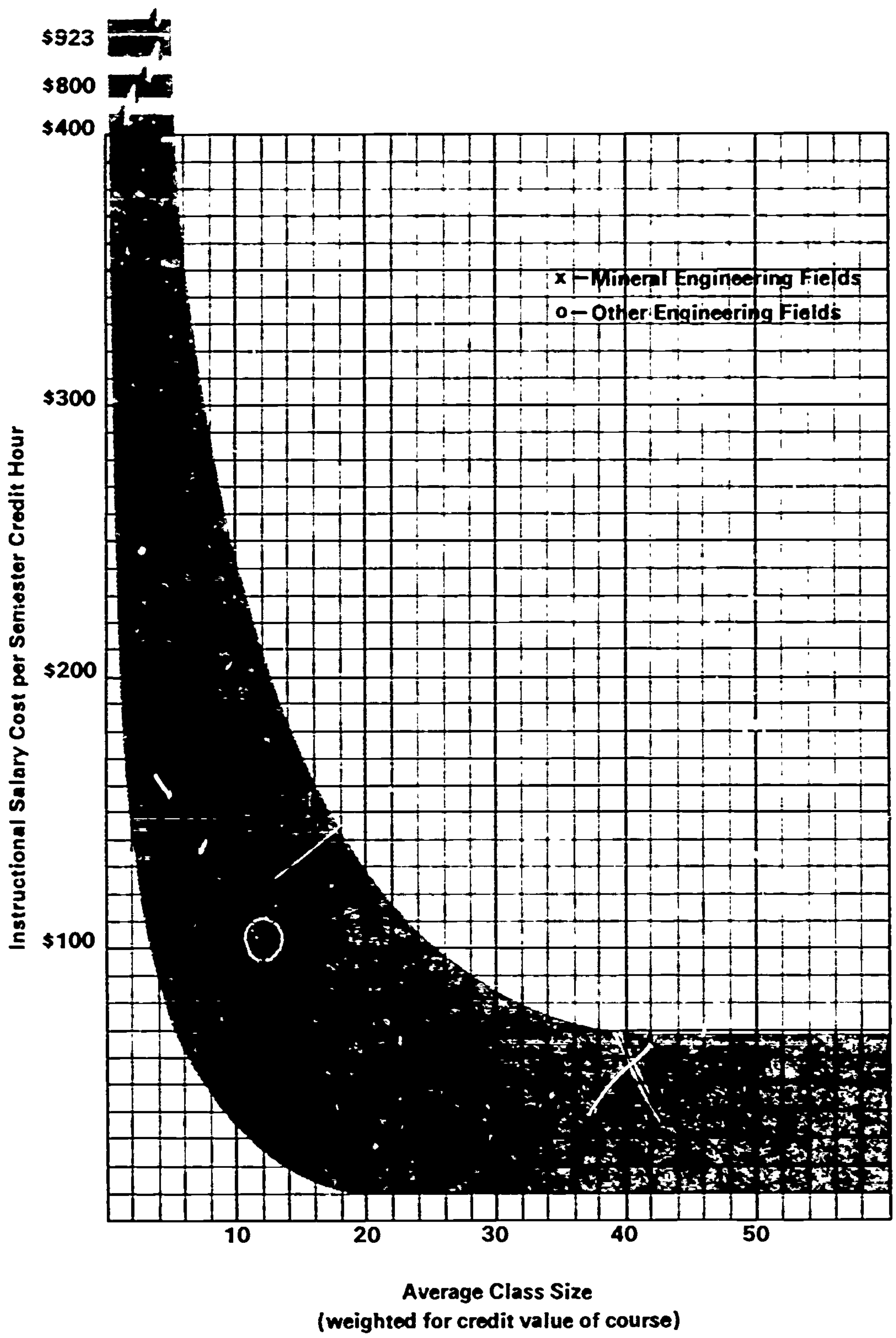
There are large differences in incremental costs at each class size and each weighted number of degrees. These differences are only affected in a minor way by differences in faculty salary scales at the institutions studied, for such differences appear to be relatively small. The primary factors causing the wide variation in such costs appear to be institutional differences in the budgeting of faculty time and the influence of the teaching of service courses for nonmajors. These factors influence both the costs per credit hour and the costs per degree. In addition, costs per credit hour will be influenced by our assumption of a constant class enrollment over the entire academic year, if such is not true, and by institutional differences in registration for thesis research credit. The degree costs would be influenced by improper weighting of degree levels.

It should also be emphasized that if one were making comparisons on a *total* cost basis, most if not all engineering fields would rank high among the undergraduate fields. Such would be particularly true if amortization costs for space and major equipment were included in such costs. But it appears most unlikely that the mineral engineering fields are any more expensive than are other engineering programs of the same size. To repeat, size of classes, the degree levels, and the numbers of degrees awarded are the determining factors. When the number of students is quite small, as in some of the institutions studied, unit costs are bound to be exceptionally high. Conversely, unit costs tend to level out when average class size exceeds 20 and the number of weighted degrees are 25 or higher.

If one assumes, however, that a mineral engineering department mainly teaches students in courses required by its curriculum and if one assumes that the students would seek another degree in the same institutions should that curriculum be discontinued, a saving of about $50,000 in annual operating costs and in indeterminate amount in capital costs would result from the removal of an offering in mineral

Figure 5

Instructional Salary Cost per Semester Credit Hour Related to Average Class Size (All Engineering Fields)



engineering at the institutions with small departments. Conversely, the minimal costs of starting a new undergraduate curriculum would be much the same. Both statements are based on the need of a minimum of three faculty members trained and experienced in the field so as to offer an accreditable curriculum.

Any industrial nation is dependent on metals and fuels from the earth. Hence there is no question but that the mineral industry will continue to need men interested in and trained for employment as engineers. Whether training for a specific industry or even a specific special part of an industry should be a responsibility of the public or of the industry itself is an open question. It would appear that most western publics have accepted the responsibility, at least to some degree, and probably will continue to do so. The mineral industry is, however, an industry primarily made up of a relatively few large corporations and the problem is one of national need, if not concern. When one compares the number of undergraduate degrees in mineral engineering and the populations on a subregional, regional, and national basis, the crucial character of the economic problem for the Mountain West[3] can be more clearly seen.

The West (WICHE states) had about 16 percent of the U.S. population in 1960, but in the academic year ending June 30, 1968 it produced over 50 percent of all degrees at all levels in the combined fields of mining, geological, and geophysical engineering. Similarly, it produced about 30 percent of all B.S. and M.S. degrees in petroleum engineering. The data on extractive metallurgy are not available for comparison, but one suspects that the percentage of such degrees at least equals that in petroleum engineering.

To concentrate the picture still further, public institutions in the states of the Mountain region with 4 percent of the U.S. population produce over 40 percent of all baccalaureates in mineral engineering. Finally, the public institution in one state—Colorado—with 1 percent of the U.S. population, produces nearly a fourth of the nation's baccalaureate degrees.[4]

The crucial problem—size of student body—is certainly related to the small college age population of the states in which these undergraduate curricula exist. The one institution with an economical size, the Colorado School of Mines, enjoys a high out-of-state component among its undergraduates, probably because of its wide reputation in the mineral engineering fields.

ALTERNATIVE COURSES OF ACTION: WESTERN STATES AND THEIR PUBLIC INSTITUTIONS

The usual three choices are available if one agrees, and we do, that baccalaureate programs in mineral engineering are not obsolete. The relevant parts of the institutions can (1) continue the struggle for survival; (2) find ways and means to increase enrollments; or (3) close up shop. The first alternative is certainly not unthinkable—at least, not to the harried administrative officers of the institutions. The political climate in most of the states is such that the third alternative is not acceptable. The choice between struggle for continued life and certain death will generally not result in a decision favoring death. We suspect that it seems far better to most university presidents to eke out the extra costs of small departments than to risk the loss of support of an important political faction for a needed institutional appropriation.

The second alternative—increased undergraduate enrollments—appears worthy of exploration. Common sense applied to the general situation leads to some pertinent conclusions. First, rules restricting the numbers of out-of-state students particularly in mineral engineering should be eased or removed entirely. There simply are too few college age youths in most of the western states to provide the numbers needed for reasonable educational economy. Further, there are good self-interests which can be served by being less concerned about out-of-state students. Assuming an appropriate out-of-state tuition, which most institutions now appear to have, it is good institutional economics to have more students in those undergraduate programs which are now small in size. In fact, if the economy of the state is considered, these students bring in enough money to make it not unthinkable simply to charge in-state tuition. After all, each of the western states strives hard to increase its tourist business, and a student from out of the state is a tourist for four years. Further, larger classes will provide more individuals to work in an important industry. And finally, a number of permanent citizens may well result.

Within the West itself, the Pacific states—particularly California—should be good hunting grounds for undergraduate students. No mineral engineering program is offered in Oregon, and the same appears to be likely to become true in Washington in the area of mining engineering. In the three Pacific states reside nearly eight times as many people as in the four inter-Mountain states of Arizona, Nevada, Utah, and Idaho. Similarly, the concentrations of population in the Midwest and northeastern United States ought to provide excellent hunting grounds for future mineral engineers.

The discussion of graduate level education is another matter. If undergraduate enrollments were more reasonable, there would be a probably valid reason why master's degrees should be offered in all baccalaureate fields. It is argued with some truth, as well as with heat, that better quality faculty can be recruited and retained if an opportunity is present for the teaching of graduate students. Hence it would appear wise to include this level of graduate work in all areas of mineral education offered by an institution. Yet, this very argument adds to the reasons why serious consideration should be given to closing down some of the smaller programs. If undergraduates are hard to find, certainly such will be more true for qualified master's candidates. Graduate students, even at the master's level, seldom pay tuition, and most require student aid. Hence, the per student costs to the state obviously will be high, unless much more support for research and graduate student aid can be obtained through federal agencies and private industry.

It would seem unwise, uneconomical, and unnecessary to increase the number of doctoral offerings in mineral engineering at WICHE schools. There is presently ample capacity in present programs for the numbers likely to be needed by industries or universities for the foreseeable future. In addition, dissertations on subjects of high interest to the mineral industry are also likely to be undertaken in the more general engineering fields such as civil, mechanical, and chemical, and in geology and its subdivisions. We are cynical enough, however, to doubt that the foregoing statement will be accepted by the faculty of departments not now offering this degree. It must be remembered, however, that it takes more than a qualified faculty, ample space and facilities, and abundant student aid to establish a sound doctoral program. It also takes a sufficient number of highly qualified students.

WHAT MIGHT THE INSTITUTIONS DO?

The character of the socio-political-economic environment differs so widely between the 14 institutions that one may expect widely different kinds of actions to be taken in the future, as they have been in the past. Mineral engineering programs have never existed in Hawaii. They were discontinued in Oregon and, for a period, in Wyoming. Mining and petroleum engineering degrees are no longer offered at California (Berkeley) and the undergraduate enrollments in all mineral engineering fields there appear to be vanishing. Mining engineering is likely to be discontinued at the two Washington schools. The general situation as it now exists in each state is summarized in Table 12, which contains in a different form the information in Table 1.

TABLE 12

UNDERGRADUATE PROGRAMS IN MINERAL ENGINEERING

Mineral Engineering Curricula Not Available in State Institutions

STATE	PRINCIPAL B.S. CURRICULA NOT OFFERED BY STATE INSTITUTION
Alaska	Ceramic engineering Geophysical engineering Metallurgical engineering Petroleum engineering
Arizona	Ceramic engineering Geophysical engineering Petroleum engineering

TABLE 12 Continued

California	Geophysical engineering Mining engineering Petroleum engineering(1)
Colorado	Ceramic engineering
Hawaii	all
Idaho	Ceramic engineering Geophysical engineering Petroleum engineering
Montana	Ceramic engineering
New Mexico	Geological engineering Geophysical engineering
Nevada	Ceramic engineering Geophysical engineering Petroleum engineering
Oregon	all
Utah	Geophysical engineering Petroleum engineering
Washington	Geological engineering Geophysical engineering Petroleum engineering
Wyoming	Ceramic engineering Geological engineering Geophysical engineering Metallurgical engineering Mining engineering

(1) Available at both Stanford and University of Southern California.

The first question to be explored at institutions contemplating the closing of programs or who have done so is the extent of responsibility that the governing board and the principal administrative officers of the state institution feel toward the provision of wide educational opportunity to the youth of its state. One answer could be that appropriate educational alternatives do exist in the state. Another might be that the state ought to provide a scholarship fund to aid resident students to obtain an education out of the state or in private institutions in fields the state does not offer. If the latter is the answer, WICHE already has a mechanism of usefulness in its Student Exchange Program. Other, perhaps simpler, methods could be administered by each state if it so wished.

There is one group of six institutions—those of the sparsely populated inter-Mountain and Rocky Mountain West—that have fairly common problems in mineral engineering education and similar socio-political environments. These are the Universities of Arizona, Idaho, Nevada, Utah, Montana College of Mineral Science and Technology, and New Mexico Institute of Mining and Technology. It is our judgment that none of these will seek to close any of its mineral engineering curricula in spite of small undergraduate enrollments. The small enrollments have resulted in high incremental costs in each of these schools except New Mexico Institute of Mining and Technology. Alaska and Wyoming represent institutions with some similarity to the forementioned ones, but they have striking differences to be considered. Fairbanks, Alaska, is a long way even from Seattle. The travel costs thus may be a deterrent to many prospective out-of-state students. Wyoming offers only petroleum engineering and hence needs more opportunities for its youth than it offers. While the Colorado School of Mines would undoubtedly be happy to increase its enrollments, there is little of the crucial need for students that is felt by the other institutions in the Mountain states.

Each of the eight "low enrollment" institutions is highly concerned that its mineral engineering departments grow. Each has tried a variety of mechanisms to accomplish such growth—generally with limited success. It might be worth considering some new individual or collective approaches. For example, each should seek to ease, if necessary, any restrictions or quotas on out-of-state students in the mineral engineering fields.

Secondly, each should consider accepting students from all other of these eight states which do not offer a particular curriculum and according them the same status as resident students. State laws or regulations may have to be modified to accomplish this.

Finally, each should consider the possibility of a collaborative effort with its sister institutions in at least two programs: a program aimed at eliciting major scholarship support from the mineral industries to be used to recruit non-WICHE students and a program of communications with high school students in the more populous states about the mineral engineering offerings available for undergraduates. A model of such a program is outlined in Appendix E. Discussions with the deans of these institutions makes it appear to be worth a trial.

The time would appear ripe to test the reality of concern expressed by the mineral industry over lack of engineers for their needs. If its financial response is modest to a program specifically designed (and proven by practice) to entice more and better young men into educational programs in mineral engineering, the university administrators will have the practical ammunition, if they wish it, to take more drastic actions.

Even with funds, it is difficult to seek out those "needles in the haystack"—the young men or women who have some interest in mineral engineering education but who feel there is no practical way to attain it. It is believed that a collaborative effort could produce more results on this task, and more economically, than can the scattered part-time efforts of individual institutions.

WHAT SHOULD WICHE DO?

Stand ready, as usual, to aid the institutions of the region in their search for ways to meet their responsibilities to the youth of the respective states. Some of the institutions may decide on collaborative efforts which will need a sympathetic agent either to administer or to advise. If such becomes a reality, then WICHE should help to seek the support necessary to permit it to meet the requests for aid from the institutions which it serves.

FOOTNOTES

1 *Mineral Science and Technology: Needs, Challenges and Opportunities,* National Academy of Sciences, National Academy of Engineering, National Research Council, Mineral Science and Technology Committee, 1969.

2 Borgmann, all institutions; Bartram, all but University of Alaska, University of California, University of Washington, Washington State University, University of Idaho, and University of Southern California.

3 Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming.

4 These figures reflect a rough estimate of the proportion of metallurgical and ceramic engineering degrees which can be classed as extractive rather than physical.

APPENDIXES

APPENDIX A 1

COLORADO SCHOOL OF MINES

Degree Offerings

Area	B.S.	Major Interests or Options mentioned in catalog	M.S.	Ph.D.
Chem. and Petrol. Refining Engin.	Yes	–	Yes	Yes
Chemistry	Yes	9 hour sequence in one of the mineral technologies.	Yes	No
*Geol. Engin.	Yes	11 hours available for specialization in structural geology, stratigraphy, minerology, petrology, paleontology, mineral deposits, soils, ground water hydrology, and geomorphology.	Yes	Yes
Geology		–	Yes	Yes
*Geophys. Engin.	Yes	–	Yes	Yes
Mathematics	Yes	12 hours sequence in one of the mineral technologies.	Yes	No
*Metall. Engin.	Yes	opportunity for some specialization through elective courses in mineral processing, production, and physical metallurgy.	Yes	Yes
*Mining Engin.	Yes	–	Yes	Yes
*Petrol, Engin.	Yes	–	Yes	Yes
Physics	Yes	10 hour sequence in one of the mineral technologies.	Yes	No

*Mineral Engineering Curricula.

APPENDIX A 2

MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY

Degree Offerings

Area	B.S.	Major Interests or Options Mentioned in Catalog	M.S.	Ph.D.
Engineering Science	Yes	None	No	No
*Geological Engin.	Yes	Mining Petro. Geol. Hydrology Eng. Geol. Minerology etc.	Yes	No
Geology	No	–	Yes	No
*Geophysical Engin.	Yes	–	No	No
*Metallurgical Engin.	Yes	Production Materials Sci.	Yes	No
Metallurgy	No	–	Yes	No
Mineral Dressing	No	–	Yes	No
*Mineral Dressing Engin.	Yes	–	Yes	No
*Mining Engin.	Yes	"Alternative Plans of Study"	Yes	No
*Petroleum Engin.	Yes	–	Yes	No

Note: First two years of study are available for majors in chemistry, economics, English, foreign languages, history, journalism, law, the arts, mathematics, physics, political science, psychology, and other areas.

* Mineral Engineering curricula.

APPENDIX A 3

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

Degree Offerings

Area	B.S.	Major Interests or Options Mentioned in Catalog	M.S.	Ph.D.
Basic Sciences	Yes	–	No	No
Biology	Yes	–	No	No
*Ceramic Engin.	Yes(new)	–	No	No
Chemistry	Yes	–	Yes (inc. Geo- chemistry & Biochemistry)	Geochemistry(1)
Computer Sci.	Yes	–	No	No
Environmental Engin.	Yes(new)	–	No	No
Geology	Yes	General Paleontology	Yes	Yes(1)
Geophysics	Yes	–	Yes	Yes(1)
Ground Water Hydrology	No	–	No	Yes(1)
Mathematics	Yes	–	Yes	No
*Metallurgical Engin.	Yes	Extractive Physical	Yes	Chemical Metallurgy(1)
*Mining Engin.	Yes	–	Yes	No
*Petroleum Engin.	Yes	–	Yes	No
Physics	Yes	General Electronics ______	Yes	Yes
Science Teaching	No	–	Yes	No

* Mineral Engineering Curricula.
(1) Field of dissertation for Ph. D. degree in Geoscience.

APPENDIX A 4

SCHOOL OF EARTH SCIENCES: STANFORD UNIVERSITY

Degree Offerings

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Geology	Yes	Physical Paleontology Theoretical	Yes(including Geochemistry)	Yes
Geophysics	Yes	–	Yes	Yes
*Mineral Engineering	Yes	Mining	Yes	Yes
	Yes	Chem. & Extr. Metallurgy	Yes	Yes
	Yes	Management	Yes	No
	No	Mineral Process	Yes	Yes
*Exploration	No	Mineral	Yes	Yes
	No	Petroleum	Yes	Yes
*Petroleum Engin.	Yes	–	Yes	Yes

* Mineral Engineering Curricula.

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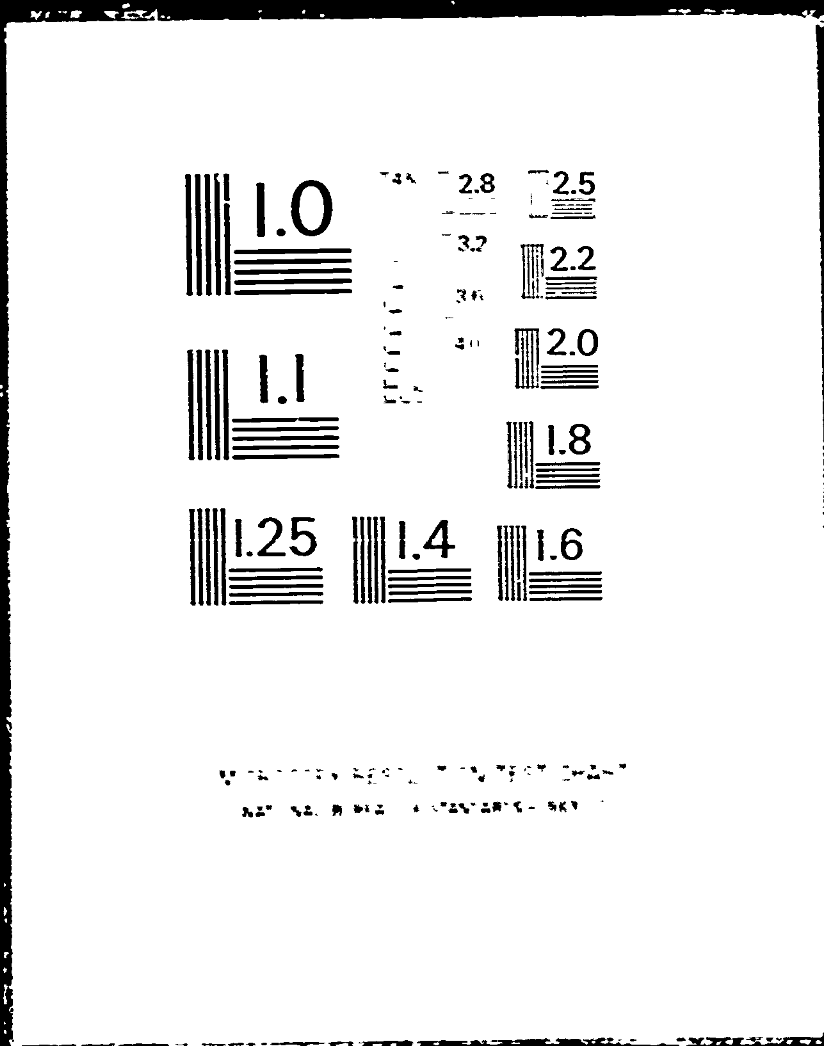

APPENDIX A 5

COLLEGE OF EARTH SCIENCES AND MINERAL INDUSTRY

DEGREE OFFERINGS–UNIVERSITY OF ALASKA

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Geography	Yes	–	No	No
Geology	Yes	–	Yes	Yes
*Geological Engin.	Yes	–	No	No
*Mining Engin.	Yes	–	No	No
*Mineral Industry Management	No	–	Yes	No
*Mineral Preparation Engineering	No	–	Yes	No
*Petroleum Engin.	"A student interested in Petroleum Engineering may complete the first two years of the Mining Engineering curriculum and then transfer to another university . . . ."			

* Mineral Engineering Curricula.

APPENDIX A 5

COLLEGE OF EARTH SCIENCES AND MINERAL INDUSTRY

DEGREE OFFERINGS–UNIVERSITY OF ALASKA

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Geography	Yes	–	No	No
Geology	Yes	–	Yes	Yes
*Geological Engin.	Yes	–	No	No
*Mining Engin.	Yes	–	No	No
*Mineral Industry Management	No	–	Yes	No
*Mineral Preparation Engineering	No	–	Yes	No
*Petroleum Engin.	"A student interested in Petroleum Engineering may complete the first two years of the Mining Engineering curriculum and then transfer to another university . . . ."			

* Mineral Engineering Curricula.

APPENDIX A 6

COLLEGE OF MINES: UNIVERSITY OF ARIZONA

DEGREE OFFERINGS

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Chemical Engin.	Yes	--	Yes	Yes
*Geological Engin.	Yes	Eng. Geology Mining Geol. Geophys. Eng.	Yes	Yes
Geology	Yes	Geology Geophysics-Geochemistry Hydrology Paleontology	Yes	Yes
*Metallurgical Engin.	Yes	--	Yes	Yes
*Mining Engin.	Yes	--	Yes	Yes
Hydrology	No	--	Yes	No
Materials Engin.	No	--	Yes	No
Geochronology	No	--	Yes	No

* Mineral Engineering Curricula.

APPENDIX A 6

COLLEGE OF MINES: UNIVERSITY OF ARIZONA

DEGREE OFFERINGS

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Chemical Engin.	Yes	--	Yes	Yes
*Geological Engin.	Yes	Eng. Geology Mining Geol. Geophys. Eng.	Yes	Yes
Geology	Yes	Geology Geophysics-Geochemistry Hydrology Paleontology	Yes	Yes
*Metallurgical Engin.	Yes	–	Yes	Yes
*Mining Engin.	Yes	–	Yes	Yes
Hydrology	No	–	Yes	No
·Materials Engin.	No	–	Yes	No
Geochronology	No	–	Yes	No

* Mineral Engineering Curricula.

APPENDIX A 7

COLLEGE OF ENGINEERING: UNIVERSITY OF CALIFORNIA (Berkeley)

DEGREE OFFERINGS

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Civil Engineering	Yes	10(quarter) units available for limited sequence in 1. Construction Engin. Photogrammetry 2. Surveying and Geodesy 3. *Geotechnical a. Soil Mechanics and Foundation Engin. b. Geological Engin. 4. Hydraulic Engin. 5. Sanitary Engin. 6. Structural Engin. 7. Structural Mech. 8. Transportation Engin. 9. Water Resources Engin.	Yes	Yes
Electrical Engin. and Computer Sci.	Yes	Prog. A - Electronics, Fields and Plasmas Prog. B - Systems, Information and Control Prog. C - Computer Sci. Prog. D - General Electrical Engin. Note: There are also six elective groups listed in the catalog	Yes	Yes
Engineering Science	Yes	1. Bioengineering *2. Engin. Geoscience 3. Engineering Math.-Statistics 4. Engin. Mathematics 5. Engin. Physics	No	No
Industrial Engin. and Operations Res.	Yes	1. Practice of Industrial Engin. 2. Grad. Study of Oper. Res. 3. Human Factors in Engin. 4. Computer Applications	Yes	Yes

Mechanical Engin.	Yes	1. Aeronautics 2. Applied Mech 3. Automatic Control 4. Electromechanical Engin. 5. Energy Conversion 6. Fluid Mech. 7. Heat Transfer 8. M. E. Design 9. Materials Processing 10. Naval Arch. 11. Nuclear Engin. 12. Refrigeration and Cryogenics 13. *Petroleum Engin. 14. Space Engin.	Yes	Yes
Mineral Technology				
*1. Ceramic Engin.	Yes	–	Yes	Yes
*2. Extractive Metallurgy	Yes	–	Yes	Yes
3. Physical Metallurgy	Yes	–	Yes	Yes
*4. Engin. Geoscience	**	–	Yes	Yes
5. Solid State Physics	Yes	–	Yes	Yes
Naval Architecture	Yes	–	Yes	Yes
Nuclear Engineering	Yes	1. Neutronics 2. Systems Analysis 3. Chem. and Materials 4. App. Nuclear Reactions and Instr. 5. Energy Conversion 6. Radiation Biology	Yes	Yes
Chemical Engin. (College of Chemistry)	Yes	--	Yes	Yes

* Mineral Engineering Curricula.
** see Geoscience under Engineering Science.

APPENDIX A 8

COLLEGE OF MINES: UNIVERSITY OF IDAHO

Degree Offerings

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Geography	Yes	--	Yes	No
*Geolog. Engin.	Yes	–	Yes	No
Geology	Yes	General Paleontology	Yes	Yes
Hydrology	No	–	Yes	No
*Metallurg. Engin.	Yes	–	Yes	No
*Mining Engin.	Yes	–	Yes	No

* Mineral Engineering Curricula.

APPENDIX A 9

MACKAY SCHOOL OF MINES: UNIVERSITY OF NEVADA

DEGREE OFFERINGS

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Chemical Engin.	Yes	–	No	No
Earth Science	Yes	Education Gov. Service	No	No
Geochem.	No	–	Yes	Yes
Geography	Yes	–	No	No
*Geological Engin.	Yes	–	Yes	Yes
Geology	Yes	–	Yes	Yes
Geophysics	Yes	–	Yes	Yes
*Mineral Exploration	Yes	–	Yes	Yes
Hydrology	No	–	Yes	Yes
*Metallurg. Engin.	Yes	Materials Science, also mention of Extractive and Chemical Metallurgy, Mineral Dressing, Physical Metallurgy	Yes	No
*Mining Engin.	Yes	Mining Operations	Yes	No

* Mineral Engineering Curricula.

APPENDIX A 10

SCHOOL OF ENGINEERING DEGREE OFFERINGS–UNIVERSITY OF SOUTHERN CALIFORNIA

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Aerospace Engin.	Yes	–	Yes	Yes
Chemical Engin.	Yes	–	Yes	Yes
Civil Engin.	Yes	–	Yes	Yes
Electrical Engin.	Yes	–	Yes	Yes
Industrial & Systems Engin.	Yes	–	Yes	Yes
Operations Research	No	–	Yes	No
Materials Science	No	–	Yes	Yes
Mechanical Engin.	Yes	–	Yes	Yes
*Petroleum Engin.	Yes	–	Yes	Yes

* Mineral Engineering Curricula.

APPENDIX A 11

STATE COLLEGE OF MINING AND MINERAL INDUSTRIES:
UNIVERSITY OF UTAH

DEGREE OFFERINGS

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
*Ceramic Engin.	Yes	–	Yes	Yes
*Fuels Engin.	Yes	–	Yes	Yes
*Geological Engin.	Yes	Construction Mining	Yes	Yes
Geology	Yes	Physical Stratigraphic Ground Water	Yes	Yes
Geophysics	Yes	General *Engineering	Yes	Yes
*Metallurgical Engin.	Yes	–	Yes	Yes
Meteorology	Yes	–	Yes	Yes
Minerology	Yes	–	Yes	Yes
*Mining Engin.	Yes	–	Yes	Yes

* Mineral Engineering Curricula.

APPENDIX A 12

COLLEGE OF ENGINEERING DEGREE OFFERINGS–UNIVERSITY OF WASHINGTON

DEGREE OFFERINGS

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Aero & Astronautics	Yes	–	Yes	Yes
Chemical Engin.	Yes	–	Yes	Yes
Civil Engin.	Yes	–	Yes (6 areas of specialization)	Yes
Electrical Engin.	Yes	9 areas of specialization	Yes	Yes
Industrial Engin.	(A second B.S. following a regular 4-year program in any department, supplemented by a fifth year with 3 areas of specialization.)			
Mechanical Engin.	Yes	–	Yes (7 areas of specialization)	Yes
Nuclear Engin.	No	–	Yes	Yes (6 areas of specialization)
Mining, Metallurgical & Ceramic Engin.				
*Ceramic Engin.	Yes	–	Yes (2 areas of specialization)	Yes
*Metallurgical Engin.	Yes	Physical Met. Chemical Met. Mineral Proc. Plant Oper. & Adm.	Yes	Yes
*Mining Engin.	Yes	General	Yes	No

APPENDIX A 13

COLLEGE OF ENGINEERING: UNIVERSITY OF WYOMING

DEGREE OFFERINGS

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Agricul. Engin.	Yes	–	Yes	–
Chem. Engin.	Yes	–	Yes	No
Civil Engin.	Yes	regular	Yes	Yes
		architectural	No	No
Electrical Engin.	Yes	regular	Yes	Yes
		bio-medical	No	No
		electronics		
General Engin.	Yes	–	No	No
Mech. Engin.	Yes	regular	Yes	Yes
		aerospace	Yes	No
		nuclear	Yes	No
*Petrol, Engin.	Yes	–	Yes	No
Atmos. Resources	–	–	Yes	No
Bioengin.	–	–	Yes	No
Water Resources	–	–	Yes	No

* Mineral Engineering Curriculum.

APPENDIX A 14

COLLEGE OF ENGINEERING: WASHINGTON STATE UNIVERSITY

DEGREE OFFERINGS

Area	B.S.	Major Interests and Options Mentioned in Catalog	M.S.	Ph.D.
Agricultural Engin.	Yes	–	Yes	†
Building Theory and Practice	Yes	–	No	No
Chemical Engin.	Yes	–	Yes	†
Civil Engin.	Yes	General Hydraulic Sanitary Structural	Yes	†
Electrical Engin.	Yes	Automation Electronics Bio-Med Applications Power	Yes	†
Mech. Engin.	Yes	–	Yes	†
*Mining Engin.	Yes	–	No	†
Physical Metall.	Yes	–	Yes (Materials Sci.)	†

* Mineral Engineering Curricula.
† Participate in an Engineering Science (interdepartmental) Ph.D.

APPENDIX B 1

COLORADO SCHOOL OF MINES

The Colorado School of Mines (CSM) traces its history to a brief beginning as a private church college which was started in 1869. It became a territorial "School of Mines" in 1874 and the state "School" when statehood was achieved in 1876. It now offers the baccalaureate, master's, and doctor's degrees in the mineral engineering fields of geological, geophysical, metallurgical, mining, and petroleum engineering and in chemical and petroleum refining engineering. It also offers the baccalaureate and master's in chemistry, physics, and mathematics in which the major is blended with one of the engineering fields. The doctorate degree in these fields, based on a simpler blending of science and mineral engineering, is actively being planned. In addition, graduate degrees are offered in geology and geophysics.

CSM has the largest undergraduate enrollments in the fields of mineral engineering that it offers and challenges the West Coast institutions in graduate degree production. It has a large percentage of out-of-state undergraduate students, particularly if bachelor degree recipients are taken as the base. Foreign students coming mainly from Canada, South America, and Europe, comprise a modest percent of the undergraduate population and approximately 35 percent of the graduate students. It is the one institution of those in this study which is not hampered fiscally by small numbers of undergraduates.

Industrial aid for students and in general support of the academic programs is reasonably good. It is, however, excellent in certain departments and poor in others. Experience with an industrially supported "national scholarship" program has been disappointing. Scholarship support by the state of resident undergraduate students is relatively high—approximately one in seven receive remission of tuition.

The academic physical plant, with two exceptions, is new (built since 1945) and in excellent condition. A graduate center, financed in substantial part by private gifts, is under construction. The building of next priority would house the mining and basic engineering departments. These are the most poorly housed departments at present.

APPENDIX B 2

MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY

Montana College of Mineral Science and Technology (MCMST) is one of the three WICHE institutions which were originally established as independent "Schools of Mines" and it has accepted students since 1900. It offers B.S. degree curricula only in engineering and, with the exception of a new program in "engineering science," all are in the mineral fields. One of the six mineral fields offered, geophysical engineering, has been recently added. Another, mineral dressing engineering, is a degree specialty unique to MCMST. The master's degree is offered in six mineral fields, with or without the word "engineering" appearing in the description of the field. Doctoral programs are not presently offered but are receiving some informal consideration by the administration.

A two-year academic program is available in a number of fields of the arts and sciences for students who may plan to transfer later to a four-year college to complete a baccalaureate degree requirement. The addition of this "junior college" function appears to have had two beneficial effects—a strengthening of the liberal arts faculty and a reduction in average per student costs.

Slightly over half of the 668 full-time and 66 part-time students are enrolled in the two-year program, and the balance are in the engineering degree programs. There are but 5 full-time and 20 part-time students enrolled in the master's degree programs. Over 90 percent of all students are from Montana (about 70 percent from Silver Bow County). Out-of-state students account for 5 percent of the total, and foreign students (60 percent Canadian) account for the balance.

The amount of graduate student aid and research support by industry appears to be high considering the relatively small graduate program. On the other hand, federal support for such purposes is relatively low. Scholarship aid from private industry and individuals appears to be about average. There are, however, three state supported programs—Freshman Scholarships, Advanced Scholarships (both open to out-of-state students), and the "High School Honor Scholarships" of the

Montana Board of Regents for Montana residents only. The amount of the scholarship is limited to registration, incidental, and (for out-of-state students) the nonresident fees.

The physical plant is quite a mixture of buildings dating from 1900 to the most recently completed one which houses petroleum engineering, engineering sciences, and geophysical engineering. Planning for a new building to house the departments of mining engineering and mineral dressing engineering is actively being pursued. Laboratory equipment appears to be quite adequate.

APPENDIX B 3

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

New Mexico Tech was authorized by the territorial legislature of 1889 as the New Mexico School of Mines. This name continued until a legislative act in 1951 and a constitutional amendment in 1960 authorized the present one. Changes instituted by a former president, Dr. Workman, altered the character of the institution until presently its emphasis is more scientific than technological. It has for some time offered undergraduate and master's degrees in metallurgical, mining, and petroleum engineering and recently has added environmental and ceramic.

A general program in the geosciences is being used as an umbrella to make the doctorate available to at least the area of chemical metallurgy.

The total number of students (all levels) has shown steady growth over the past six years—from 341 to over 700. Judging from data on degrees, it is estimated that not more than 25 percent of the students are in mineral engineering. Approximately 40 percent of the undergraduates come from out of state, but the foreign component is low. At the graduate level, however, the proportion of foreign students is quite high. Student and faculty morale appeared to be exceptionally high.

The amount of private scholarship support is about average. The institution, using funds of the Research and Development Division, supplies a substantial amount for the purpose. The state also provides a number of tuition remission scholarships for state residents. The private support of graduate students and research is relatively low as is federal support in the mineral engineering areas. The institute, however, provides the best student (all levels) support found among the institutions studied through employment on projects of both the Bureau of Mines and Mineral Resources and the Research and Development Division.

The physical plant has had excellent maintenance and is quite adequate for the present levels of academic activity. A library building is being planned as the next addition, and such appears to be a most needed building. Laboratory equipment is judged to be modern, well-used, and in good condition.

APPENDIX B 4

SCHOOL OF EARTH SCIENCES: STANFORD UNIVERSITY

The School of Earth Sciences, reorganized in 1945, has four departments–geology, geophysics, mineral engineering, and petroleum engineering. The two departments of interest have essentially become graduate departments, with 5 undergraduate and 47 graduate students in attendance the autumn quarter of 1968. Mineral engineering includes mining engineering and chemical and extractive metallurgy. Physical metallurgy is taught in the materials science department of the College of Engineering. Master's level programs are offered in exploration for metallic minerals and for petroleum. Such would be found in some other institutions under geological engineering.

There is a heavy component of foreign students in the graduate programs–estimated at 45 percent in the mineral engineering fields and 80 percent in petroleum engineering.

There is quite modest scholarship support specifically available to undergraduates in the school. All are, however, eligible for the general scholarship funds of the university. Graduate student aid comes primarily from research contracts. Private and university sources provide the balance. Research is supported in large part by federal grant funds. Industrial funds for research, even with strings, are modest in amount.

The present physical plant is both old and inadequate. A $4.2 million building is, however, in the process of construction. Private sources have provided the bulk of the construction funds. The laboratories appear to be very well equipped.

APPENDIX B 5

COLLEGE OF EARTH SCIENCES AND MINERAL INDUSTRY: UNIVERSITY OF ALASKA

Mining engineering was among the courses offered when the Alaska Agricultural College and School of Mines, previous name of the university, opened its doors to students in 1922. The College of Earth Sciences and Mineral Industry is composed of three departments—Mineral Engineering, Geology, and Geography. The latter is newly added to the college. Geological and mining engineering are the two fields of mineral engineering now offered.

The number of undergraduate students is small, yet approximately 40 percent come from out of state. The graduate programs in engineering are presently at a very low ebb and prospects for greatly increased enrollments are dim for the near future.

Because of low enrollments and high unit costs, the baccalaureate program in metallurgical engineering was phased out a few years ago. The baccalaureate program in mining engineering is now being replaced by a new core curriculum entitled mineral engineering, with options in exploration, mine development, mineral processing, and mineral economics. Hence, in reality, both mining and the mineral process portion of metallurgical engineering will be continued at the undergraduate level. The change has been made in hopes that more students will be enticed by the new specialties.

Scholarship and fellowship support is quite low—either from industry or from governmental sources. Research support over and above the $48,000 of state funds for the Mineral Industries Research Laboratory is modest. A grant or two have been received from the U.S. Bureau of Mines and the Corps of Engineers. The Alaska NORTH Commission has added major support. Much of this outside support has been for surveys of metallic mineral resources.

The college is quite adequately housed in a building completed in 1952. The laboratory equipment is modern and appears to cover all needs quite well. In hopes of attracting the State Division of Mines and Minerals, a larger staff of the Alaskan Geology Branch of the U.S.G.S. and a new unit of the U.S. Bureau of Mines, serious discussion is underway which will hopefully result, in the not too distant future, in a new $6.0 million complex of which the college will be a central part.

APPENDIX B 6

COLLEGE OF MINES: UNIVERSITY OF ARIZONA

The College of Mines was one of three divisions of the Territorial University when it opened its doors for students in 1891. It became the College of Mines and Engineering in 1915 and then divided in 1940 into the present Colleges (Mines and Engineering). It offers degrees in three fields of mineral engineering—geological, metallurgical, and mining. With the recent approval of the Ph.D. in mining engineering, each field provides programs at all academic levels.

The undergraduate enrollment totals approximately 400, of which 176 are in the three mineral engineering departments. About two thirds of the mineral engineering undergraduates are Arizona residents, slightly more than 20 percent are from other U.S. states, and 11 to 12 percent are from foreign countries. The domicile pattern of graduate students is also somewhat different than in most of the other institutions with a smaller proportion of foreign students.

There are a variety of scholarships available through the university. State funds appear to be involved in only two types at the university-wide level—one which remits tuition and fees for foreign students and the other as part of awards to the high schools of the state and elsewhere. Individuals and industry provide a number of scholarships which are restricted to the College of Mines. There is a mixture of federal, state, and private funds to support graduate fellowships and research assistantships. The only federal research grant of size is in the field of physical metallurgy. Otherwise research support for mineral engineering students from any outside source appears to be modest.

The present principal building dates from 1940 with an addition completed in 1957. A substantial grant from a mineral industry helped with the construction costs of the original building. While space is getting to be at a premium, there is presently no active planning for additional construction. The laboratories appear to be well planned and well equipped.

APPENDIX B 7

COLLEGE OF MINES: UNIVERSITY OF IDAHO

The College of Mines was established in 1917 as an administrative unit of the university and has continued to date in this relationship. It is organized into two departments—Geology-Geography and Mining-Metallurgical Engineering. The mineral engineering programs offered are in geological, metallurgical, and mining engineering. The college enrollment for the fall semester, 1968, totalled 127 undergraduates and 45 graduates. Of these, the students in mineral engineering numbered 39 undergraduates and 5 graduates.

Approximately 60 percent of the undergraduate students in mineral engineering are residents of Idaho. Only one is from out of the country. Scholarship, fellowship, and research funds are judged to be quite low in the mineral engineering departments.

The college is housed in a building completed about eight years ago. The funds to construct this building came in almost equal parts from the state and the private sector. While it is quite new, space is already becoming a problem. The laboratory equipment appears quite adequate for the present teaching and research programs.

APPENDIX B 8

MACKAY SCHOOL OF MINES: UNIVERSITY OF NEVADA

The Mackay School of Mines admitted its first students in 1888 and has continuously offered degrees in the earth sciences and mineral engineering. It is presently organized in three departments, as follows: Geology-Geography, Chemical and Metallurgical Engineering, and Mining Engineering. Mineral engineering degrees are offered at the baccalaureate and master's level in geological, metallurgical, and mining engineering and at the doctor's level in geological engineering.

Fifty of the 145 undergraduates and 6 of the 54 graduate students pursuing studies last fall in the Mackay School are in these mineral engineering programs. About half of the 50 undergraduates are Nevada residents, a third are from California, and two are from other countries. For some strange reason, six of the 15 students in metallurgical engineering are from New York. Five of the six graduate students are U.S. citizens.

The scholarship aid specifically for mineral engineering is quite modest, as is fellowship aid at the graduate level. Similarly, outside research support from industrial and federal sources is low.

The physical plant of Mackay School has two parts—the original Mackay building and a wing of the relatively new Scrugham Engineering-Mines building. The rest of Scrugham houses, as the name implies, some departments of the College of Engineering. While the school and its ancillary activities (the Bureau of Mines and the Mining Analytical Laboratory) are now somewhat crowded, it is likely to be several years before additional building space is available. Laboratory equipment for teaching and research appears to be quite ample for the needs.

APPENDIX B 9

STATE COLLEGE OF MINES AND MINERAL INDUSTRIES: UNIVERSITY OF UTAH

A School of Mines was authorized by the legislature in 1901. This grew into the School of Mines and Engineering as other engineering curricula were added. In 1946 the school divided into the present College of Engineering and State College of Mines and Mineral Industries. The college offers degrees at all levels in five curricula—ceramic, fuel, geological, metallurgical, and mining engineering—and, as an option, in geophysical.

While exact figures on the domicile of students in the college are not available, that of the 239 undergraduates (fall 1967) is probably similar to that of the university as a whole. The out-of-state enrollment amounts to about 15 percent of the total. Foreign students account for about 1.5 percent of the university as a whole, but probably for a much higher proportion of the 109 graduate students in the college. Nearly two thirds of the university students claim Salt Lake County as their domicile.

The support of undergraduates by privately funded scholarships is probably the highest at any of the institutions. Two bequests, one for students in mining engineering and the other for those in metallurgical engineering, provide an excellent base. Private financial aid for graduate students and for research is fairly good but that from federal sources is quite limited. Limited state funds are also available, on a university-wide basis, to support research.

The physical plant is old and well worn. A major new building is funded for $3.2 million, however, and will be available in the near future. Industrial support for an auditorium is being sought but without success. The mineral engineering departments appear to be reasonably well equipped, and it is likely that they will be even better off for equipment upon completion of the new building.

APPENDIX B 10

COLLEGE OF ENGINEERING: UNIVERSITY OF CALIFORNIA, BERKELEY

The Department of Mineral Technology administers the programs in ceramic and metallurgical engineering and the graduate program in engineering geoscience. Degrees in mining and petroleum engineering are no longer awarded by the university. There are, however, options in civil and mechanical engineering at the undergraduate level and research interests of faculty members which provide in some part for students motivated toward these specialties. There is also a geoscience option under the general undergraduate engineering science program. Further discussion, however, will be confined to programs of the department. The graduate programs dominate the departmental activity, and it is possible that within a few years undergraduate degrees will no longer be given in ceramic and metallurgical engineering.

Besides funds administered on a university-wide basis, a few privately supported scholarships are available to the department alone. It is interesting to note, however, that there are still as many restricted to petroleum engineering students as there are in mineral technology. A few privately supported and federal fellowships are available, but the principal support of graduate students is as research assistants paid from federal and industrial research grants.

The facilities are relatively old but quite ample to house the present activities. Some relief has been given by the transfer of some ceramic and physical metallurgy research to the new Inorganic Materials Laboratory. The research and teaching laboratories appear to be well equipped.

APPENDIX B 11

COLLEGE OF ENGINEERING: UNIVERSITY OF SOUTHERN CALIFORNIA

Petroleum engineering was established as a department in the College of Engineering in the late 1920's. Degrees are offered at all levels. The graduate courses, however, are offered in the evening to provide for a relatively large number of students who hold full-time positions with industrial firms located in the Los Angeles area.

The undergraduate enrollment has been modest in size, but it is experiencing a healthy growth at present with a four-year total of 30-plus students this year. Approximately half of these students, however, are foreign—primarily from the Near East and North Africa. The majority of the full-time graduate students are likewise from out of the country. The master's program has been quite productive over the past several years. It is at the doctoral level, however, that the greatest gain has been made. The award of three or four doctorates a year will soon be experienced.

While industrial support of scholarships averages about $10,000 per year and an endowment yields another $4,000 annually, the high tuition needed to be charged by a private university means that a relatively few students can be supported. Graduate fellowship and research support by industry is relatively good, but federal support is nil.

The Chemical and Petroleum Engineering Building was erected with private funds in 1958. The space and equipment appear to be quite satisfactory, although the recent growth of the doctoral program is beginning to cause some squeeze on space.

APPENDIX B 12

COLLEGE OF ENGINEERING: UNIVERSITY OF WASHINGTON

Mineral engineering was authorized at the University of Washington in 1893 but it did not become a going concern until 1898, and the first degree in mining engineering was awarded in 1900. First named the School of Mines, it became College of Mines in 1911. The three curricula, mining, metallurgical, and ceramic engineering became, in 1947, the School of Mineral Engineering within the College of Engineering. The name was changed to the Department of Mining, Metallurgical, and Ceramic Engineering in 1968.

Presently the doctorate is offered by ceramic and metallurgical engineering while mining offers the master's degree. Ceramic engineering is the largest division of the department at both graduate and undergraduate levels, and mining is the smallest. The undergraduate students are almost exclusively from the state. In ceramic and metallurgical engineering the emphasis is on physical rather than process and this trend is growing. At the graduate level in these two fields, the emphasis on physical is higher still. The graduate students in metallurgical engineering have a heavy Indian flavor—some 13 of the 24 are from that country.

The scholarship support specifically for the Mineral Engineering Department is exceptionally low. The fellowship and research support in mining is negligible but is fair in the other two fields. A recent NASA grant has provided a major boost in ceramic and metallurgical engineering.

The principal building dates from 1927, but a major addition to house primarily the graduate research activities of the two materials departments was completed in 1966. The divisions of ceramic and metallurgical engineering are well equipped for the present program and even for a larger one. The equipment for mineral processing is quite good, but its use appears to be low.

APPENDIX B 13

COLLEGE OF ENGINEERING: UNIVERSITY OF WYOMING

Petroleum engineering is the only curriculum in mineral engineering at the University of Wyoming. An earlier program in mining engineering was a victim, in 1933, of the depression. Petroleum engineering was an option in general engineering from 1950 until 1961, when the present curriculum was established. It is now showing a healthy growth at the baccalaureate level, but the master's program is presently at a low ebb. Even so, there are many signs that a doctoral program is strongly desired by the department.

About half of the 75 undergraduate students are from Wyoming, about a third are from out of state, and a sixth from foreign countries, primarily Canada.

The petroleum industry has supported the department quite well. Funds for undergraduate scholarships amount to approximately $8,000 a year and a number of fellowships have been made available. In addition, the petroleum and allied industry equipped the laboratories at the time they were built (1961) by contributing over $150,000 in cash, plus gifts of equipment as well. One or two federal research grants have been received and the Bureau of Mines Petroleum Laboratory makes one fellowship available a year and permits use of its laboratories for graduate student research as well as for some undergraduate use. The contracts between petroleum engineering and the Geology Department or the Geological Survey of Wyoming are minimal. Similarly, the relationships between the Petroleum Engineering Department and the Mineral Division of the Natural Resources Research Institute are limited.

The department is housed in the wing added to the engineering building in 1961. Space appears adequate and the equipment reasonably good.

APPENDIX B 14

COLLEGE OF ENGINEERING: WASHINGTON STATE UNIVERSITY

Mining engineering has had a varied life at Washington State. It was one of the early offerings, but it has enjoyed but little popularity in recent years. In 1945, an effort was made to stimulate interest in mineral engineering generally by establishing a School of Mines as a separate division. Geology, however, was moved into the Arts and Science College in 1948, and ten years later the school was absorbed back into the College of Engineering. The only mineral engineering degree now offered is in mining engineering, but this year there is but one student--a senior--and one faculty member who is at retirement age. It would appear that all educational activities in mineral engineering are being dropped.

The Mining Experiment Station, established in 1946, is an excellent facility and well equipped for development work in mineral dressing. The facility has unfortunately had but little use.

APPENDIX C 1

COLORADO SCHOOL OF MINES

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	37	44	48	42	27	28	24	21	13	11	22	18	23
Geophys. Engin.	5	16	20	16	18	16	10	20	14	13	21	15	23
Metall. Engin.	26	33	33	39	39	48	41	44	50	35	42	34	35
Mining Engin.	21	20	25	23	34	35	32	28	35	29	38	26	37
Petrol. Engin.	42	30	34	27	26	22	18	10	25	20	16	11	25

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	2	8	3	6	1	4	3	10	2	2	3	2	10
Geophys. Engin.	2	1	2	1	4	4	4	2	3	3	1	4	7
Metall. Engin.	1	3	4	1	1	2	3	1	2	9	13	12	14
Mining Engin.	3	3	1	3	4	2	11	5	2	2	2	2	5
Petrol. Engin.	3	1	4	3	1	0	2	3	1	1	7	4	3

Doctoral Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	1	1	1	0	0	3	1	0	0	3	3	6	7
Geophys. Engin.	1	0	1	0	0	3	0	0	2	3	2	2	2
Metall. Engin.	1	0	0	0	0	2	0	1	2	1	6	5	4
Mining Engin.	0	0	1	1	1	0	1	0	1	0	2	0	0
Petrol. Engin.	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX C 2

MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	8	10	3	10	7	9	6	5	3	7	3	4	4
Geophys. Engin.	0	0	0	0	0	0	0	0	0	0	2	1	2
Metall. Engin.	5	6	11	9	8	2	7	8	8	3	10	5	1
Miner. Dress. Engin.	1	3	2	6	1	0	1	5	9	6	5	4	2
Mining Engin.	9	8	10	3	5	5	12	4	7	4	2	3	4
Petrol. Engin.	7	10	12	10	12	4	6	8	10	11	6	2	10

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin	0	2	2	1	0	0	0	1	2	3	1	2	0
Geophys. Engin.	0	0	0	0	0	0	0	0	0	0	0	0	0
Metall. Engin.	0	1	0	0	2	0	1	1	1	0	8	2	2
Miner. Dress. Engin.	2	0	2	2	3	0	2	2	0	4	1	4	3
Mining Engin.	0	1	0	4	2	0	0	0	3	1	0	1	2
Petrol. Engin.	0	0	0	1	1	1	1	0	1	0	0	0	0

APPENDIX C 3

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Metall. Engin.	2	1	4	6	2	3	0	4	2	2	5	1	4
Mining Engin.	2	1	6	7	5	6	3	0	2	1	2	2	6
Petrol. Engin.	4	6	2	9	7	9	13	5	3	1	1	2	1

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Metall. Engin.	none offered		0	0	0	1	0	0	0	2	1	3	2
Mining Engin.					none offered previous to '68 →								0
Petrol. Engin.					none offered previous to '69 →								

APPENDIX C 4

STANFORD UNIVERSITY

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Metall. Engin.	0	1	4	5	10	0	0	0	0	0	1	0	0
Mining Engin.	0	2	5	1	0	0	1	2	0	1	1	0	1
Petrol. Engin.	0	0	7	9	7	3	6	2	2	4	3	3	2

Masters' Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Metall. Engin.	3	3	3	5	6	2	0	0	0	5	4	2	2
Mining Engin.	1	2	1	1	4	2	2	6	3	6	4	4	7
Petrol. Engin.	2	10	12	7	7	5	3	1	5	3	3	3	5
Mineral Engineer	0	0	0	0	0	0	0	0	0	0	1	1	2
Petrol. Engineer	0	0	0	0	0	0	0	0	2	1	1	0	0

Doctoral Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Metall. Engin.	1	0	0	0	2	0	0	0	0	1	0	1	1
Mining Engin.	0	0	0	0	0	0	0	0	0	0	1	2	1
Petrol. Engin.	0	0	0	0	0	0	1	1	1	1	4	2	0

APPENDIX C 5

UNIVERSITY OF ALASKA

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	0	1	1	0	1	0	0	0	2	0	1	2	1
Metall. Engin.	0	0	1	1	1	1	1	0	0	not available			
Mining Engin.	4	1	4	6	3	3	2	2	0	1	1	1	1

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Mining Engin.	not available			3	1	0	0	0	0	0	0	0	0
Mineral Ind. Mgt.	not available			- -	- -	- -	- -	- -	→	1	0	1	0
Mineral Prep. Engin.	not available			- -	- -	- -	- -	- -	→	1	1	0	0

APPENDIX C 6

UNIVERSITY OF ARIZONA

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	9	12	13	20	8	14	5	2	6	2	4	3	5
Metall. Engin.	4	8	20	14	10	7	10	5	10	8	13	9	10
Mining Engin.	6	10	12	16	10	6	13	8	13	9	8	9	11

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	not available →									2	3	6	3
Metall. Engin.	1	2	4	3	6	0	3	5	3	8	2	2	2
Mining Engin.	0	3	2	3	1	2	5	6	1	0	2	3	1

Doctoral Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	not available →									0	0	1	0
Metall. Engin. (metallurgy)	not available →				0	0	0	1	2	3	1	4	2
Mining Engin.	not available →												0

APPENDIX C 7

UNIVERSITY OF CALIFORNIA, (BERKELEY)

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram. Engin.	0	0	2	2	4	7	2	4	6	3	4	4	3
Geol. Engin.	0	5	1	4	1	2	7	0	1	1	2	2	2
Metall. Engin.	8	10	16	9	8	10	5	5	2	6	4	6	4
Miner. Explor.		1											
Mining Engin.	2	4	6	5	0	2	1	3	3	1	not offered		
Petrol. Engin.	15	8	15	6	6	2	4	4	2	1	2	3	not offered

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram. Engin.	1	3	0	1	3	5	4	5	6	2	8	6	6
Engin. Geosci.	not offered →									0	5	4	3
Metall. Engin.	4	9	9	8	13	9	10	12	13	10	11	13	13
Mining Engin.	1	2	4	6	5	2	9	6	7	10			
Petrol. Engin.	3	0	6	3	3	6	5	4	6	3			

Doctoral Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram. Engin.	not offered			0	1	2	4	4	4	5	3	3	4
Engin. Geosci.	not offered →									0	2	2	0
Metall. Engin.	1	3	2	2	3	2	3	8	4	8	14	9	5
Mining Engin.	0	0	0	1	0	0	0	1	2	3	not offered		
Petrol. Engin.								0	0	3	not offered		

APPENDIX C 8

UNIVERSITY OF IDAHO

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	4	5	1	3	5	8	4	4	4	4	4	2	1
Metall. Engin.	3	2	7	4	6	3	6	6	3	3	8	10	3
Mining Engin.	4	4	2	2	2	6	5	5	0	3	4	1	3

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	1	1	0	0	1	0	0	0	2	0	0	1	0
Metall. Engin.	0	1	3	2	5	4	4	2	1	3	3	3	3
Mining Engin.	0	1	0	0	0	1	1	2	1	3	1	0	0

APPENDIX C 9

UNIVERSITY OF NEVADA

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	3	4	2	5	7	3	5	5	3	4	4	4	1
Metall. Engin.	2	5	1	3	6	3	3	5	4	3	4	7	3
Mining Engin.	6	5	8	8	7	6	3	7	6	5	3	2	4

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.	1	2	2	2	4	3	1	2	0	4	3	3	4
Metall. Engin.	3	3	2	2	0	0	1	1	0	6	3	1	0
Mining Engin.	2	0	1	1	0	0	0	3	1	1	0	3	1

Doctoral Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Geol. Engin.		not available			→	→	→	→	→	→	→	1	1

APPENDIX C 10

UNIVERSITY OF SOUTHERN CALIFORNIA

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Petrol. Engin.	9	20	14	11	10	6	5	11	1	4	3	6	3

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Petrol. Engin.	8	12	6	14	6	11	10	6	11	12	8	9	11

Doctoral Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Petrol. Engin.	0	0	0	1	0	0	0	1	1	0	1	1	0

APPENDIX C 11

UNIVERSITY OF UTAH

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram. Engin.	1	3	4	1	7	6	3	3	5	4	2	9	4
Fuels Engin.	1	0	0	1	2	3	2	0	0	1	0	0	1
Geol. Engin.	5	7	3	6	8	4	4	2	4	0	0	1	3
Metall. Engin.	3	7	6	6	7	9	6	7	6	5	3	5	4
Mining Engin.	4	3	9	3	8	1	8	3	4	5	2	8	3

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram Engin.	0	0	1	0	1	0	1	1	1	0	1	1	0
Fuels Engin.	0	0	0	0	0	0	0	0	1	0	0	1	0
Geol. Engin.	0	0	0	3	0	3	3	1	0	1	1	0	0
Metall. Engin.	1	3	4	2	4	6	6	1	4	4	3	1	4
Mining Engin.	0	2	0	1	2	0	1	3	3	2	2	0	1

Doctoral Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram. Engin.	0	1	0	0	2	0	3	4	3	3	3	7	1
Fuels Engin.	3	0	2	1	0	1	2	3	0	3	2	4	1
Geol. Engin.	0	0	1	1	0	0	1	1	1	0	0	2	2
Metall. Engin.	8	4	2	3	4	0	8	3	2	3	7	9	3
Mining Engin.	0	0	0	0	0	0	1	0	0	1	0	1	1

APPENDIX C 12

UNIVERSITY OF WASHINGTON

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram. Engin.	4	9	13	14	17	8	13	12	14	16	10	18	12
Metall. Engin.	6	5	6	10	12	13	8	12	12*	8	7	10	8
Mining Engin.	4	5	6	4	7	6	4	3	3	0	6	3	5

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram. Engin.	3	2	2	3	3	3	3	4	3	5	7	3	8
Metall. Engin.	1	3	2	2	2	3	7	6	5	7*	8*	6	9*
Mining Engin.	2	0	3	1	0	0	0	1	2	2	2	1	1

Doctoral Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Ceram. Engin.	0	0	0	0	0	0	0	0	0	0	0	1	2
Metall. Engin.	0	0	0	0	0	0	0	0	0	2	2	1*	2**

* one degree given in Metallurgy
** two degrees given in Metallurgy

APPENDIX C 13

UNIVERSITY OF WYOMING

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Petrol. Engin.	not available				0	7	11	2	5	6	2	5	10

Master's Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Petrol. Engin.	not available ——→					0	0	0	1	1	4	0	3

APPENDIX C 14

WASHINGTON STATE UNIVERSITY

Baccalaureate Degrees for Year Ending June 30

Curriculum	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68
Mining Engin.	6	1	4	3	1	3	2	2	0	2	1	0	1

APPENDIX D 1

Method Used in Developing Index of Departmental Cost per Weighted Degrees

The primary output of educational programs in engineering is graduation of persons with degrees in the field. It is useful to have an index of annual departmental costs per degree granted in evaluating the effect of program size on unit cost.

In most areas of engineering, the primary departmental activity is associated with courses at the upper division and graduate level leading to degrees in that field. Most mineral engineering departments do not provide extensive service course work for students majoring in other fields.

Departmental cost as used in this analysis is the departmental operating budget supported by general institutional funds. It includes faculty, teaching assistants, secretarial and technical staff, supplies, and other expense. The index is much more sensitive to variations in degree production than to minor variations in expenditure classification. These cost figures *do not* include other costs that would be part of a total cost study such as instructional costs of courses taken in other departments, administrative, library, and physical plant operating costs. Departmental cost as used here does not include any capital costs involved in housing the department or providing it with its stock of major equipment.

The departmental cost data in this analysis are taken from the 1968-69 institutional budget. We have related it to the degree production of the 1967 (July 1, 1966 through June 30, 1967) and 1968 fiscal years. The degrees have been averaged for the two years to smooth the data. We recognize that the financial data and degree data are gathered from different periods but do not believe that this variation affects the general conclusions. The principal distortions would occur in departments that had a marked increase or decrease in degree production in 1968-69.

Recognizing that there is more departmental cost involved in the teaching of graduate students, we had intended to employ the relative weights used in *Quality and Equality: New Levels of Federal Responsibility for Higher Education*, Carnegie Commission on Higher Education, December 1968. Discussions with deans and senior faculty indicated that most of the mineral engineering master's degrees were thesis degrees and involved more faculty time so the master's degree weighting was adjusted from 1.5 to 2.0. Thus, bachelor's degrees have been given a weight of one, master's degrees a weight of two, and doctor's degrees a weight of five.

The following equation shows how the index of annual departmental costs per degree was calculated:

$$\frac{\text{Departmental Cost}}{\left[\frac{BS(FY67) + BS(FY68)}{2} + 2\,\frac{(MS(FY67) + MS(FY68)}{2} + 5\,\frac{PhD(FY67) + PhD(FY68)}{2}\right]} = \text{Index}$$

The index figures resulting from these calculations on a number of engineering departments demonstrate the basic trends. The data should not be regarded as a sensitive indicator for interdepartmental or interinstitutional comparisons because of such factors as fluctuation of the number of degrees from year to year, the extra costs that some departments incur in providing service courses (such as geological engineering departments providing all the geology courses for other degree departments), and the weights assigned to the various degrees (a "course-work" master's has the same weight as a "thesis-type" master's degree in this analysis).

APPENDIX D 2

Method Used for Determining Instructional Salary Cost Per Semester Credit Hour As Related to Average Class Size

One of the useful tools of institutional analysis is the instructional salary cost per semester credit hour. In this report we have related it to weighted average class size in Figure 5.

The Instructional Salary Cost used here is the salary cost for academic personnel charged to the departmental instructional budget for the 1968-69 academic year. Academic personnel includes lecturers, graduate assistants, and associates as well as the usual faculty titles. The instructional salary cost omits any portions of faculty time budgeted for other functions and does not include secretarial and technical assistance.

Data on Semester Credit Hours (SCH) and Average Class Size were developed from institutional reports of class enrollments for the fall term, 1968, at the close of the drop-and-add period. For those institutions on the quarter system, the data were converted to semester equivalents. To reduce the amount of data handled, it was assumed that enrollments for the subsequent terms would be equivalent to the fall term. This reduces the precision of the results but not the general validity.

A semester credit hour is the enrollment of one student for one semester hour of credit. The semester credit hours resulting from a class are the product of the credit value of the course times the number of students enrolled (e.g., 30 students in a three-credit course for a semester result in 90 semester credit hours). The number of semester credit hours for the department is the sum of SCH for all the classes of the department in that semester. If the institution gives credits for thesis registrations, these were included in the total.

The credit hour data for the fall semester or quarter were converted to an annual equivalent in semester credit hours by multiplying by two. (For quarter institutions, the conversion is Quarter Credit Hours X 3 X the conversion factor of 30/45 or QCH X two.)

The Instructional Salary Cost for the year divided by the Semester Credit Hours for the year provides the cost per student credit hour index figure.

The Weighted Average Class size was determined on data without thesis registrations. It first involved determining the sum of the credit hour value of the classes taught without regard to the number of students enrolled in them. (Where courses had variable credit, the average value of the variable credit was used.) The total student credit hours divided by the total credit hour value of the classes taught yields the average class size weighted according to the credit value of the various classes. For example, assume a department with two courses:

Course A			
Sec. 1	2 credit hours	40 students	80 student credit hours
Sec. 2	2 credit hours	30 students	60 student credit hours
Course B	3 credit hours	21 students	63 student credit hours
Total	7 credit hours		203 student credit hours

203/7 = weighted average class size of 29

This index datum should not be used by itself for interdepartmental or interinstitutional comparisons. The index figures will be low and class sizes relatively high in departments that have large service course responsibilities. Variations in the institutional practice on thesis credit and institutional support of faculty research time also introduce significant variations.

APPENDIX E

Recommended Plan for Student Exchange in Certain WICHE States

The States to be Involved

Alaska (U. of Alaska)
Arizona (U. of Arizona)
Colorado (Colo. Sch. of Mines)
Idaho (U. of Idaho)
Montana (Mont. Col. of Min. Sci. and Tech.)
Nevada (U. of Nevada-Reno)
New Mexico (New Mex. Inst. of Min. Tech.)
Utah (U. of Utah)
Washington (U. of Washington) Optional*
Wyoming (U. of Wyoming)

The Plan

Each relevant state institution of higher education would seek authority to admit students domiciled in any of the other states into those of its mineral engineering programs which are not offered in the students' home states and to consider such individuals as state residents in their relationships with that institution.

Examples

I. Wyoming

a. The University of Wyoming would accept students in petroleum engineering from Arizona, Idaho, Nevada, Utah, and possibly Washington, with resident status.

b. Its residents would receive similar treatment in the following fields and institutions:

*The University of Washington offers ceramic engineering, but does not seriously need additional students. Hence there is a question about its inclusion on a full basis.

1. Geological engineering–U. of Alaska, U. of Arizona, Colorado Sch. of Mines, U. of Idaho, Montana Col. Min. Sci. and Tech., U. of Nevada, and U. of Utah.

2. Metallurgical engineering–U. of Arizona, Colo. Sch. of Mines, U. of Idaho, Montana Col. Min. Sci. and Tech., U. of Nevada, New Mexico Inst. of Min. Tech., U. of Utah, and U. of Washington.

3. Mining engineering–U. of Alaska, U. of Arizona, Colorado Sch. of Mines, U. of Idaho, Montana Col. Min. Sci. and Tech., and U. of Washington.

4. Ceramic engineering–New Mex. Inst. of Min. Tech., U. of Utah, and U. of Washington.

5. Geophysical engineering–Colorado Sch. of Mines, Montana Col. Min. Sci. and Tech.

II. Utah

A. The University of Utah would accept students in the following fields and from the indicated states with resident status:

1. Ceramics engineering–Alaska, Arizona, Colorado, Idaho, Montana, Nevada, and Wyoming.

2. Geological engineering–New Mexico, Washington, and Wyoming.

3. Metallurgical engineering–Alaska, Wyoming.

4. Mining engineering–Washington, Wyoming.

B. Its residents would receive similar treatment in petroleum engineering at Colorado Sch. of Mines, Montana Col. Min. Sci. and Tech., New Mexico Inst. Min. Tech., and U. of Wyoming.

Discussion

The inclusion of Washington has been questioned and a similar question could be raised about Colorado. An alternative to their inclusion is to recommend that these states, as recommended for

California, Oregon, and Hawaii, meet their obligations for wider educational opportunity for their youth in mineral engineering through a state scholarship approach.

For the states and institutions that are agreed upon, it is urged that the terms of agreement be as simple as possible. It would appear wise for each to accept the relatively small inequity that may occur between itself and its sister states than to pay for the record-keeping and red tape involved in any periodic attempt to "balance the books."

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