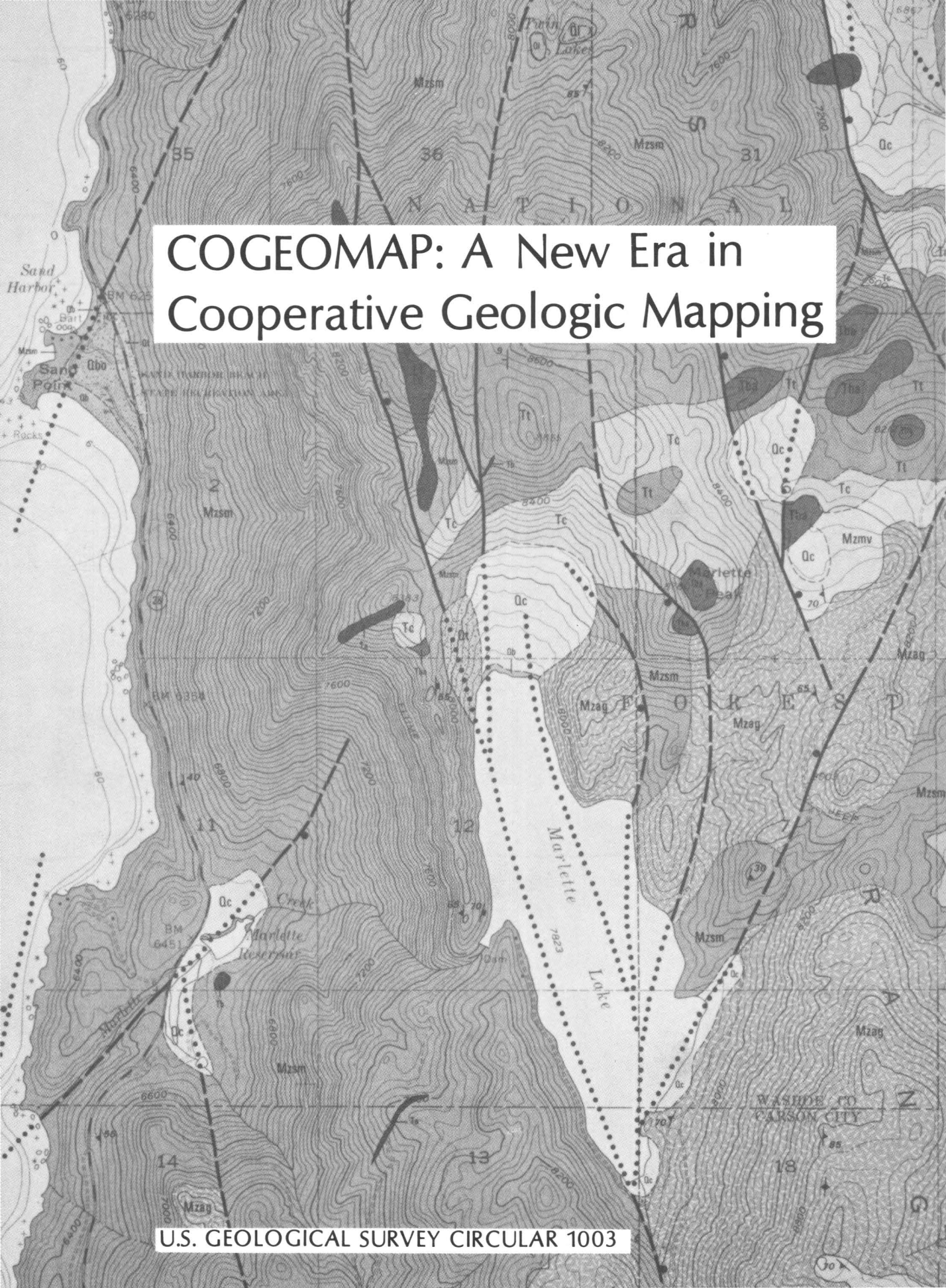

COGEOMAP: A New Era in Cooperative Geologic Mapping

U.S. GEOLOGICAL SURVEY CIRCULAR 1003

Cover: A portion of the Marlette Lake, Nevada, 7.5-minute quadrangle mapped by T.L.T. Grose with the support of the COGEOMAP program and published by the Nevada Bureau of Mines and Geology in 1986.

COGEOMAP: A New Era in Cooperative Geologic Mapping

By JUERGEN REINHARDT and DAVID M. MILLER

The partnership between the Federal and State governments described in this document has brought renewed attention to the task of providing up-to-date geologic and geophysical maps for the Nation at a variety of scales

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COGEOMAP: A New Era in Cooperative Geologic Mapping

By Juergen Reinhardt *and* David M. Miller

Abstract

A program of cooperative geologic mapping was established between the U.S. Geological Survey and the State geological surveys in fiscal year 1985. The main purpose of the program is to increase general-purpose geologic mapping throughout the Nation. By combining State and Federal resources for geologic mapping through this cooperative program, new mapping has been started, and both geologic and geophysical maps that resulted from the program have already been published.

The program grew from mapping projects in 18 States in fiscal year 1985 to a program involving 29 States in 1986, as the combined State and Federal resources in the program grew from about $2 million to nearly $3 million. As the program enlarges its scope, it faces the challenge of producing high-quality maps with uniform standards while promoting the use of new technologies to increase the speed of geologic and geophysical mapping and map production.

Introduction

The Federal-State Cooperative Geologic Mapping (COGEOMAP) program, initiated in response to the increased needs for geologic maps, was designed to promote new geologic mapping that meets high-priority Federal and State objectives. Elements of the program support detailed geologic mapping, preparation of State geologic maps, acquisition of geologic and geophysical data to further understand geologic map relations, and preparation of a State digital geophysical map series. The program began in Federal fiscal year (FY) 1985 with $1.0 million in appropriations and was expanded in FY 1986 to $1.5 million. It is hoped that COGEOMAP will continue to grow in order to meet all of the State requests for cooperative geologic mapping that are consistent with the program objectives.

The program was designed through joint discussions and planning by the U.S. Geological Survey (USGS) and many State geological surveys. In particular, State Geologists, especially working through the Association of American State Geologists Liaison Committee, have encouraged the growth and cooperative nature of COGEOMAP from its inception. This Circular describes the development of COGEOMAP during FY 1985 and 1986, the present state of the program, and plans for the program in the future.

A Union of Resources

The fiscal and human resources for geologic mapping have been extremely limited recently for both the USGS and State geological surveys. COGEOMAP has combined the available monetary resources and personnel to support new geologic mapping projects of the highest priority. In many cases, the State geological surveys have provided mapping personnel and logistical support (services in kind) for projects, while the USGS has provided monetary support, laboratory services and facilities, and regional mapping expertise. The projects are for the most part constituted on a 50:50 Federal-State matching basis, where the Federal portion may not be more than one-half of the total project funding.

COGEOMAP was initiated as a cooperative USGS-State geological survey program during FY 1985, covering the costs of 21 projects in 18 States. In FY 1986, the program expanded to 31 projects in 29 States.

Initial plans for the program were discussed with State Geologists at the annual USGS-State survey coordination meetings with clusters of States in the eastern, central, and western regions during FY 1984. The States' evaluations of the program were incorporated into a prospectus and a Request for Proposal and sent to each State survey in the spring of 1984. The initial timetable for submitting project proposals was flexible, and the proposal format was kept informal to encourage a broad range of proposals and to keep the discussion of projects as open as possible.

The overwhelming response by the State geological surveys necessitated clearer definition of both the format for proposals and the range of proposal types for the second year of the program. As a result, the proposal format for FY 1986 was more structured, and the entire

program was closely coordinated with the USGS Branch of Procurement and Contracts. The USGS has, however, tried to maintain an open and direct dialog with the State geological surveys during the evolution of this program, because without the full cooperation and interest of the State surveys, COGEOMAP cannot hope to meet the geoscience mapping needs of both the Federal and State governments.

COGEOMAP strives to avoid duplication of effort with other USGS programs. In some cases, topical studies in projects from other programs are augmented by work done under COGEOMAP to produce geologic maps. Whereas most other USGS programs focus on national needs, COGEOMAP focuses on geographic areas where both the USGS and State surveys have common interests in the geologic information to be obtained.

History of the Federal-State Partnership in Geologic Mapping

For many years, the USGS has cooperated closely with many States in the preparation of State geologic maps; the most recent publication from such cooperation is the Wyoming State geologic map. Other cooperative programs, both formal and informal, have produced State geologic maps of Kentucky, Massachusetts, Connecticut, Colorado, Arkansas, and the Commonwealth of Puerto Rico. The following brief histories of a few past cooperative programs provide a background for the evolution of COGEOMAP.

Kentucky

The U.S. Geological Survey began a cooperative program with the Kentucky Geological Survey in 1960 to map the geology of the entire State at a scale of 1:24,000. The program was completed in 1978 with the publication of the last of 707 U.S. Geological Survey geologic quadrangle reports. The total cost of the project was just under $21 million, shared equally by the Federal Government and the State. In addition to the geologic quadrangle maps, the program yielded well over a hundred topical reports, culminating in detailed descriptive reports of the rocks by age group, a geologic map of the entire State at a scale of 1:250,000, and an explanatory summary of the geology of the State. In addition, the detailed geologic base maps have attracted earth scientists from numerous universities to conduct topical research, thus expanding the understanding of the geology of Kentucky at little or no cost to the State. The economic benefit of the program to the State has been estimated as greater than $1 billion, or more than 50 times the cost of the program.

Puerto Rico

A cooperative mapping program between the Puerto Rican Development Corporation and the USGS, begun in 1952, was aimed at providing the Government of Puerto Rico with economic assistance by assessing the island's mineral resources. The lack of adequate geologic maps for such an assessment, however, forced a reorientation of the original program. The program was revised to complete geologic mapping of the island's 62 1:20,000-scale quadrangles. A reduction in funds available to the Department of Natural Resources (DNR), the cooperator to succeed the Puerto Rican Development Corporation, forced an end to the cooperative in 1978. The USGS continued the study independently as resources permitted, and all but 2 of the 62 quadrangles have either been published or are in the final printing process. A color geologic map of the island, at a scale of 1:100,000, is also nearing completion. The geologic mapping and topical studies undertaken by the USGS-DNR cooperative have provided important information on mineral resources as well as for urban planning and hazard mitigation, especially for landslide hazards.

Massachusetts

The Massachusetts Cooperative Project was started in July 1938 with the objectives of preparing modern bedrock and surficial geologic maps of all of the State's 7.5-minute quadrangles and eventually publishing State bedrock and surficial compilation maps. Engineering studies along proposed highway routes and strategic minerals surveys also were conducted under the project during World War II. Funding levels gradually increased during the life of the project and reached a maximum in the late 1970's, when the combined State and USGS budget for the project exceeded $400,000. The project ended officially in September 1982.

During the tenure of the project, 100 colored maps of 7.5-minute quadrangles were published, including maps of bedrock geology, surficial (glacial) geology, or both. In addition, a similar number of quadrangle maps were released in a less formal, uncolored series. Another 100 maps of smaller, larger, or irregularly shaped areas were also released, many having been prepared as specific site studies along proposed highway routes. In 1983, a color bedrock geologic map of the State was published at a scale of 1:250,000. A surficial geologic map at 1:125,000 is nearly complete. These maps have benefited studies concerning water resources, hazardous material disposal sites, and mineral resource exploration, in addition to providing vital background information for planning around urban centers.

Cooperation—The Key to Success

The guiding principle of cooperative arrangements under previous cooperatives and under COGEOMAP

recognizes that it is both expedient and cost effective to jointly identify the highest priority geologic mapping needs for the Nation and individual States. The specific instruments used for consummating these cooperative agreements have been streamlined to minimize the amount of paperwork needed to transfer monies between the USGS and the specific States. Each project represents shared financial support for geologic studies; in many cases the Federal share consists of both cash and services in kind, and the State share consists mostly of services in kind. The specific financial sharing arrangement for the first 2 years of the program is shown in table 1.

COGEOMAP is one component of a larger program called the Geologic Framework and Synthesis Program administered by the Office of Regional Geology within the Geologic Division of the USGS. The Office of Regional Geology is responsible for coordinating the geologic mapping activities within the USGS and providing leadership and coordination for the National Geologic Mapping Program, which encompasses geologic mapping activities of other Federal agencies, the States, and universities.

Although COGEOMAP has supported many geologic mapping activities, the program has not become an "umbrella" for all prior formal and informal cooperative mapping arrangements between the USGS and State geological surveys. Rather, the program has facilitated new geologic mapping projects involving cooperation between the States and the USGS. In addition, COGEOMAP has increased and improved communication between geologists and managers of the USGS and the various State geological surveys through the joint planning process.

Based on the needs of both the States and USGS, COGEOMAP includes several types of projects. In one type, staff of the State geological survey conduct the geologic mapping with the advice and review of USGS staff. A second type more directly involves USGS geologists, both in the field and in the laboratory, supplying information to support mapping by the State surveys and to provide the regional framework for the geologic mapping projects. In a third type, the State provides cash support for USGS geologists to conduct studies. A fourth type of project involves compilation and synthesis of digital geophysical data for State digital geophysical maps. The range of products included in the cooperative program is described in the "Annotated List of Projects" section of this Circular.

Program Priorities—Greatest Needs for Geologic Mapping

COGEOMAP priorities are designed to anticipate the demands placed upon both the State geological surveys and the USGS for applied earth-science information, especially for mineral or energy resources, geologic hazards, and geologic engineering. The justification for geologic mapping is the same as in any program: adequate geologic baseline information is necessary before an agency can respond quickly and accurately to specific questions having an earth-science component. COGEOMAP strives to achieve a balance between maps useful to individuals and maps produced for a National overview. Three primary program priorities were designed to provide the necessary baseline geologic information: two are for producing and compiling geologic maps, and the third is for producing digital data and geophysical maps.

The first priority is to conduct multiyear, multidisciplinary, large- and intermediate-scale geologic mapping projects of interest to the USGS and State geological surveys. Many of these projects conduct bedrock and surficial geologic mapping aimed at producing 7.5-minute and 15-minute quadrangle maps. In addition, county geologic maps at an inch-to-the-mile scale (1:62,500) and intermediate-scale (1:100,000) geologic maps are included. A map's usefulness for site-specific studies is directly proportional to its scale. Special emphasis is given to making maps in areas where geologic information is needed and large-scale geologic map coverage presently is inadequate. As such, the immediate goal is to produce high-quality geologic maps in areas of high priority for both the States and the Nation, rather than promoting complete coverage of entire regions or States. In many cases, other USGS programs have used small-scale mapping and compilation to synthesize geologic data over broad geologic and physiographic regions; in contrast, COGEOMAP tends to focus on the need for more detailed information that can be satisfied only through larger scale geologic mapping.

Utilizing chronostratigraphic and (or) biostratigraphic data is especially important in these new large- and intermediate-scale mapping projects. These data help to verify the stratigraphy and geologic structure of a region and provide geologic cornerstones for future geologic mapping.

COGEOMAP's second priority is to provide monies and personnel for major revisions of State geologic maps. Prior to the COGEOMAP program, the USGS budget had no place for projects in support of State geologic map preparation and publication. This activity not only helps focus attention in both State and Federal agencies on specific areas in which geologic data are lacking but it makes especially obvious the areas of inconsistency between existing local maps during the compilation and preparation of State geologic maps.

This second priority may include small-scale (1:250,000) geologic mapping projects that are intermediate steps to the longer term goal of completing a new State map, as in the case of the COGEOMAP projects in Virginia and Arizona. Several types of activities are especially useful in support of State geologic maps. First,

Table 1. Summary of COGEOMAP funding

[Does not include funding for the State Geophysical Map project; services in kind include mapping personnel and logistical support; values are in thousands of dollars]

State	State funds		Federal funds		Total
	Cash	Services in kind	Cash	Services in kind	
Fiscal year 1985					
Alaska	0	111	0	58	169
Arizona	0	65	46	19	130
Arkansas	0	50	20	30	100
Connecticut	0	10	10	0	20
Illinois	0	100	100	0	200
Maine	0	7	7	0	14
Maryland	0	65	25	40	130
Minnesota	0	41	20	0	61
Nevada	0	18	18	0	36
New Hampshire	0	10	10	0	20
New Jersey	200	0	0	200	400
New Mexico	0	20	20	0	40
Oklahoma	0	75	35	40	150
Oregon	0	110	0	110	220
Tennessee	0	55	0	55	110
Vermont	0	6	6	0	12
Virginia	0	98	20	0	118
Wyoming	0	18	18	0	36
Total	200	859	355	552	1,966
Fiscal year 1986					
Alabama	0	58	35	23	116
Alaska	0	61	44	10	115
Arizona	0	82	63	19	164
Arkansas	0	70	40	30	140
Hawaii	35	0	0	35	70
Idaho	0	43	6	0	49
Illinois	0	138	100	15	253
Louisiana	0	26	4	0	30
Maine	0	15	15	0	30
Maryland	0	45	0	45	90
Minnesota	0	20	20	0	40
Montana	0	21	17	0	38
Nebraska	0	26	10	8	44
Nevada	0	21	18	0	39
New Hampshire	0	20	20	0	40
New Jersey	0	293	0	290	583
New Mexico	0	20	10	10	40
North Carolina	0	12	12	0	24
Oklahoma	0	120	70	50	240
Oregon	0	79	24	45	148
South Dakota	0	15	0	15	30
Tennessee	0	55	0	55	110
Texas	0	41	41	0	82
Utah	0	30	30	0	60
Vermont	0	9	0	9	18
Virginia	0	70	20	0	90
West Virginia	0	58	15	42	115
Wisconsin	0	24	0	24	48
Wyoming	0	18	18	0	36
Total	35	1,490	632	725	2,882

States sometimes can benefit from consulting with the USGS on the preparation of a State map. Second, monetary support makes workshops, field conferences, and other consultation possible. Third, new Federal or State geologic mapping can be supported in those areas where existing geologic maps are not sufficiently detailed or are in disagreement with more recent studies. Combining such efforts can make State geologic maps both state-of-

the-art representations of our geologic knowledge and valuable planning documents for more detailed mapping projects.

COGEOMAP's third general program priority is to support the compilation of digital geophysical maps and digital geophysical data. The project funded by COGEOMAP to produce a State digital geophysical map series is within the Office of Mineral Resources, Branch of Geophysics. In addition to supporting this project to produce digital State maps, COGEOMAP is also attempting to strengthen the tie between the use of digital geophysical data and geologic mapping. In a number of cases, the program has encouraged the cooperative and concurrent compilation of geologic maps and geophysical data to give a better three-dimensional picture of the Earth's crust.

The State digital geophysical map series is unique in the COGEOMAP program in that it is funded entirely by the USGS. For States that have sufficiently complete coverage, geophysical data are compiled and manipulated digitally.

The primary products of the State Geophysical Maps project are black-and-white contour maps of the complete Bouguer anomaly gravity field, magnetic field maps, and radiometric maps showing the surface concentration of potassium, uranium, and thorium. These maps are prepared at the same scale as the State geologic map and thus augment the geologic map. In addition to the map products, digital tapes are made available through the EROS Data Center in Sioux Falls, South Dakota. Numerous subsidiary map products for the three basic geophysical data sets can be made and generally are published in color at smaller scales than the State geologic map.

In the process of formulating new geologic map products, geologists approach geologic mapping in a variety of ways. The COGEOMAP program, as part of the National Geologic Mapping Program, is concerned with bringing appropriate standards to geologic mapping, and in particular to the map products resulting from this program. As COGEOMAP develops, this issue of standardization in map products is becoming a fourth priority for the program. Strong interest of the State geological surveys in geologic map standards seems to be unanimous, and the States are encouraging the USGS to promote standards for compilation and production of geologic maps at various scales. During a time when technological advances are making it possible to speed the compilation and production of map products, COGEOMAP is also working with States (Wyoming and Illinois, for example) in the cooperative transfer of new technologies.

Getting a Project Started

The present procedure for project selection can be summarized as follows: (1) early solicitation of informal project proposals from the States; (2) discussion of these informal proposals with the various science managers within the Geologic Division; (3) a formal Request for Proposal solicited through the Branch of Procurements and Contracts with a complete contracts package sent to each State geological survey; (4) formal review of the State geological survey proposals by managers throughout the Geologic Division; (5) panel review, discussion of proposals, and selection of projects; and (6) negotiation with State geological surveys by the Branch of Procurement and Contracts and awarding of contracts for cooperative geologic mapping.

Several steps in the selection process merit additional explanation. The review of informal proposals by the various science managers in the Geologic Division (step 2) is intended to increase the interchange between project scientists and to improve the scientific aspects of the proposals by ensuring that individuals and facilities are available to adequately support possible projects. This step also provides feedback on the National perspective of the State's high-priority problem. The formal review (step 4) is conducted specifically by those USGS managers whose scientists are likely to be involved directly with projects proposed by a State. The Assistant Chief Geologist for Program, the Office Chief of Regional Geology, the Project Chief of the State Geophysical Maps project, and the Program Coordinator for COGEOMAP served as the selection panel (step 5) during FY 1985 and 1986.

The review of proposals is based on published selection criteria; these criteria are included in the Request for Proposal sent to each State geological survey and are listed below. Proposals are evaluated by the USGS panel following review by the science managers of the USGS branches directly involved in, or closely affected by, the cooperative geologic mapping projects. The proposals are ranked by region, using three regions of the United States as defined by the Geologic Division, in order to ensure that projects are not concentrated in one area of the United States. The managers evaluate various scientific aspects of the proposal, which in 1985 were:

1. Does the proposal address a high-priority mapping problem?
2. Are the proposed project personnel well qualified to carry out the mapping?
3. Is the work plan conceived within a reasonable and realistic time frame?
4. Are the available support services adequate to resolve structural, time-stratigraphic, and biostratigraphic problems?

In addition to the scientific evaluation, the USGS selection panel considers programmatic criteria in ranking the proposals. The programmatic criteria for selection are:

1. Does the proposal fit the program priorities for (a) new large- and intermediate-scale geologic mapping and for (b) conceptualizing and compiling State geologic maps?
2. Does the proposal indicate that a sufficient level of joint planning between the USGS and the particular State geological survey has taken place to ensure a good working arrangement?
3. Does the proposal conflict with or complement other cooperative projects between the USGS and the State geological survey?
4. Are the benefits of the mapping program in line with the proposed budget and work plan?

Projects selected for their scientific and programmatic merit are sent by the Office of Regional Geology to the Branch of Procurement and Contracts, which evaluates the fiscal data in the proposal and informs the States of required changes.

Once the projects have been selected within the limitations of the budget authority established by Congress, the Branch of Procurement and Contracts completes the contracts with the States. In cases where monies are transferred to the USGS from the States or in cases where the cooperative agreement requests matching services with no cash flow, the Chief Geologist prepares a Joint-Funding Agreement to serve as the official fiscal agreement. The informal proposal process begins in May of the year prior to the initiation of a project; the selection process is completed near the beginning of the fiscal year (October 1); and the contract is awarded prior to the beginning of the contract period, typically from January 1 to December 31. Projects may, however, have any starting date and can be of a duration longer or shorter than 1 year.

Annotated List of Projects

The following list summarizes the projects funded by the COGEOMAP program during FY 1985 or 1986. The descriptions indicate the variety of objectives and the multiplicity of potential applications. Table 2 contains topical and map-scale information about the projects, and figure 1 shows the geographic location of the projects.

Alabama

A 2-year project entitled "Stratigraphic Framework of the Black Warrior Basin" is attempting to identify a workable stratigraphic subdivision of Pennsylvanian coal-bearing units in the Black Warrior Basin. The surface and subsurface study will concentrate on the Jasper intermediate-scale quadrangle and adjoining areas. Results of the work will have broad applications to coal resource models for other parts of the Appalachian Basin and provide detailed information for coal resource analysis in northwestern Alabama.

Alaska

A 2-year project concerning the surficial geology of the western Arctic Coastal Plain within the Arctic National Wildlife Refuge was started to delineate the distribution, age, and physical characteristics of the late Cenozoic deposits. The geologic map products of this project are also designed to show geomorphic and structural features in sufficient detail to allow informed land-use decisions in this potentially oil-rich and environmentally sensitive area.

Another 2-year project entitled "Kenai Peninsula Tertiary Basin and Coal Resources" will produce maps showing compilations of geologic data related to Tertiary coal-bearing strata. The products of the project will provide a modern and complete geologic analysis of the Tertiary sedimentary rocks on the southern Kenai Peninsula and will aid in the effective management of the coal resources and the land.

Arizona

In the past 5 years, geologists from the State Geological Survey and the USGS have jointly worked toward completing a new geologic map of Arizona. It has been mutually agreed that the State survey would concentrate its mapping in the Phoenix 1°×2° quadrangle and adjacent parts of west-central Arizona. In the past 4 years, State geologists have completed 1:24,000-scale geologic maps of many ranges and are now continuing their studies under a COGEOMAP project. New mapping was in the Bighorn, Belmont, and Hieroglyphic Mountains; this mapping, along with coordinated geochronology and mineral resource studies, has made major strides toward understanding complex Tertiary stratigraphy and structure. The State map project will continue until about 1990.

Arkansas

See Oklahoma and Arkansas

Connecticut

This 1-year project involved mapping of critical lithofacies in the Lower and Middle Jurassic intervals of the Hartford Basin. Identification of major conglomeratic lobe deposits and their facies relations to gray-black shale

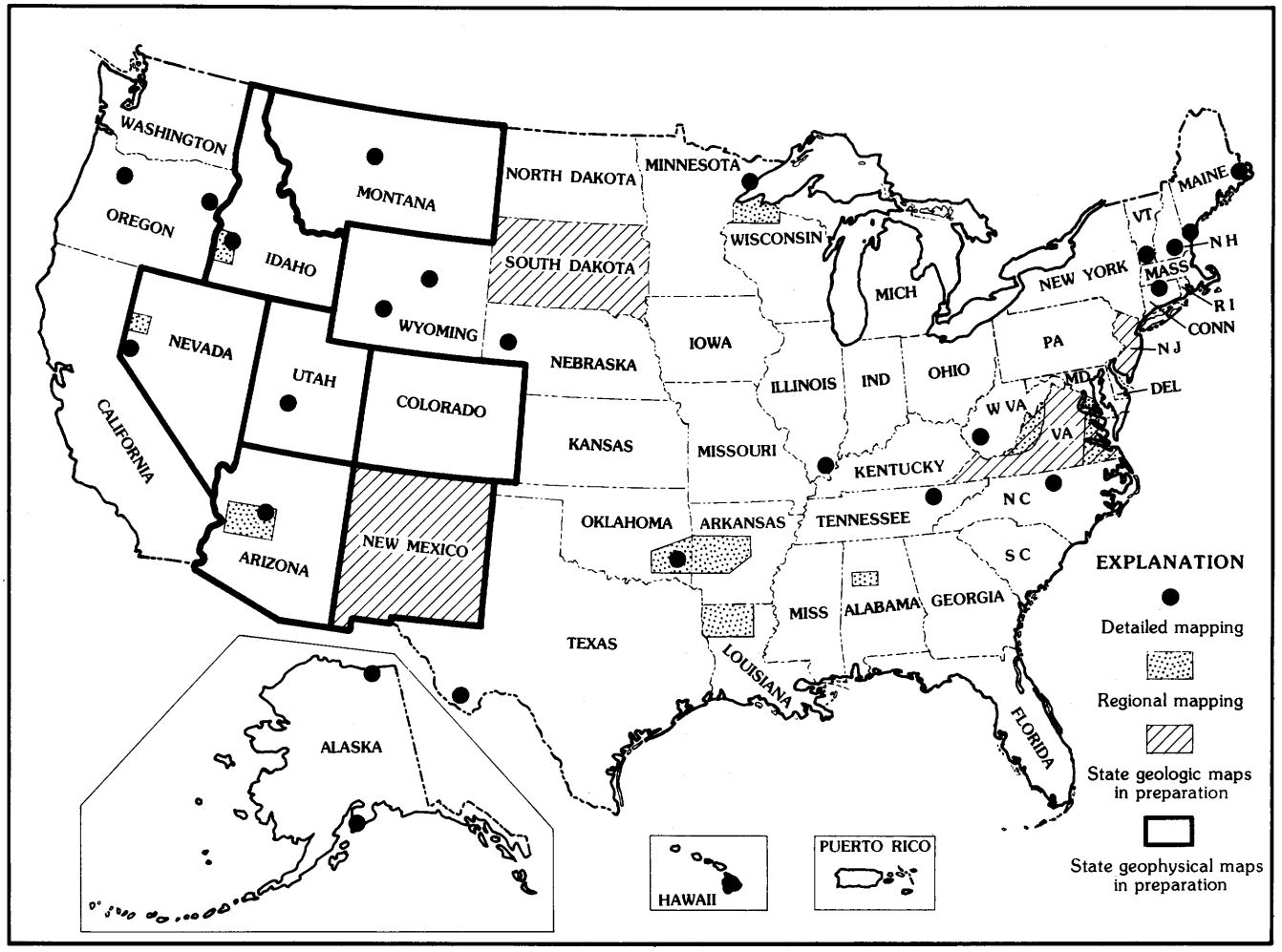

Figure 1. Location of COGEOMAP projects

beds indicate that earlier mapping in the area is simplistic, misleading, or incorrect.

Hawaii

A new geologic map of the "Big Island," based on modern data and methods, is needed for geothermal, volcano hazard, and ground-water assessments. Detailed mapping of selected areas will complete modern mapping of the Island of Hawaii. Mapping is needed in about one-third of the island covering about 10 7.5-minute quadrangles and parts of several others. This project is expected to continue through FY 1988, when a map of the island at 1:100,000 will be completed.

Idaho

A project entitled "Late Cenozoic Geology of the Boise 1°×2° Quadrangle" involves study of the area's Cenozoic sedimentary and volcanic rocks to determine the volcanic, climatic, and tectonic history of the basin. Results will be applied to petroleum exploration, geothermal and mineral-resources exploration, and ground-water studies. This is a long-term project that will produce numerous short-term, large-scale map products.

Illinois

"Southern Closure of the Illinois Basin" is a project along and beyond the southern limit of glacial drift in Illinois. The bedrock is primarily the Lower Pennsylvanian coal-bearing sequence but includes rocks as old as Silurian. The coal that these rocks contain has the highest heating value of any coal in the Illinois Basin, and many of the coal beds are thought to have a relatively low sulfur content. The mapping promises to stimulate and guide new exploration for oil, gas, coal, minerals, and construction aggregate, all of which are known to occur in the study area. This project is well under way and may be completed prior to its projected end in FY 1989.

Louisiana

"Geologic Map of Shreveport 1°×2° Quadrangle" is a project designed to begin a new compilation of the surficial geology of Louisiana to be published as 1:250,000-scale quadrangle maps. Studies of the State's surficial geology are critical in land-use planning and mitigation of land loss due to coastal erosion or river flooding.

Maine

The project "Bedrock Geology of Eastern Washington County" focuses on the need for bedrock geologic maps in southeastern Maine. Major concerns in this study include rapid crustal subsidence, relatively high seismic activity, and the problems of hazardous waste disposal and possible ground-water contamination by area industries. In addition, there is renewed interest in mineral resources associated with Lower Devonian volcanic and plutonic rocks.

A second project, entitled "Surficial Geology of Southwest Coastal Maine," recognizes that detailed surficial geologic mapping is needed in areas of high population and development potential. Information gained will aid in land-use planning and ground-water protection.

Maryland

New geologic maps of Charles and St. Marys Counties (present edition 1939) will address both scientific and applied geologic objectives. Scientifically, the relation of structural zones to basement structures is being addressed. On the applied side, studies are designed to determine the location, quality, and quantity of sand and gravel resources, which may be critical during this period of urban expansion. The geologic mapping has already been completed and the applied studies are now in progress.

Minnesota

The Finland-Beaver Bay area of the Middle Proterozoic Duluth Complex bridges previously mapped areas of the coeval North Shore Volcanic Group along the north shore of Lake Superior and areas well inland along the basal part of the Duluth Complex. Geologic mapping will provide a better understanding of the tectonic and magmatic processes in hypabyssal and plutonic environments of the Midcontinent Rift System. The Duluth Complex has received considerable economic interest ever since the discovery of a marginally commercial copper-nickel deposit. Interest in the complex also stems from the recent recognition of platinum-group elements, which may occur in economic quantities. Good progress is being made in this large-scale mapping project, which is expected to continue until FY 1989.

Montana

A project entitled "Geologic Map of the Great Falls 1°×2° Quadrangle" involves mapping the southeastern quarter of the Great Falls quadrangle at a scale of 1:100,000 for eventual contribution to a new State geologic map. This quadrangle contains the most complex geology within the Great Falls 1°×2° quadrangle and is now about 80 percent mapped, with completion of field work anticipated in 1987. Geologic mapping will contribute to landslide assessment and ground-water and mineral-resource applications.

Nebraska

This project will map Morrill County at a scale of 1:62,500. Excellent exposures of the Cenozoic strata are widespread in the region, allowing the stratigraphic problems of western Nebraska to be addressed. Selected Oligocene and Miocene volcanic ashes will be studied geochemically. These data will help in assessment of regional water resources and mammalian biostratigraphy. Further, the project should provide a partial history of volcanic activity in the Western United States.

Nevada

This is a two-part, 1-year project. Mapping of the Steamboat 7.5-minute quadrangle will contribute to detailed geologic knowledge of the Reno area, useful for a variety of societal reasons. Compilation of the Kumiva Peak quadrangle (1:100,000 scale) also will be completed with COGEOMAP support, leading off the new State publication series at this scale by publishing the geology in the urbanized Reno corridor.

New Hampshire

The State of New Hampshire needs detailed modern surficial maps to aid in land-use planning, evaluation of ground-water supplies, and development of sand-gravel and mineral resources. An extensive program of surficial mapping has been planned for (1) the Merrimack Valley, (2) the coastal region, (3) the Connecticut Valley, and (4) the Saco and Androscoggin River drainages. The project, using faculty members and graduate students, is attempting to fulfill specific needs of the New Hampshire State surficial map project.

New Jersey

The present State geologic map (1:250,000 scale), published in 1910–12 and revised in 1931 and 1950, is

the oldest State geologic map in the Eastern United States. A new map is needed to clearly and completely describe the present geologic data base for the State and present stratigraphic, tectonic, and surficial geologic units within a modern regional lithotectonic framework. The new 1:100,000-scale State geologic map, which should be completed by FY 1990, will greatly augment the aquifer studies mandated by the New Jersey Water Supply Master Plan.

New Mexico

The "Geologic Map of New Mexico" is a multiyear project to revise the 1965 edition of the State geologic map of New Mexico, particularly to incorporate abundant new geologic information on volcanic units in the southwestern and south-central part of the State.

North Carolina

"Geology of the Northeast Durham 7.5-minute Quadrangle" is a project to map in detail sheetlike diabase bodies in Mesozoic strata near Durham to determine their character and structural relations. The mapping is expected to contribute to a better overall understanding of Mesozoic basins, which are widespread in the Eastern United States, and to the understanding of the strategic and critical mineral resources associated with diabase.

Oklahoma and Arkansas

A project entitled "Ouachita Mountains of Oklahoma and Arkansas" was designed to increase understanding of the geologic history and framework of the Ouachita Mountains and to compare that history and framework with those of surrounding regions, especially the southern Appalachian Mountains and the southern edge of the North American craton. Two tasks that will accomplish this goal are (1) completing the detailed geologic mapping of the Oklahoma part of the Ouachitas and (2) collecting and interpreting geophysical data that recently have been obtained for the Ouachitas in both States. The resulting maps and interpretations will be major contributions to petroleum and natural gas exploration, as well as exploration for copper, lead, zinc, barite, mercury, vanadium, and other mineral commodities.

Oregon

The project entails geologic mapping of several 7.5-minute quadrangles in eastern Oregon and study of their mineral deposits. The quadrangles lie in a complex belt of Paleozoic and Triassic greenstone, argillite, chert, and mafic rocks that were intruded by Jurassic quartz diorite. The project is part of a new detailed geologic mapping effort by the State.

South Dakota

This 3-year project will update the geology and publish a new version of the 1953 State map, which is out of print. The scale will be 1:500,000; the USGS will publish the map.

Tennessee

The goal of this project is to use the framework established by 7.5-minute quadrangle maps in Kentucky and extend it throughout the Tennessee part of the Pine Mountain overthrust block. Detailed mapping here will contribute to coal and hydrocarbon resource evaluations.

Texas

Geologic mapping of the Christmas Mountains and Hen Egg Mountain 7.5-minute quadrangles will outline the details of an early Tertiary alkaline intrusive complex in west Texas. Petrologic and geochronologic studies will be coordinated with the mapping. The results of these studies will complement mineral-resource investigations and contribute to future compilation of the Emory Peak-Presidio (1:250,000 scale) quadrangle, which is currently out of print.

Utah

The Quaternary history of the Sevier Desert will be outlined in a 2-year project aimed at understanding the origin of the basin and the history of the Sevier River. Complex interactions among rivers and lakes in Pleistocene and Holocene times and shifting deltaic depocenters will be examined. The history of Lake Bonneville in the Sevier arm will be fully documented. The results of this work will be applied to studies of ground-water and surface-water hydrology, mineral resources, and seismic hazards.

Vermont

Vermont has been faced with serious decisions concerning the exploration and potential exploitation of uranium and other radioactive mineral resources, the exploration for hydrocarbons in the northern extension of the Eastern Overthrust Belt, and the search for a high-level radioactive waste repository in crystalline rocks. The COGEOMAP project has focused on obtaining detailed knowledge about Proterozoic core sequences including the Green Mountain Massif and the Athens and Chester Domes. The intent is to extend into Vermont the structural

and stratigraphic framework previously established by detailed mapping of the Precambrian and associated "cover sequences" in Massachusetts.

An additional supportive mapping project involves remapping of Paleozoic Taconic and Acadian terranes in light of the modern accretionary terrane model. A reevaluation of stratigraphic units as tectonically created units is now under way. The initial map products of these projects will be at 1:24,000 scale or smaller, while the long-term goals include new bedrock and surficial maps of the State. The large-scale maps (1:24,000 and smaller) are thought to be essential for supporting the State's programs of ground-water protection, solid and hazardous waste disposal, mineral-resource assessment, slope stability studies, and land-use planning.

Virginia

The project "Tectonic Map of Western Virginia" involves study of the Eastern Overthrust Belt in Virginia. The map and accompanying cross sections will show the relation between surface and subsurface geology, thus aiding in oil, gas, and coal exploration. This project will contribute toward the multiyear compilation and completion of a new State geologic map; "The Coastal Plain of Virginia" (1:250,000 scale), a compilation map, has already been completed under COGEOMAP.

West Virginia

The project "Geologic Mapping in Southwest West Virginia" is designed to map 7.5-minute quadrangles that delineate the stratigraphically complex region between Kanawha and Mingo Counties. This project will produce geologic quadrangle maps that will complement USGS Branch of Coal Resources studies in the area, which are being conducted as part of the Evolution of Sedimentary Basins Program.

Wisconsin

Bedrock geology of the Superior 1°×2° sheet will be prepared as part of an 8-year effort to compile a new State map. The Superior sheet includes Precambrian rocks that contain extensive iron and copper deposits; the new geologic mapping may better define the potential of these deposits, in addition to determining the potential for base and precious metals, oil, gas, and uranium.

Wyoming

One project is a 3-year effort to map the South Pass greenstone belt of the southern Wind River Mountains at the 7.5-minute quadrangle scale. Maps of accessible underground mines also will be made. The area is underlain by an Archean supracrustal sequence of metasedimentary and metavolcanic rocks and granitoids that host known precious metal and iron deposits; the geologic maps will aid and stimulate further exploration for these commodities.

A second project will map 7.5-minute quadrangles over a 10-year period on the southeastern side of the Bighorn Mountains. The area is a poorly mapped region of Paleozoic strata that is a major recharge area for Paleozoic aquifers and Mesozoic strata that have potential for shallow oil or tar sand.

State Digital Geophysical Map Project

- Gravity maps, including derivative products, have been prepared for Ohio, Nevada, and Idaho and are under way for Montana and Utah.
- Magnetic maps, with derivative products, have been prepared for Ohio and Nevada and are under way for Montana and Utah.
- Radiometric maps have been completed for Ohio, Nevada, New Mexico, and Utah and are under way for Arizona and Colorado.

Future Directions

COGEOMAP will evolve in the next few years as needed to meet more effectively the needs of State and Federal participants. Although specific modifications are difficult to predict, some needs for change can be anticipated, including expansion to meet State offerings that currently far exceed Federal appropriations, incorporation of the program into a new National geologic mapping plan, and some modifications in operation.

Even with an expansion of Federal appropriations by 50 percent in FY 1986, several high-quality State proposals could not be accepted and other cooperative projects had to be limited in scope. FY 1987 proposals have offered about $3 million in State matching funds, indicating that the program could experience significant increases from the FY 1986 appropriation before meeting State needs. The chief limitation on offerings by States is probably imposed by the financial resources and the number of professional staff members employed by the State geological surveys; the constraints limit the number of projects that can be undertaken. Requested Federal contributions to projects currently range from $4,225 to $290,000, with the majority of the projects being relatively small. Of these projects, only New Jersey approaches the scale of previous cooperative projects like

Table 2. COGEOMAP project descriptions and products

State	Fiscal years	Type of study	Products
Alabama	1986	Regional stratigraphic framework	1:100,000 maps; reports.
Alaska	1985	Surficial geology, northeastern Alaska	1:63,360 compilation maps.
	1986	Geology of Kenai Peninsula	1:63,360 maps; coal resource map.
Arizona	1985-86	Geology of Phoenix quadrangle	1:48,000 maps; 1:100,000 compilation map.
Arkansas	1985-86	Geology of Ouachita Mountains	Compilation maps and reports.
Connecticut	1985	Geology and lithofacies of Hartford Basin	1:24,000 maps; 1:125,000 compilation map.
Hawaii	1986	Geology of Island of Hawaii	1:100,000 map.
Idaho	1986	Cenozoic geology of Boise quadrangle	1:24,000 map; 1:250,000 compilation map.
Illinois	1985-86	Geology of southern Illinois Basin	1:24,000 maps.
Louisiana	1986	Surficial geology of Shreveport quadrangle	1:250,000 compilation map.
Maine	1985-86	Geology of eastern Washington County	1:62,500 maps.
	1986	Surficial geology of southwestern coastal Maine	1:24,000 maps.
Maryland	1985-86	County map folios	1:62,500 map folio.
Minnesota	1985-86	Geology of Duluth Complex	1:24,000 maps.
Montana	1986	Geology of Great Falls quadrangle	1:100,000 maps.
Nebraska	1986	Geology of Morrill County	1:62,500 map.
Nevada	1985	Geology of urban areas	1:24,000 maps.
	1986	Geology of Steamboat and Kumiva Peak quadrangles	1:24,000 map; 1:100,000 map.
New Hampshire	1985-86	Surficial geology	1:24,000 maps.
New Jersey	1985-86	Geology of the State	1:24,000 and 1:100,000 maps.
New Mexico	1985-86	State geologic map	1:500,000 compilation map.
North Carolina	1986	Geology of Mesozoic basins	1:24,000 maps.
Oklahoma	1985-86	Geology of Ouachita Mountains	1:24,000 maps.
Oregon	1985-86	Geology of eastern Cascades, Blue Mountains	1:24,000 and 1:62,500 maps.
South Dakota	1986	State geologic map	1:500,000 compilation map.
Tennessee	1985-86	Geology of northeast Tennessee	1:24,000 maps.
Texas	1986	Geology of Christmas Mountains	1:24,000 maps.
Utah	1986	Surficial geology, Sevier Desert	1:100,000 map.
Vermont	1985-86	Geology of Green Mountain Massif	1:24,000 maps.
Virginia	1985-86	State geologic map	1:250,000 maps.
West Virginia	1986	Geology in southwestern West Virginia	1:24,000 maps.
Wisconsin	1986	Geologic compilation of Superior sheet	1:250,000 map.
Wyoming	1985-86	Geology of southeastern Wind River and Bighorn Mountains	1:24,000 maps.

Kentucky, Massachusetts, or Puerto Rico. The limitations on project size hamper the development of major new mapping programs and preclude the provision of multiyear funding in a lump sum. Many States can best conduct a geologic mapping project if assured of multiyear funding. If appropriations increase to the point where large outlays can be sustained, funding may be provided for 2- or 3-year intervals, allowing improved and more efficient planning and better methods for securing funds at the State level.

COGEOMAP was initiated to respond to the increasing needs nationwide for geologic maps to be applied to local, State, and National earth-science issues. Following the implementation of the program, the entire range of Federal geologic mapping activities has been scrutinized to develop new plans for a reorganized National Geologic Mapping Program that will coordinate and augment current geologic mapping. Coordination between Federal and State geologic mapping is an essential element of the new program, and COGEOMAP accordingly fits naturally into the program as a discrete element. The main changes required for the new program involve (1) reorganizing Federal mapping, (2) initiating a grants program for university mapping support, and (3) developing a coordinated plan to modernize the map-making process. Federal-State cooperatives will remain in COGEOMAP without changing its current program priorities.

Geophysical State maps are currently prepared for those States in which data coverage is sufficient at the appropriate scale (generally 1:500,000). The geophysical maps are prepared by the USGS and funded solely by a fixed percentage of COGEOMAP appropriations. If appropriations increase, it is anticipated that acquisition of the geophysical data needed to fill "holes" in inadequate data bases for State map publication will be included. This data acquisition plan should be jointly funded by the States and the USGS and proposed in much the same manner as are current geologic mapping projects.

Summary

This Circular has presented information on the development and operating philosophy of the Federal-State Cooperative Geologic Mapping program. The program, while still in its infancy, is already making significant contributions to the production of high-quality geologic maps throughout the United States. The informal joint planning process and the cooperative funding of the projects have ensured that a substantial return of information results from the expenditure of the limited resources available for geologic mapping in both the State geological surveys and in the USGS.

COGEOMAP is attempting to meet the need for (1) high-quality large- and intermediate-scale geologic maps in many parts of the United States, (2) up-to-date State geologic maps, and (3) State geophysical maps. Challenges for the program during the years ahead include bringing the standards for geologic maps being produced in the United States toward greater uniformity and promoting the use of new technologies for increasing the speed of the geologic mapping process while decreasing the time for map publication.

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