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# THE COSTS AND VALUES OF GEOSCIENCE INFORMATION

edited by

Connie J. Manson

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Cover photo: Aerial view looking east across Salt Lake City, site of the 1997 Geological Society of America annual meeting. The Wasatch Range (background) is the escarpment of a major fault with a recurrence interval of about 500 years. Photo by Tim Walsh.

# PREFACE

The Geoscience Information Society (GIS) was established in 1965 as an independent, nonprofit, professional society. Members include librarians, information specialists, and scientists concerned with all aspects of geoscience information. GIS has members from academia, business, and government from 15 countries. GIS is a member society of the American Geological Institute and an associated society of the Geological Society of America (GSA). The GIS annual meeting is held concurrently with the GSA annual meeting, and the papers and posters about geoscience information are part of that GSA meeting.

Oral presentations of the papers in this proceedings volume were given at the 1997 GSA Annual Meeting in Salt Lake City, Utah, October 19 through 23, 1997. This proceedings volume is presented in two parts:

I. Invited papers, presented at the GIS Symposium, "The Costs and Values of Geoscience Information", October 21.

II. Contributed papers, presented at the GIS Technical Section, October 22.

The papers are arranged in the order they were given. They have been edited slightly for consistency. The authors are solely responsible for the opinions and ideas expressed here.

I thank the authors both for presenting such timely, significant, and thought-provoking papers at the meeting and for crafting those papers for this volume. I especially thank Mary Krick, the co-convenor for the Symposium, and Joanne V. Lerud and Lisa Wishard, the co-convenors for the Technical Session.

This volume was prepared at the Washington Division of Geology and Earth Resources, with thanks to Kitty Reed, Jari Roloff, and Tim Walsh for their technical assistance.

Connie J. Manson
GIS President

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# THE COSTS AND VALUES OF GEOSCIENCE INFORMATION: INTRODUCTION

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In recent years, various portions of the geoscience community have been asked to justify their worth. Administrators, legislatures, and taxpayers are asking: What good is a geological survey or a bureau of mines? A geoscience library costs us a lot of money: Why should we pay for it? Are we getting our money's worth? What's in it for us?

Recently many geological surveys have experienced major decreases in funding and even closure. The Washington State survey's state funds have been reduced by 60% since 1990, and in 1994, both the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (USBM) were threatened with closure by the U.S. Congress, as part of the "Contract with America" initiative. The USGS survived, but the USBM did not. However, because some critical functions the USBM had long performed (e.g., mineral statistics gathering) are no less important today than they had ever been, those programs and many of those same program specialists were simply transferred from the old USBM to the USGS, with no significant cost savings.

Geoscience libraries have had similar experiences. In 1997, administrators within the USGS needed to reduce costs. In looking for programs that could be trimmed, they thought to reduce the serials budget of the USGS libraries, administered by the USGS Geologic Division. They viewed the $1,000,000 per year serials budget as excessive and proposed reducing that to $500,000. This proposal met with a thundering outcry from the national and international scientific community (Nature, 1997) and was later rescinded. (See Holser, this volume.)

There are other questions within the geoscience community. Why does it take so long to get a report through editing? Why do books and journals cost so much? Electronic or e-journals are not just fun and flashy, their interactivity and links to related materials make them powerful research tools--but will we still have access to those reports, in their original form, intact and unchanged, in 20 or 50 years? And who will be responsible for maintaining the "journal of record" for these e-journals in perpetuity?

These are important issues. The battles to defend the surveys (the research process) and the libraries (the research results) have been wrenching, but they also provide the opportunity to re-examine and demonstrate their value to society. If the research process and results are only a worthless extravagance, then there's no need for society to fund them. But if that process and the results ***are*** worth what they cost--in geologic hazard mitigation, engineering geology practice, mineral resource discovery--then that should be provable, both qualitatively and quantitatively. Strong arguments could then be made for their continuation.

Previous information scientists have addressed the costs and values of information (Brinberg, 1989; Deruchie, 1992; Elliott, 1992; Koenig, 1992; Repo, 1989; Schiller, 1991). Brinberg (1989) says,

> **The true function of information is to be a catalyst... The content's value lies in making better decisions, providing for the optimum combination of other resources, speeding the movement of goods and services through the economy, reducing waste, avoiding crises, and gaining a competitive advantage. In other words, information adds value and, therefore, has value to the extent that it increases the overall values of the other resources.**

Studies of the value of information have been hindered by the belief that it couldn't be done. In a classic work (Machlup, 1962), the author said,

> **It is not possible, even in the vaguest sense, to quantify the use made of any bit or piece of information.**

This belief still pervades, in the notion that "the productivity of white-collar work can't be measured" (Ken Solt, Washington Department of Natural Resources, personal communication, 1992). But it *can* be done, and it has been. A famous example was done by Margaret Graham and her colleagues at the Exxon Research Center in the mid-1970s (reported by Weil, 1980) in which the authors concluded that the observable benefits of providing information were 11 times greater than their costs. Other studies (reviewed by Koenig, 1992), found

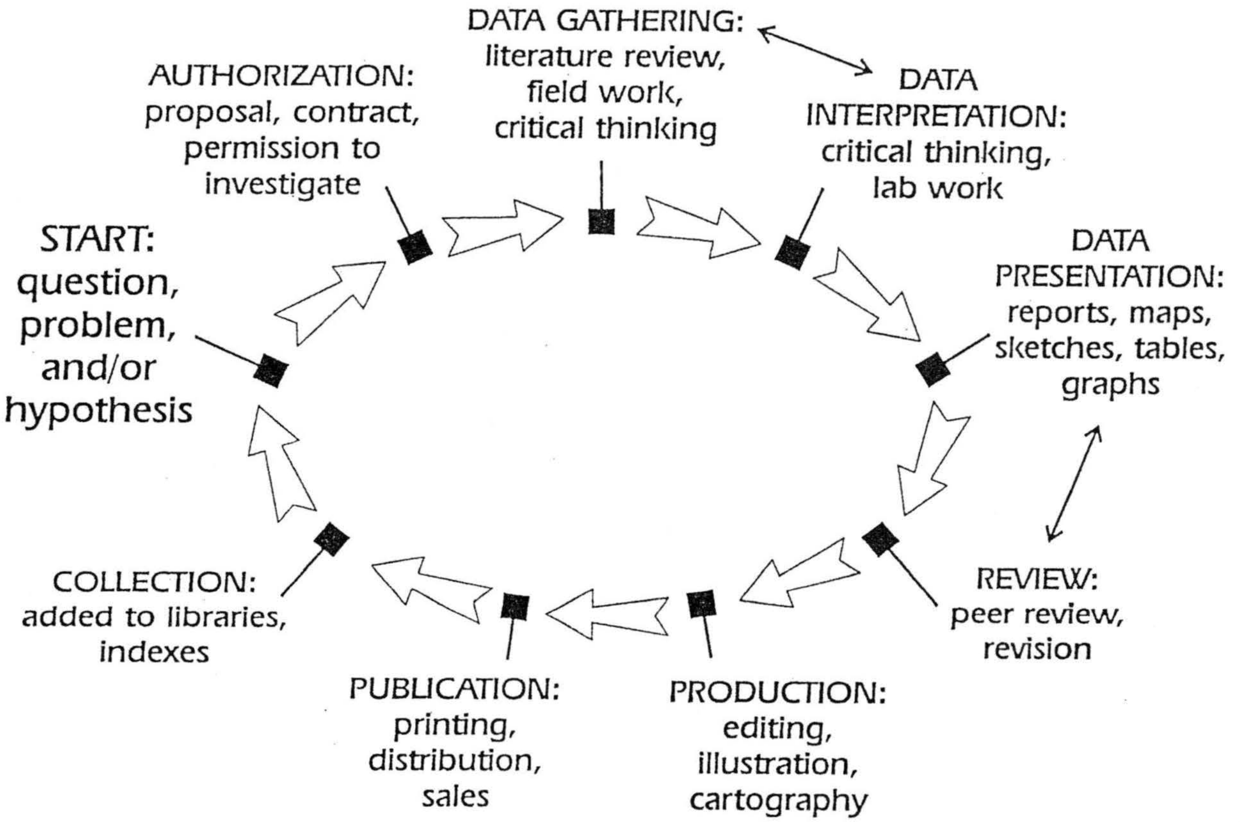


**Figure 1.** The life-cycle of the geoscience report.

less dramatic results, but in all cases examined, the benefits clearly exceeded the costs, with the benefits ranging from 2 to 8 times the costs. Similar studies of productivity in industry have found similar results (Orpen, 1985), with high productivity clearly linked to active and open use of the scientific and technical literature. A recent study of the societal value of geologic maps (Bernknopf and others, 1993) found that the benefits ranged from 2 to 4 times the cost.

The "life cycle of the geologic report" is the progression from the first idea to the final product (Figure 1). These steps are:

* The question: a hypothesis to be tested, a specific problem to be solved. *(For example, have there been earthquakes on the Cascadia subduction zone? When? Where? How big? How often? And what does that indicate about earthquake hazards in the Pacific Northwest today?*
* The authorization or funding to proceed
* The iterative process of data gathering and critical thinking
* The iterative process of presentation and review, including peer review
* Editing and illustration to produce the report
* Publication and distribution of the report
* Adding the report to libraries, indexes, and private collections, so it can be used, the next time there is a hypothesis to be tested or a specific problem to be solved.

Geology is a cumulative discipline. Experience has shown that the date a report was issued has relatively little to say about its validity, because while the understandings and techniques evolve, the rocks stay the same. So while in other disciplines the older materials are superseded by the new, in the geosciences, the older materials are the foundation for the new. In this way, the body of geologic knowledge and understanding is continually enlarged and refined, to the benefit of all.

Basic geologic research can be costly. Walsh and Reed (this volume) found that the total costs to produce a 7.5-minute quadrangle geologic map were about $100,000.

If that report is available to other researchers, however, that cost can be seen not as an expense, but as an investment. Laprade (this volume) reports on five cases in which his company was able to provide very high quality products for their clients at low cost by using the information in existing reports. Information is an unusual commodity in that it can be used repeatedly without being depleted.

Geologic publishers are seeing dramatic changes in the ways the reports are produced and delivered, as reported here by Buchanan and Carr; Walsh and Reed; Holoviak; van der Hoek; and Duff.

Librarians are seeing dramatic changes in the ways the materials are obtained and used, especially with the increasing use of interactive electronic materials, as reported here by Derksen and Haner.

Techniques for managing this increasing mass of information are still being refined, and there are pitfalls and perils to be avoided, as reported by Browne and Love.

This symposium, "The Costs and Values of Geoscience Information" looks at these issues from the viewpoints of the geoscientists who use and create the reports, the editors and publishers who bring them to life, and the librarians who manage them so that their usefulness continues. Geoscience information has more than intrinsic value, it has quantifiable value that *can* be measured, even in this rapidly evolving era.

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# USE OF GEOSCIENCE INFORMATION BY THE CONSULTING GEOSCIENTIST COMMUNITY

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*Abstract*--Throughout the United States, private geologic/geotechnical consultants are being asked to make difficult decisions on marginally stable and hazardous ground. Among others, these include site selection studies, structural foundations studies, groundwater and pollutant migration studies, seismic risk determinations, and mass wasting inventories. They are performed for industrial, government, commercial and residential clients. Under the present economic system, these clients cannot afford the time or money to perform original research on their sites.

More than ever, the private consultant relies on government-supported research and mapping to resolve the "big issues". Analogous situations in one part of the world or country can be of great assistance to practicing professionals elsewhere. Their publication in the media, including electronic media, benefits all levels of society, from the prevention of economic and natural disaster to the development of factory and home.

Five case histories illustrate how basic research of geologic process and site conditions were used on consulting geotechnical, engineering, and groundwater projects to serve government, industrial, and other private clients. In some of the cases, the information was a direct transfer of site-specific data; however, in other cases, the research was performed at distant locations, but a description of the geologic process aided the geologist in recognizing the local situation and proposing engineering solutions.

## INTRODUCTION

The consulting geoscientist serves the public, from the homeowner to the federal government, and private industry, from the small business to the large corporation. None of this is possible to accomplish in a timely or cost effective manner without the geologic research and mapping that is carried out by state and federal government agencies. Engineering geologists, geological engineers, geotechnical engineers, and hydrogeologists rely on up-to-date information that is disseminated on a timely and widespread basis to serve their clients.

Without this government research and regional mapping, each consultant would either have to expend an exorbitant number of hours to solve a problem or they would serve their clients, the American public, poorly. The expenditure of time for individual projects would involve many small research studies, the results of which would never receive wide distribution. Another inefficiency would involve mistakes in the interpretation of regional geologic issues that commonly cannot be comprehended by looking at local outcrops of soil or rock or by taking borings on a single property.

The geotechnical/environmental community serves the broad spectrum of society. They serve the following categories of people, agencies and industries, among others:

* Homeowners
* Railroads
* Departments of Transportation
* Forest Industry
* Attorneys
* Governments
  - Municipal
  - State
  - Federal
* Developers
  - Residential
  - Commercial
* Universities
* Armed Forces
* Mining Industry

The wide range of clients is obvious from this list. The projects for these clients not only range widely in the type of service offered, but in the amount of budget that is necessary to complete the studies. Some consultants specialize in only one portion of the market, while others attempt to serve them all. Those that serve all client classes commonly have a local or regional focus, and derive their expertise from their knowledge of local or regional geologic conditions.

## FORMS OF INFORMATION

The research products used by geotechnical/ environmental consultants come in several forms. The most common, and probably the oldest, form are maps, both basic geologic or soil maps and specialty maps. The basic maps include bedrock or surficial deposit maps, as produced by federal or state geologic surveys, or soil survey maps published by the Natural Resources Conservation Service. Although not used as frequently, specialty maps provide the geotechnical specialist a significant resource. They include some of the following: slope stability, liquefaction, channel migration, alluvial fans, peak ground acceleration, metals concentrations, extent of aquifer, depth to aquifer, wellhead protection areas, and watershed maps. When these useful maps are available, they can save the consultant, and therefore the client, thousands of dollars. Even more importantly, the product has been carefully reviewed by other professionals. This review process is important in that it assures a well-reasoned, thoughtful consideration of geologic principles as well as a broader point of view, bringing into account regional geologic perspectives.

Geologic research reports are used by consultants for two reasons. The first instance in which a consultant would use such information is in a preliminary literature search to learn the basics of a certain topic, or in other words, for general education. However, when working on an assignment, it is commonly necessary to examine the details of a subject or locale. At that time, the research becomes an important ally in the solution of a particular problem.

Water well logs and municipal records fall into the same general category of basic data from which information about local surface and subsurface soil, rock and groundwater conditions can be gleaned. These are contained in historical books, local departments of ecology, and city halls. They are open to the public, and copies can usually be made for the consultant or the client directly.

Professional journals are a constant and reliable source of thematic and regional geologic issues. In some cases, they are refereed and require very high standards, whereas, in other cases, they are published with little scrutiny. To professionally serve their public, consultants must be aware of the differences in the quality of the information and the credentials of the author and journal.

Two types of bibliographic information are available: standard paper bibliographic reference lists and GeoRef. Bibliographies are produced by two chief agencies: state and federal geological surveys. The U.S. Geological Survey provides an extensive list of new publications of their agency; however, this ignores the majority of the literature that is turned out by the research and consulting communities. Perhaps the most important source of old and new publications on a regional basis is the geological survey of an individual state. For instance, the historical indices and the constant updating by the librarian of the Washington State Division of Geology and Earth Resources is an invaluable resource for all consulting geoscientists in the northwestern United States. GeoRef also continues to be an important tool in finding citations for subject matter in the geosciences, and is used widely and frequently throughout the consulting community.

## TYPICAL USES BY GEOTECHNICAL/ ENVIRONMENTAL CONSULTANTS

How do geotechnical/environmental consultants serve their clients? They perform a myriad of services for them. Traditionally, the most common type of study is for foundations of structures. Although it is inevitably necessary to drill and sample to verify the type of soil and/or rock and the types of discontinuities beneath the structure, preliminary planning and the preparation of an informed scope of work requires general information of the type that is commonly found on a geologic map or in a geologic report. Seismic studies use the same sort of information, relying on fault maps and reports on seismic shaking for a particular area and for particular types of subsurface materials.

In some cases, the general distribution of mass wasting (landsliding processes) is required to put a particular landslide in context or to calculate landslide densities. In other cases, site-specific landslide studies completed by researchers give us insight into landslide processes in other locations, thereby resulting in a solution to a client's problem.

One common use of published research is for litigation, wherein the parties to the lawsuit must find analogous situations to use in legal arguments. A body of literature can be of substantial aid in furthering a legal argument, combined with in-depth knowledge of the subject site. However, accurate mapping of the subject area is still essential in forming the facts of the case.

Existing accurate geologic mapping is necessary for the preliminary planning stages of new or improved highway, railroad and pipeline alignments. Once the geoscientist has an understanding of the geologic conditions, the reconnaissance and exploration programs for the new or upgraded facilities can be planned. Good planning can save money for the client, increase efficiencies in the national economy, and prevent time-consuming delays during the subsurface explorations.

Although not normally a large monetary portion of a consultant's practice, the serving of residential clients is a necessity in this society. Such projects are typically small budget, but to the homeowner, such problems can be crucial, because their property and residence is their most precious possession. Any information that can keep the cost of such service reasonable is serving the public well.

Products of mapping or research that aid the hydrogeologist in understanding the movement of groundwater or pollutants through the regolith are of utmost importance to society. Scientists from this profession provide the water that we drink and use for processing the products that we use every day, and they are also actively involved with solving the problems of pollution below the ground surface. They make use of basic research and regional aquifer information to serve individuals and society as a whole. Without basic research into groundwater issues, progress in hazardous waste cleanup would be slow and expensive for those directly affected.

## CASE HISTORIES

Five case histories are presented below to illustrate how government-supported research or geologic mapping aided a consulting geoscientist to solve a problem and benefit society. All of the case histories are taken from the files of Shannon & Wilson, Inc. in Seattle, Washington between 1991 and 1997. Shannon & Wilson, Inc. has a 130-person office in Seattle comprised of geotechnical engineers, engineering geologists, geological engineers, hydrogeologists, and environmental engineers. The case histories come from Washington and Alaska, and reflect sites primarily with a mixture of glacial sediments and bedrock.

All geotechnical or environmental projects start with a search of existing geologic literature, because without such information, the geologist is groping in the dark for the basics of the landscape. So, for everyone in the profession, a survey and study of existing literature is a necessity. The case histories discussed below combined additional research and insight. It is probably not unique to geologic investigations that a "light bulb" goes on sometime during the work when the investigator connects something that he or she has read that is then translated to the information that has been observed or learned in the field. Such is the case in most of the case histories below.

### Cedar River Landslide, King County, Washington

In 1996, the City of Seattle Water Department requested that a Shannon & Wilson geologist evaluate a landslide that occurred following a prolonged period of heavy rain and a particularly wet winter. The slide occurred at the 3,000-foot elevation level on a small tributary to the upper reaches of the Cedar River. The Cedar River supplies water to one of the two reservoirs that comprise the City of Seattle water supply. Although not pristine, the Cedar watershed is mostly undisturbed. Therefore, a large pulse of sediment from erosion or a landslide is considered a significant event that can harm the water quality. Such sources of sediment need to be dealt with immediately.

The scope of work for this evaluation included a literature review, a site reconnaissance, and preparation of a report. A geologic report prepared by the U.S. Geological Survey was available for the site at 1:100,000-scale, "Preliminary geologic map of the Snoqualmie Pass 1:100,000 quadrangle, Washington," 1984 by five authors (Frizzell and others, 1984). This research gave the consulting geologist a general idea of the types of bedrock and sediment that would be found at the site prior to the reconnaissance.

The slide was about 200 feet long and 75 feet wide; however, the slide necked down to only about 30 feet at the western end of the slide, just before the slide entered a small creek. The headscarps and sidescarps of the slide were vertical, as shown on the photograph, Figure 1. The soil in the scarps was a clayey, silty, gravelly sand and was very dense. However, the soil in the slide debris was very loose, and even after a few days, could barely support the weight of a geologist.

Based on the proximity of a logging road about 50 feet upslope from the head of the slide and a stream of sandy sediment leading from the road switchback to the top of the slide, it was evident that the water from the logging road ditch was the primary causative factor of the landslide. During the site reconnaissance, the water was no longer flowing.

The evidence of the slide body (vertical scarps, the necking of the slide, and very loose disturbed soil), pointed to the presence of a sensitive clay; however, the glacial soils in this area are not known to contain highly sensitive clay minerals. Subsequent reading of the geologic map and the description of the bedrock unit that was adjacent to the glacial soil at the site indicated that the bedrock weathers to smectite. Smectite is a clay mineral that is the same as montmorillite, a highly sensitive clay. Therefore, it became clear that the glacial till had incorporated the smectite into its matrix, such that the matrix controlled the engineering characteristics of the soil.

Based on this conclusion, the Shannon & Wilson geologist was able to conclude that the culprit of the slide was the ditch water and that the reason for the liquid nature of the long earth flow was the smectite clay minerals in the matrix of the glacial soil. Based on recommendations in the geotechnical report, the client diverted the ditch water and the slopes of the slide were allowed to remain standing vertically, hopefully for many years.


**Figure 1.** Longitudinal view of landslide in alpine till with smectite fine-grained particles. Headscarp in background is about 20 feet high.

**Port Blakely, Bainbridge Island, Washington**

In 1990, Shannon & Wilson, Inc. undertook a study of a 1,100 acre property on the south end of Bainbridge Island, a large island in the middle of Puget Sound, about 5 miles west of Seattle. The large expanse of wooded land surrounding Blakely Harbor (see Figure 2) was owned by a timber company which could not harvest trees any longer owing to urban pressure. The timber company decided to open the land to residential development. A multi-disciplinary team of scientists was formed by the landowner to study the earth and biota of the site as baseline conditions in preparation for environmental studies and site layout.

The scope of geologic work included a review of existing literature, site geologic mapping, public presentations of the geologic conditions, interaction with the other scientists studying the site, and preparation of a report with the results of the study.

At the same time that Shannon & Wilson's studies were being performed, a team of scientists from the U.S. Geological Survey was studying several different aspects of large faults within the Puget Sound region. In particular, Brian Atwater was studying deposits exposed by excavations for a new sewage treatment facility along the shoreline of Seattle, and Robert Bucknam was studying a swamp deposit at Restoration Point, immediately east of the proposed residential community. Both of these studies hoped to gain data that would give some insight into movement along the enigmatic Seattle fault. As luck and painstaking scientific research would have it, both researchers came up with corroborating evidence regarding the existence and timing of the last movement along this fault. In addition, three other researchers found evidence for a large seismic event at about the same time. The findings of all five of the scientists were published in the same issue of *Science* in 1992 (Bucknam and others; At-

**Figure 2.** Aerial photograph of Blakely Harbor at the south end of Bainbridge Island, Washington. The terrace rimming the harbor was uplifted about 1,100 years ago during a major seismic event.

water and Moore; Karlin and Abella; Schuster and others; and Jacoby and others).

They concluded that the Seattle fault had moved about 1,100 years ago along an east-west alignment, the western end of which was about 5 miles north of Blakely Harbor. They also determined that this had resulted in about 7 meters of vertical uplift on the south side of the fault. Shortly after the announcement of their conclusions, an archaeologist working with the multi-disciplinary team for the proposed residential development reported that he was having no luck locating any "early man" sites around the perimeter of the harbor. At a team meeting, the Shannon & Wilson geologist, having learned that the land around the harbor had been uplifted about 20 feet about 1,100 years ago, suggested that the archaeologist look again but at the 20-foot-contour. Within one week, he had located a shell midden at the head of the harbor and it was subsequently dated at older than 1,100 years.

**Kingdome, Seattle, Washington**

In 1996, Shannon & Wilson, Inc. was asked by King County, Washington to undertake a study of the seismic risk of the Kingdome, a multi-purpose stadium on the south side of downtown Seattle. The owner of the city's professional football team was in the process of moving the team and was using seismic instability of the structure as the reason for breaking his lease with the county. Shannon & Wilson's seismic engineers studied existing records and borings from the original geotechnical investigation of the stadium, and then drilled and sampled several new borings.

As discussed above, the U.S. Geological Survey had studied the Seattle fault and published the information in 1992 (Bucknam and others; Atwater and Moore; Karlin and Abella; Schuster and others; and Jacoby and others). Note the proximity of the Seattle fault to the Kingdome on Figure 3. They had continued to study the fault to determine the amount of offset, the recurrence interval of the

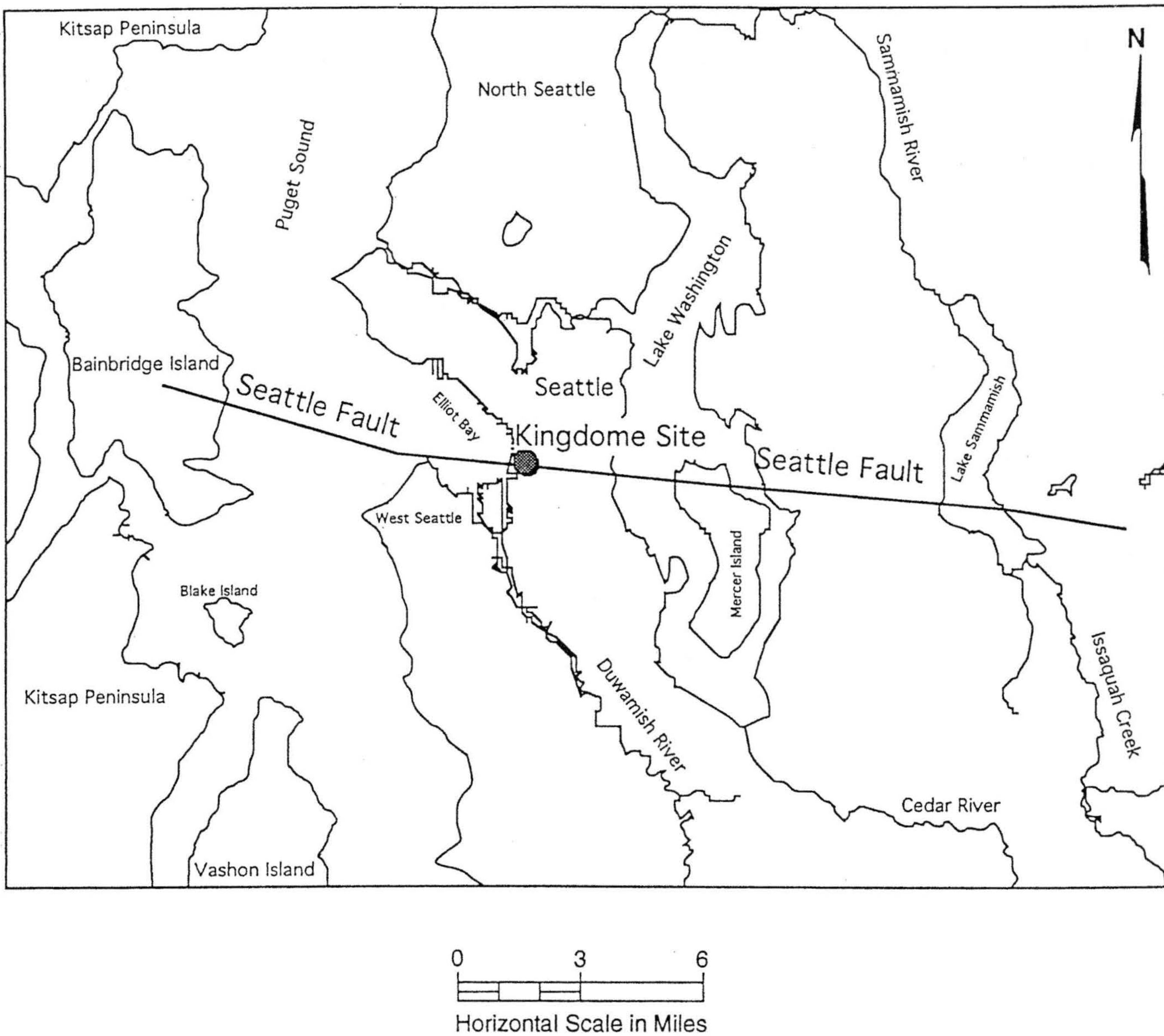


**Figure 3.** The Seattle fault runs approximately east-west across the Puget Lowland, roughly beneath the site of the Kingdome, Seattle's indoor football and baseball stadium.

fault, and the degree of shaking that could occur on this structure. Shannon & Wilson's engineers were able to use the information provided by the U.S. Geological Survey scientists to determine the peak ground acceleration and the ground response spectra. They provided this information to structural engineers for analysis of the Kingdome. Without the research information gained by government scientists, such analysis by seismic engineers would not have been possible. The use of this information was invaluable in saving the county millions of dollars and a football team.

**Granite Falls Arsenic Contamination, Snohomish County, Washington**

In 1996, a Shannon & Wilson geologist performed a study to determine the sources of the arsenic that was found in many of the drinking water wells in Granite Falls, Washington. The problem had been studied by

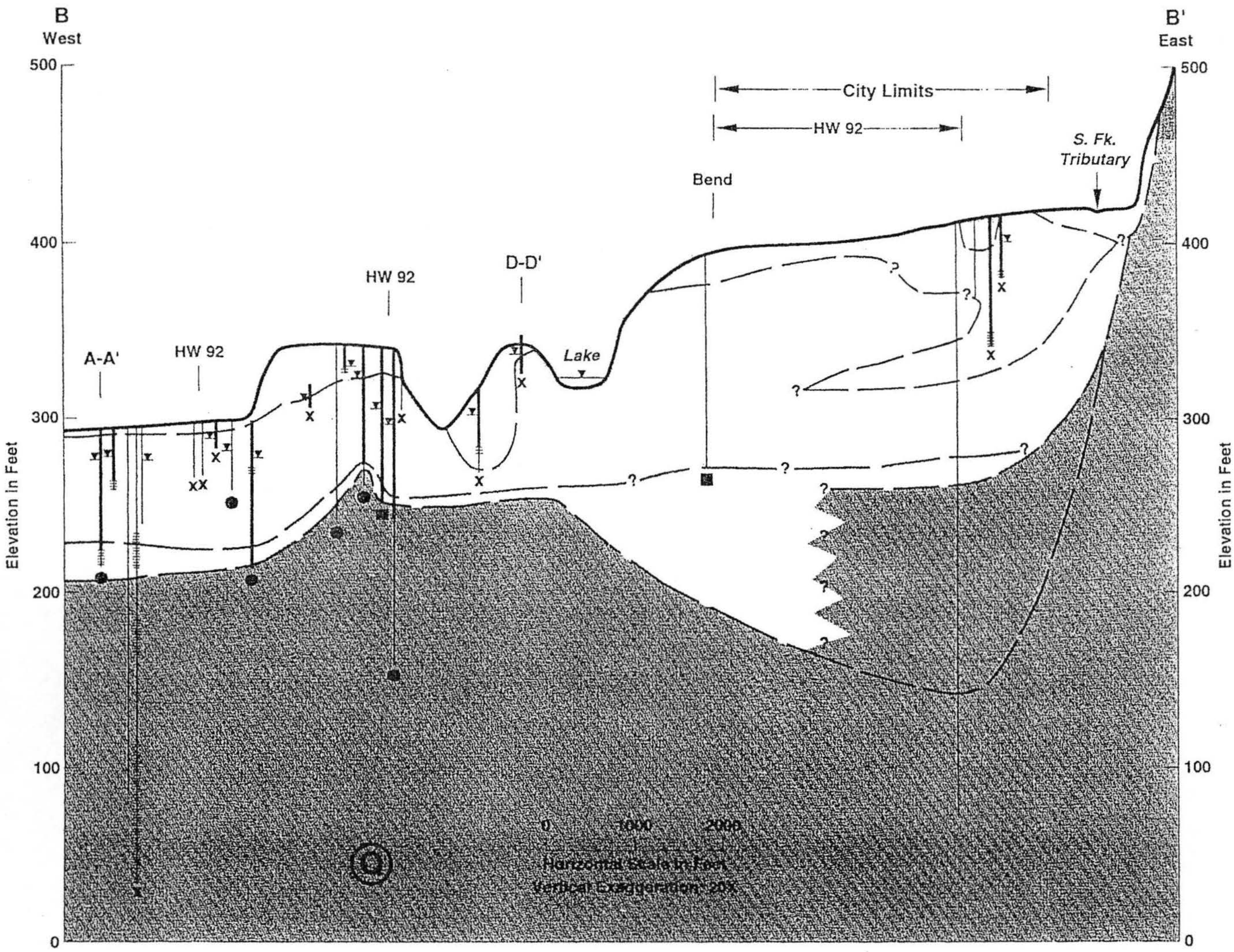


**Figure 4.** A geologic cross-section through the Granite Falls, Washington area shows the relationship of geology to arsenic-contaminated wells. The wells with significant concentrations of arsenic are shown by dark circles.

scientists at the Washington Department of Ecology and by the Snohomish County Department of Health; however, they had not been able to make any definitive conclusions regarding the source of arsenic.

The Shannon & Wilson geologist believed that the answer lay in the geologic record. Using existing records, consisting of water well logs, well water quality tests, and geologic maps of the vicinity, she prepared surficial geologic maps and geologic profiles. The profiles showed clearly that the water wells with arsenic contamination were closely related to the bedrock, as indicated on Figure 4. Old geologic reports pertaining to the hard rock mining areas near Granite Falls indicated that the metamorphic rocks contained trace amounts of arsenic. Research by the geologist showed that nearly all of the wells completed in or close to the bedrock were contaminated, but the more shallow wells were clean. Thus, without drilling any sampling holes or testing a single additional water sample, she was able to indicate the correspondence between arsenic contamination in the wells and natural arsenic in the underlying bedrock formation.

### Amchitka Island, Alaska

In 1996, Shannon & Wilson, Inc. was hired by the U.S. Army Corps of Engineers to study the location and amount of contamination in soils at seven areas on Amchitka Island, Alaska. Amchitka Island is one of the most distant islands in the Aleutian Chain that drapes across the southern end of the Bering Sea. This uninhabited island is about 42 miles long and only three to four miles wide. The sources of contaminants were from

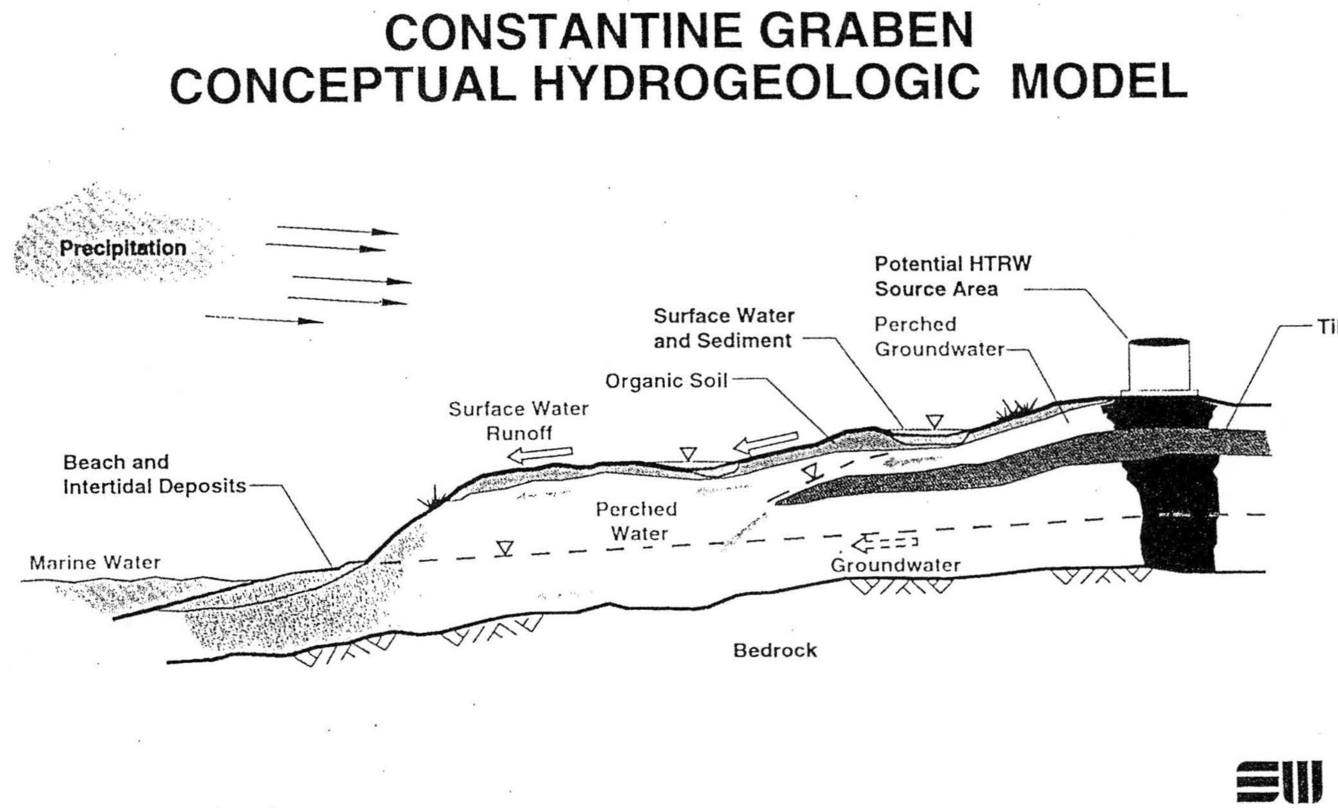


**Figure 5.** A conceptual model of groundwater movement was developed in the area surrounding Constantine Harbor based on previous scientific studies.

three different occupations by the United States military. The first contamination came from the U.S. Army occupation during World War II when Amchitka was the westernmost outpost against the Japanese army in the Aleutian Islands. The second period of contamination was in 1965 to 1971 by the Energy Research and Development Administration when this agency was testing nuclear explosions in deep underground caverns. The large caverns were far underground; however, surface facilities were required by the agency to support the research. The third period of contamination in 1987 to 1993 was when the U.S. Navy constructed an over-the-horizon radar site on the island to monitor Soviet navy movements. The construction consisted of a transmitter at one end of the island and a receiver at the other end; contamination was created at each of the sites.

As in any contamination cleanup study, a preliminary evaluation had to be made prior to investigating the site so a suitable plan could be devised. An investigation plan and health/safety plan are essential to the successful and safe deployment of personnel to the site. Fortunately, the federal government completed a monograph in 1977 for Amchitka Island following the government's work on the nuclear testing program. The monograph, "The environment of Amchitka Island, Alaska" (Merritt and Fuller, 1977) covered aspects of the history, geology, biology and human occupation, providing a complete picture of the natural and human history of the island. From this book, Shannon & Wilson geologists and environmental engineers were able to piece together information to create a model of groundwater movement so they could formulate a proposal, a work plan and a health/safety plan for the U.S. Army Corps of Engineers in a timely and cost-effective manner (Figure 5). Data in the report also provided scientific information to aid in the preliminary analysis of the contaminated sites. Had the government not conducted such studies and made them available to the public in the form of this monograph, they would not have been the benefactors of a cost and time savings.

## CONCLUSION

Citizens and developers cannot afford a wide-ranging or research project to support their project or problem. The benefits to society of basic or applied geologic research are in the form of safe and cost-effective development of new commercial, industrial, governmental and residential property on decreasingly suitable sites. Such property development keeps the economy going, and the judicious use of geologic information reduces deleterious effects of natural disasters. Natural disasters, such as landslides, earthquakes, land subsidence, and floods, are going to have increasingly more effects on a growing population and their need for land on which to live and work. In order for the consulting geoscience community to serve all of the public well and cost-effectively, it is incumbent upon federal and state research institutions to provide professional research for earth and water resources.

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# RECENT SCIENTIFIC PUBLISHING BY THE U.S. GEOLOGICAL SURVEY

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*Abstract:* The mission of the U.S. Geological Survey (USGS) is to provide the Nation with reliable, impartial information to describe and understand the Earth. Because of the relatively flat funding profile in recent years, changes in the USGS organization that have included down-sizing, and technological changes, one might expect to see a decline in the number of scientific publications produced by the USGS. Instead, this study found that the scientific publications of the USGS continue to grow at a relatively steady rate

The mission of the U.S. Geological Survey (USGS) is to provide the Nation with reliable, impartial information to describe and understand the Earth. Information is at the heart of its mission. The USGS activities encompass all aspects of information, from scientific research through the communi-cation of the results. This paper will focus on the communi-cation of information through USGS scientific publications.

To accomplish the USGS mission, Congress has appro-priated about $600 million per year over the past several years. This amount has fluctuated some, but has remained relatively constant (Figure 1.[1]) With the slowly rising inflation rate, however, the purchasing power of the USGS is gradually declining.

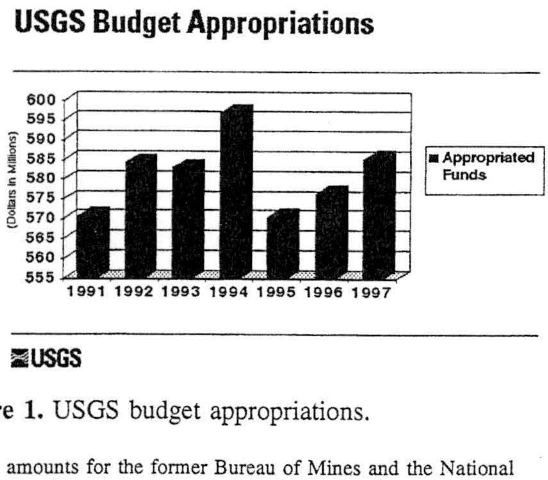


**Figure 1.** USGS budget appropriations.

[1]The amounts for the former Bureau of Mines and the National Biological Service have been deducted from fiscal year 1996 and 1997 amounts to keep the base constant. It should able be pointed out that the budget year is the Congressionally mandated fiscal year that extends from October 1 to the Following September 30. This is not consistent with publication year.

Because of the relatively flat funding profile in recent years, changes in the USGS organization that have included down-sizing, and technological changes, one might expect to see a decline in the number of scientific publications pro-duced by the USGS. This paper examines this hypothesis by analyzing the types and numbers of USGS publications from 1991 through 1995 listed in *Publications of the U.S. Geo-logical Survey.*

USGS publications were examined in three groups using the publication date[2] of each publication shown in *Publica-tions of the U.S. Geological Survey.* The three groups were formal series, informal series, and outside publications. The three groups had very different characteristics.

The first group reviewed were formal publications; these are published in four series: Professional Papers, Bulletins, Circulars, and Water Supply Papers (Figure 2.) Among the formal series, Professional Papers were consistently second in the number of titles published each year, ranging from 19 to 29 titles. The Bulletins had the highest number of titles published each year, between 35 and 62. The number of Water Supply Papers more than doubled during the period examined, from 9 to 22 titles per year. Circulars had a very narrow range of 11-15 titles per year, with an average 13.3 titles each year.

Informal publication series of the USGS include Open File Reports and Water Resources Investigations; these series provide an important means for scientists to make prelim-inary findings available to colleagues. The numbers of titles published in the informal series is an indication of the information provided (Figure 3.) Consistently over 600 titles

[2]The publication dates were based on imprint dates, which is a calendar year, since there was no reliable way to determine the fiscal year in which the title was published. This is not consistent with the budget year.

were published in the Open File Reports series; the range was very narrow, fluctuating by 7% or less each year. The Water Resources Investigations fluctuated from 168 to 270 during the period studied, growing by over 40% between 1994 and 1995.

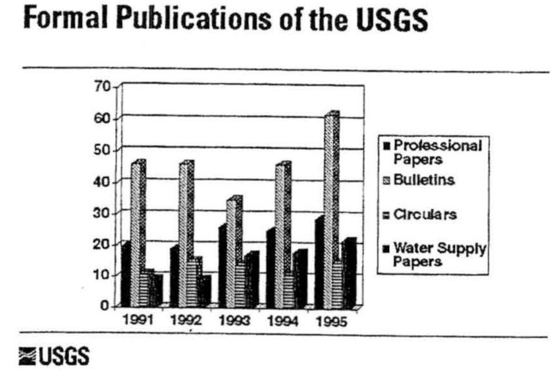


**Figure 2.** Formal publications of the USGS.

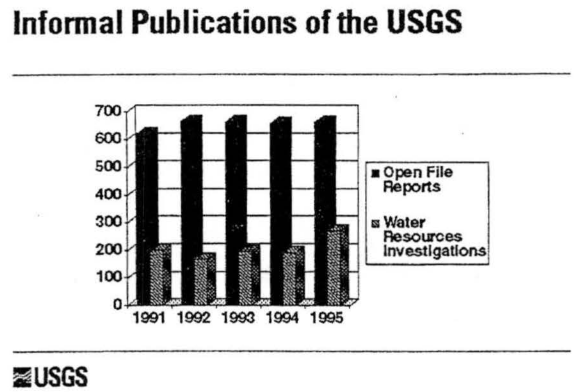


**Figure 3.** Informal publications of the USGS.

Outside publications listed in the *Publications of the U.S. Geological Survey* include a combined category of articles and reports and a separate category of abstracts. These publi-cations represent a wide range of scientific literature; the number of USGS scientists publishing in outside publications provides for wide dissemination of scientific information from the USGS (Figure 4.) Articles and reports experienced a small fluctuation of about 20% in the yearly number of titles during the period examined; however, it was nowhere near fluctuation in numbers of abstracts. Abstracts experi-enced an 83.7% increase between 1991 and 1992 only to see a 29.6% decrease the next year.

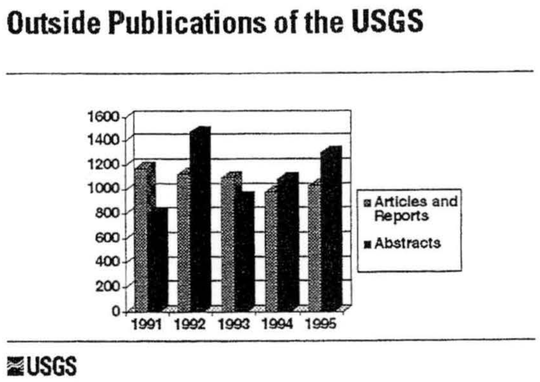


**Figure 4.** Outside publications of the USGS.

Comparing the categories, one sees a very stable picture of relatively steady growth (Figure 5.) Formal publications grew by 49%, breaking 100 titles in 1995. Informal publica-tions increased by nearly 14% (13.8), breaking 900 in 1995. The total number of USGS titles published in outside publi-cations spiked by 31% in 1992, but overall showed 18% growth during the period. This figure also shows the high proportion of USGS titles that are published in outside publications. This proportion exceeds 50% in every year examined.

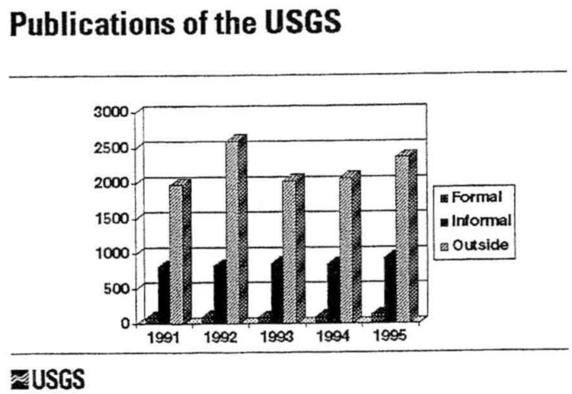


**Figure 5.** Publications of the USGS.

The increasing use of the World Wide Web to dissemin-ate information can be seen by the increasing number of USGS pages on the Web (Figure 6.) Although Web pages do not correspond to publications, it is worth noting the trend. Authors are starting to publish some informal USGS publica-tions only on the Web. This method of communication is growing among scientists since it can provide a more rapid and less expensive means to publish research information.

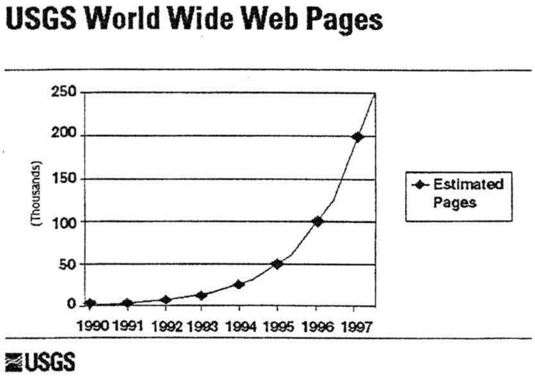


**Figure 6.** USGS World Wide Web pages.

In conclusion, this study found that the scientific publications of the USGS are growing at a relatively steady rate even with organizational and technological changes that might have negatively affected the flow of USGS scientific publications. The high number of USGS titles being pub-lished in outside scientific publications was noted. Also this study identified the additional USGS scientific publishing that is beginning on the World Wide Web. This study should be repeated as the USGS undergoes further changes to pro-vide information in determining the most effective means to disseminate scientific information from the USGS.

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# THE IMPACT OF ELECTRONIC DISSEMINATION: THE EXPERIENCE OF A STATE GEOLOGICAL SURVEY

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*Abstract*--As a state agency and a division of the University of Kansas, the Kansas Geological Survey (KGS) is charged with statutory responsibility to disseminate geologic information. Electronic communication has enabled the KGS to make major changes in the way it fulfills that responsibility. The electronic methods used for dissemination vary according to the type of information provided. The earliest changes came in map production. Since the 1980s, maps that the KGS sells to the public have been generated on-demand from digital data, with output to an electrostatic plotter. That process saves inventory costs, the expense of a large press run, and allows easy correction and updating. A 1996 survey of our customers verified their preference for on-demand maps; the survey showed that obtaining information as quickly as possible (both in hard copy and digital formats) was a high priority, and that pricing and printing quality were less of a concern. For the past three years, the KGS has used the World Wide Web to disseminate geologic reports, and particularly data. Electronic dissemination has proven appropriate for searchable data bases, such as the KGS bibliography of Kansas geology; for short, time-sensitive papers about current research; and for open-file reports, especially those that include color figures. It also appears especially appropriate for disseminating data that would be too expensive to make available in hard copy. A digital petroleum atlas, under construction for the past two years, is heavily used by clients who want immediate access to data, particularly in digital form. Electronic methods, then, have been effective for map production and data dissemination, and are beginning to affect the way the KGS communicates research results. That allows the KGS to make more information available quickly, in a variety of formats.

## INTRODUCTION

At the Kansas Geological Survey, our statutory charge is to study the state's geology and "to prepare reports on the same..." (Kansas Statutes Annotated, 1989), giving us a legal responsibility to make available the information that we produce. That statutory charge does not identify how we should prepare those reports or disseminate them, and over the past 30 years, the process has changed dramatically. We have gone from a time of traditional, hard-copy bulletins that were given away, to today, when we use a variety of methods, from the personal to the electronic, to provide information in the most appropriate format. In this paper, we discuss the impact of electronic dissemination on Survey products, focusing particularly on the response of our clients to those changes. First, let us briefly describe the Survey's role in state government. We are a division of the University of Kansas. Our researchers are considered the equivalent of the univer-sity's faculty and are judged according to their research and service output in the form of publications, grants and contracts, and other scholarly and service activity. We are also a branch of state government, in the sense that the state's legislature, agencies, private organizations, and citizens look to us for information about the state's geologic resources and hazards. We have no regulatory authority, we don't enforce any laws.

## MAPS

Until about 30 years ago, the Survey's products came in two forms, both of them printed--maps and reports. We now generate a variety of products, many of them specifically tailored for the audience and the type of information we are disseminating. For our information dissemination efforts, the impact of computerization began in a big way with the production of maps. The Kansas Geological Survey has not printed a map, by traditional printing methods, since 1983. Since 1988, we have produced and sold on-demand versions of thematic maps (Buchanan and Steeples, 1990). Most of the thematic maps that we sell are related, in some fashion or another, to oil and natural gas, water, or basic geology (see, for example, Ross, 1991, or Yoder and others, 1995). They are generated from a 44-inch Calcomp electrostatic printer, with a resolution of 400 dots per inch, or a Hewlett-Packard inkjet color plotter on a 36-inch format. We made the decision to produce these maps on-demand because we thought it was in our best interest in terms of turnaround time (we can produce the computer-plotted maps much more quickly), in terms of the quality of the information (we can correct mistakes immediately), in terms of the variety of information (we can make available maps that would have been uneconomic to print), and in terms of the cost of storing inventory. We assumed that our customers agree that turnaround, quality of information, and variety of maps were also important to them. On-demand printing means that individual copies of a map are relatively costly to produce (though our total costs may be less because we do not have to pay for a large print run), and we had to raise prices to compensate for that.

In August and early September, 1996, we surveyed our map customers through mailed questionnaires and by phone interview, asking for information about our customers and their opinions about our maps (see Buchanan, 1996). Of the questionnaires distributed, 28 were returned. This is a very small sample size. The respondents divided themselves between highly technical specialists, such as geologists working for petroleum companies or managers of groundwater management districts, somewhat less technically informed users, and more general users or members of the general public, who are often most interested in geologic maps. For the most part, our customers believe that the quality of our maps is high (Table 1). On a scale of 1-5, with 5 connoting high quality and 1 connoting low quality, our customers rated the maps' overall appearance a 4.25. They rated paper quality a 3.70. Our electrostatic plotter uses paper that is relatively thin, fragile, and doesn't hold up well with heavy use. Our customers apparently recognize that, yet they do not seem overly concerned. They rated the type, or lettering, on the map a 4.21, the highest of any specific category, and they rated the colors on the map, in terms of evenness and appropriateness, a 4.16. Because of the small sample size, these variances probably are not statistically significant, but they are instructive. We can assume that our customers are generally happy with our maps, but they recognize problems with color and paper.

**Table 1.** How would you rate the quality of the following characteristics of the map or maps that you purchased? (Rated on a scale of 5-1, with 5 connoting High Quality, 1 connoting Low Quality)

| | | |
|---|---|---|
| a. overall appearance | N=28 | mean=4.25 |
| b. paper quality | N=28 | mean=3.70 |
| c. type | N=28 | mean=4.21 |
| d. colors | N=28 | mean=4.16 |

Of the respondents, about 68 percent said they preferred computer-plotted maps to traditional maps; 18 percent said that it depended on the situation; and 14 percent said they preferred traditionally published maps (Table 2). If you combine those responses, nearly one-third of our customers either prefer traditional maps, don't care, or believe the method of production depends on the map. To

**Table 2.** Which would you prefer: computer-plotted maps that are available quickly or traditionally printed maps that take longer to produce?

| | |
|---|---|
| computer-plotted maps | = 19 (67.86%) |
| traditionally printed maps | = 5 (17.86%) |
| both/depends on the situation | = 4 (14.29%) |

n=28

cover the cost of producing these maps from the plotter, we increased the prices substantially over a short period of time. As late as the mid-1980s, we had charged, for example, $5.00 for a 1:500,000 scale map of the state's oil and gas fields or our geologic map of the state, two of our most popular products. With the conversion to on-demand plotting, we increased these prices to $20.00 over the course of a year or so. We got a few verbal and written complaints about these increases. Our assumption (again untested) was that, for the most part, many of our customers do not worry too much about prices. They want the information and they are willing to pay for it; a few dollars one way or another does not matter that much to them. If you can believe what the respondents say, that seems to have been borne out by this survey. Eighty-two percent of the respondents said our maps were priced about right or priced less than they should be. Eleven percent said they were too expensive (Table 3). If they had a concern about our maps, it was generally related to access to the digital data used to create the maps, that they

**Table 3.** Considering the information on the maps and the price of other maps, are Kansas Geological Survey maps priced appropriately?

N=28

| | |
|---|---|
| too expensive | = 3 (10.71%) |
| priced about right | = 19 (67.86%) |
| priced less than they should be | = 4 (14.29%) |
| don't know | = 2 (7.14%) |

be able to get it, and that they get it in formats that are most useful. With their capabilities, they can now use our data to create their own customized maps on-the-fly, as they need them.

**BOOKS**

Other than the method of production, traditional printed books have probably changed less than for maps, but they have changed. For example, since 1993, we have produced an annual collection of short papers on regional geology, primarily focusing on Kansas (see, for example, Kansas Geological Survey, 1993). The idea is to supply an outlet for peer-reviewed, region-specific research that might not be appropriate for national journals. The audience here is technical: academics, consultants, people in governmental agencies. Because the studies tend to focus on a small area, this audience is relatively small, and press runs for this bulletin generally reflect that, sometimes as small as 500.

Beginning in 1996, we decided to take advantage of electronic dissemination and produce the bulletin on-line (http://www.kgs.ukans.edu/Current/index.html). We believed that most of the current audience had access to the internet, and by publishing the papers electronically we could reach the existing audience plus a much larger potential audience than currently sees them. It allowed us to provide some types of figures, especially those in color, that would be very expensive in a traditional hard-copy publication. In addition, electronic publication gave us the option of making the papers available in much shorter turnaround time. We can post the papers as they are ready, rather than waiting for an artificial deadline of every quarter or every year. In essence, the unit of publication is no longer a book or an issue of a journal; instead, each paper is a unit of publication.

One issue in this decision-making process was, of course, how libraries would react. We send complimentary copies of bulletins to 133 U.S. libraries, most of them at major universities. In the fall of 1996, Kansas Geological Survey librarian Janice Sorensen asked them their reaction to making the *Bulletin of Current Research* available electronically. Fifty-six libraries responded. The majority wanted notification by e-mail when the new issues of Current Research were on line, but 47 libraries (or 83 percent of the respondents) wanted to continue to receive hard copies. That indicates that, at least for our traditional bulletins, libraries at that point were not comfortable with electronic-only publication.

The decision to produce these papers electronically engendered a strong reaction from another group: the authors. Several disliked the idea of electronic-only publication, to the point that they were willing to pull their submissions or to contribute grant funding to help pay for traditional printing. As a result, we have decided to do mirror publications for at least a year or two, producing the papers on-line and then producing a hard-copy version at the end of the year. That approach seems to reach both goals of wider dissemination and keeping authors happy, but it also adds to the work load, necessitating the normal editing process for traditional printing, and the vastly different job of preparing a paper for the internet.

We know a little bit about the audience that is at least looking at these papers. Based on the homepage hits, the audience for the electronic version of the papers, like the audience for the paper copies, is not huge. Not counting hits from the Survey's own computers, the first paper to be posted, which was made available in March, was hit 69 times. A later paper was visited 49 times in September. Thus, while we are not expanding the audience greatly, we appear to be expanding it somewhat, and probably reaching a different audience than the one that would see a paper copy.

**THE WEB**

A third, related method of disseminating information, one that had no previous analogue for us, is the internet in general, and our World Wide Web site in particular. Our view is that electronic communication can provide the earth science community and other segments of our audience with rapid, cost-effective access to natural resource data, information sources, publications, and technology (see Carr and others, 1997). Electronic publishing seems to be particularly effective in providing access to fundamental geologic and geographic data, to data compilations, and to the latest research and technical studies. One of the major advantages of electronic publishing is that these products can be made available on-line as they are completed or updated. In other words, when people search our data bases via the Web, they are using the same products that we use, products that are absolutely current. Dynamic publications with relational links and search engines allow users to modify the scale and focus to their particular requirements, and permit access to data in a compatible format for research validation and risk analysis.

The Kansas Geological Survey is working on a number of projects in electronic publication (htttp://www.kgs.ukans.edu). This has been particularly effective for reference publications, such as the online version of the Bibliography of Kansas Geology (http://www.kgs.ukans.edu//General/Bibliography/bibstart.html). By making the bibliography available on-line, we allow wider access, we can update it regularly, making a current bibliography available to our clients, who previously had to wait several years for printed updates to the bibliography. It gives clients a product that they can search on-line. This approach may have cost us a few sales of the hard-copy version of the bibliography, but we believe it better answers our statutory charge to disseminate information. By making that bibliographic information more widely available, we probably also sell other hard-copy reports that our clients would not otherwise have been aware of. Electronic dissemination is also particularly appropriate for what is, essentially, data. Our Annual and Cumulative Oil and Gas Production Report (http://www.kgs.ukans.edu/PRS/petroIndex.html) is now made available on-line so that users can search for what they want, and retrieve only that portion of the data they request. User control of search and retrieval improves the efficiency over the original paper publication, and electronic updating decreases the effort and cost of providing current information.

The Digital Petroleum Atlas (http://www.kgs.ukans.edu/DPA/dpaHome.html) attempts to radically change traditional approaches to generating and disseminating petroleum field, play, and basin studies. The Digital Petroleum Atlas (DPA) is an online product that gives users access to underlying data that is typically unpublished. The DPA alters the relationship between interpretative result and data. Active links, graphical user interfaces, and search mechanisms of the DPA provide a dynamic product with which the reader can interact. The DPA also contains forms of publication that can only be displayed in an electronic environment. These include hypertext search and manipulation functions to customize maps and view animated products (e.g., exploration histories through time). Electronic products such as the DPA have one advantage over print: they are far easier to transmit for purposes of resource sharing. Products modified to better fit user needs can be created on demand out of available digital materials.

We are still learning about the kind of client base that knows about us from the Web site, what kind of information they are looking for and what kind they find. As of this fall, our Web site averaged about 40,000 hits a month. Much of this is noise. Many of those visits are by people who did key-word searches that directed them to our page, even though they appear to have no interest in it, and do not explore it once they arrive. About 65 percent of our visitors view only one or two pages, and 85 percent visit five or fewer pages. But even with those numbers removed, the site provides information to several thousand people a month, and that number continues to increase. Many of our Web publications receive 20 to 60 visits a month from people who look at all the information presented. Four hundred people a month download programs from the petroleum technology transfer section of our site, and the Digital Petroleum Atlas may be visited as many as 3,000 times a month by people who visit 10 to 50 different pages (Dana Adkins-Heljeson, personal communication).

A less recognized, but perhaps more important, consequence of this electronic approach to dissemination is that it has forced us to put our own house in order. It has given us the motivation to collect, organize, and make available data sets that we have had for a number of years. It has forced us to think more about data base managers and the best way to store and make that information available.

**FIELD CONFERENCE**

While electronic communication is good for some segments of our population, is does not work for others. One particularly important segment of our audience is one that we've labeled decision-makers. These are mainly legislators (particularly from committees that deal with natural resource and environmental issues), state agency heads, business leaders, the heads of environmental organizations, and teachers' groups. These people are important to us because they need to be aware of the information we have available, and they need to use that information in their decision-making process. They are, in an important way, our tie to society, to the ultimate utility of the information that we produce.

For the past three years we have brought those people together in a three-day field conference, a statewide version of a national energy and minerals field institute operated by the Colorado School of Mines (see Sawin and others, 1996). We invite 25 participants for three days of looking at issues in the field, including presentations at the site and during travel from location to location, and in the evening. This field conference makes participants far more knowledgeable about and aware of issues, familiarizes them with other people involved with these issues, and gives them resources to use when dealing with those issues after the field conference. We seek co-sponsors for these field conferences from among other state agencies, so we not only cement relationships with the participants, we have improved relationships with other agencies. This also allows the conferences to be self-supporting, with the exception of the considerable cost of the staff time devoted to them. Every year we do extensive evaluations of that conference, and change the following year based on those responses. In 1997, we visited 14 locations in the field conference, which focused on the impact of urban expansion on the use of natural resources. When asked to rate the usefulness of those stops on a scale of 1-5, with 5 connoting high usefulness and 1 connoting low usefulness, the responses averaged from 3.61 to 4.76 (Table 4). Their overall rating of the field conference was 4.70 (Table 5).

From this information, and from discussions with participants, it is clear that this program has struck a chord in the state. We know that reaching this group requires something beyond the usual methods of information dissemination. Because this audience is so busy, this kind of personal, hands-on delivery of information seems to be the best way of imparting information. The benefits that we

**Table 4.** Please rate the usefulness of the following activities on a scale of 5 (very useful) to 1 (not useful).

| | |
|---|---|
| Site 1 - East Topeka Reclamation | 3.90 |
| Site 2 - Big Springs Quarry | 4.30 |
| Site 3 - Jefferson-Douglas County Landfill | 4.65 |
| Site 4 - URAMP | 4.05 |
| Site 5 - Kansas River Sand Dredging | 4.70 |
| Site 6 - Hillsdale Water Quality Project | 3.90 |
| Site 7 - Ritchie Sand and Gravel Operation | 4.63 |
| Site 8 - Sand and Gravel Reclamation | 4.21 |
| Site 9 - Gilbert & Mosley Site | 4.00 |
| Site 10 -Cheney Water Quality Project | 4.26 |
| Site 11 -Brooks Landfill | 4.39 |
| Site 12 -Proposed New Landfill, Furley Site | 3.61 |
| Site 13 -Equus Beds GMD | 4.35 |
| Site 14 - Equus Beds Groundwater Recharge | 4.76 |
| Wednesday Evening Session | 3.82 |
| Thursday Evening Session | 4.37 |
| Discussions on the Bus | 4.67 |

N=20

**Table 5.** How would you rate the value of the Field Conference on a scale of 5 (excellent) to 1 (poor)?

| | |
|---|---|
| Professional Value | 4.40 |
| Educational Value | 4.65 |
| Enjoyment Value | 4.65 |
| Overall Value | 4.70 |

N=20

have derived from this process--in terms of political support, in terms of increased awareness of issues and information, in terms of our activity in helping deal with some of the issues in the state that we believe should be dealt with--all make it clear that this method works to reach this audience.

In short, then, the audience for our information is segmented--into decision-makers, academics, businesses and consultants, interested organizations, the interested general public. The way our information is disseminated varies according to each group and its needs. In some cases, our means of dissemination require little human interaction and allow us to reach huge numbers of people in very little time; in other cases, our methods are extremely personal and time-consuming. We have become far more concerned about getting information into an appropriate format, as opposed to simply putting it out there and expecting our clients to use it in the way that is most convenient to us. All of this is part of our statutory charge, but we believe that our role in society, and our institutional survival, depends upon it.

**ACKNOWLEDGMENTS**

The authors would like to acknowledge the assistance of Dana Adkins-Heljeson, who provided information on KGS internet usage; Janice Sorensen, who provided information on library responses to electronic publication; Robert S. Sawin, who provided evaluations of the KGS field conference; and Marla Adkins-Heljeson for manuscript review. Electronic transfer of petroleum technology and data is supported by the U.S. Dept. of Energy (Bartlesville Project Office) under agreements DE-FG22-95BC14817 (http://oil.bpo.gov/10092.html) and DE-FC22-93BC14987 (http://oil.bpo.gov/10165.html).

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# GEOLOGIC REPORT PRODUCTION IN THE 1990s: EXAMPLE FROM THE WASHINGTON STATE GEOLOGICAL SURVEY

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*Abstract*--The Washington Division of Geology and Earth Resources (DGER) is a small division of the state's Department of Natural Resources, which is a leader in GIS technology. However, DGER's budget is now more than half dedicated to outside-funded grants and contracts to support its 13 geologists and 11 other staff members, and we have been unable to modernize as aggressively as the rest of the Department. Recognizing the realities of the 1990s, we are moving toward digital publication, but paper versions of our reports still out-sell digital versions by about 20 to 1. We have begun to prepare urban geohazards maps in ARC-INFO (the Department standard), which is an excellent tool for analysis. Geologic maps are being drafted digitally but are still being published as traditional paper maps. We are converting geologic maps to ARC-INFO for land management purposes (and as part of the National Cooperative Geological Mapping Program), but we have not yet been able to systematize distribution of digital maps (for instance, through an FTP site) due to security concerns and different priorities of our Department. Because of our external funding constraints, we now produce about 200 copies of briefer, more narrowly focused contract research reports on tight, externally applied deadlines instead of the 1,000-copy press runs of multi-year applied research reports of the early 1990s. We do, however, still ensure that titles are included in bibliographic databases. Eventually we expect to produce fully digital color reports, searchable map indexes, and CD-ROM or Web versions of our bibliographies. However, we expect that the transition to fully digital publications will take several more years of hybrid digital/manual methods as long as it makes sense both for us and our clientele and while we continue to acquire appropriate hardware and software and upgrade our cartographic skills.

## INTRODUCTION

The Washington Division of Geology and Earth Resources is the state's geological survey and a small part of the Department of Natural Resources. The Division's mission is "geology in the public interest". To achieve the related goals we, like many of our survey counterparts, perform the fieldwork and research necessary to acquire the needed information and publish several kinds of book and map reports, a free quarterly journal (*Washington Geology*), some digital products, and fact sheets. Prices of our publications are based only on the cost to reproduce them. Revenue from sales of our publications goes directly to the state's general fund and is unavailable to us. We have a modest Web page under the aegis of the Department. In addition, we maintain a strong library that is generally recognized as the nation's finest collection of information about Washington's geology.

During the previous ten years, the Division has seen its budget seriously eroded. The Division's response has been to seek grants and contracts to keep the geological and support staff intact and assist us in pursuing Division goals, especially production of a new state geologic map. At present, our funding is about 60 percent from non-Department sources. Largely for this reason, we have not been able to upgrade our production tools as steadily as has the rest of the Department.

During this same ten years and like many of our sister surveys, our report production has changed from the traditional formal report of long-lived research projects to shorter informal (open-file) reports in smaller runs. Part of this transition is in response to the grant and contract mode of life, and part reflects the cost of shelf space in warehouses to assure a reasonable availability of the reports.

Even though we offer a few products, such as our bibliographies of the geology and geologic resources of the counties, on disk, our customers request paper copies far more often than they want the searchable disk or e-mail versions. *Washington Geology* reaches nearly 7,000 "subscribers", but we have no plans to go digital with this medium. We are, however, making the transition from completely manual map making partly because scribe coat and peel coat materials are being phased out by the industry. Our 1997 release of a full-color 1:250,000 map of the southeast quadrant of the state (Schuster and others, 1997a) is likely our last completely manual map. We have gradually increased our use of digital tools like AutoCAD and ARC-INFO. We have printed some geohazard maps directly from electronic files, but only in the last few months have we released maps as digital-only products. And this production is largely possible because we obtained two cooperative agreements from the National Cooperative Geological Mapping Act's STATEMAP program. We look forward to being able to compete successfully for enough more of these agreements to complete digital geologic map coverage of the state at 1:100,000.

## COSTS

Because our staff is involved from idea germ to printed (sic) page of every report, we also bear all the costs associated with the life cycle of a report (Figure 1). Rough calculations show that the cost of producing the 1:24,000-scale map of the Gilbert quadrangle in the North Cascades (Dragovich and others, 1997) was about $100,000. This cost represents planning efforts, time in the field, travel, analyses, cartography, editing, and printing. Of that total, our press run of 1,000 copies of the four-color map and a 67-p. self-cover text cost (with tax and markups) about $3,950. We prepared press-ready materials by a time-honored combination of a negative of the U.S. Geological Survey's topographic map of the area and color separations produced by AutoCad. In a sense, for $4.00 the customer gets the benefit of $100,000 worth of our efforts. Interestingly, we have learned that a European counterpart agency incurred about the same expenses for a similar product (H. P. Schuenlaub, Geological Survey of Austria, personal communication, 1997).

A recent formal report of 92 pages, with full-color photo cover and 63 black and white halftones (Walsh and others, 1995), cost $6,320 to print 1,350 copies. Cooperating agencies paid for the color cover. The total cost of the project was about $120,000.

*Washington Geology* combines information generated by our geologic staff, our library staff, and outside contributors. We use a non-current version of Corel/Ventura to produce camera-ready copy, and, by a process of competitive bids, the state printer arranges for the printing of about 7,100 copies. The jobber mails about 6,700 copies via a subcontractor who produces the bar-coded labels for domestic mail. A contractor in New York handles foreign mail for us. On average, each copy of *Washington Geology* costs about $1.10 to print and mail, but the construction of each issue requires from 50 to 100 hours of editorial and layout work. This is our main contact with our "customers", but it also consumes about 40% of our printing budget.

If one were to use these figures as a basis for calculating the worth of the information in the Division's library, it would not take long to arrive at a total cost of several billion dollars to re-do the work and re-issue the reports housed there.

## VALUE

We once came upon an article in a national journal which purported to list all the important geophysical datasets available for various western states. The single largest gravity database for Washington State, available from the DGER and described in our of our open-file reports, was conspicuously absent from the listing. It was obvious that the author had not been aware of the report, and the value of his report was seriously diminished. As far as we knew the author had not asked us if we had any relevant information. This instance and our desire to be of the most service possible made it clear that we had to be more visible. We soon started sending copies of all our reports (both published and open-files) to selected research libraries and the U.S. Geological Survey libraries, to be certain those titles were included in both GeoRef and in the on-line catalogs. The goal is to prevent wheels from being reinvented and be certain that information is visible. For a truly nominal cost (essentially the cost of a few copies of the report and postage), we hope we are reaching the vast majority of persons wanting to know about Washington's geology.

The Division firmly believes that information has no real value until the public knows it exists. (While contract reports are certainly of most interest to the contractor, these reports can contain site-specific data that have carry-over value to other projects.) We offer a free list of the more than 300 products available from us. We announce everything we release in *Washington Geology*. We send our formal reports to our state library system and to about 100 other libraries nationwide that we selected because they have important geologic collections or are known as regional resources. Our open-file reports go to our state academic libraries, some public libraries, and a few other destinations within Washington and beyond. As noted above, copies of everything we publish go to the U.S. Geological Survey in Reston, where (eventually) they are added to the AGI GeoRef database.

Having spent about $100,000 on the Gilbert report, we could not in good conscience not spend about $50 more to see that it gets to places where people can easily access the information. (We have no method of electronic release for this kind of report, we suspect few of our clients have

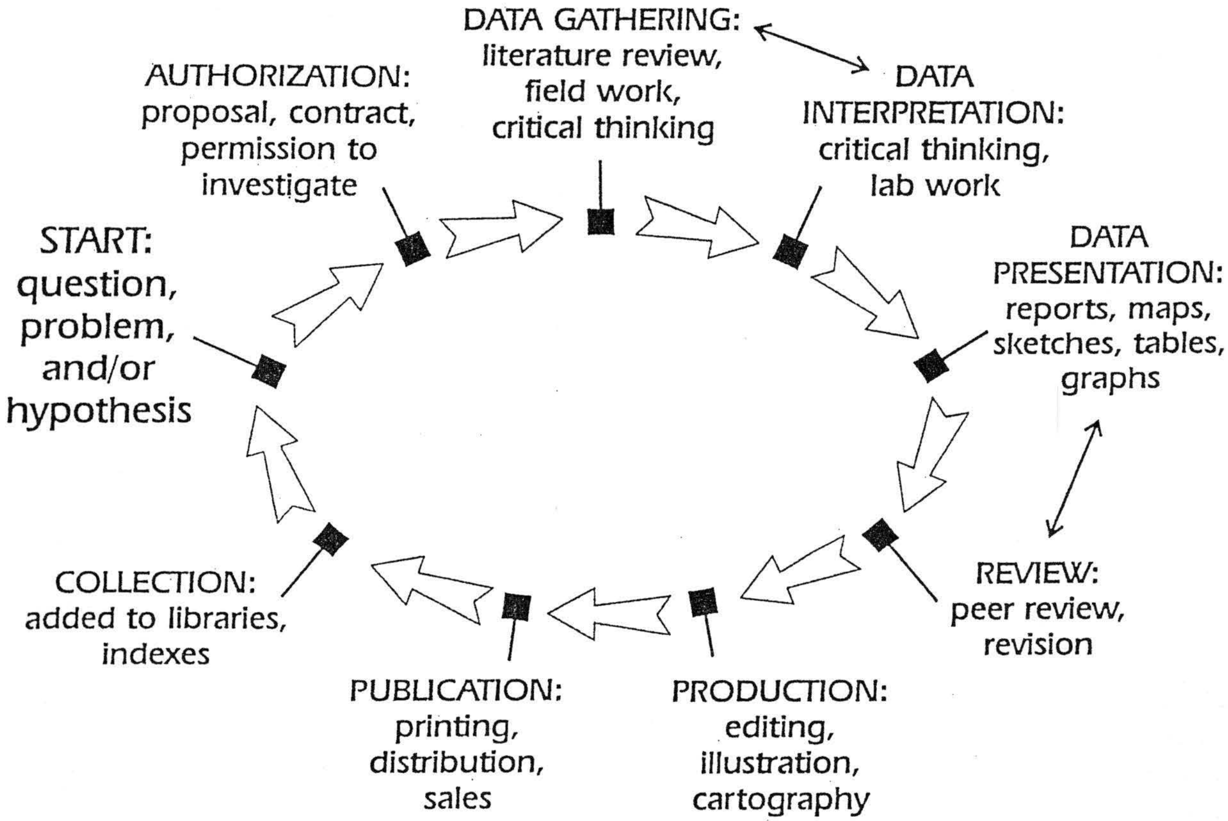


**Figure 1.** Life cycle of the geoscience report.

the equipment necessary to retrieve and print digital maps, and we perceive that our clients are still heavily dependent on paper versions.) The same kinds of relative expenses are involved in sending out our other products.

But the Division geological staff is not the only purveyor of this kind of information. Our librarian has developed a series of bibliographies (added to annually) that list (and index) everything we can find and have in our collection about Washington's geology, from theses to contract reports, to articles in obscure foreign journals. Our bibliographies are more complete than GeoRef can be for local materials, and the value of these volumes to researchers is probably large. In addition, we list selected library acquisitions in each issue of *Washington Geology.* We have been slowly preparing the library catalog for electronic release.

By the means described here, we think we are reaching the majority of potential users, and we hope to expand our information delivery soon by making more use of the Internet for education and for data transmission.

**THE DIGITAL PRESENT AND FUTURE**

At the present time, the Department is taking a conservative approach to the Internet. All new Web page information is reviewed on a departmental intranet before it is posted to the Internet. There is a strong firewall between us and the net. Market saturation of these clients is not attainable for the moment.

While we have a rudimentary web page, we have no system or staff dedicated to upkeep and additions to this page on any regular basis. Only a few of our machines are UNIX capable, and we still use old versions of WordPerfect that cannot do HTML. Some of the staff have access to the web at their desks. We are fully aware of the potential and are working toward increasing our web presence.

We have now digitized more than half of the 1:100,000 quadrangles in Washington, and about half of those are available as digital (ARC) files. We have "translated" some maps produced by geologists of the U.S. Geological Survey into our method for presenting map units: time/lithologic units, not formations. As we prepared the 1:100,000-scale maps that were combined to make up the 1:250,000 quadrant maps, we developed a system of time/lithology map units and a symbology that permitted us to show the many Tertiary rocks in Washington. This seems to us to be the most logical way to deal with mappable units that are lithologically gradational across their extent and those that are time transgressive. (We provide information about the formations included in these units or that compose the units.) We have gone on from there to prepare our own data structure (briefly described in Schuster and others, 1997b) based on these time/lithology units. Our system (and unit symbols) is not going to be easily added to the U.S. Geological Survey's national mapdatabase.

We do not now have any means of sending the map files from an FTP site, although we have been negotiating with a university and have had discussions about acquiring our own server, contracting a server, and using the U.S. Geological Survey's capabilities. We continue discussion of our digitial needs with the management of the Department of Natural Resources. At this time. to order an ARC file, a client simply has to contact us, and we spend the staff time to make a tape copy and send it back. We ask the client to send us a blank tape. In this manner, we have been getting a good idea of who wants our information and what they want it for. We then know whether we are meeting their needs and how much demand there is. We continue the tradition of personal service.

The time will come when we may not be able to conveniently continue this individual service. An interim solution is likely to be a CD-ROM, to which we may be able to add the list of the library holdings and text and graphics from selected Division reports. We are watching with interest the experiences of our sister agencies and the technology.

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# COST AND ADDED VALUE OF ELECTRONIC PUBLISHING

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*Abstract*--After a centuries-long period of stability, the publishing industry is now undergoing a major change, from conventional paper-printed to electronic information products. As a first step, the industry now has started to offer individual journals and journal packages in electronic form to both libraries and individuals, allowing desk-top access. Basically these products mimic their paper pendants and offer ease of delivery, searching and storage but not much else. These systems are now being improved by using an integrated total publishing concept benefitting optimally from the facilities offered by the electronic medium. The basis for this at Elsevier is formed by the Electronic Warehouse which offers: (i) generic storage of all articles in SGML (ii) generic storage of multimedia material, such as video, sound, datasets, geological maps (iii) generic storage of links, including linking of references with an abstracting service. Material is stored in a platform-independent way, so that articles in the future can be represented in line with the interfaces of that time. This system allows the design of products that can range from simple delivery of pdf files to a library client, up to a service provider with a user-friendly WWW interface, offering all desired journals with extensive search capabilities and a link to a secondary service.

The economics behind this process have quite some influence on a publisher's balance sheet. Investments in the Elsevier Warehouse run into millions, and there are also high annual running costs. To ensure a generic product, typesetters will need to work entirely differently and more expensively. In the long term, it is hoped that all parties will benefit: the librarian by having lower operational costs, and being able to integrate primary and secondary literature, the author by having multimedia means of enhancing his manuscript, the reader by increased efficiency and the publisher by being able to offer much more material for a marginal extra fee. If future electronic publishing systems will indeed allow a publisher to sell more units, unit prices may very well go down.

## INTRODUCTION

In 1665 the *Journal de Sçavans*, the first scholarly journal, was launched, followed a few months later by the *Philosophical Transactions of the Royal Society of London* which is still in existence. In the three centuries following this event little changed in the publishing industry, except for an enormous growth in article production by the scientists, and a huge proliferation in the number of journal titles.

Conversions from print to electronic publishing commenced over two decades ago with the abstracting and indexing (a/i) services, such as *Chemical Abstracts*, *Geobase* and *GeoRef*. The electronic version of a/i services has dramatically improved efficiency and accuracy, compared with the previous labourious process of going through the paper-printed issues and collective indexes. There is little doubt that a/i services are now mostly used in their electronic form, and that this is highly appreciated by the users.

An early experiment in primary electronic publishing, the Adonis project, started a decade ago. A number of publishers provided publications in the life sciences to the Adonis consortium. These publications were put in bit mapped form on CDs, which were sent weekly to subscribers. Several other experimental programmes followed, such as TULIP (http://www.elsevier.nl/inca/homepage/about/resproj/tulip.htm).

New possibilities were created by the recent advent of the World Wide Web, and the user-friendly browsers such as Netscape and Internet Explorer. Publishers realise that on the one hand the market is demanding electronic publishing, and that on the other hand WWW gives them the

| player | conventional publishing | electronic publishing |
|---|---|---|
| author | typewritten manuscript<br>mail submission | compuscript<br>e-mail submission |
| reader | "paper" interface<br>retrieval by indexes | electronic interface<br>retrieval by search engines, easier browsing with hyper-links |
| librarian | shelves & volumes | virtual library<br>Local Area Network Provider |
| publisher | slow production<br>printing & mailing of issues<br><br>publishing per issue | rapid production<br>electronic production & distribution<br>database publishing<br>integrated and customised product offerings |

opportunity of doing a better job with more efficient production, distribution and retrievability of scientific material. Still, the vast majority of scientists use the traditional paper-printed products for keeping abreast of the primary literature and as the preferred method for publishing and documenting their research.

**What are the consequences of electronic publishing?**

Transition to an electronic publishing world leads to various changes for authors, readers, librarians and publishers. For a brief overview, see Table above.

**Present electronic publications**

Often headed by the large learned societies, publishers are now instigating many initiatives in particular on the Web. These include:

1. Alerting services on the Web: these are mostly free of charge, and include contents lists and often abstracts. Surrounding infrastructures such as search engines are provided. Good examples can be found on the AGU Web-pages also (http://www.agu.org/pubs/inpress.html). The National Centre for Petroleum Geology and Geophysics offers an excellent overview of the Web-presence of earth science journals (http://www.ncpgg.adelaide.edu.au/journals.htm). Publishers hope that giving this service to the potential readers will lead to an increased readership and exposure of their journals.

2. Publish "unprintable" items on the Web, such as movies, sound, or computer programmes which are connected to conventionally published articles. One example is the programme library of *Computers & Geosciences*. Elsevier publishes sound files with the journal *Speech Communication*. The Geological Society of America maintains the GSA Data Repository which contains data supplementary to articles published in GSA's journal.

3. Existing journals in pdf format. Springer (http://link.springer.de/ol/gol/) has most of its journals in pdf format which basically offers readers the possibility of reading (or printing) the articles in exactly the same form as they are printed in their respective journals.

4. Electronic journals in HTML format. An early example is *Earth and Planetary Science Letters* (http://accept.elsevier.nl/journals/epsl/Menu.html), which features electronic datasets, and also provides the abstracts of the literature references. Newer journals include *Earth Interactions* (http://earthinteractions.org/).

**What is the value of the present initiatives?**

The limitation with the present publications in electronic form is that they follow the format of the paper printed product. It is hard to improve on the magnificent interface offered by the paper print medium. After all, this has developed over millennia from the ancient times of clay tablets and book scrolls to the present straightforward "interface" offered by a paper issue. This "interface" features not only page numbers, a list of contents and keyword indexes but it also offers ease of reading, convenience of flicking through pages, and portability. On the other hand, the desktop computer used for the present range of e-publications is not portable, awkward to read, even harder to browse, may have inexorably slow connection times, and from time to time a breakdown. For most present electronic publications, the main value is that it can inexpensively replace a personal subscription, and possibly offers better search possibilities. I still think, that I can absorb the contents of a traditional paper-printed issue much faster than reading its electronic equivalent from a PC.

**Value of Geoinformation**

For a scientist, the value of information denotes *efficiency*: how can he be kept abreast of the recent advances in his field with a minimum effort? And how can a scientist get, with as little exertion as possible, an answer to his queries? The publisher will continue to play a role in the publishing process if and only if he can continue to add value. A number of added value features are summarized below:

***1. Standards***

Scientists are more likely to go to electronic literature, once this offers a fairly complete overview, and if a common representation and interface are used by all information providers. To facilitate this, publishers should use the same standards.

In the paper-printed era, the situation was very straightforward and simple. The publishers printed their material, and the libraries archived it in the usual way. Helped by secondary abstracting services and all kinds of internal indexing systems, the scientific literature could be retrieved by the library's clients, the scientists. Almost automatically, the whole author-publisher-library-reader system has used the same standards.

In an electronic environment there are a variety of standards, such as HTML version 3.0 but also portable document format (pdf) or postscript. There are various computer platforms, such as UNIX, PC or Macintosh. Finally, interfaces are changing, such as new versions of Web-browsers (beginning with Mosaic, later followed by Netscape and Internet Explorer, both in various versions).

There is no doubt that in the next few years platforms, standards and interfaces will continually change.

In order to be able to cope with this, publishers need **to code articles in a generic way,** to (i) achieve preservation, (ii) to produce information in any format and (iii) to be able to improve full-text searching and linking. Many publishers (including the IEEE, ACM and Elsevier) adhere to SGML (Standard General Mark-up Language), which allows them to generate articles in a contemporary format (at this time this is conventional print, pdf and HTML3.0; five years ago it was print, postscript and HTML1.0).

With SGML the text is exhaustively coded (tagged). In Figure 1 the header plus abstract of an article is shown coded in SGML (lower half of figure), along with the representation this would have in a print medium. Tags are in between the charcters "<" and ">". It can be noted that specific text elements are coded, such as the abstract (begins after tag <abs>) or keywords (between tags <kwd and </kwd>). Other elements, such as author name, affiliation and title are also separately coded. Another example is shown in Figure 2 where a literature reference is shown in SGML and in the printed form. Again, author name, journal, publication date and so on are coded.

This SGML-coded text is generic, and allows an easy translation to the required representation, be it HTML, postscript, pdf or conventional print--in addition, the reference can be represented in the desired form such as numbered or alphabetical. This coding also allows specific searches, such as on title or keywords. Indexes can be generated very easily, as well as brief "snapshots" of an article, which consists of for instance abstract and figures. The richly coded text also allows a publisher to link references to abstracts (from GeoBase or GeoRef) automatically, and even to link to literature on other sites.

***2. In the prepublication stage***

Authors should be able to submit manuscripts electronically to the journal's editor. An example for this is the Virtual Editorial Office (http://veo.elsevier.nl/plb.hep-th2-/index.htm) now under development with Elsevier. Also the AGU has such facilities (http://EarthInteractions.org-/E-JOURNAL/ei-submit.html). Along this line, prepublication servers would be possible, for instance as used by the AGU who publish abstracts of their forthcoming articles on the AGU site (http://earth.agu.org/GRL/grlonli4.html). And finally, Elsevier has a system where authors can follow the production stages of their papers (http://www.elsevier.nl/oasis/)

***3. Good searching methods***

In this era of article overflow, *finding the information will become as important as the information itself.* At present most search engines are based on computer logic--something is either true or false. Search selections are made with the help of Boolean logic. This is complicated, and often gives too many results with a high degree of irrelevant articles, as well as missing important publications. A more promising search method is a "fuzzy logic" search mechanism, which works more along the line humans reason: answers are not strictly "yes" or "no", but can also be " maybe". Queries with fuzzy logic use natural language and may be helped by a good thesaurus, and results can be ranked logically.

***4. Link the primary literature with secondary literature***

If a scientist wishes information, the most common way is to find the literature references by a computer-aided search in *Geobase* or *Georef.* A scientist will then check the thus indicated primary literature in the library. In the electronic era, these two processes are combined. In Elsevier's *ScienceDirect* (only life sciences at present) (http://www.sciencedirect.com/), a scientist finds refer-

*Research report*

**Decomposition of organic hydroperoxides on cation exchangers**

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*Received 4 July 1994*

**Abstract** The acid catalyzed decomposition of p-tert butylcumene hydroperoxide results in acetone and p-tert butylphenol as the main products. This paper deals with the experimental results obtained on strongly acidic activated cation exchanger resins. ...

**Keywords** Acidity; Cation exchangers; Organic peroxides decomposition.

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acidic activated cation exchanger resins.
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**Fig. 1.** Example of the beginning of an article marked up in SGML.

ences by a computer search in EMBASE, the abstracting/indexing service. A scientist can then hyperlink to the resulting articles in full-text electronic form, if they are included in *ScienceDirect.* Hereby the secondary literature database is connected with the electronic archive of the primary literature.

Another alternative is also possible--a connection of articles in the primary literature with abstracts of cited articles. Readers often wish to inspect the literature references. A first step to facilitate this is to provide abstracts of articles cited at the end of an article. In our HTML-journal *Earth and Planetary Science Letters Online* most literature citations listed at the end of each article have a hyperlink to their respective abstracts. The abstracts in question are automatically picked up from Elsevier's abstracting/indexing service in the earth sciences, *Geobase.*

*5. **Use the medium to the fullest.***

There are quite some electronic gadgets that can be added to articles which improve the presentation of information and increase the efficiency of the reader. To give an example, a brief computer animation can say more than pages of text. Examples include:

* Multimedia files, such as animations, movies and sound; Java code
* "Living" articles: articles that can be continuously revised and updated after publication
* computer programme code, plus test runs.

**[1] Paivio, A. & Becker, L.J. *et al.* (1975) Comparisons through the mind's eye. Cognition, 37 (2), 635-647.**

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**Fig. 2.** SGML coded literature reference

Current examples include the programme library of *Computers & Geosciences* (can be accessed from http://www.elsevier.nl:80/inca/publications/store/3/9/8/). This programme library is freely accessible and there are now over 100 programmes available for immediate downloading in Unix or DOS format. Descriptions of the programmes including manuals and test-runs can be found in the journal itself, which is full-text on-line (http://www.elsevier.nl/locate/cgonline) since 1997.

Elsevier publishes sound files with the journal *Speech Communication.* (http://www.elsevier.nl/inca/publications/store/6/0/0/8/5/5/). The option offered to authors to submit sound files to "illustrate" their article has been quite successful, and hundreds of such files can be found on this site.

The Geological Society of America maintains the GSA Data Repository (http://www.geosociety.org/pubs/drpint.htm) which contains data supplementary to articles published in GSA's journal. Such data include tables with detailed measurements.

**Electronic Publishing: Consequences**

As said above, several individual journals of a number of publishers are now available electronically on the World Wide Web. In Elsevier's case, we have a few earth science journals (*Tectonophysics, Computers & Geosciences,* and *Earth and Planetary Science Letters Online)* available on WWW.

Up-scaling from these individual journals to all of Elsevier's 1,100 journal titles is quite an accomplishment. A uniform tagging system needs to be established and production of impeccable SGML code needs to be arranged with the many subcontracting typesetters. A special hardware configuration (called the "Electronic Warehouse") has been constructed to store the over 130,000 articles published annually by Elsevier. Our firm now has 300 life sciences journals available in HTML/pdf in the project "ScienceDirect" (http://www.sciencedirect.com/), which have a direct link with EMBASE, Elsevier's secondary service in the life sciences. We will soon expand this to all our 1,100 primary science journals.

**Commercial side of publishing electronically: costs/ benefits**

Price increases from the publishers are generally based on (at least) inflation, but also on the growth of scientific articles (worldwide output goes up by circa 3 percent per annum and publishers respond to this by publishing more or thicker issues). As library budgets grow at best at the rate of inflation, this has led to a slow downwards trend in subscription numbers for many a mature journal (publishers call this "erosion" or " attrition"). A reaction to this by the publisher is to increase the price even more, to compensate for loss of resulting income. And so, publisher and librarian alike, are caught in a spiral of price increase/subscription erosion. As a sad result, libraries can offer fewer journals to their clients.

Investments for electronic publishing are quite substantial. In our own organisation, the above-mentioned Electronic Warehouse needed an initial outlay of many millions of dollars. The annual run-on costs are also very high. The process of having our many subcontracting typesetters produce SGML coded text is by no means trivial, and logistically a nightmare. It of course also leads to increased production costs especially in a period where we have to incur costs for both the print and electronic production processes. Quality control is complicated and labour-intensive. Selling electronic subscriptions is much more expensive and, contrary to paper, the after-sales cost, such as installment and helpdesk, are considerable. Cost savings in printing and distribution do not compensate the extra costs by a long way. And yet, most publishers feel they have to invest in all this, lest they will lag behind. The publishing industry in an electronic environment appears to be getting more competitive, where economies of scale are becoming more important to make the required investments possible.

Electronic publishing offers many advantages for libraries. To give an example, Elsevier's present e-publishing system, *Elsevier Electronic Subscriptions (EES)*, has been licensed to a number of large consortia, such as all universities in Taiwan, 49 universities and other research institutes in Ohio, and 8 university institutes of the German state Nordrheinland-Westphalen. By means of special, tailor-made arrangements with these consortia, the institutes have access to practically all of Elsevier's journals in electronic form, for only a limited extra surcharge over what they used to pay for the printed products. For the Ohio consortium deal, 49 institutions now have access to 1,100 Elsevier Science journals via *Elsevier Electronic Subscriptions.* The arrangement provides desktop access to the entire Elsevier Science list for the Ohio students and faculty statewide.

Other advantages for these groups of libraries are considerably lower archiving costs, as well as a much higher efficiency in making the literature available to the desk top of their client, the scientist. In the future their operational cost is likely to go down even further, because most publishers will use standard available World Wide Web technology for their electronic publications. Having said all this, substantial extra savings in library running costs are not to be expected in the short term, as both a paper and an electronic archive will need to be accommodated and maintained, and the investment in and maintenance of the electronic infrastructure is not likely to be inexpensive.

In the longer term, all parties will benefit: the library by having lower operational costs, and being able to integrate primary and secondary literature, the author by having multimedia means of enhancing his manuscript, the reader by much-improved efficiency, and the publisher by being able to offer much more material including new functionalities for a marginal extra fee. Following the premise that the future electronic systems will allow a publisher to sell more units, electronic unit prices may very well go down, in particular for principal clients who wish to order more material for a modest surcharge. By the publishers' creation of total publishing packages, it is hoped that the libraries will once again be able to offer a broad selection of the scientific literature in a user-friendly manner, thereby breaking through the present vicious circle of dwindling subscriptions and consequent price increases.

**Conclusions**

1. On the whole, the future information supply will improve both the efficiency of libraries and the efficiency of scientists, in particular when the primary and secondary information integrate.

2. The present trend of libraries becoming less well-stocked may be reversed

3. Electronic publishing has added value by providing authors and readers with multimedia interfaces to improve the value of scientific information. In addition, electronic products will have considerably more value once a comprehensive collection of science journals can be offered in an integrated way.

4. Electronic publishing can be offered in a more tailor-made form than the conventional paper-printed products.

5. Adhering to generic standards in electronic publishing will become a necessity.

What will the future bring us? Some of the traditional roles/functions of the publishing industry, such as composing, printing and distributing of articles are vanishing and are being replaced by new ones like interlinking the body of scientific publications and customising information delivery. And, although the paper publication medium is hard to beat, I am sure that the publishing industry is developing electronic publication systems which really will have a positive impact on the efficiency of scientists consuming the earth science literature in the future.

# ELECTRONIC SOCIETY JOURNALS: TIME-HONORED VALUES AT NEW COSTS

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*Abstract*--Tight budgets, bad spending decisions, and unwise publishing practices seem to be hastening the downward spiral of scientific journal subscriptions. Will the electronic media hasten the system to utter collapse, be its salvation, or have little long-term effect on what truly matters to the scientific community? To be effective, electronic publications must carry forward the time-honored values of the scientific publication process. Among these is access by individual scientists to validated contributions to the body of knowledge -- contributions that the reader can trust as the authentic version of the work. Scientific quality of publication will continue to be the highest priority. The methods of reaching these objectives may differ somewhat in the more fully electronic system than they do in the print-on-paper environment. One thing is certain: sustaining the values will not be free, and some sector(s) of the overall communication cycle will have to pay. To date the great savings predicted for electronic publications have been elusive. Those who claim otherwise are not doing an accurate accounting job. Savings in paper and postage have been replaced by new costs for hardware, software, personnel training, and even higher salaries for more highly skilled staff. New features possible in electronic journals come at higher costs. For example, the interactive features of AGU's electronic journal *Earth Interactions* require added time in the production process, may ultimately require special licenses, and take more computer resources; however, the advantages for the authors and readers are enormous. So long as both print and electronic formats must be provided, there will be duplications in costs and effort. Yet are we ready to rely only on the electronic version? Perpetual care of the electronic files is a moral obligation for publishers--one whose costs are currently unknown. Experimentation is a given and experimentation costs money. What will all this mean for society journals and those who depend on them?

## THE STATE OF THE JOURNAL

Scientific journals are at considerable risk. Actions of both friends and foes of the formal publication process are adding to the stress on the system. The economic picture is bleak. There are new and growing pressures from technological changes. It is unclear whether the advent of electronic communication will hasten the scientific journal system to utter collapse, be its salvation, or have little long-term effect on what truly matters to the scientific community. It is clear that technological changes have dramatically increased the risks, at least in the short term.

Strident advocates for the demise of the scholarly journal, like Paul Ginsparg and Steven Harnard, highlight interesting possibilities for electronic communication while overlooking important values provided by the organized journal literature. In their scenarios there is little if any need for the traditional players in the communication chain. Authors will go straight to the readers, reviewing can be dispensed with or be a totally open system in which uninvited comments are also "published" on the Web. Some may find their vision a scientific publication run amuck. However, such extreme positions have caused movement toward electronic dissemination of journals by scientific societies that was overdue. Without this impetus, the first experiment by the American Physical Society with electronic delivery with OCLC may not have happened.

Today self-publication is a reality for anyone with access to the World Wide Web, a little knowledge of text markup, and some experience with computer graphics. Scientists throughout the world are making articles available directly from their own Web sites. Whether they realize it or not, they are publishing their works. For those who do not wish to manage their own distribution, preprint servers like the one at Los Alamos will take on this chore.

Both approaches, self-publication and preprint servers, provide instantaneous access to new ideas and are excellent ways of communicating work in progress. At the same time, these approaches are a threat to the survival of the organized body of knowledge. Self-publication cannot guarantee accessibility in the future. Preprint servers are claiming they will provide continuing access, but there is no reasonably certain income source backing up that guarantee. For science and other scholarly pursuits, it is imperative for future researchers to have access to prior results.

With tighter library budgets, subscription cancellations are the norm. Can publishers count on this source of revenue to pay for the migration to electronic publishing? For many society journals, page charges are another source of revenue--but a problematic one. Page charges are voluntary and authors can choose to spend their monies elsewhere.

The growing calls for university authors to retain their own copyrights will limit not increase how the journal literature can be developed and distributed. Without full rights to the intellectual property, publishers may be restricted in creating new ways of disseminating the scientific results. We cannot foresee all possibilities and therefore cannot know up-front which rights are critical. For this reason, AGU requires the transfer of all rights.

Technological disenfranchisement of parts of the scientific community is a reality we must face. For some time, a major worry for scientific societies has been how we can continue to serve scientists in the developing world who may not have the wherewithal to obtain or use modern computerized communication tools or be allowed to use the Internet. Now we have added a new and very different concern. We must worry about cross-platform incompatibility lest we disenfranchise the Unix and Mac users in the developed world. The so-called neutrality of the World Wide Web has not lessened this problem. New techniques are not available to all users. The major browsers handle different Web programming outputs differently--or not at all. These worries are real but hopefully only short-term problems.

As we approach the time when the electronic journal will be the journal of record, we need to be concerned about much larger issues. We face the possibility of single points of failure that could destroy accessibility. More importantly, we must get serious about what it will take to maintain the electronic archive and migrate it before software and hardware systems make that archive obsolete. Publishers who think they can pass the archiving chore to the library community must not be planning to do much more than provide the old, flat, printed page on a screen. True electronic journals will be alive with links and functionality that will require individualized technical care and feeding.

Technology provides wonderful opportunities, but its rapid changes make it difficult for us to have confidence in any single path to electronic publication. If we are too rigid in our choice of this path, we could have a very rude awakening. For small societies, it is particularly disconcerting to learn that so much of electronic publication is still undefined. The cost of entry to the electronic journal world is a big unknown. The continuing expense for publishing an electronic journal is unclear. We do not know whether or when electronic journals can generate sufficient revenue to sustain themselves, let alone cover the costs of development. In the sciences, no one is recovering their costs yet.

I have painted a grim future for scientific journals. Does this mean I'm ready to fold up the tent and steal away? Not at all. I believe that the "values" scholars demand of their communication system will make the difference. These time-honored values will bring order out of what could become chaos if we allow the worst case scenarios to become reality.

## TIME-HONORED VALUES

Simply because scholars will be working with new tools, I see no reason to expect an upheaval in their value system. As we move further into the uncharted territories of electronic journal publishing, existing values may acquire even greater importance as they highlight the discriminating factors between what is worthy of attention and what is not.

There are many intermediaries in the scientific communication chain. But the system exists for scientists. Their values will prevail because the system must serve their needs. I therefore have great faith that the electronic journal system will evolve in a way that strengthens the underlying fabric of scholarship. (An interesting printed debate on this theme was led by Kaufman and Miller, 1992.)

The communication of the future system will be driven by the needs of scholars. What they value will ultimately come to the fore as changes occur in the system. Thus, the services of greatest value to the scientists will not go away. Neither will the costs for these services go away.

Before looking at some of the economic issues, let us take a look at some of the values we should expect of the electronic journal system:

* Originality
* Validation
* Authentication
* Accessibility
* Preservation

Whether scientific information is distributed as ink smeared on trees or as electronic bits over fiber optic lines, scientists will continue to value originality and will continue to respect the priority of discovery and ideas. Originality will not lose its importance as a filter for determining what should be added to the formal record of contributions to the body of knowledge.

The peer review system--regardless of its shortcomings--appears to be the best mechanism for determining which pieces of information become part of the record. So long as the review process continues to play this key validation role, it has value and will be a part of the electronic future.

Some are arguing that the university should take over the scholarly publication system for its own faculty. In my experience, scientists demand independence in the review system. They depend on criticism from colleagues external to their own institutions to enhance the usefulness of their research. A scholarly publication outlet dominated by a single institution is unlikely to succeed because it is at cross purposes to the value system of scholars. However, considerable time will continue to be spent on this debate in some circles and it cannot be ignored.

The validation process will be ever more important in the world of electronic distribution because it can help researchers do a "quality" sort on the glut of available information. Scholars simply will not have the time to sift through all that chaff for the kernels of new and useful information. Time is not expanded by the new technologies, whereas the number of demands on that precious commodity will continue to expand.

Once found, the authenticity of a given piece of information must be known. It is very difficult to tamper with an individual article in a printed journal and pass it off as the original. In the electronic world, all sorts of changes could be introduced innocently or maliciously and the now counterfeit article be passed along as though it were the original. Authentication for their journals is an important role that scientific societies expect to under-take. Techniques for succeeding in this role may vary. Some methods being discussed include various types of cryptography, electronic signatures, and electronic watermarking. The successful techniques for the purpose of authentication must do more than trace the original source. They must let the reader check whether the material has changed on its path from that source to her.

There is another aspect of authentication we could inadvertently overlook. In the print-on-paper world, we can each go to the source document and find exactly the same information. In the electronic environment, what we find in the source document from the "authentic" distributor could depend on when we accessed the document.

A policy question each publisher must face is whether there are any circumstances under which the electronic file should be changed and the corrected article re-posted. Is it okay to fix a spelling or grammatical error? Well, what about a typo in an equation or in a table of data? Obviously, readers should have the most up-to-date information--but not at the risk of compromising the integrity of the record. AGU's solution is to attach to the original article a "correction file" complete with the date of publication of that correction. This approach is useful to the reader of the original article who now has a way of knowing that a correction has appeared at later date, or in print terms has appeared in a subsequent issue.This method leaves the original article intact. There is no question about what the article said or when it was said, and yet readers also have immediate access to corrections or addendum.

Accessibility is another time-honored value we require of the scientific information system. Unless other researchers can make use of the published record, it does not serve the needs of the community.Accessibility is achieved in different ways. Scientific societies price their journals to disseminate the research as broadly as possible. Having a rate that is affordable by individuals optimizes distribution and assures that many researchers have personal copies near at hand. Libraries provide access for students, for those in related scientific fields, and most importantly for future generations.

In the print environment, preservation is provided by the wide distribution of journals in academic, public, and government libraries around the world and by the care given to the journals by professional librarians. Many publishers have relinquished totally any responsibility for preservation to the library. Although AGU has maintained a microform collection stored under strict environmental conditions as an archival backup for the printed journal, we do not consider ourselves the primary archivist for the printed journal.

Preservation of the electronic journal is an entirely different matter. The journal is no longer a static document that can be maintained by a multitude of different caretakers using different systems. At the simplest level, the electronic journal contains an ever changing array of links to other papers, which make the journal a living document. For example, AGU's *Water Resources Research* online has both forward and backward reference links to the full text of other articles in the 1990-1998 database. Every new issue posted appends information to articles previously published. How can anyone except AGU maintain this changing database? If the links are not retained in the archive, the electronic journal loses some of its value.

Originality, validation, authentication, accessibility, and preservation--that is my list of the time-honored values of the organized scientific literature.

**NEW VALUES**

Computer technologies are creating new values as they provide new ways for enhancing the journal literature. For example, authors are no longer required to reduce information to static two dimensions for publication. Right now

AGU's fully electronic journal, *Earth Interactions*, provides a whole array of features that exploit the computer technology for presentation of scientific results and has others in the plans.

Animation and virtual reality: Researchers regularly use animated graphics to show changes in both observed and modeled phenomena and are beginning to use virtual reality displays. Whereas they can share these approaches at poster session of meetings, they have been limited when trying to convey this information in the journal literature. *Earth Interactions* currently supports MPEG and Quick Time for display of image loops and animations, because Web viewers are widely available for these formats, and the VRML format for authors who want to publish virtual reality displays. Authors can even narrate these features so that the reader is not forced to jump back and forth between the graphics and the text of the article. *Earth Interactions* may be the first scientific journal that needs to include pointers on diction in its information to authors.

Datasets: *Earth Interactions* permits small datasets to be incorporated directly into an article. Readers can draw these data into their own models or use them in other ways because they are stored as discrete electronic bits, not graphical renditions of tables. The journal also provides active links to external data archive facilities that house larger datasets. The data can be in a form that can be directly ingested by analysis packages for further study. To assure that the externally housed data are available for future readers, authors must store their data with facilities that have a mandate for its long-term care.

"Live math" and numerical code: "Live math" refers to equations presented in a symbolic form that can be ingested by a mathematical analysis routine (such as Mathematica or Matlab) and through that facility manipulated interactively. For example, rather than only displaying a static graph of an equation with a particular parameter set to a few common values, the equation and parameters could be held as a live math set so that a reader could produce graphs for values he or she chooses to enter. *Earth Interactions* currently supports the inclusion of Mathematica Notebooks. Authors can also provide the numerical code for their models and thereby share this kind of analysis tool with the readers.

Three-dimensional images: Software already exists that allows true interactive 3D display (so that a reader can rotate a 3D object and view it from any desired angle). The standards for Web-capable viewers are yet not firmly established and so *Earth Interactions* is not supporting 3D displays yet.

A full description of how this new kind of journal was conceived and is being operated appears in another online journal devoted to electronic publishing (Holoviak and Seitter, 1997).

We can certainly envision other useful formats for presenting science. For example, in tomorrow's journal, holograms may become as common as photographs.

Electronic journals easily provide for full-text searching and links within an article from text citations to the reference list.Some journals are providing links from the references to external databases of abstracts.

The electronic medium provides new added values for many types of information. But these enhancements are adding to the overall cost of the scientific information system and will make the problems of preservation even more difficult.

## COSTS OF ELECTRONIC PUBLICATION

To date the great savings predicted for electronic publications have been elusive. Those who claim otherwise are either fooling themselves or are not doing an accurate accounting job.

As a rule of thumb about 80 percent of the cost of publication of a scientific society journal is related to what is known as the first copy costs. First copy costs include the review process, copy editing, composition, and setting up the press and bindery equipment. Most of these costs will continue for the electronic journal. Some of the activities could be more expensive on a page-of-science basis.

The cost of supporting the peer review process for the Journal of Geophysical Research is about $700k per year or close to $25 per page published. This amounts to 17 percent of the JGR costs. I see little reason to expect the cost involved in supporting the review process to decrease. When all submissions are electronic, we will see a decrease in the amount of express mail used. However, a 14-month experience with a fully electronic submission and review system for Geophysical Research Letters has proven that the faster electronic system has new costs of its own. The computer servers, storage, and maintenance are not free. Skilled staff members must constantly manage the files, help authors and reviewers with their questions, and make improvements to the underlying software.

The expenses of the review process are an ongoing cost of scientific publication regardless of the distribution format. Likewise, the salaries for copy editing and preparing material after acceptance of an article will not go away for the electronic journal. These functions represent about 25 percent of the current JGR costs. As we incorporate more electronic features, the costs will rise. The special features require computer expertise, and finding and keeping such talent cost much more than a highly skilled, traditional copy editor or production staff member. I do not have hard numbers yet, but in the short-term, I am expecting a 30 percent increase just in the personnel costs. Additionally, we will have the costs of hardware, software, and computer systems people needed to support the editorial or the production staff.

As you can see, in the traditional printed journal we have expended about 50 percent of the cost of publishing before the composition phase has begun. For journals that are composed electronically, the composition costs are not likely to change much. However, for more than 75 percent of the material AGU publishes, authors supply camera-ready copy on paper. Our challenge is to get this material into a usable electronic form without significantly increasing the costs that would have to be recovered from subscription revenue or page charges.

To engage commercial composition to get the electronic files for JGR would add about 20 percent of the current costs to our economic picture. If we had no equations or non-ASCII characters, using authors' electronic files would be relatively straightforward. But we have many equations and JGR's transition to fully digital text will not be simple - if we are to keep the costs down.

So long as we must produce both print and electronic versions of journals to satisfy users, the only possible savings of electronic publication will be in the paper and postage for those subscribers who decide to forego a paper copy. Some overseas subscribers may choose this route in order to save the postal surcharge and to get faster access. For the next 3 to 5 years, however, I suspect we will be producing dual formats, if only because many are not yet ready to rely solely on the electronic version.

What about the real costs of electronic distribution? Their effect on overall costs may depend on how one goes about the process.

As a scientific journal publisher, I could employ a vendor to prepare the electronic files, mount them on a server, provide the user front-end, and do the ongoing maintenance. Each month the vendor will bill me for these services. Thus, I will definitely know the additional costs I am incurring for the electronic version. I see some questions surrounding the vendor approach. In the print environment, moving from one commercial printer to another is easy.However, it may not be so easy to transfer files that have been created for one electronic delivery system to another vendor with a different system. What if the vendor I select does not keep up with the technologies I want to use? Could I be prevented from including new special features such as those *Earth Interactions* is now using? How tightly have I locked myself into a specific direction which could prove to be a dead end? Just how many of these vendors and their wide varieties of delivery systems will survive when the technological and economic shakedown occurs?

For publishers who have decided that the print journal is the journal of record, these concerns may not be serious. For the near term they may be satisfied to have breaks in their electronic journal runs if that becomes the price of changing vendors. For AGU, these points are critical because we have decided the electronic version will be the journal of record. The online journal will contain substance that is available only in digital form. AGU's online journals will differ from their print counterparts. We must have a useful, complete, and up-to-date file of everything we publish in the electronic version.

For various reasons, some societies have decided to develop their own systems. AGU is one of those. We decided that building for ourselves is the best long-term course for both economic and functional reasons. At least creating the underlying files and controlling how they will be distributed will give the publisher more options than linking up with a single vendor. At this early stage in the development of electronic journal publishing, I believe that it is critical to remain flexible. We simply do not know enough about the future to risk all on a course that constrains options.

At AGU we are expending considerable energy on choosing the standards for archiving text, graphics, data, and the other material that are now a distinctive part of the journal. To preserve this material for future access, AGU has committed to protect and refresh the electronic files and more importantly to migrate them to new media or new systems when technologies change. And change they will. We have no way of knowing what this caretaking will cost. To assure AGU can meet its obligation to the scientific community, in December 1996 the AGU Council established a Perpetual Care Trust Fund for the electronic journal archive. This fund has very strict rules. We will have the monies available from this trust when they are needed. This archival role is a new cost directly related to electronic publishing.

Protecting the archive is not the only new cost for AGU's electronic publishing activities. Because we have decided to deliver journals from our own site, we are investing in hardware, upgrading operating software, adding computer experts, buying off the shelf programs where we can, and developing programs specific to our needs when necessary. These development costs are new and real. Last year I heard a major commercial publisher say that most of these costs can be ignored, because computers after all are a necessary expense of doing business. By ignoring these expenses, this same publisher was claiming to drop 50 percent of his cost. I do not see how he can remain solvent if necessary costs are overlooked when calculating the revenue needed to support electronic publishing, including investment in change.

I think that experimentation will also be a necessary cost of electronic publishing for a long time to come. I was appalled to learn that a recent National Academy of Sciences workshop had suggested that all scientific journals should try to adopt a single approach for electronic publishing now. The electronic publishing environment is simply too new for us to settle on a single approach. Electronic journals will be richer because many societies and commercial publishers are trying different routes. Unfortunately, this situation is disquieting for the small societies just getting started. My only advice to them is to stay flexible. They may take some comfort in knowing that even societies the size of the American Chemical Society "are groping our way toward the murky future" according to Bob Bovenschulte, their director of publications (Morton, p. 13).

One thing is clear. Change is the only constant in electronic journal publishing. This change can be positive, but only if we focus on the fundamental purposes for scientific journals and cherish and protect the time-honored values that have made them useful in the advancement of knowledge.

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# ACCESS AND COST OF GEOSCIENCE INFORMATION IN THE TECHNOLOGY ERA

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*Abstract*--A survey was sent to academic, government agency and corporate libraries seeking detailed information on how libraries provide access to resources, spatially referenced digital data, GIS systems, and the cost of providing more equipment to support technological change. A detailed review of the citation patterns of faculty and interlibrary loan activities at Stanford University was investigated to evaluate the ability of libraries to accommodate changes in programs and research activities when library budgets nationally are flat or decreasing as money is spent on gaining electronic resources.

Results from the survey indicate that since 1990, computers have increased in academic libraries by over 400 percent and in government agency libraries by 300 percent. Coping with daily PC problems are library staff decisions but networked systems are the domain of systems staff. Increased technology has added challenges of new email systems, word processing packets and library online catalogs are entering a major change in format. These changes are often introduced with minimal training and little documentation. The cost in corporate and government libraries has been between 15-20,000 dollars per institution, and a little less in academic settings.

Today's users may have greater access to information, but providing speed and cutting edge technology continues to be a burden on library budget and support staff.

## INTRODUCTION

Libraries have traditionally been thought of as depositories of printed material, but today, access to earth science information may be on a stand alone workstation, a networked CD-ROM collection, Telnet sessions or the Internet. Earth sciences libraries have traditionally provided and served their patrons in three areas: acquiring, providing access, and archiving earth science information. In the late 1990's, providing access in libraries has expanded to include the sometimes complicated and time consuming task of patron authentication (and patron definition) to the satisfaction of the publishers and/or vendors of electronic information. How is this being done in the current environment? What is the cost to do so? This paper seeks primarily to address the methods and cost of providing access to earth sciences information. Expenses considered include: staff time, equipment, and shelving, as well as the original costs of materials.

### Sources Used for Examining Access and Cost Information

Data was collected from the following sources:

- A survey of geoscience librarians,
- *GeoRef* information,
- An older, comprehensive study of the Stanford and UCLA earth sciences collections (Derksen and Noga, 1993; Noga and others, 1993),
- Geoscience Information Society Collection Development Committee data,
- *Ulrich's International Periodicals Directory*,
- Cost data and other information from Stanford and UCLA.

### The Survey

A questionnaire was developed to discover how geoscience librarians were providing information when increasingly information was distributed in an electronic format, and how they were affected by the impact of technology on their work environment since 1990

(Appendix I). Survey objectives were to find from each respondent library:

- The type of library, number of staff, and the primary emphasis of the clientele they served,
- The current databases and especially those in the geosciences available to their clients and how access was provided,
- Availability of the USGS digital data series and other earth science data sets for their clients,
- Availability of GIS facilities, as maps were now being created in a digital format,
- How had computer access changed in their library since 1990, and what were the costs involved,
- How changes to work environment has affected the ability of library staff to provide information for users.

The survey was distributed as an enclosure in the April issue of the GIS *Newsletter*. An electronic version was mounted at Stanford University and two announcements were placed on the Geonet-L Listserv in May and June as reminders to increase response.

A total of forty-three responses were returned, approximately one sixth of the GIS membership. Sixty-three percent of the returns were from academic libraries, 21 percent from government libraries, nine percent from corporate libraries and seven percent from research and other libraries (Table 1). Further analysis of the academic libraries showed that in this survey thirteen of the libraries (48 percent) were separate geology libraries, 9 were part of a central library (33 percent), otherwise 2 were part of a science and engineering library (7 percent) and one return each came from a physical science library, and a combined geology/physics library. In the government arena six returns were from separate libraries, two from a library where geology was within another agency, and one from a central library. In the corporate environment two were considered to be stand alone geology libraries, one was combined with science and engineering. In the research institute category two were separate and one was combined. From the responses it appears that the field of geology is served by geology focused libraries but only by a small majority (53 percent).

**Staffing Patterns**

The number of respondents in some library categories was too small to obtain valid staffing comparisons. Thus only staffing patterns for those respondents in the stand-alone categories: academic, government, corporate and research are presented (Table 2).

From Table 2, it can be seen that government libraries have fewer staff by a factor of three. Academic libraries rely very heavily on student assistants, who are relatively inexpensive hourly labor; however, the amount of training time taken up by introducing new students to the complex work required is quite expensive. Bringing student workers fully up to speed on the automated circulation systems (which are not intuitive), to say nothing of the myriad CD-ROMs and abstracting services available through campus systems, is not realistic in the short time available.

Corporate and Research libraries have a higher percentage of librarians per clerical staff member than do the Academic Libraries. Some of the government libraries only have a lone librarian or part of one, and little or no support staff.

**Earth Sciences Subjects Served by Survey Respondents**

Each respondent was asked to indicate the research and instructional areas which they served from a list adapted from the *GeoRef* subject category list. Figure 1 shows that most of the government and the majority of the academic libraries are providing support for the greater number of the earth sciences subdisciplines; only Meteorology, Soils, and Remote Sensing are areas of focus for a small number of schools. This broad range of subdisciplines has expensive implications in terms of the number of journal and series subscriptions needed and the number of new books that should be purchased on a yearly basis. It also has costly implications for Reference Index subscription dollars and the staff time to maintain these resources. In contrast, programmatic requirements for both the Corporate and the Research Institutions are more focused.

## GAINING ACCESS TO INFORMATION

**The Catalog**

To provide access to both their monographs collections and then through indexes and abstracts to the serial collection, libraries have changed from the card catalog to the online catalog, the OPAC, and from paper indexes to online databases.

To evaluate these trends, respondents were asked to indicate how they provided their library catalog and whether it would be available from the office of a faculty member, student or researcher (Table 3).

Because libraries today provide access by multiple methods the totals exceed the number of libraries in the academic setting. Libraries in the academic environment are truly open to the world as nearly half are Web accessible and Telnet connections are available to all but one. Corporate libraries have chosen to make catalogs accessible to their in-house clientele only through local area networks. Three or 27 percent of the government library respondents still are not able to provide desktop access to the catalog to their own users at all, but five of the eleven government libraries responding to the survey can provide it via Web or Telnet.

**Table 1. Institutional Affiliation of Survey Respondents**

| Category | Separate | Central | Other | TOTAL |
|---|---|---|---|---|
| Academic | 13 | 9 | 5 | 27 |
| Government | 6 | 1 | 2 | 9 |
| Corporate | 2 | 0 | 2 | 4 |
| Research Institute | 2 | 1 | 0 | 3 |
| **TOTAL** | **23** | **11** | **9** | **43** |

**Table 2. Staffing Patterns - Stand-Alone Earth Sciences Libraries**

| | **Academic/** | **Government/** | **Corporate** | **Research** |
|---|---|---|---|---|
| | **Separate** | **Separate** | **Total** | **Total** |
| Tot.# Surveys returned | 13 | 6 | 2 | 2 |
| FTE (total) | 71.70 | 6.95 | 7.00 | 6.40 |
| librarian | 18.60 | 5.76 | 5.00 | 3.00 |
| clerical support | 27.00 | 0.36 | 2.00 | 3.00 |
| Students | 25.10 | 0.25 | 0.00 | 0.00 |
| Technician | 1.00 | 0.58 | 0.00 | 0.00 |
| Volunteer | 0.00 | 0.00 | 0.00 | 0.40 |
| | | | | |
| **Ave # of Staff** | | | | |
| librarian | 1.43 | 0.96 | 2.50 | 1.50 |
| clerical support | 2.08 | 0.06 | 1.00 | 1.50 |
| Students | 1.93 | 0.04 | 0.00 | 0.00 |
| Technician | 0.08 | 0.10 | 0.00 | 0.00 |
| Volunteer | 0.00 | 0.00 | 0.00 | 0.20 |
| total Ave. FTE | 5.52 | 1.16 | 3.50 | 3.20 |

**Table 3. Access Methods to Library Catalogs**

| | **Academic/ Separate** | **Academic/ Central** | **Academic/ Other** | **Government** | **Corporate** | **Institution** |
|---|---|---|---|---|---|---|
| **LAN** | 1 | 2 | 1 | 3 | 6 | 0 |
| **Web** | 6 | 4 | 5 | 2 | 0 | 0 |
| **Telnet** | 12 | 6 | 4 | 3 | 0 | 1 |
| **Client/Server** | 0 | 0 | 2 | 0 | 0 | 0 |
| **Not electronic** | 1 | 0 | 0 | 3 | 0 | 0 |
| **TOTAL** | 20 | 12 | 12 | 11 | 6 | 1 |

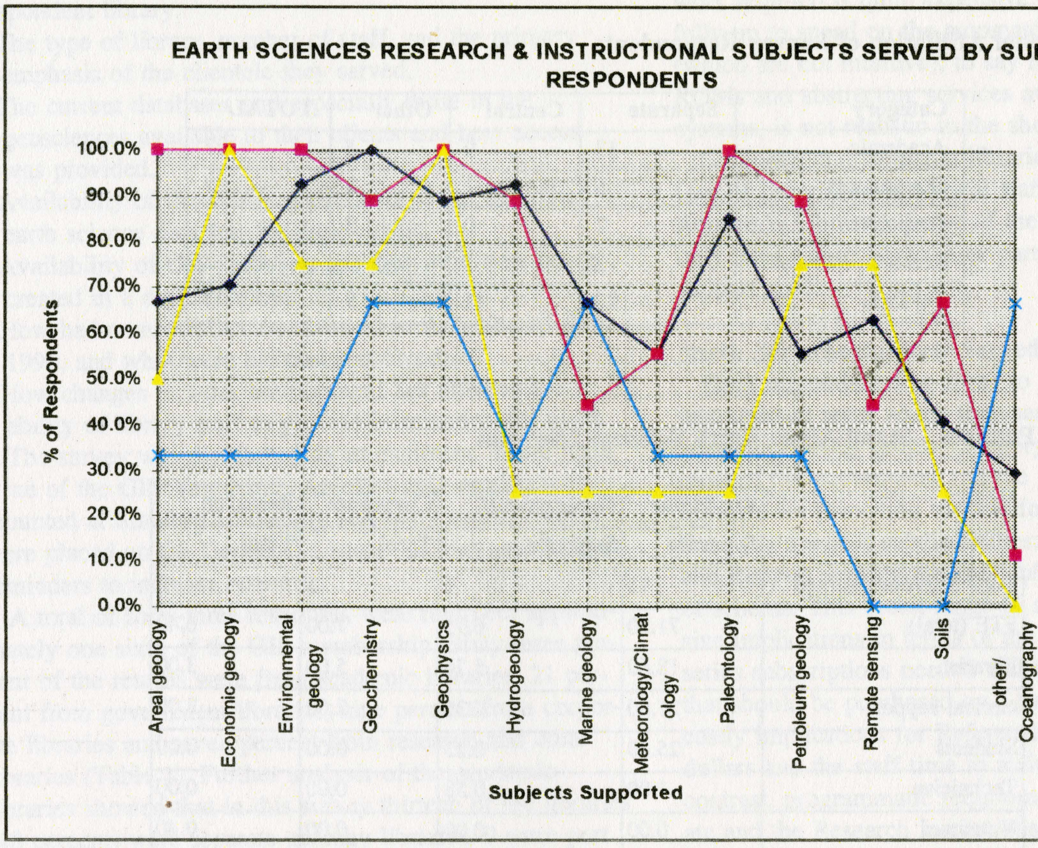


**Figure 1. Earth Sciences Research & Instructional Subjects Served by Survey Respondents**

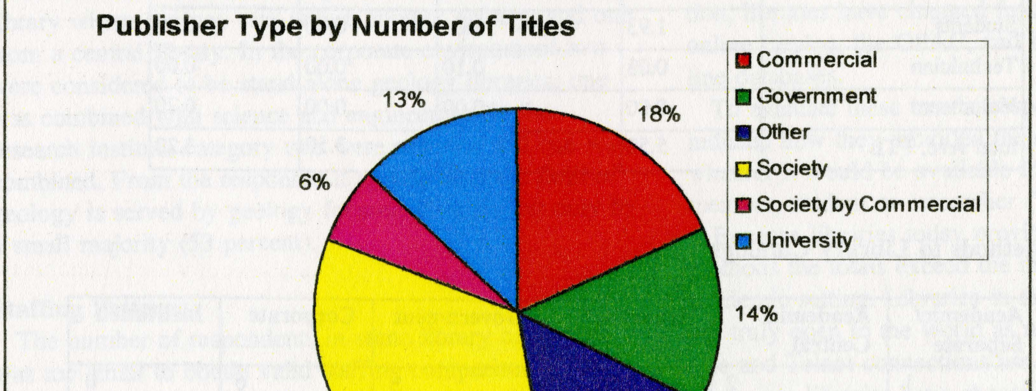


**Figure 2. Stanford/UCLA Journal Subscriptions: Publisher Type by Number of Titles**

**Indices and other Reference Material**

One of the major costs of accessing earth sciences information is that of abstracting and indexing services. Earth sciences is a very broad field with many subdisciplines; there is not one comprehensive and exhaustive index; there is not an equivalent to *Biological Abstracts* or *Chemical Abstracts* for the earth sciences.

*GeoRef (Bibliography and Index of Geology)*, *GeoAbstracts*, *GeoBase*, *Pascal* (*Bulletin Signalitique: Earth sciences sections*), and *Zentralblatt fuer Geologie und Palaontologie* and *Zentralblatt Mineralogie* are the large, comprehensive indexes in the field. None of these indexes thoroughly cover all of the major subdisciplines and all of the Areal Geology divisions; in order to search most subjects exhaustively it is necessary to use more than one of these indices, other than that of the Areal Geology of the country/political divisions where the index is published (Derksen, 1985). Several years have passed since this study was completed, thus it would be useful to redo, particularly since *GeoRef* has tape-loaded many citations from the other indices.

There were thirteen subdisciplines mentioned above; serious students in any one of these probably need to use one or more of the comprehensive indexes plus one or more subdiscipline or area specific indexes. An examination of five of these subdivisions as examples reveals varied indexing needs for each. For physical oceanographers there are three indexes to choose from: *ASFA*, *Oceanographic Literature Review*, and *Oceanic Abstracts*; for geophysicists and meteorologists *INSPEC* and *Meteorological and Geophysical Abstracts* (MGA) respectively would be the additional indexes to use. Petroleum geologists need access to *Petroleum Abstracts;* engineering geologists should consult *EI/Compendex* in addition to the geology indexes. (A comprehensive index list for most earth sciences subdisciplines is available at the Stanford Earth Sciences Web page at http://www-marine.stanford.edu/branner/tips.html)

Table 4 shows the subscription costs for some of the indexes used by earth scientists at Stanford in 1997. Included are the subdisciplines most apt to use the tool, the cost, the present mode of access and the supplier. It highlights the relatively varied number of indexes needed by researchers and students, the diverse means of access and the various sources of the information.

The actual price of the index subscription is only the most visible part of the cost of these tools; due to the multiplicity of formats and sources there can be a lengthy process of selecting the access mode. *GeoRef* is a good example. For the *Bibliography and Index of Geology*, there is a single price, which has remained unchanged since 1991. The CD-ROM has multiple prices with the following variables: organization type, print subscription, and number of sites. Internet and online vendors and prices may differ from that of the CD-ROM vendor. There are, of course, significant differences, largely advantages and restrictions relating to the Internet.

Prices for a direct annual subscription to *GeoRef* updates for use in an organization or group of organizations are based on the CD-LAN 2-4 user prices (Mulvihill, 1997). For academic institutions, this system works better than for commercial and non-profit organizations. Consortia pricing for CD, online or Internet networks, is again different. As the methods of access have multiplied, the complexities of pricing for each have grown. Ten years ago, there was just the price of the Bibliography.

Once a decision is made as to access mode, allow 6-8 weeks for contract negotiation. The contract should be reviewed both by library and legal staff in order to insure that the conditions of access are viable from both perspectives. Aspects that may need to be negotiated or defined include: definition of the site, authorization/authentication methods for access, definition of authorized users, time period of contract, and appropriate use of the search results. Usage data should be supplied on a regular basis. Technical support, library staff instruction, and end-user aids are other services may also need to be included in the license agreement. It is worth the effort to develop an "ideal" license agreement that contains a checklist of important things that should be included in the license agreement, definitions of site and user for your institution, and "deal killers" that are unacceptable in an agreement. Sharing this document at the outset of negotiations may shorten the time needed and help insure that staff doing the negotiations are all using the same criteria when talking with vendors and producers. Be sure to get test access in order to assess the quality of the interface as well as the amount/quality of the content before signing a contract. Explore consortial arrangements to reduce expenditures and to share staff workload.

Allow a minimum of four to six weeks for implementing and developing instructional materials for a new resource. Implementing a file is rarely a one-time activity. File structures and/or the sources from which databases are purchased are constantly shifting, sometimes with every subscription year.

While this brief discussion has centered on acquiring databases, many of the same factors also apply when acquiring electronic journals. There are the added caveats of spending monies to license rather than to own materials, archiving materials, cataloging resources, linking

**Table 4. Selected abstracts and indexes used by earth scientists and their costs in 1997. (Stanford data)**

| Subdiscipline | Title | 1997 $ Costs | Delivery Agency | Current Format |
|---|---|---|---|---|
| All | Arctic & Antarctic | $ 982 | NISC | CD-ROM |
| All | Dissertation Abs. | $13,400 | OCLC First Search | Gateway |
| All | UnCover Reveal | $ 4,633 | CARL | Web & Gateway |
| Earth Systems | Environ. Sci. Pollution Management Package | $ 5,235 | Cambridge Scientific | Web |
| Eng. Geol. | Applied Sci. Tech. | $ 2,100 | OCLC First Search | Gateway |
| Eng. Geol. | EI/Compendex | $16,050 | SUL/AIR | Magnetic Tape |
| Eng. Geol. | NTIS | $ 3.507 | Dialog | CD-ROM |
| Geochemistry. | Gmelin Crossfire | $13,350 | Beil. Info. Sys. | Client-Server |
| Geology | GeoRef | $ 3,750 | Local Campus | Magnetic Tape |
| Geophysics | Inspec | $45,000 | Local Campus | Magnetic Tape |
| Hydrology | Water Resources Abs. | In ESPM Pkg | Cambridge Scientific | Web |
| Meteorology | Meteorological & Geoastrophysical Abs. | $ 3,000 | MAGA on the Web | None |
| Oceanography | ASFA | $ 6,374 | Cambridge Scientific | Web |
| Ore Deposits | IMMAGE | $ 800 | London Inst Mining | CD-ROM |
| Paleontology | Biosis | $13,253 | Local Campus | Magnetic Tape |
| Petroleum Geol. | Petroleum Abs. | $ 839 | Dialog | CD-ROM & Print |
| Soil Science | Agricola | $ 1,000 | OCLC First Search | Gateway |

**Table 5. Price Increases by Publisher Type**

| Publisher Type | 1993 | 1994 | 1995 | 1996 | 1997 | Increase 1993/1997 |
|---|---|---|---|---|---|---|
| **Univ./Commercially Pub** | 34.05% | 18.25% | 18.31% | 28.90% | 11.06% | 168.47% |
| **Commercial** | 26.01% | 4.65% | 9.87% | 24.85% | 11.86% | 102.35% |
| **Society/Commercially Pub.** | 19.29% | 2.70% | 11.32% | 24.15% | 12.52% | 90.50% |
| **Institute** | 12.41% | 4.29% | 11.03% | 12.32% | 6.49% | 55.69% |
| **Society** | 7.31% | 8.21% | 8.06% | 9.94% | 5.60% | 45.67% |
| **University** | 0.93% | 3.62% | 8.84% | 10.57% | 15.31% | 45.13% |
| **Translations** | 6.89% | 6.19% | 8.01% | 10.27% | 6.41% | 43.86% |
| **Gov. Agency** | 1.60% | 5.87% | 7.31% | 9.58% | 7.94% | 36.54% |
| **Median Per Cent Increase/Year** | 20.95% | 5.15% | 9.28% | 21.46% | 10.70% | 86.86% |

articles to indexes, etc. that all add to the complexity of implementing access to the campus community.

Even though it's a lot of work, the payoff comes in more efficient and effective information access on the part of researchers and students. It also positions students to be more competitive when they apply for jobs or continue their educational studies.

## JOURNAL and SERIES PUBLICATIONS

Even though abstract services can be very costly, title by title; the largest expense in earth sciences information is that of journal subscriptions.

### Journal Subscription Costs

Ongoing journal costs take the largest bite in any earth sciences library budget. Where is the money going? Due to changes in the local systems, sufficient well-founded local data was not available to us this year. Thus we made use of a previous study of the Stanford/UCLA collections (Derksen and Noga, 1992) in the early 1990's which is still valid information.

Figure 2 shows that journals published by societies were the largest segment of the journal population. Commercial publishers accounted for 18 percent of all the titles published. Even adding to this figure the number of journals published commercially for societies, commercial publishers provided only 24 percent of the earth sciences library titles - leaving 76 percent of the journals published by the non-profit sector. However, the following diagram (Figure 3), shows that commercially published titles accounted for more than half of the journal expenditures, even though they made up only 18 percent of the collection.

These results were compared with the ongoing Current Journal Price Data Study provided by Michael Noga of MIT for Geoscience Information Society (GIS) members. This project tracks the yearly institutional cost of 202 journal titles held by UCLA and by MIT earth sciences libraries. (Noga considers these titles 'somewhat core' for the average earth sciences library. Inclusion in his study, however, is actually based upon whether he could easily get reliable price data).

Commercially published titles make up a much larger percentage of the whole in this study than they do in that of the Stanford collection. Conversely, University, Government, and Research Institute publications make up a smaller percentage in this study than is true in the Stanford collection. This probably reflects, in part, the fact that prices of these publications are harder to acquire than are those of commercial publishers (Figures 4 and 5).

The commercially published titles in this set of journal titles make up 43 percent of the total number but account for 75 percent of the total dollars spent during the year.

One difference between the earlier Stanford/UCLA study and the GIS/Noga study is that a new category of publisher has been added: Commercially-Published-University publications; so far there are only four of them in Noga's list. In addition, seven titles previously published by a society itself are now being published by a commercial publisher - albeit still sponsored by one or more societies. Another trend is that commercial publishers have been getting one or more societies to agree to sponsor a journal that was simply a commercially published title. There are now six journals in this category. Apparently Elsevier *et al.* have been taking earth sciences librarians seriously, who report that society titles are being retained in lieu of commercial titles when cancellation projects occur. These are disturbing trends, particularly in the light of the price increases seen in the following table; note particularly the top 3 lines of Table 5, all variations on the commercially published journal amounting to an increase of 361 percent compared with 227 percent for the remaining five categories for the period 1993-1997.

As part of another study, Stanford Earth Sciences faculty bibliographies for publications authored by School of Earth Sciences faculty in 1996 were analyzed (Figure 6). The publications lists were taken from the faculty members' resumes in the annual report prepared for the School of Earth Sciences Advisory Board.

Although journals were the favored location for publications, conference proceedings were also found to be important (one should consider the division between books and conference proceedings as publication types to be somewhat fluid). Conference proceedings can be very expensive, as well as costly in staff time to acquire. Stanford didn't own 7% of the publication sources at all; all but one of these are conference proceedings and books. This is a continuing problem: libraries are not able to collect all of the conference proceedings that are apparently important to earth scientists. Because budgets are limited and because conference proceedings tend to be expensive, deciding which ones to purchase can be very difficult. Getting conference proceedings a few months after the conference has been held is often impossible. Periods of monograph purchase slowdown or moratorium (even for a short time) result in measurable, injurious gaps in the collection.

### New Journal Starts

Are new journals being started that earth sciences collections cannot afford to collect? Data on earth sciences journals from *Ulrich's Online*, was examined to evaluate the number of new journal titles being started in the earth sciences. Available figures from this database indicate that the number of new journals being started in earth sciences continues to fluctuate but appears to be

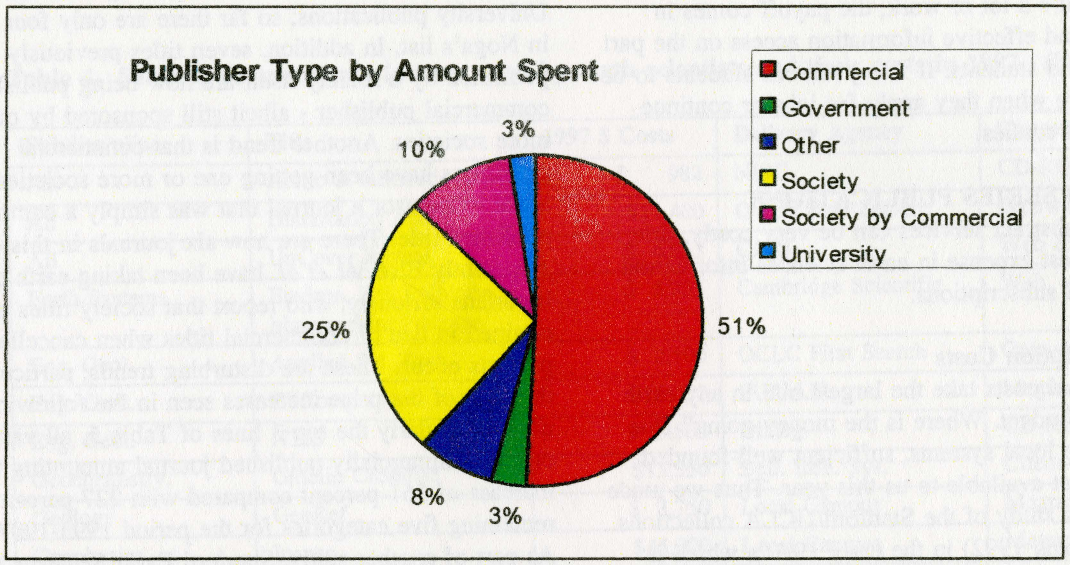


**Figure 3. Stanford/UCLA Journal Subscriptions: Publisher Type by Amount Spent**

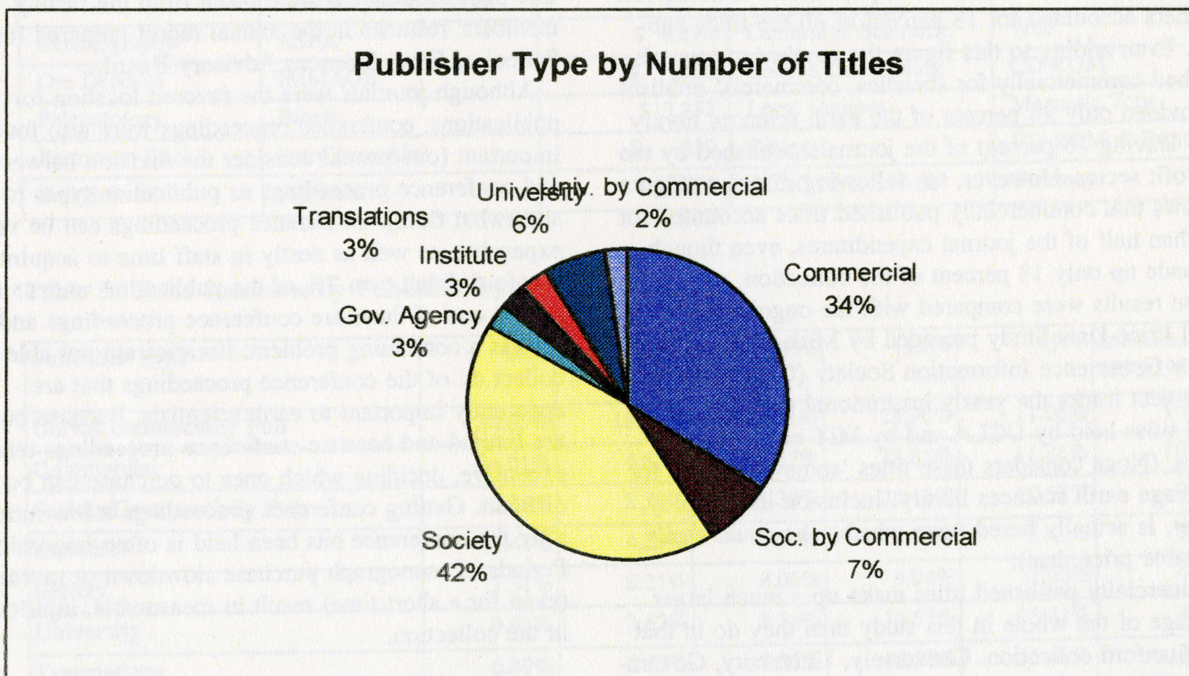


**Figure 4. GIS/Noga Data - Journal Subscriptions: Publisher Type by Number of Titles**

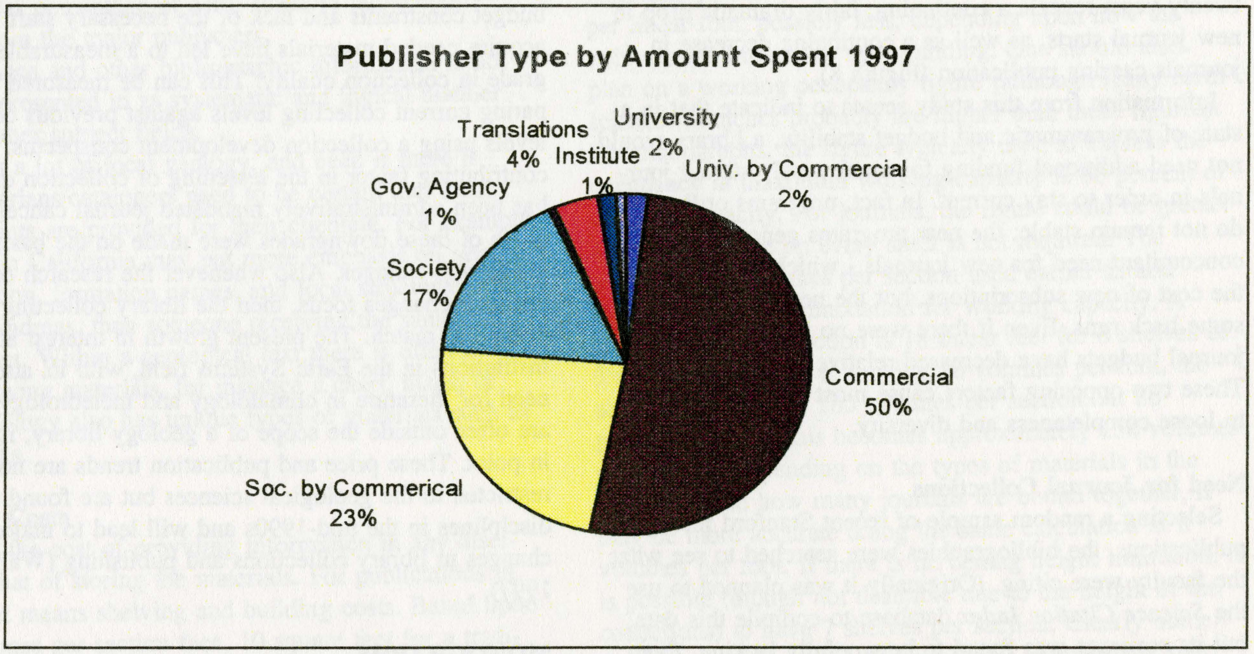


**Figure 5. GIS/Noga Data - Journal Subscriptions: Publisher Type by Amount Spent**

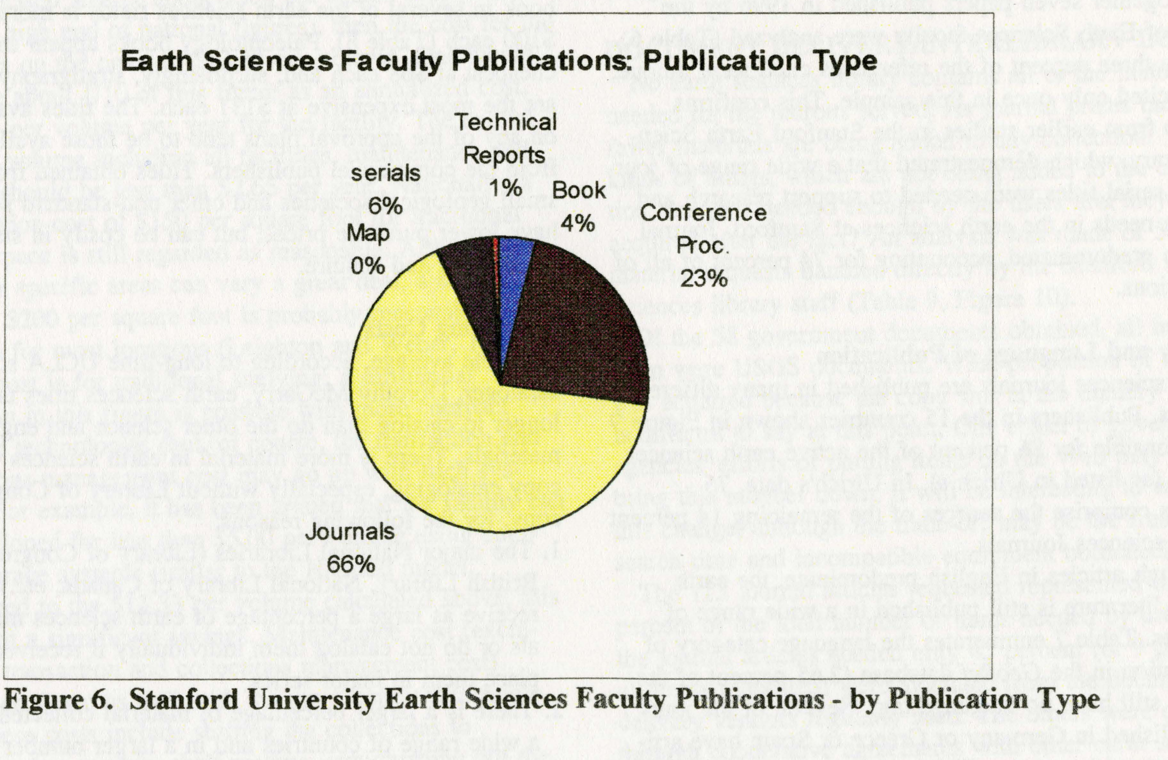


**Figure 6. Stanford University Earth Sciences Faculty Publications - by Publication Type**

dropping as is the number of titles ceasing publication (Figure 7).

A close look at just the new journal starts in the past twenty years reveals a continuing, fairly dramatic drop in new journal starts, as well as a continuing decrease in journals ceasing publication (Figure 8).

Information from this study seems to indicate that in a state of programmatic and budget stability, a library would not need additional funding for many newly started journals in order to stay current. In fact, programs ordinarily do not remain stable; the new programs generally have a concomitant need for new journals - which means not just the cost of new subscriptions, but the need to fill at least some back runs. Even if there were no program changes, journal budgets have decreased relative to journal prices. These two opposing factors cause most of our collections to loose completeness and diversity.

### Need for Journal Collections

Selecting a random sample of recent Stanford faculty publications, the bibliographies were searched to see what the faculty were citing. (Originally it was planned to use the *Science Citation Index* database to compile this data, but its coverage was found to be woefully lacking. Even articles published in the journal *Nature* were missing from the database; thus these compilations were done manually.) Altogether seven papers published in 1996 by the School of Earth Sciences faculty were analyzed (Table 6).

Thirty three percent of the references cited were unique; that is, cited only once in this sample. This confirms findings from earlier studies in the Stanford Earth Sciences Library, which demonstrated that a wide range of journal and serial titles were needed to support research and teaching needs in the earth sciences at Stanford. Journal citations predominated, accounting for 74 percent of all of the citations.

### Country and Language of Publication

Earth sciences journals are published in many different countries. Publishers in the 15 countries shown in Figure 9 are responsible for 86 percent of the active earth sciences journals (as listed in Ulrich's). In Ulrich's data, 75 countries comprise the sources of the remaining 14 percent of earth sciences Journals.

Although articles in English predominate, the earth sciences literature is still published in a wide range of languages. Table 7 enumerates the language category of each citation in the *GeoRef* database (2.65 percent of the citations still have no language tag). Several of the journals published in Germany or Greece or Spain have articles in several languages. This wide range in country and language for earth science publications has major implications in terms of cost for acquisition, cataloging and document delivery.

At least at the Stanford/UCLA libraries, collection budget constraints and lack of the necessary staff to acquire needed materials have led to a measurable downgrade in collection quality. This can be measured by comparing current collecting levels against previous collecting levels using a collection development conspectus. Another contributing factor in the lessening of collection quality has been administratively mandated journal cancellations. None of these downgrades were made on the basis of programmatic changes. Also whenever the research or study program changes focus, then the library collecting needs to change to match. The present growth in interest at some institutions in the Earth Systems field, with its attendant need for literature in climatology and meteorology which are often outside the scope of a geology library, is a case in point. These price and publication trends are not restricted to the geological sciences but are found in all disciplines in the mid-1990s and will lead to major changes in library collections and publishing (Walker, 1997).

## MONOGRAPHS

According to information garnered from the Blackwell North America Approval Plan data, the average cost of a book in several of the earth sciences fields is more than $100 each (Table 8). Paleontology books appear to be the cheapest at $68 each and, surprisingly, stratigraphy books are the most expensive at $131 each. The titles available on any of the approval plans tend to be those available from the commercial publishers. Titles obtained from the small geological societies and other non-standard sources have lower purchase prices, but can be costly in staff time to seek out and acquire.

### Cataloging Costs

On the average, according to long-time UCLA science cataloger, Dorothy McGarry, earth sciences titles take longer to catalog than do the other science and engineering materials. There is more material in earth sciences without copy cataloging, especially without Library of Congress copy, for the following reasons:

1. The major National Libraries (Library of Congress, British Library, National Library of Canada, etc.) don't receive as large a percentage of earth sciences materials or do not catalog them individually if received, but place them in major series,
2. There is a larger percentage of material collected from a wide range of countries and in a larger number of

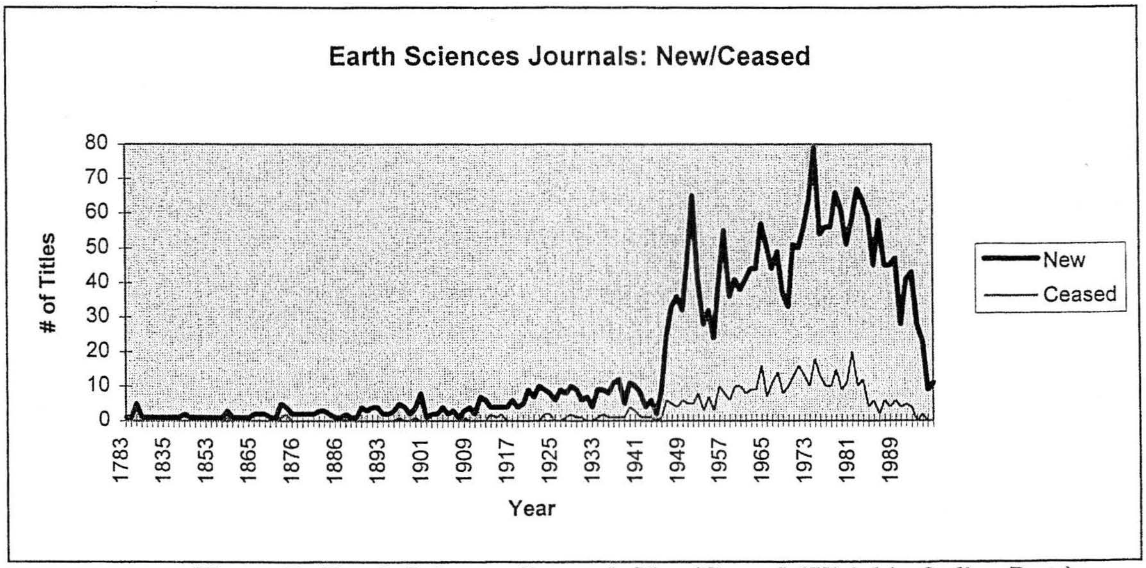


**Figure 7. Earth Sciences Journals New/Ceased (*Ulrich's Online Data*)**

Note: Search strategies used descriptor codes for the subject areas, status codes, and the publication code index (e.g. (s ca=55? or ca=56? or ca=QE?)and not pc=ir). Search results were then ranked by first year of publication.

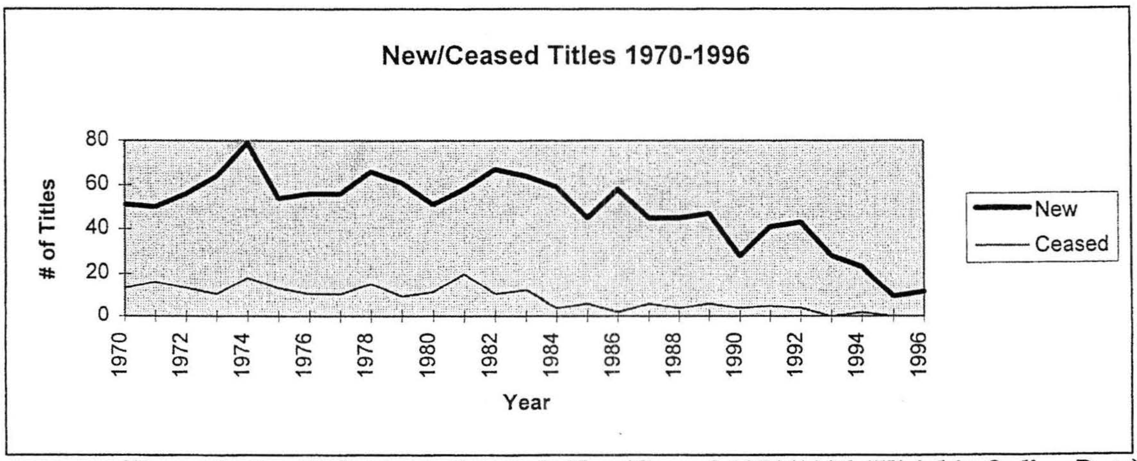


**Figure 8. Earth Sciences Journals New/Ceased 1970/1996 (*Ulrich's Online Data*)**

languages than for the other science and engineering disciplines,
3. A smaller percentage of earth sciences publications come from the major publishers,
4. Title pages and other bibliographic information is not always presented in as systematic and logical manner as for other subject fields.

There is a lot of local geology; and even if there is copy, librarians/catalogers need to be certain that local access points are provided for their clientele. For example, someone in California may put more emphasis on geographic location, formation names, and local structures, e.g. the San Andreas, than someone receiving the same piece in Vermont. Within a geological text there is often more accompanying materials, for instance a chart, maps, or disks. Geology also has unique types of materials such as guidebooks.

**Shelving Costs**

Part of the cost of providing information in any discipline is that of storing the materials. For publications in paper that means shelving and building costs. Based upon 150 volumes per section face, 10 square feet for a traditional fixed section arranged to meet ADA standards, and a typical construction cost including the shelving in the San Francisco area of about $200 per square foot (which is at the high end of national figures), then the cost for the facility is on the order of $13.33 per volume. One would calculate about 1/10 of this figure as an annualized cost, or $1.33 per volume per year for the facility. The annual cost per volume including all facilities, maintenance and utilities should be less than $2.66 per year. Nationally, a construction cost of $150 per square foot for traditional library space is still regarded as reasonable. Although costs for specific areas can vary a great deal, a cost of $150 to $200 per square foot is probably reasonably accurate for most locations (Leighton and Weber, 1998).

This cost is for traditional shelving; a substantial reduction in this figure is possible with more compact shelving technologies (but, of course, the transaction and collections management cost may go up with such systems). For example, it has been argued that the facility can be developed for less than $5.00 per volume using compact storage systems similar to the Harvard model. Compared to the $13.33 per volume calculated above, this represent a significant savings. Maintenance cost (exclusive of transaction and collections management cost) should go down as well with the more compact technologies; these costs include shifting the collections to accommodate growth, shelf reading, straightening out the books on the shelf, moving collections to accommodate a change in operating program, etc.

The average number of volumes per shelf including journals is a little more than 10 volumes per linear foot. Normally journal volumes tend to be closer to 8 volumes per linear foot, possibly less, depending upon how the volumes are broken up upon binding. One should also plan on a working occupancy figure (although many earth sciences branches probably are higher than these figures). For monographs, the figure typically used to express the occupancy at maximum working capacity is 86 percent of absolute capacity. For journals, the figure could be greater since open space on every shelf is not required. The assumed 150 volumes per section used earlier should include some accommodation for working capacity. A standard shelving section is 18 linear feet for 6 shelves of 3 feet. For journals, estimating 10 volumes per foot, the absolute capacity is 180 volumes per section. At 86 percent capacity, this becomes approximately 154 volumes per section. Depending on the types of materials in the collection and how many journals are bound together, it may be more accurate doing the same calculation at 8 volumes per foot. If there is no ceiling height limitation, it is possible (though not desirable due to the height of the collections) to have 7 shelves per section. Clearly numerous assumptions are possible; but 150 volumes per standard shelving section is probably reasonable for discussion (Leighton, 1998).

**DOCUMENT DELIVERY/INTERLIBRARY LOAN**

No earth sciences library contains all of the materials needed for the patrons served. As journal prices increase, fewer materials are being added to any collection. What kinds of things, which are not being added to the collection, are then needed enough by the users that they are acquired after the fact? An analysis was made of 553 material requests handled directly by the Stanford Earth Sciences library staff (Table 9, Figure 10).

Of the 58 government documents obtained, all but 11 of them were USGS documents. What proportion of these was acquired because the copy was at the bindery or lost is difficult to say at this point. One effect of government agencies' efforts of putting items on the Web may be to bring this number down. It will be interesting to watch this change, although the trade-off may be the frustrated search time and incompatible equipment bottlenecks.

The 113 journal articles requested represented only 44 percent of the total number of items needed by users. Of the journal articles needed only 45 percent (or 9 percent of all items requested) were available from the document delivery vendors regularly used. The others were obtained through cooperative agreements with other earth science libraries. Forty-five percent of the articles came from eighteen journals titles which Stanford had previously held. In addition, six articles were requested from four

**Table 6. Citations in 13 School of Earth Sciences Faculty Papers Published in 1996**

| | Total | Earth Sci. Library | Stanford | Not Held at SU | # of Unique Titles |
|---|---|---|---|---|---|
| Books | 53 | 43 | 6 | 4 | 53 |
| Conferences | 19 | 9 | 0 | 10 | 19 |
| Maps | 6 | 5 | 0 | 1 | 6 |
| Journals | 520 | 479 | 33 | 8 | 96 |
| Serials | 83 | 73 | 5 | 5 | 37 |
| Theses | 18 | 15 | 0 | 3 | 18 |
| Software | 1 | 0 | 0 | 1 | 1 |
| Tech report | 1 | 0 | 0 | 1 | 1 |
| Totals | 701 | 624 | 44 | 33 | 231 |

**Table 7. GeoRef References by Language**

| No. of items | Language | % of Total |
|---|---|---|
| 1511867 | English | 73.23% |
| 175793 | Russian | 8.51% |
| 106738 | French | 5.17% |
| 89231 | German | 4.32% |
| 36803 | Spanish | 1.78% |
| 34746 | Chinese | 1.68% |
| 29086 | Japanese | 1.41% |
| 15049 | Italian | 0.73% |
| 10817 | Portuguese | 0.52% |
| 2010130 | Total | 97.35% |

**Table 8. Cost of monographs in major geoscience disciplines**

| | 1992-3 | 1993-4 | 1994-5 | 1995-6 | TOTAL | AVERAGE |
|---|---|---|---|---|---|---|
| Geochemistry | 123.76 | 104.49 | 105.06 | 99.74 | **433.05** | **108.26** |
| Geophysics | 92.28 | 91.90 | 69.63 | 119.61 | **373.42** | **93.36** |
| Hydrology | 132.36 | 87.71 | 116.39 | 87.06 | **423.52** | **105.88** |
| Mineralogy | 104.20 | 113.19 | 109.89 | 134.63 | **461.91** | **115.48** |
| Paleontology | 68.15 | 58.65 | 79.85 | 68.17 | **274.82** | **68.71** |
| Petrology | 83.16 | 83.42 | 82.98 | 103.94 | **353.50** | **88.38** |
| Stratigraphy | 116.58 | 141.15 | 148.74 | 117.30 | **523.77** | **130.94** |
| Structural | 109.88 | 151.30 | 72.69 | 73.69 | **407.56** | **101.89** |
| TOTAL | **830.37** | **831.81** | **785.23** | **804.14** | | |
| AVERAGE | **103.80** | **103.98** | **98.16** | **100.52** | | |

Data from Blackwell North America Approval Plan Coverage: GIS Collection Development Committee 1996, chair Steve Hiller.

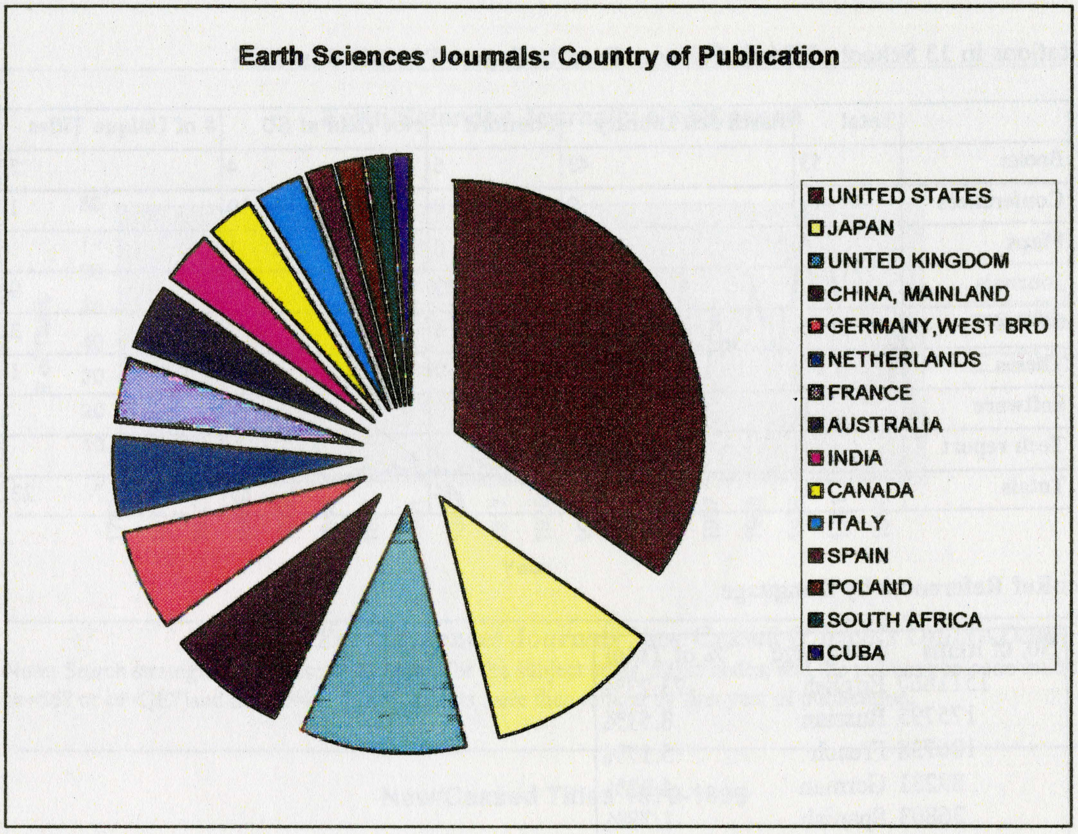


**Figure 9. Earth Sciences Journals by Country of Publication**

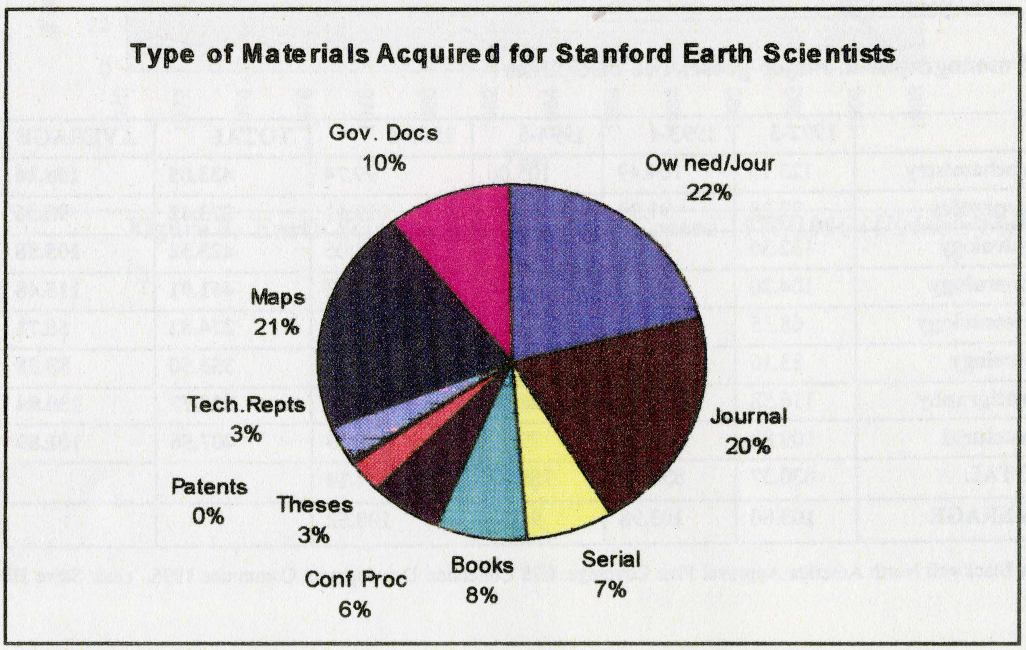


**Figure 10. Document Delivery Requests for Stanford Earth Scientists - By type of Publications**

titles held by the Library, but the holdings did not include the needed article. Gaps had occurred after restarting the journal following cancellation and the back issues were no longer available.

Altogether, 40 requested volumes from thirty monograph series titles via the Earth Sciences Library's in-house document delivery efforts were obtained. The number also acquired via Interlibrary Borrowing (ILB) is unavailable. Many other needed volumes had to be ordered rush (which is costly in terms of staff time) because there were no accessible sources found. Of these 40 requests, 68 percent were from series titles which the Earth Sciences Library seeks to obtain/has on standing order. However, the lack of sufficient staff to monitor the series titles and obtain these needed volumes results in extra efforts to obtain the volumes when patrons have urgent need of them. Unfortunately, many of these titles are not of the fast document delivery vendor types. Fortunately, it was possible to obtain many of them from other California earth science libraries. Thus the recent cancellation projects in those libraries as well as the severe cutbacks in the gifts/exchange program at USGS will greatly impact the ability of earth sciences libraries to meet users' needs.

## ACCESS TO ELECTRONIC PUBLICATIONS

Electronic publications are not new to earth sciences. Geology indexes were some of the first available and the coverage was historically extensive, almost from the beginning. *GeoRef* went online with SDC in 1977; the full database, back to 1785, has been available since the early 1980's. The French equivalent, the earth sciences section of *Pascal*, is available online back to 1715.

The amount of data available electronically in the field of earth sciences is measured in the gigabytes in many fields, and has been for more than a decade. Most academic libraries are still not providing much of this data to their respective communities. The United States Geological Survey (USGS) and several other government agencies including NASA, NOAA, and NCAR have been providing digital data in the form of CD-ROMs. Many academic libraries receive these disks as part of the GPO Federal Government Depository Library Program; these disks cover a broad spectrum of data from maps, photographs, and large data sets.

Included on the survey questionnaire were the 32 items in the USGS Digital Database Series (DDS); respondents were asked if access to these titles was provided. Table 10 shows a marked contrast between their access in academic /government libraries on the one hand, and corporate libraries on the other, where they must be purchased. It must be remembered that in a corporate or special library, the material acquired focuses on the generally more specific research needs of its clientele. The data set which all libraries had available was Digital Data Series No 6: *Stratigraphic nomenclature databases for the United States, its possessions, and territories.*

In only one instance were any of this series placed on a network. When made available for use within a library, DDS titles are usually mounted on a stand-alone machine, but predominantly they circulate for use in the laboratory where they are needed. Some fifteen percent of the respondents do nothing with these discs.

It seemed clear from the survey respondents, that generally a server is used for the large bibliographic databases and local stations provide access to data sets (if that access is available at all). It is interesting to note that a respondent reported that in the "corporate environment the costs for networking are much higher and it is hard to justify when a site license covers too small of a user group." The online catalog is supplied from a central server and increasingly large databases with a broad spectrum of users are also available from central servers. It is not clear whether this distinction is a reflection of anything more than the possibility that administrators may understand bibliographic files, but not understand the use of other types of information.

### Workstations

This glamorous term can reflect anything from a dumb terminal to a truly elaborate SPARK workstation. Since 1990, the questionnaire responses showed that during this period of many changes, the overall number of computers now available in the responding libraries has at least doubled (Table 11).

There have been spectacular jumps in academic central libraries and institutions, where the number of workstations have increased dramatically. In fact, it is the separate geoscience libraries which have lagged behind in the rush to acquire computer access, reflecting perhaps that these small branch libraries lack space, do not have enough customers to warrant large increases, their clients have their own terminals on their desks, or they are overlooked in the rush to increase terminals in the central libraries.

Who services this equipment? To whom can the librarian turn for help? Here an interesting contrast emerges between maintaining the stand-alone workstation, and the server, in the academic environment versus the government, corporate and institutional libraries. (In Table 12, all three academic settings have been merged into one criteria, academic). These percentages clearly highlight the differing role of the systems staff in the various types of libraries. For work with the main server, the systems

**Table 9. Document Delivery/Interlibrary Loan Requests handled directly at Stanford's Earth Sciences Library** (Does not include ILL requests sent on to the ILL department.)

| Year | 1992/1993 | 1993/1994 | 1994/1995 | 1995/1996 | 1996/1997 | Totals |
|---|---|---|---|---|---|---|
| Journal | 9 | 38 | 11 | 22 | 33 | 113 |
| Serial | 3 | 3 | 7 | 11 | 16 | 40 |
| Hopkins/Jour | 2 | 12 | 5 | 1 | 13 | 33 |
| Hopkins/Other | 3 | 4 | 4 | 4 | 22 | 37 |
| Owned/Jour | 4 | 8 | 7 | 7 | 10 | 36 |
| Owned/Other | 3 | 1 | 3 | 3 | 0 | 10 |
| Books | 4 | 4 | 14 | 6 | 14 | 42 |
| Conf Proc | 3 | 8 | 9 | 3 | 8 | 31 |
| Theses | 0 | 2 | 7 | 5 | 4 | 18 |
| Patents | 1 | 0 | 0 | 0 | 0 | 1 |
| Tech. Repts | 2 | 8 | 8 | 0 | 0 | 18 |
| Maps | 3 | 10 | 1 | 33 | 69 | 116 |
| Gov. Docs | 23 | 9 | 10 | 8 | 8 | 58 |
| **Totals:** | **60** | **107** | **86** | **103** | **197** | **553** |

Notes: 1 Government Document requested was in CD-ROM format. All Maps requested were also Government Documents as were all but 1 of the Technical Reports, and 9 of the series titles. Therefore total number of items requested that were government documents was 201, or 36 percent of the total requested. Of the books requested in 96/97 year, only 50 percent were in English (4 in Russian, 1 in Mongolian, 1 in Spanish, and 1 in German).
Added Note: Each request is in the chart only once.

**Table 10. USGS Digital Data Series Deployment**

| | Academic/ Separate | Academic / Central | Academic/ Science | Governme nt | Corporate | Institute |
|---|---|---|---|---|---|---|
| Receive | 12 | 5 | 1 | 6 | 1 | 1 |
| Received elsewhere | 2 | 1 | 1 | 2 | 0 | 0 |
| Purchase | 0 | 0 | 0 | 1 | 3 | 0 |
| Stand alone | 8 | 5 | 0 | 3 | 3 | 0 |
| Network | 0 | 0 | 0 | 1 | 0 | 0 |
| Circulate | 11 | 4 | 2 | 2 | 0 | 0 |
| Do nothing | 1 | 3 | 0 | 2 | 0 | 1 |

Table 11. Number of Workstations Available by Library Type

| | Academic/ Separate | Academic/ Central | Academic/ Other | Governmen t | Corporate | Institution |
|---|---|---|---|---|---|---|
| 1997 | 39 | 86 | 31 | 43 | 3 | 15 |
| 1990 | 20 | 15 | 11 | 9 | 1 | 2 |
| Factor of Increase | 1:2 | 1:5.7 | 1:3 | 1:4.8 | 1:3 | 1:7.5 |

Table 12. Workstation Support by Library Type

| | Academic | | Government | | Corporate | | Institution | |
|---|---|---|---|---|---|---|---|---|
| | Wkstn | Server | Wkstn | Server | Wkstn | Server | Wkstn | Server |
| Librarian | 32% | 12% | 33% | 0 | 50% | 0 | 62% | 45% |
| Support Staff | 26% | 28% | 0 | 0 | 0 | 0 | 8% | 0 |
| **Systems Staff** | **32%** | **52%** | **66%** | **100%** | **50%** | **100%** | **31%** | **55%** |
| Students | 10% | 4% | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | | 4% | 0 | 0 | 0 | 0 | 0 | 0 |

Table 13. Minimum computer requirements to effectively utilize the Alexandria Digital Library

**Hardware**

| | |
|---|---|
| Pentium | 166 Hz (min.) |
| CD-ROM Drive | |
| Graphics Card | |
| Hard Disk | 3 GB (min.) |
| System Ram | 64 MB (min.) |
| Video Ram | 4 MB (min.) |
| 21" monitor | |
| keyboard/mouse | |

**Software**

Netscape 4.0
Windows 95 or Windows NT

Table 14. Workstation Costs

| Cost in $ | Academic/ Separate | Academic/ Central | Academic/ Other | Government | Corporate | Institution |
|---|---|---|---|---|---|---|
| <2,000 | 1 | 1 | 0 | 1 | 0 | 0 |
| 2,000-5,000 | 5 | 0 | 1 | 0 | 0 | 0 |
| 5,000-10,000 | 4 | 1 | 0 | 0 | 1 | 1 |
| 10,000-15,000 | 1 | 0 | 0 | 0 | 0 | 1 |
| 15,000-20,000 | 0 | 0 | 0 | 1 | 1 | 0 |
| >20,000 | 2 | 0 | 0 | 2 | 0 | 0 |

department role is dominant. In government libraries the key role of systems staff in the operation of both local workstations and the main server is easily recognized. This is not true in either the academic, corporate or institutional setting. The role of student assistants in the academic environment should be noted. Also, the use of outside expertise when maintaining the new generation of client servers depicts another new trend in libraries.

What are the capabilities of these workstations? How does the average library workstation compare with a basic set of requirements issued by the Digital and Imagery Laboratory at the University of California, Santa Barbara, who are developing the Alexandria Digital Spatial Library under the auspices of the National Science Foundation and other partners (Hill, 1995). The minimum requirements for this system to operate efficiently in a library are listed in Table 13 (M. Larsgaard, pers. comm.) and would cost approximately $3,200 in October 1997 to buy. Respondents indicated that over sixty percent had moved from 286s to Pentiums, and the remainder had upgraded from a 286 to a 486. Most people have 16 MB of RAM available but it could range from four megabytes to one gigabyte.

Technological changes require new hardware and software packages, costs of which must be borne by library budgets. Pricing expenditures for these packages clearly reflect the size and type of the organizations. In the academic separate branch libraries, expenses are seen to be in the $2,000 to $10,000 range, but in the corporate and government environment in the $15,000 to over $20,000 range (Table 14).

### Geographic Information Systems in Libraries

Although many of the digital data series and GPO depository CD-ROMs contain Geographic Information System (GIS) data, it is only in the academic and government libraries where GIS products are being provided for patrons (Table 15). The academic libraries are dominated by the ArcView system and this may reflect the strong impact of the ESRI corporation in supporting the government document librarians in introducing this program into libraries. Also this is a program which requires less expertise in handling the data. In contrast, in government libraries, both ArcView and ArcInfo are supported, reflecting the major impact this system has had in the actual creation of digital maps. The use of Integraph in some government departments is shown by its presence in the government libraries. In academic circles, GIS has been spearheaded by the librarian; it is the librarian and support staff who maintain the program and not the systems staff as in the government environment.

### Electronic Journals

Regarding the Internet and electronic journals, there are still only a handful available in 1997. Electronic earth sciences journals still appear to be more smoke and mirrors than reality. However, this will change very quickly. As an example, one project about to bring journals to the desktop is the *Science, Technology and Industry Collection* coming soon to the UC system. Over four million dollars have been allocated to create a critical mass of electronic literature that could become available over the next three years in the areas of science, technology and medicine. It is viewed as the opportunity to:

- Provide scholarly material in a convenient and timely way to faculty and students, facilitating research activities and building the support and infrastructure for electronic access,
- Serve as an opportunity to learn and experiment,
- Serve as an opportunity to develop partnerships with business and industry.

The project will cover a wide range of materials including scientific literature, theses, and reports created by the UC system. It will gain access to heavily used high quality scientific commercial journals, society-based publications, and government publications. In a few years this challenging transition period will be forgotten, but now the cost is tremendous as new computers, systems, and peripherals are purchased and the learning curve to catch up and efficiently use this new technology impacts everyone. The result is money from the top, but flat budgets or declining budgets "locally". This is a tough paradigm. Ohio-link and Michigan are other consortia moving in this direction.

In the past two years, the fastest growing area of electronic publication has been in government monographs and monographic series volumes. These are well done, professional, fairly stable URLs (except for Canada's), information rich, with reliable and timely information, quickly published and all freely accessible. The biggest problem has been finding and then keeping track of them. MARCIVE records used to provide access to government documents. GeoRef used to index all USGS and many other relevant government publications. Now surfing is required to find many of them, which includes wading through hundreds of similar sounding but useless or duplicate sites to find the relevant materials. A critical challenge will be cataloging and indexing these documents now and archiving them soon. Libraries could play a significant role in providing reflectors for government sites and archiving for government documents.

**Table 15. Geographic Information Systems in Libraries and Their Maintenance**

| System/ Maintenance | Academic/ Separate | Academic/ Central | Academic/ Other | Government | Corporate | Institutional |
|---|---|---|---|---|---|---|
| ArcView | 7 | 4 | 3 | 6 | 0 | 0 |
| ArcInfo | 1 | 2 | 0 | 6 | 0 | 0 |
| Integraph | 0 | 0 | 0 | 1 | 0 | 0 |
| MapInfo | 2 | 0 | 0 | 0 | 0 | 0 |
| **Staff/ Maintenance** | **Academic/ Separate** | **Academic/ Central** | **Academic/ Other** | **Government** | **Corporate** | **Institutional** |
| Librarian | 6 | 2 | 0 | 1 | 0 | 0 |
| Support Staff | 3 | 1 | 0 | 0 | 0 | 0 |
| Systems Staff | 1 | 1 | 0 | 2 | 0 | 0 |
| Students | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 1 | 0 | 0 | 0 | 0 |

**Table 16. Integrated Library System Changes**

| | Academic/ Separate | Academic/ Central | Academic/ Other | Government | Corporate | Institution |
|---|---|---|---|---|---|---|
| **New Main Frame** | 6 | 3 | 1 | 2 | 0 | 1 |
| **New Integrated Library** | 5 | 5 | 2 | 4 | 2 | 1 |
| **Changed Network** | 9 | 5 | 2 | 3 | 1 | 2 |
| **Changed Platform** | 4 | 4 | 1 | 2 | 0 | 0 |

## IMPACT OF TECHNOLOGY ON THE WORK ENVIRONMENT

What are the changes in the everyday working life of librarians and library staff? One strong shift has been from WordPerfect to Word, reflecting a constant change towards a windows environment. In terms of communication packages though, there's no dominant system. The email system may have started off with a basic VAX language but now there is a world of exotic names from Eve to Eudora, Pine and Pegasus.

All respondents indicated that the main system, upon which library processing work is done, has undergone some form of change during the period covered by the survey (Table 16). Although a necessary part of business, these changes are costly in terms of staff productivity, at least in the short term. However, the question arises as to how long is the period between changes? It seems to be getting shorter; thus probably shortening the period of time for which staff productivity level will be on a high plane.

These changes require concomitant new hardware and software packages, the costs of which must be borne by library budgets.

How have these changes impacted the way earth sciences librarians do their work? Comments made by the survey respondents might answer this question, better than any other way.

**Positive**

- All have improved my ability to access information, retrieve information, send information to others and communicate to others tremendously
- All have made it better
- GeoRef CD SilverPlatter is the most positive change constant
- Just like we haven't read every book - we haven't learnt every computer product
- The introduction of remote access to GeoRef via our local server and institution-wide access to the Web have tremendously improved access to research information for our staff and efficiency has increased tremendously.
- The Web has hugely impacted the data available to our users and I suspect will soon begin to impact our collections in a more significant way than CD-ROMs and networks.
- Improved (a word which was echoed throughout)

**Negative**

- There was a strong impression of overload from: more information available in different formats; more information available at the desktop and via remote/dial up access. More for users to wade through, learn to navigate, learn to be selective and often can overload the user.
- Training time is a luxury we can ill afford. Our daily obligations for reference circulation, reserves, materials processing, collection development etc. leave little time. Wish I had two hours per week to devote to getting myself up to speed.
- If I were a reference librarian in the main library, I'd have more time to learn software, hardware, networking etc. My job demands keep me from this, and I'm at a disadvantage, I think although and can call on system's people. I think our users fair OK/fine, but I could use someone IN the library on our staff for computer maintenance.
- computer systems staff are only called if support staff and librarian unable to solve, especially when computer systems staff 200 miles away.
- Never enough time (a constant quote)
- Impossible to answer, too much changes, breakdowns, updates, etc.
- Just keeping up with the sources available on the Web would be great, but there is not enough time given my administration and user-support responsibilities. It's the same problem as trying to "keep up with the literature"
- tends to be relegated to lower priority, given more immediate needs.

## SUMMARY COMMENTS

**Budget**

1. Most libraries have been maintaining a careful watch on journal prices and journal use for several years. Cancellations are generally made with these two factors carefully in mind, as well as the waxing and waning of programmatic need.
2. Monograph series volumes of many titles are probably not all acquired, due to insufficient funds.
3. Conference proceedings may be the largest gap in any monograph collection.

**Staffing**

1. Critical collection gaps stem from insufficient staff to monitor and claim the large number of difficult-to-acquire monograph series.
2. Staffing for acquiring and distributing gifts and exchange materials (as done in the earth sciences field) remains very important.
3. Staff for servicing equipment and introducing new technologies are the same staff providing the more traditional services.
4. Staff do not have time or resources to be trained on new tools/software.

**Equipment**

1. CD-ROM and other digital information formats have been prevalent in the earth sciences since the latter part of the 1980s. Many of these products come on deposit. It has been a constant struggle to acquire the appropriate number of powerful workstations for patron access to these materials.
2. Space on local servers for earth sciences information has been needed for almost ten years. Although there has been a lot of talk over the years, for all but a handful of the titles (*GeoRef* and a few others) there is still no access on the horizon.

**Trends in the field**

1. There is a rapidly increasing movement towards e-reports, e-series volumes and even e-journals on the part of government agencies. These are provided to all freely; however, tracking them is going to be extremely staff expensive, at least in the beginning.
2. Commercial publishers are courting and winning societies and even university press and government agency publishers. The rate of increase of these newly commercially published materials is very high.
3. Gifts and exchange materials continue to be very important to obtain, even though the number of formal exchanges are dropping. These materials can be hard to interlibrary loan and impossible to acquire from most document delivery services. Cooperative work, for these materials in particular, will become even more important.
4. With the current cutbacks in the USGS library system (and more possible), there is no longer an earth sciences master collection extant and certainly there will not be one in the future - unless the move to make the USGS library a true national library has any success. The earth sciences collections will need to work together to bridge the gap; the large academic and government collections, in particular, will need to pull their own weight. Participation in cooperative agreements, both formal and informal, such as the Rookwood Accords in California, will be critical in order to acquire, provide access, and archive earth sciences material for future generations.

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## APPENDIX 1

## Survey: Earth Sciences Libraries & Information Delivery

The results of this survey will be presented at the annual meeting of the Geological Society of America this fall.

1. Type of library: *(circle one)*
   a. Academic b. Corporate c. Government
   d. Public e. Research Institute f. Other ________________

2 Is your library: *(circle one)*
   a. Separate Earth Sciences Library d. Science Library
   b. Physical Sciences Library e. Central Library
   c. Science/Engineering Library f. Other ______________________

3. How many staff are in your library or what is the share of staffing for earth sciences support? Please give in % of FTE if possible:
   a. Librarian _____ b. Clerical/Support ______ c. Students: _____ d. Other _______

4. What EARTH SCIENCES research/instruction areas do you serve: *(Circle all appropriate)*
   a. Areal geology b. Economic Geology c. Environmental Geology
   d. Geochemistry e. Geophysics f. Hydrogeology
   g. Marine Geology h. Meteorology/Climatology i. Paleontology
   j. Petroleum Geology k. Remote sensing l. Soils m. Other

5. For the following earth sciences information products what access is provided?
   Types of Access:
   a. Not Available b. Paper c. Stand alone d. Networked CD/ROM
   e. Campus system f. Campus Web system g. Dialog/Class Room
   h. First Search i. Silver Platter/Web j. Mediated Search
   l. Other *(please specify)*:_________________

*(Please circle type of access and No. of Simultaneous Users)*

| PRODUCT | TYPE OF ACCESS | NO OF SIMULTANEOUS USERS |
|---|---|---|
| Arctic & Antarctic regions | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| GEOREF | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| GEOBASE | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| GEOARCHIVE | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Meteorological & Geoastrophysical Abstracts | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| MinSource | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| PASCAL | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Petroleum Abstracts | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Water Resources Abstracts | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Other EARTH SCIENCES databases: ______________: | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Other: ______________ | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |

7. USGS Digital Database series CD-ROMs?

| | | |
|---|---|---|
| a. Do you receive this series on deposit/gift/exchange? | Yes | No |
| b. Is the series in another location/library on campus | Yes | No |
| c. If no, do you purchase some/all of the volumes | Yes | No |

*If you hold any of this series, how do you provide access? If the answer is the same for all volumes, please circle here: If access varies per title, please circle method below for each title that you hold.)*

**a. Stand-alone workstation** **b. Networked** **c. Circulate** **d. Don't do anything**

**a b c d** No. 1 National geochemical data base : *superceded by NO. 18A.*
**a b c d** No. 2 Geology of Nevada : a digital representation of the 1978 Geologic map of Nevada
**a b c d** No. 3 A Geologic map of the sea floor in western Massachusetts Bay
**a b c d** No. 4 U.S. GeoData: 1:2,000,000-scale digital line graph (DLG) data.
**a b c d** No. 5 National energy research seismic library--processed seismic data for 29 lines in the N.P.R.A.
**a b c d** No. 6 1994 Stratigraphic nomenclature databases for the United States, its possessions and territories.
**a b c d** No. 6 1996 Stratigraphic nomenclature databases for the United States, its possessions, and territories.
**a b c d** No. 7 Digitized strong-motion accelerograms of North and Central American earthquakes, 1933-1986.
**a b c d** No. 8 U.S. Geological Survey Photographic Library. Photographs from the U.S.G.S.. Library.
**a b c d** No. 9 National geophysical data grids: gamma-ray, gravity, magnetic, and topographic data for ..U.S.
**a b c d** No. 10 Modern average global sea-surface temperature.
**a b c d** No. 11 Geology of the conterminous United States at 1:2,500,000 scale:...
**a b c d** No. 12 Photographs of historical mining operations in Colorado and Utah from the U.S.G.S.. Library.
**a b c d** No. 13 International phase of ocean drilling : seismic line 1 demultiplexed data, Cape Hatteras.
**a b c d** No. 14 National geochronological and natural radioelement data bases.
**a b c d** No. 15 CD-ROM atlas of the deepwater parts of the U.S. Exclusive Economic Zone in the Atlantic
**a b c d** No. 16 Deep seismic reflection studies in the Pacific northwest United States data visualization.
**a b c d** No. 17 Geology and mineral and energy resources, Roswell Resource Area, New Mexico.
**a b c d** No. 18-A National geochemical data base : national uranium resource evaluation data for the .. U.S.
**a b c d** No. 18-B National geochemical data base..
**a b c d** No. 19 Geology and resource assessment of Costa Rica at 1:500,000 scale folio I-1865.
**a b c d** No. 20 Mineral resources data system (MRDS).
**a b c d** No. 21 Earth science photographs from the U.S. Geological Survey Library.
**a b c d** No. 23 Photoglossary of marine and continental ichnofossils.
**a b c d** No. 24 Images of Kilauea east rift zone eruption, 1983-1993.
**a b c d** No. 25 500-MHz ground penetrating radar data collected during an intentional spill of tetra
**a b c d** No. 27 Monthly average polar sea-ice concentration.
**a b c d** No. 30 1995 national assessment of United States oil and gas resources.
**a b c d** No. 31 Profiles of gamma-ray and magnetic data for aerial surveys over parts of the western United States
**a b c d** No. 32 National Energy Research Seismic Library, Powder River Basin, Montana-Wyoming.
**a b c d** No. 35 Digital map data, text, and graphical images in support of the 1995 national assessment of US oil.
**a b c d** No. 36 Tabular data, text, and graphical images in support of the 1995 national assessment of US oil

8. Do you have Hydrodata, Earth Info, or other **water data** available electronically? *(Please list titles available and indicate access.)*

a. Stand-alone b. Networked c. On a server d. Via the web e. Circulating

Titles:

How many total DISKS?_____ How many did you receive on deposit/exchange?_______

9. Do you have electronically published **weather/climate data** products available to your users? *(Please list titles available and indicate access.)*

a. Stand-alone b. Networked c. On a server d. Via the web e.Circulating

Titles:

How many total DISKS?_____ How many did you receive on deposit/exchange?_______

10. To which of the following products do you provide access, that **your Earth Sciences users** consider important tools: *(Circle all appropriate)*

**a. Not Available b. Paper c. Stand alone d. Networked CD/Rom e. Campus system f. Campus Web system g. Dialog/Class Room h. First Search i. Silver Platter/Web j. Mediated Search l. Other :** ____________________

| PRODUCT | ACCESS | NO. OF SIMULTANEOUS USERS |
|---|---|---|
| Agricola - | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| ASFA - | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Beilstein/Gmelin - | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| BIOSIS - | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Chem. Abstracts - | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| EI/Compendx | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Enviroline | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| INSPEC - | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| SCI - | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Other ________ | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |
| Other ________ | a b c d e f g h i j k l | 1 2/5 6/10 unlimited |

11. How is your library catalog provided to your users' desktops?: *(Circle all appropriate)*

a. LAN b. Web c. Telnet d. Not provided

e. Other (please describe) ____________________

12. WORKSTATIONS:

a. How many workstations do you have available in your library/branch **for providing access to Earth Sciences information?** ________

b. How many **were available in 1990** in your library/branch for providing access to Earth Sciences information? ________

c. If possible, indicate the increase in computing power [if any].

13. STAND ALONE WORKSTIONS. Who maintains them? *(Indicate average time per week for all appropriate)*

a. Librarian ________ b. Library support staff ______ c. Computer systems staff ________ d. Student Assistant ________ e. Other (describe)____________________

f. How much RAM/MEMORY does your average workstation(s) have____________

g. What types of things do you put up on a stand-alone workstation?

14. SERVERS: Who maintains them? *(Indicate Average time per week for all appropriate)*

a. Librarian ________ b. Library support staff ______ c. Computer systems staff ________ d. Student Assistant ________ e. Other (describe)____________________

f. To how much space on the server do you have access? ____________

g. What types of products do you put up on a server?

15. Do you have any GIS products available? *(Circle all appropriate)*

a. ArcView? b. ArcInfo c. Atlas GIS d. Other? Please list: ____________

16. Who maintains the GIS workstation?
a. Librarian _________ b. Library support staff ______ c. Computer systems staff ________ d. Student Assistant __________ e. Other (describe)_________________________________
Staff member trained in GIS? *(Please describe)*

Amount of time spent per week on maintenance? ____________________-

17. Since 1990 has your library/institution invested in any of the following. *(Check all appropriate)*

| INTERFACE CHANGE | MANUALS PROVIDED? | TRAINING PROVIDED? | TIME AVAILABLE TO LEARN? |
|---|---|---|---|
| ___ New Main Frame computer | | | |
| ___ New integrated library system | | | |
| ___ Changed to a networked environment | | | |
| ___ Changed platforms across the system, e.g. from MAC to Windows? | | | |
| ____ Changed word processing package: from _________ to ________ | | | |
| ____ Changed e-mail systems: from _________ to ___________ | | | |

1. How have the above changes impacted the quality of earth sciences information provided to your users?
2. How much time do you spend (per average week) learning new earth sciences products?_____
3. How much do you feel that you need to spend?_______________
4. Additional comments regarding training time?

20. If you are in an earth sciences branch library or if you can come up with an appropriate share for earth sciences support, please estimate the cost for computers (for accessing earth sciences information) spent in your library in the last six years.
Less than $5000______ $5000 - 10,000______ $10,000-15,0000______
$15,000 - 20,000 _______ $20,000 - $25,000 _______ Over $25,000 _________

21. **Other comments**:

If you would prefer to use e-mail for filling out/sending back the form, please send e-mail request to: cderksen@marine.stanford.edu; please indicate whether you want the form as ASCII or Word (and version thereof). It was also available on the web at: HTTP://www-marine.stanford.edu/branner/survey.html.
Please return this survey by May 30, 1997 to: Charlotte Derksen & Barbara Haner. THANK YOU for your help.

Charlotte Derksen & Barbara Haner
Branner Earth Sciences Library
Mitchell Bldg
Stanford University
Stanford, CA 94305

# THE DIGITAL PROGRAM OF THE GEOGRAPHY AND MAP DIVISION, LIBRARY OF CONGRESS

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*Abstract:* The Geography and Map Division of the Library of Congress has embarked on a program that will incorporate digital forms of geography and cartography into its collections of services. The same technologies that make digital forms of geography and cartography possible can also be used for reproducing and sharing historical materials in the Division's collections. Since January 1995, the Division has been working on the acquisition of equipment and software to accomplish the goal of sharing its collections, and the first major collection of the Division to be made available over the World Wide Web consists of late 19th and early 20th century panoramic maps of American cities and towns.

## BACKGROUND

The Geography and Map Division of the Library of Congress has the world's largest map collection. Its collections are comprised of some 4.6 million maps, 63,000 atlases, hundreds of globes, a few thousand raised relief models, and miscellaneous other cartographic items. The earliest piece in the collection, a portolan chart of the Mediterranean, dates from approximately 1350 CE. The Division collects comprehensively for the entire world, which differentiates it from other national libraries which generally collect cartographic materials only for their sphere of influence.

Beginning in the early 1990s, the Division began investigating the digital developments that had been changing the nature of mapmaking and had created whole new geographic disciplines, such as satellite imagery. There was a realization in the Division that these digital developments represented the most significant change in the nature of cartography since the production of the printed editions of Ptolemy's great works in the late 1400s. What was not known, however, was how these digital technologies fit into a library and what resources and skills would be needed to successfully understand and work with them.

In late 1992, the Division appointed its first Geographic Information Systems Specialist, who was charged with investigating such fields as geographic information systems (GIS), automated mapping, and remote sensing and begin making recommendations about what to acquire for the Geography and Map Division and what types of services might be offered. The early 1990s witnessed an explosion of innovation in the geographic information systems technologies, and the Division realized that it would be difficult to catch up with this field, let alone stay abreast of all the new developments. With that in mind, the Division decided to seek the assistance of the companies that were driving the digital geographic and cartographic industries.

In November 1993, the Geography and Map Division received a grant of $30,000 from the James Madison Council (the major private support group of the Library of Congress) as seed money for the establishment of a corporate support group through which contacts and support of geographic and cartographic firms could be channeled. Much of 1994 was spent making preliminary contact with potential supporters of this effort, and the first formal meeting of the Center for Geographic Information of the Library of Congress was held in January 1995 with eight firms participating.

From the beginning of this organization, there were two major thrusts: digital forms of geography and cartography had a place in the collections and services of the Division; and modern geographic technologies could be used to better share the existing collections with the nation, the education community, and industry.

## THE NATIONAL DIGITAL LIBRARY PROGRAM FOR CARTOGRAPHIC MATERIALS

The formation of the Center for Geographic Information coincided with a major new initiative of the Library of Congress, the National Digital Library Program. Started with a five million dollar grant from the Lucille and David Packard Foundation, this program had the stated goal of making digital reproductions of some five million items from the Library's varied collections available over the Internet by the year 2000. Maps were to be included as part of that project. An administrator from the office coordinating the development of the National Digital Library Program described the project to the members of the Center for Geographic Information at its first meeting.

Shortly after that first meeting, Tangent Engineering of Englewood, CO, now known as Tangent Imaging Systems, a division of Scangraphics, Inc., offered to donate to the Division a full scanning system so that the Library could proceed with the digital reproduction of maps. By April of 1995, a system had been delivered that consisted of a flatbed, 24-bit color, 300/600 dot per inch scanner capable of handling an image up to 24" x 34", a Hewlett-Packard DesignJet 650C color printer, and a Sun Sparc 20 workstation. The first image scanned by the Division was George Washington's 1766 manuscript plan of a portion of his estate at Mount Vernon.

Additional support for the Division's efforts came quickly thereafter, as the Hewlett-Packard Company's workstation division offered a suite of powerful workstations to support the scanning program as well as provide the foundation for the use of GIS software. Hewlett-Packard's equipment began arriving in October of 1995, and included a K400 server, a 165ST optical storage jukebox, a 715 workstation, three 712 workstations, a DesignJet 755 large-format printer, six PCS, two DeskJet 1600 color printers, and a LaserJet 4MV printer. Several of these items were intended to support the post-processing of maps after they were scanned. Hewlett-Packard subsequently donated a J200 workstation to be used as the controller for the scanner and two Vectra WindowsNT machines for post-processing.

Developing the scanning program was a long and sometimes challenging process. The Library's network was not fast enough to move large files quickly from one workstation to another. Scanned images were usually in the range of 200 megabytes in size. Maps larger than 24" x 34" had to be scanned in more than one file and then pieced together, a process that took close to a year to perfect, and even then required considerable time to perform.

Finding a way to display maps on the World Wide Web was another difficult problem. The Division wanted to display maps in a form that would be useful for research, which required that users would be able to see the smallest significant piece of information on the map. It had been determined through testing that a scanning resolution of three hundred dots per inch yielded excellent detail. But the large file sizes that resulted from such scanning resolution presented several problems: it would take an incredibly long time (many hours to days, depending on the speed of the user's modem) to download a single image; many users would not have enough storage space on their computers to store the image even if they were willing to pay the enormous cost of downloading such a large file; and few people had computers or software powerful enough to handle such large files.

The solution to the display problem came from a company that joined the Center in 1996, LizardTech, Inc., of Seattle, Washington, which markets a version of wavelet compression technology that originated in the Los Alamos Research Laboratory known as Multi-Resolution Seamless Image Database (MrSid). LizardTech's software also assisted in another issue, storage of the files. Using MrSid software components, the Division first compresses the scanned images by a factor of twenty-two. A two hundred megabyte file is thus reduced to slightly more than nine megabytes, a much more manageable file.

The display of scanned images with MrSid proceeds as follows. When users of the Division's Web site request maps, they are first given an option for various types of searches from which to select maps to view. Once they have selected a specific map, a pre-formatted thumbnail version of the image is shown, accompanied by the bibliographic information for that map. By clicking on the thumbnail image, the Library's Web server then retrieves the MrSID file of that map and extracts and decompresses just enough information to produce a image big enough to fit into a standard window in a Web browser, then converts that image to a GIF format and sends it to the user. The user can then select an image size for subsequent views and choose from among several levels of zooming, after which they point to a desired area in the image and click their mouse. The Library's Web site then decompresses just enough information to produce the image at the selec-ted resolution and size centered on the user's area of interest, converts it to a GIF image and sends it to the user.

This technology allows users of the Library's Web site to zoom in and out of a scanned image so that they can study the map at various levels of detail. An important asset of this technology from the Library's point of view is that users are not required to obtain any special plug-ins for their browser software. Also, any common color or laser printer yields excellent prints from the GIF images, thus making the maps available to virtually any individual or school owning a computer that is capable of browsing the Web.

Now that the basic technology has been put in place to make its materials available to others over the World Wide Web, the Geography and Map Division will focus on finding ways to improve productivity. Scanning will focus on several major collections of core historic Americana: panoramic maps of American towns and cities; land ownership maps and atlases; ward maps; railroad maps;

Civil War and Revolutionary War maps; fire insurance plans; and a collection of miscellaneous "cartographic treasures." The Division will be mounting only those maps which are in the public domain. The technology described herein can be viewed by going to the Library of Congress homepage at http://lcweb.gov or http://www.loc.gov. Once at the site, select the American Memory Homepage, which is the first choice available, and then select Maps.

# MORE THAN BOOKS AND JOURNALS: A PLEA FOR GREATER INCLUSIVENESS IN DEFINING 'GEOSCIENCE INFORMATION'

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*Abstract:* Although the advent of the digital computer has allowed significant advances in the management and dissemination of geoscience information, there remain two areas of information that have not received appropriate attention from the geoscience information community. Manuscript collections often contain unpublished or draft papers, significant unpublished technical information such as geochemical analyses or stratigraphic sections, and supporting documentation such as annotated aerial photographs, wire-line logs, and geophysical data. Although the papers of many significant figures in the history of geology and the geosciences have been retained, access is hampered by the lack of any coherent nationwide data base on holdings; locating a manuscript collection is often more a matter of luck than science.

The geosciences place heavy emphasis on the analysis of three-dimensional artifacts, such as hand specimens, thin sections, and fossils, yet these collections are poorly maintained in many cases, often falling outside the collection development statements of many libraries and institutional collections. These specimens are often separated from the manuscript collections they rightfully belong to, with the result that researchers may be aware of one portion of a collection and unaware of others.

One of us (JDL) is presently attempting to overcome these problems in the deposit of his personal papers and specimens in an appropriate repository. Unfortunately, while some institutions are interested in the manuscript collection, they are not interested in the specimens; other institutions are interested in both parts of the collection, but lack the long-term endowment that curation of the collection demands. The ideal repository should probably be one modeled on herbaria and other biological science collections, perhaps in a regional natural history museum.

We will illustrate these collection management problems with an analysis of our recent work in attempting to reconstruct and publish Part I of Arnold Hague's U. S. Geological Survey Monograph XXXII on Yellowstone National Park - a nearly complete manuscript that was apparently shelved and largely forgotten after Hague's death in 1917. The manuscript was located in the National Archives, the hand specimens (but inexplicably not the thin sections) in the Smithsonian Institution, and a newly-discovered Part III of the monograph, with supporting botanical specimens, in the University Herbarium at the University of California, Berkeley.

# THE ROLE OF GEOLOGICAL SURVEYS IN THE INFORMATION AGE

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*Abstract:* The governmental mandate of geological surveys to capture geoscientific information through mapping, monitoring and RTD has extensively been applied since their early days of foundation as a basis for decisions relevant for the environment and economic resources. In many industrialized countries due to global economic and environmental pressure, however, the involvement into traditional tasks of geological surveys such as the construction of railways, roads, tunnels and canals, exploration of hydrocarbon reservoirs, mining and the exploitation of various mineral resources has diminished in recent years. In addition, many surveys have seriously been affected by financial and personnel cuts. The majority of geological surveys have successfully adopted these new challenges and has re-evaluated their working programmes. Their new strategic concepts primarily address society's fundamental needs and define customer demands of high priority with focus on issues like thematic mapping, recognition of natural hazards, supply of water, exploitation of raw material, urban geology, land-use planning, waste disposal, soil contamination and related applied research activities. Following this relaunch of geological surveys Earth science-related data will be made accessible by implementation of sophisticated IT. In fact, national surveys are gradually becoming a 'virtual geodata-warehouse' built within a 'geocyberspace' in which all available object-oriented information is managed through digital relational databases. Those data which are of actual interest for a customer will be provided at ones finger grips just-in-time and online. Flexible data modelling will permit further applications and cross-references with data from other sources.

# TOWARD A NATIONAL LIBRARY OF GEOSCIENCES

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*Abstract*--The U.S. Geological Survey Library (GSL) was threatened in April 1997 with a cut of 50 percent in its subscription journal allotment. The outcry from across the country was noisy and well deserved. This paper first describes the situation in which the GSL finds itself today. I demonstrate that the GSL is running a world-class operation, in which a superbly managed international publication exchange program has built up the Library's holdings over more than five decades to become the best geological reference collection *in the world.* It is time that this preeminance be both recognized and safeguarded. The three present national libraries, all situated in the vicinity of Washington D.C. (and especially the oldest of these, the National Library of Medicine, founded in mid-century in the office of the Surgeon General of the U.S. Army) provide an informative analogy for a possible transformation of the GSL to the National Library of the Geosciences (NLG). The principle revelation of this analogy is a peek into the chaos to which legislative action seems to be inherent in a century-long auto-de-fe, during which the maturing NLM was buffeted successively and concretely by the U.S. Army, its Surgeons General, the Library of Congress, the First and Second Hoover Commission, the Speaker of the House, Senators Hill and Kennedy, President Eisenhower and assorted commissions and committees--a cautionary tale that means "nothing's certain, and all's fair in politics and war".

## THE ASSAULT ON OUR NATIONAL TREASURE

The Library System of the U.S. Geological Survey (GSL) is a federally sponsored science-engineering library with a high subject concentration in the earth-sciences. Library directories and surveys all agree that the GSL's earth science holdings are, by actual count, the most complete and most comprehensive, not only across the United States, but worldwide as well (Ash and Miller, 1993; Evinger, 1993; Faerber and Rowe, 1997; Hilker, 1987; Kadec and Watts, 1988; Manson and Gordon, 1997). So, in addition to serving the scientific operations of the Geologic and other divisions of the Survey, the Library functions as a reference source of last resort. With such a distinguished record of service to the geological profession, both in and out of the Survey, one might have expected their organization to have been relatively free of the plague of bloody cost-cutting and rumor mongering that seem to characterize some less professional branches of government service. Well, you almost missed it! An editorial on the front page of the science journal *Nature* on April 17, 1997, sounded the alarm, "National Vandalism at the U.S. Geological Survey". The facts were even more alarming: the Survey's Chief Geologist Dr. Patrick Leahy sent down a notice that the budget for serial subscriptions was to be cut 50 percent for the coming fiscal year, and it was hard to see how the book budget was going to fare any better. This was mayhem, lavished on a national treasure. The outcry was strident throughout the Survey and across the country. The Chief Geologist withdrew his order, at least temporarily, and some moderating phrases were written into the budget hearings by the House Committee. However, the incident still raises fears of an uncertain future (Holser, 1997). In this paper we will explore the options that might reduce the impact of any future squeeze.

## THE GEOLOGICAL SURVEY LIBRARY: POWELL'S PLAN

The long-term *raison d'etre* of the U.S. Geological Survey Library system was laid out in the beginning by John Wesley Powell. Powell, the Survey's second Director, in his essay titled "The Business Organization of the Survey" (U.S. Geological Survey, 1889):

*It is essential that the geologic investigator, if he seeks to remain and maintain a place in the foremost ranks of science, shall keep himself constantly familiar with the current geologic literature of this and other countries, and since it is the policy of the Survey to employ the ablest geologists it is important that the means of keeping well abreast of geological science shall be afforded them. Accordingly provision has been made for securing the* *publications of foreign institutions of learning and science and of scientific specialists as promptly as possible, both by exchange in the manner already set forth and by purchase. No effort is made, however, to build up a general scientific library, but only to make such a collection of scientific books, periodicals, pamphlets and maps as they relate to geology or will be of use in the prosecution of the work of the Survey; but certain scientific books and periodicals being of general character, including contributions to geology in connection with matters relating to other subjects, it is sometimes necessary to obtain publications devoted to general scientific subjects in order to secure the geologic matter. Thus the library of the Survey is fairly supplied with current scientific literature in general and is especially rich in current geological literature.*

*The operations of the Geological Survey extend over the entire country; and in order to avoid duplication of labor it is necessary that geologists shall be acquainted with the work of other students in the regions upon which they are engaged. It is therefore important that the Library of the Survey shall include all publications upon the geology of the country, whether reports of investigations undertaken by the Federal Government, reports of State surveys, or memoirs embodying results of the work of unofficial geologists. Great efforts have been made to render the Survey library as complete as possible with respect to these domestic publications and all the more important ones now on its shelves.*

*Although the most important publications in geology as in other sciences are made either in the form of considerable volumes in that of articles in standard periodicals, many treatises of considerable importance are either privately printed or published in small editions, generally in pamphlet form and in order that the Library shall be complete it is necessary that these scattered ephemeral publications shall be collected and preserved. The library is rich in geological literature of this character.*

## THE SURVEY LIBRARY: CLASSIFICATION

The GSL is classified by librarians as a special library, and among these it is recognized as a scientific-technical library; with high subject concentration in geology and related fields (Manson and Gordon, 1997). It is a federally sponsored and funded library operating under an open shelf policy. The Library is widely recognized as the largest and most comprehensive geoscience collection across the United States and around the world (Table 1). By 1997 the holdings of the main collection were as follows (Manson and Gordon, 1997):

| | |
|---|---|
| Volumes | 800,000 |
| Journal Subscriptions | 1,262 |
| Other Serials | 7,835 |
| Maps | 300,000 |
| Pamphlets | 275,000 |

**Table 1.** Holdings of the GSL, National Center, Reston, VA.

In addition, the GSL operates three branch libraries located at Field Centers in Denver, CO, Menlo Park, CA and Flagstaff, AZ whose collections total about one half of the National Center in Reston. The Reston collections are particularly rich in the publications of series of geological surveys and scientific societies, worldwide, from the nineteenth century to the present (U.S. Geological Survey, 1977). These exemplary holdings are a result of an acquisition policy dominated by longterm reliance on an extremely efficient exchange program enhanced by a program targeting exchange sources that could fill gaps in the series (Regan, 1991; Irving, 1962, p. 43-51; U.S. Geological Survey, 1889). One can only estimate the completeness with which the GSL covers the serial literature. Serials account for roughly 75 percent of the bibliographic items picked up and indexed by GeoRef (American Geological Institute, 1990; see below.) The other 25 percent are monographs or miscellaneous publications. The input of serials (subscriptions, both periodical and aperiodical, in paperback) in the most active (unbound) part of the library stacks will be sustaining an average flow of (1,262 + 7,835) = 9,797 total subscription titles during a year. However in GeoRef (American Geological Institute, 1990) 4,000 citations were collected by searching 3,500 serial titles. Of gaps remaining, it seems likely that many will be proxyed by individual reprints from their collection of 275,000 pamphlets that have been accumulating since the collection was started in the last century. The above statements demonstrate, what has been claimed for the past century: the GSL is certainly the most important geoscience library in the world. The major subjects in the past (Manning, 1974) have been geology, paleontology, petrology, mineralogy, ground and surface water, cartography and mineral resources, augmented by significant holdings in mathematics, engineering, physics, chemistry, geochemistry, and soil science; and an increasing number of entries reflect the GSL's concern with environmental problems, earth satellites and remote sensing, geothermal resources, astro-geology, and the conservation of resources (U.S. Geological Survey, 1974).

**BIBLIOGRAPHIC POWER PLAYS**

The reputation and indeed the practical usefulness of a library depends as much on the honing of its bibliographical tools as it does on its book and serial holdings. The GSL was an active pioneer in the development of bibliography and index tools, which have potentiated its usefulness. The most important bibliographical tool is the *Bibliography and Index of Geology* (BIG) which was planned by John Wesley Powell in the first years of the Survey, (U.S. Geological Survey, 1885). The first volume of the index (Warman, 1893) appeared at a time in history when such useful tools were an innovation: the widely used reference volumes of the Catalog of Scientific Papers by the Royal Society of London had only started in 1867, and *Index Medicus* (see below) started at about the same time, 1879, and Chemical Abstracts (1907) was scarcely a gleam in the eye of the American Chemical Society. It is of interest to the present analysis that the BIG appeared for the geological profession at nearly the same early date as the *Index Medicus* appeared for the medical profession, and both occurred in the United States. These two events have in common not some obscure cause- and-effect, rather it was a common cause in the fast development of science in America in the period between the Civil War and World War I.

During its early years, in deference to the legislation establishing the Geological Survey, citations were restricted to North America (i.e., Nickles, 1923, 1924). Beginning in 1933, citations were expanded to worldwide coverage in a collaborative effort with the Geological Society of America . In 1969 the compilation of BIG was taken over by the American Geological Institute. The current reincarnation of the BIG is issued as a computer-based data bank of two million items, GeoRef, in addition to the paper version appearing monthly. The original BIG represented for its time an innovative venture that was also an additional manifestation of the maturation of geology as a truly American science.

The extension of *Index Medicus* to a worldwide provenance was attained at a price: the backlog of subject indexing was never overcome--indexing never caught up with the outpourings in the worldwide developments of medical science and its parallel in medical publication. The increasing backlog of bibliographical items waiting to be indexed had reached a million by 1920 and the *Index Medicus* was finally abandoned in 1950. The final score for *Index Medicus* was 61 volumes with over 500,000 author titles and 2,500,000 article titles (Miles, 1982, p. 325). In comparison the BIG, which had only started up for North America in 1886, was able to fill in the older literature as a bibliography (only) cumulative for 1732-1891 that came out (Darton, 1896) within four years, and later was indexed for the period 1785-1918 (Nickles, 1923, 1924). Some other bibliographical tools in the development of which the GSL participated, are: *The Lexicon of Geological Names Formations of the United States* first published in 1902 (Weeks, 1902), *Data of Geochemistry* first edition 1908 (Clarke, 1908) and *The Guidebook of the Western United States* (Darton, 1915) describing geology along the Western railroads. The GSL collaborated with the Library of Congress (LC) in the production of LC printed catalog cards, and with the American Library Association in the preparation of the Union List of Serials. As a natural extension of the bibliographical projects, the libraries also ran exchange programs based on their own publications. After 1865, four institutions (the Library of Congress, the Smithsonian Institution, the Army Medical Library and the U.S. Geological Survey) took part in a succession of programs for distributing documents throughout the United States and on an exchange basis with foreign institutions. For the U.S. Geological Survey, the GSL under John Wesley Powell assumed responsibility for an extended exchange program begun by Dr. F.V. Hayden in an invitational letter (U.S. Geological Survey, 1889), sent to most of the scientific societies and geological surveys that were active in 1879. I am convinced that the pre-eminence of the GSL among technical libraries can be ascribed to the fidelity of maintaining this communication network through the decades since it was first founded in the Geological Survey (Regan, 1991). In 1898 the list of addresses numbered 1,707, of which 802 received complete exchange (U.S. Geological Survey, 1900). From 1887 to 1902 the number of books accessioned from the exchange program averaged 81 percent; only the remaining 19 percent was accessioned by purchase. In other words most of the incoming books, that are today the base of the GSL's well-deserved reputation, were gained for the collection by exchanges. During the entire 11 year period of 1883 to 1893 the Survey publications for exchange cost the Survey a total of only $32,500, and transport and supplies for packing added an additional $11,000 (U.S. Geological Survey, 1898). This amounts to $4,000 per year overall. This frugal assignation was mirrored in the allotment for purchase of books for the GSL, which started at $2,000 in 1889 and remained at that same level of $2,000 a year until 1931 when it was raised to only $2,500. About $600 of this was actually for books used by the field parties of the Survey (U.S. Geological Survey, 1931). In the following years the allotment for books was considerably expanded. These examples of professional innovation and an aggressive accessions policy testify to the high level of professional work at the GSL, and support a putative transformation of the GSL to a National Library of Geosciences.

## NATIONAL LIBRARY WARS

What is a National Library? There has been some misunderstanding about the characteristics of "national libraries." One view is that it is a very large library, usually the most comprehensive collection of the nation, and it is accorded special status as a *national library* and officially represents the various aspects of that nation's culture (see Table 2). So for example the United Kingdom has its British Library in London (with 810,000 volumes), and France has its Bibliotheque national in Paris (with 8 million books and pamphlets) (Steele, 1976). Germany does not really have a national library (Mittler, 1997), but instead assigns responsibility for a time interval to each of the seven major libraries. The Deutsche Bibliothek in Frankfurt am Main is the largest of these with responsibility for publications up to 1945 and holdings of 5 million volumes (in all fields).

Our own Library of Congress is unique: Its Legislative Reference Service is the real working library for Congress, but the remaining larger fraction of the institution functions as a de facto National Library of the United States. It is governed by the Senate/House Joint Committee on the Library (Cole, 1978; 1979). The size and collections of its staff have tripled since 1950 and its annual appropriation has increased from $9 million to $330 million and its collections total more than 100 million items with a staff of 5,000. It is one of the worlds leading cultural institutions, but does not (presently) seek to serve technical-scientific fields in as thorough a manner as, e.g., the three national libraries. The term *national library* is used in this paper in a somewhat different sense, to designate not just a general library that holds the most important collection in a nation, rather it describes a collection that is unique in its subject coverage, in a worldwide context. When the phrase *national library* is understood in this second context we find there are three great libraries that have been accorded this distinction: the National Library of Medicine in Bethesda, MD since 1956 (Chapman, 1994; Lindberg, 1987); the National Agricultural Library in Beltsville, MD since 1962 (Fusonie 1988); and the National Library of Education at Washington, D.C. since 1994 (Floyd, 1994). (See Tables 1 and 2). A further proposed library for a National Institute for the Environment does not seem to be going anywhere since the bill was introduction in 1993 (Lemons, 1993). Perhaps it lacks a leadership more dynamic than the Committee for the National Institute of the Environment. Both the Library of Congress and the Smithsonian Institution in the 19th century implemented an expansionist philosophy, which might have swallowed up the Army Medical Library/ National Library of Medicine (AML / NLM). The variegated and eventful history of mergers and takeovers are abstracted in the time line illustration in Appendix I. In the mid-19th century Charles Coffin Jewett of the Smithsonian Institution crusaded for a combined Library of Congress and the Smithsonian to create a national bibliographical center (Cole, 1978, p.9), however he was dismissed in 1864 by the Smithsonian Director Joseph Henry, ending any possibility that the Smithsonian might become a national library. Heavy-handed infighting and territorial boundary disputes like these were a constant ingredient of museum politics throughout the century. The NLM was the brainchild of John Shaw Billings, who was a decorated Army surgeon wounded at Gettysburg, turned bibliophile. His passion for collecting medical books and periodicals helped to establish the expanding phases of an Army Medical Library (AML), (Chapman, 1994; Miles, 1982, p. 355). The multiple changes that the AML/NLM actually encountered on the way to recognition as a National Library of Medicine are sketched in Appendix I. The renewed NLM is governed by a Board of Regents of 10 members appointed by the Secretary of Health and Human Services, and half a dozen ex-officio members. The Board of Regents directs policy and acts as a stabilizing influence and it is probably a viable model for an National Library of Geosciences (Appendix II). The assorted power plays and machinations retailed in the time-line of Appendix I may well be the normal hurdles of the legislative process, but they contain a caution for anyone proposing to launch a National Library of Geosciences. The experience of Dr. DeBakey (Appendix I, III) in the final round of the campaign indicates that any move of this sort should depend heavily on the input of knowledgeable experience and pragmatic advice.

**Acknowledgment**

Execution of this review, in unfamiliar narrative territory, depended heavily on Thomas D. Holser, and he has my heartfelt thanks.

**Table 2.** Comparisons of the USGS Library to Other Libraries

Table 2A. Comparisons to National Libraries

| **Library** | **City** | **Country** | **$10^6$ Vol.** |
|---|---|---|---|
| Library of Congress | Washington | United States | 18.0 |
| Lenin State Library | Moscow | Russia | 12.0 |
| National Library | Beijing | China | 9.5 |
| Bibliotheque National | Paris | France | 9.0 |
| British Library, British Museum | London | England | 8.0 |
| Deutsche Bucherei | Leipzig | Germany | 6.5 |
| State Public Scientific Library | Novosibirsk | Russia | 5.6 |
| Biblioteca National Central | Firenze | Italy | 4.5 |
| National Library of Agriculture | Beltsville, MD | United States | 1.60 |
| Eidgenossche Technische Hochschule | Zurich | Switzerland | 1.50 |
| National Library of Medicine | Bethesda, MD | United States | 1.40 |
| **U.S. Geological Survey** | **Reston, VA** | **United States** | **0.80** |
| Deutsches Museum | Munich | Germany | 0.45 |
| American Museum of National History | New York, NY | United States | 0.40 |
| Museum of Comparative Zoology | Cambridge,MA | United States | 0.23 |
| Smithsonian Institution | Washington | United States | 0.12 |

Table 2B. Comparisons to University Libraries

| **University** | **$10^6$ vol.** |
|---|---|
| Harvard University | 9.0 |
| Yale University | 6.4 |
| University of Illinois | 5.1 |
| University of Toronto | 4.8 |
| University of Michigan, Ann Arbor | 4.8 |
| Columbia University | 4.6 |
| University of California Berkeley | 4.5 |
| Cornell University | 4.2 |
| University of Tokyo | 4.0 |

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## APPENDIX I
## Evolution of the National Library of Medicine

| | |
|---|---|
| 1818 | Congress established permanent Medical Department of the U.S. Army. The new Surgeon General soon began purchasing reference books and journals. |
| 1818 - 1864 | The collecting phase of the Library for the medical department of the Army |
| 1864 | First printed catalog totaling 2,100 volumes. |
| 1865 - 1869 | Development of the collection, as the Library of the Surgeon General. |
| 1870 - 1876 | John Shaw Billings develops the collection to 50,000. First use of the term "National Medical Library" |
| 1879 | Billings and Robert Fletcher published *Index Medicus*, a monthly classified record the current medical literature of the world. |
| 1895 | Completion of the first series of the Index Catalog with 176,000 author entries. |
| 1915 | Proposal to merge Army Medical Library (AML) into Library of Congress. |
| 1918 - 1919 | New building proposed for AML and Congress appropriated $350,000 for land purchase. World War I caused project to be canceled. |
| 1927 | *Index Medicus* was merged with Quarterly Cumulative Index, published in association with the American Medical Association. |
| 1929 | Proposal to merge AML into Library of Congress. |
| 1930 | AML forced to vacate old building, however large national deficit prevents action. |
| 1931 | Reorganizing the AML; American Library Association considered this, but considered such a move unwise. |
| 1937 | Pioneer system of microfilming of medical literature. |
| 1941 | The Current List of Medical Literature began publication from the library. |
| 1943 | NLM inspected by a team of professional librarians. |
| 1944 | The American Library Association committee proposed transferring the AML to the Federal Security Agency however, formal authorization for the very existence of the library was so tenuous that no change could be effected. |
| 1949 - 1950 | Medical advisory committee to the Secretary of Defense (Cooper Committee) considered future of the library and recommend it be considered a civil function operated by the Department of the Army. The Federal Security Agency had already included a working library for their Bethesda research center which the Bureau of the Budget considered a duplication. Task force of management committee recommended transfer of the AML from the Department of Defense with three alternatives: (1) transfer to the Department of Health, (2) annexation to the Library of Congress or (3) establishment as an independent agency under supervision of the Library. |
| 1949 | Publication of the first annual catalog of the Army Medical Library. Hoover Commission Report on organization of Executive Branch; Tracy Voorhees, Chairman. Voorhees takes DeBakey to visit President Hoover and DeBakey persuaded Hoover to recommend legislation of a National Library of Medicine. |
| 1950 | Secretary of Defense recommended to the president that the National Research Council study the Library function and place in government. |
| 1952 | The Secretary of Defense renamed the institution as the Armed Forces Medical Library. |

| | |
|---|---|
| 1955 | A task force of the Second Hoover Commission recommended that the Library be designated as the National Library of Medicine (NLM). Second Hoover Commission Report. Discontinuation of the Index-Catalog. |
| 1956 | Senator Lister Hill and Senator John F. Kennedy submitted Congress Senate Bill S. 3430 (House Bill HR.2826) setting up a National Library of Medicine. Committee amended S.3430 for operating the Library by the Public Health Service. Amended bill on May 29 and passed Senate on June 11, 1956. DeBakey and others had difficulty persuading Surgeon General not to oppose the legislation. Despite Senator Rayburn's opposition, Dorothy Vredenburgh (Secretary of the Democratic National Committee) as a favor to DeBakey pressured Rayburn and the bill was reported and passed the Senate on June 11, 1956. President Eisenhower signed NLM into law. Board of Regents formed to govern the NLM. Senator Everett Dirksen tried to influence the legislation to locate the new library building with the AMA headquarters in Chicago. DeBakey and others insisted on the Washington D.C. area, operating as a medical institution independent of the Library of Congress. President Eisenhower signed legislation transforming the Armed Forces Medical Library into the National Library of Medicine which was placed in the Public Health Service. |
| 1957 | The Board of Regents of the NLM choose the Bethesda location for the NLM's new building. |
| 1959 | Public Health Service and American Medical Association set up agreement for joint publication of NLM's Index-Medicus and AMA's Quarterly Index-Medicus. |
| 1960 | NLM developed computerized bibliographic system (Medlars). The NLM collection reaches 976,000 volumes of books; 13,800 serial titles, handled by a staff of 224 and $1,600,000 appropriation (Miles, 1982, p. 473). |
| 1961 | The 125th anniversary of the Library's founding as the Library of the Surgeon General. |
| 1962 | New building for NLM opened on the Public Health campus Bethesda, MD |
| 1965 | Celebration of Billings Centennial. Medical Library Assistance Act, to build a network of 7 regional medical libraries, 135 resource libraries and about 5,000 other medical libraries. The NLM collection surpasses 1,058,000 books and 16,600 serial titles with a staff of 291 and a $4,000,000 appropriation. |
| 1966 | NLM began to publish the National Library of Medicine Current Catalog. |
| 1967 | Formation of a network of 11 regional medical libraries. |
| 1968 | Transfer of the NLM from the office of the Surgeon General of the Public Health Service to the National Institutes of Public Health. Lister Hill National Center for Biomedical Communications signed by President Johnson. |
| 1970 | Medlars starts abridged Index-Medicus. The NLM collection totals 1,232,000 books and 21,000 serials with a staff of 475 and a budget of $19,600,000. |
| 1971 | MEDLINE. |
| 1975 | Medlars II. The NLM collection totals 1,339,000 books and 25,200 serials with a staff of 458 and a budget of $28,900,000 (Miles, 1982). |

## APPENDIX II
## The Public Health Service Act, Sec. 465-466
## Part D - National Library of Medicine
## Subpart 1 - General Provisions
## PURPOSE, ESTABLISHMENT, AND FUNCTIONS OF THE NATIONAL LIBRARY OF MEDICINE

**Board of Regents**

Sec. 455. (286a)(a)(1)--(A) The Board of Regents of the National Library of Medicine consists of ex officio members and ten members appointed by the Secretary.

(B) The ex officio members are the Surgeons General of the Public Health Service, the Army, the Navy, and the Air Force, the Chief Medical Director of the Department of Veterans Affairs, the Dean of the Uniformed Services University of the Health Sciences, the Assistant Director for Biological, Behavioral, and Social Sciences of the National Science Foundation, the Director of the National Agricultural Library, and the Librarian of Congress (or their designees).

(C) The appointed members shall be selected from among leaders in the various fields of the fundamental sciences, medicine, dentistry, public health, hospital administration, pharmacology, health communications technology, or scientific or medical library work, or in public affairs. At least six of the appointed members shall be selected from among leaders in the fields of medical, dental, or public health research or education.

(2) The Board shall annually elect one of the appointed members to serve as chairman until the next election. The Secretary shall designate a member of the Library staff to act as executive secretary of the Board.

(b) The Board shall advice, consult with, and make recommendations to the Secretary on matters of policy in regard to the Library, including such matters as the acquisition of materials for the Library, the scope, content and organization of the Library's services, and the rules under which its materials, publications, facilities, and services shall be made available to various kinds of users. The Secretary shall include in the annual report of the Secretary to the Congress a statement covering the recommendations made by the Board and the disposition thereof. The Secretary may use the service of any members of the
Board in connection with matters related to the work of the Library, for such period, in addition to conference periods, as the Secretary may determine.

(c) Each appointed member of the Board shall hold office for a term of four years, except that any member appointed to fill a vacancy occurring prior to the expiration of the term for which the predecessor of such member was appointed shall be appointed for the remainder of such term. None of the appointed shall be eligible for reappointment within one year after the end of the preceding term of such member.

**APPENDIX III**
**"The Politics of a National Library Bill"**
**Personal reminiscences of Dr. Michael E. DeBakey, Department of Surgery, Baylor College of Medicine, Houston, TX (1991).**

In 1956, the Democratic National Convention was approaching. The powerful Speaker of the House, Sam Rayburn of Texas, was aware of the pressures building up in Chicago and Washington, but he knew little about the Library and decided not to let this issue create a political problem. When hostilities developed for the Democratic National Committee on an issue of so little significance, at least in his mind, Rayburn simply tabled the matter. He was not going to let the bill go through. These events were reported in July 1974 in an article entitled "How Congress Almost Aborted the National Library of Medicine," by Ted Klumpp, MD, who became Chairman of the Medical Services Task Force of the Second Hoover Commission when Chauncey McCormick, the first Chairman, died. Senator Hill called me and said, "Mike, we have the votes, and we could pass the Library bill, but the Speaker won't let it come up because of the political situation. Do you know anyone in Texas who has influence with him?" I had just recently moved to Texas and was not yet widely acquainted, and my inquiries among a number of well- known citizens came up blank. Rayburn was from a small town and fiercely independent. Then I recalled that I had operated on the husband of the Secretary of the Democratic National Committee, Dorothy Vredenburgh, and I had gotten to know her and her husband very well. I called Dorothy and said, "You could do a great service to the nation. We need to get a National Library of Medicine established, and we have the votes but Representative Rayburn is holding up the bill. Since you know him well, perhaps you could persuade him to let the bill go through ... I don't want to see the bill passed up this year; we may have difficulty getting it through next year. All we need is to get it out of committee." She said, "Mike, I'll see what I can do." A few days later she called and said, "It's all set. He's going to release it." Senator Hill was delighted, of course. Dorothy Vredenburgh's role in this important matter was never widely known. She retired in 1989 as Secretary of the Democratic National Committee. After 40 years of debate and diversion, President Eisenhower signed into law the National Library of Medicine Act on August 3, 1956, and the National Library of Medicine was created as a national civilian institution. Even after the legislation passed, NIH Director James Shannon exerted some resistance to putting the Library on campus. A Board of Regents was established, and it was the Regent's task to select a suitable site for the new building. As a member of that founding Board, I suggested a lovely spot adjacent to the NIH - an old golf course- which I thought would be an ideal site. A lively debate ensued. Despite NIH Director Shannon's vigorous objections, I stuck to my guns that the Library belonged at the MH. I felt strongly that the Library had to be related to a substantive medical seientific activity.

# THE NATIONAL GEOLOGICAL MAPPING PROGRAM OF MOROCCO

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*Abstract*--Geological and thematic mapping is necessary for the development of a country, particularly for: mining and hydrocarbon exploration, ground water evaluation, and land use planning survey. The country is insufficiently covered by this needed basic information. Therefore, the geological survey has launched an important National Geological Mapping Program with four main conponents: Establishment of 480 geological maps to a scale of 1/50.000 and 1/100.000, ground and airborne geophysics (low altiitude), 100 geochemical maps on areas of mining interest, thematic maps for land use planning and finally creation of a geoscientific database. The execution of this program will last 20 years for an estimated cost of 200 million dollars US. More than 65% of the program will be realized by contractors, the rest by own staff of the survey. This later has to establish standards for the elaboration of geological maps and geophysical survey. It is also needed a training plan for the own staff of the survey to enable our geologists to work according the forestablished standards for contractors. Two important actions as accompanied measures for the National Program: creation of six regional centers through the country with own management and changement of status of the actual geological survey to permit it to have budget autonomy from the tutel Ministry.

*Editor's note:* Although the author was unable to present this paper at the 1997 GIS Technical Session, the abstract is included because it was accepted for that session.

# FRAMEWORK FOR A NATIONWIDE HARD ROCK MINING DATABASE

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*Abstract:* Despite the social, economic, and environmental importance of hard rock mining, our knowledge of the location, size, and commodities of active and inactive/abandoned mines in the United States is poor. Much of the information needed for a national environmental hard rock mining database is available from state agencies and other sources, but there is no computerized national repository for the information that is easily accessible to all interested parties. As a result, there is a strong need to develop a national environmental hard rock mining database that can be incorporated into a GIS framework. This database would facilitate large-scale (i.e., regional landscape) analyses of adverse effects on surface water, fisheries, and terrestrial resources, and would aid in socioeconomic, regulatory impact, and policy studies by incorporating mining information with environmental and demographic data sets. This database would allow the production of accurate and comprehensive GIS maps that show the distribution of mines over public and private lands and detail the proximity of mines to population centers, national parks, endangered species habitats, drinking water sources, etc. In addition, these data could be coupled with topographical and geological information to produce GIS models capable of predicting potential environmental hazards associated with mining. Public agency efforts in the past have produced mining databases (U.S. Bureau of Mines/U.S. Geological Survey's MAS/MILS database), but the information contained within the databases is inadequate for addressing these large-scale issues using GIS technology.

## 1. INTRODUCTION

Recent advances in the development and application of Geographic Information System (GIS) technology and the availability of demographic and environmental databases containing local, regional, and national information have created the opportunity to modernize the spatial analysis of environmental risks associated with mining. GIS provides a relatively easy-to-use tool for overlaying and analyzing diversified data sets that relate to each other by location on the Earth's surface. Mining databases, when coupled with demographic and environmental databases in a GIS framework, can facilitate large-scale (i.e., regional landscape) analyses of adverse mining-related effects on surface water (Fig. 1), fisheries (Fig. 2), and terrestrial resources, and aid in socioeconomic, regulatory impact, and policy studies. For example, consider these hypothetical situations:

- A closed, acid-generating, metals mine in Gold City, Oregon, is thought to be the source of low-pH, heavy metal laden water that is eradicating downstream fish populations. As part of the ecological risk assessment,

**Figure 1.** Acid mine drainage from a metals mine in Idaho.

**Figure 2.** Brown trout exposed to high concentrations of metals

aquatic biologists quantify potential impacts to salmon and trout populations within the affected watershed. GIS technology can then be used to overlay the location of the mine, the watershed where the mine is located, available contaminant concentration data within the watershed, the stream reaches where salmon and trout runs are located, and those reaches where toxicological thresholds are exceeded. This allows predictions to be made concerning the risk of fish population injuries caused by the mine and could aid in assembling a multimedia sampling strategy.

- A federal agency conducts a study to determine whether human population centers are located near inactive or abandoned mines. Using GIS technology, the U.S. Census database is coupled with a national mining database, and it is determined that approximately 6% of the population is within 5 miles of an inactive or abandoned mine and 4% is within 1 mile of an inactive or abandoned mine. This information may be eventually used to develop better public policy initiatives concerning the proximity of proposed mines to population centers.

- In order to receive state approval for the proposed expansion of its open-pit gold and silver mine, a mining company is required to conduct research to determine whether existing pit lakes in the western United States serve as stopover or resting areas for avian migratory species. GIS technology is used to overlay existing pit lakes and migratory flyways. Because birds are selective and will search for a preferred habitat type in which to stop over, other large water bodies are plotted on the map in order to show the proximity of clean water to potentially contaminated (pit lake) water and the probability that birds will pick a clean water source.

While each of these hypothetical examples are typical of the situations encountered in the regulatory and impact assessment arenas, they are difficult to answer because the current public-domain national mining database, the U.S. Bureau of Mines (BOM)/U.S. Geological Survey's (USGS) Minerals Availability System/Mineral Industry Location System (MAS/MILS), was not designed with today's GIS applications in mind, and in some cases it contains inaccurate and out-of-date information. Hence, the appropriate use of GIS technology in these environmental applications related to mining is difficult, at best. Unfortunately, the lack of a better mining database leaves users little choice but to use what is available. For example, recently, a book was released by a non-profit environmental organization, which included a map of the United States showing the distribution of mines by watershed (Da Rosa and others, 1997). Information contained in the map was out of date because it was generated from the MAS/MILS.

This paper discusses the history and limitations of the MAS/MILS database and presents a format for the development of a new state-of-the-art mining database that incorporates demographic and environmental data sets in a GIS framework.

## BACKGROUND

The MAS/MILS was first developed in the 1960s by the BOM and was in their possession until closure of the BOM in 1996. At that time, responsibility for the MAS/MILS was transferred to the USGS. The MAS/MILS contains information on 221,000 mine sites (USGS, 1995).

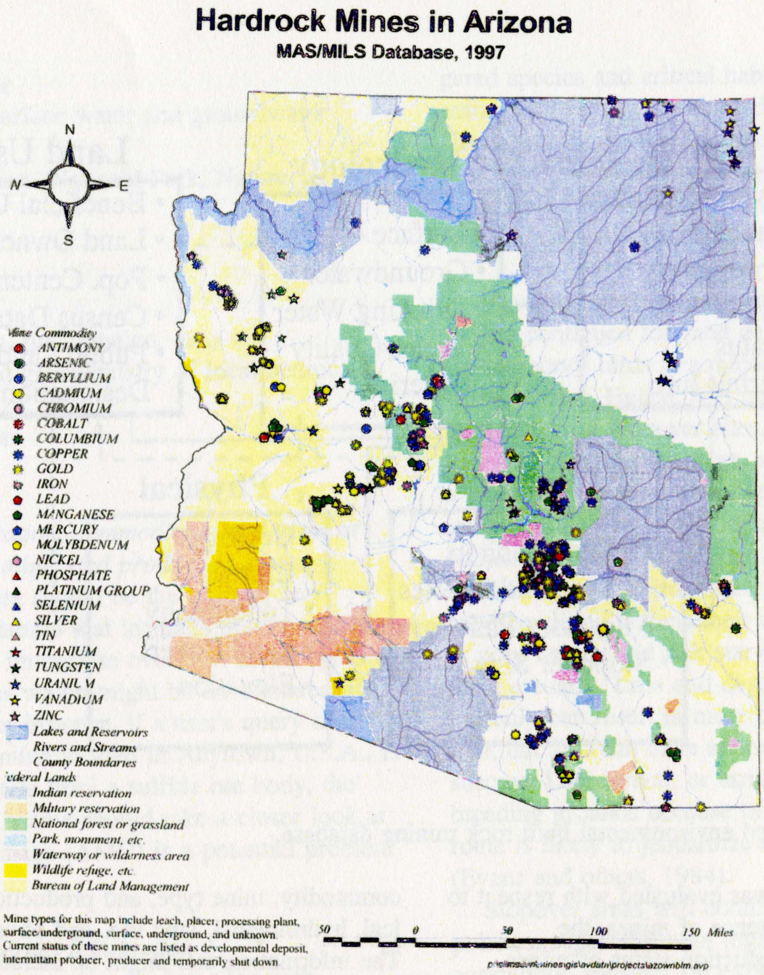


**Figure 3.** Map of Arizona showing MAS/MILS mining locations.

Information reported in the database includes occurrences; deposits; mine names; processing facilities; locations including digital latitude/longitude; current mine status (e.g., producer, temporary shutdown); mine type (underground, surface); and commodity mined. The intended use of the MAS/MILS was to provide mining experts with a tool for quickly extracting information on mines and mineral deposits. This included information on exploration and development of new and existing mineral deposits, producing mines, advanced mining projects, and suspensions/closures, as well as mining methods. Information on U.S. mine sites was sporadically collected and entered into MAS/MILS through the 1980s by BOM personnel and various university researchers and their students, making quality assurance/quality control difficult (Bill Ferguson, USGS, personal communication, 1997). As a result, the MAS/MILS soon became out of date and inaccurate.

An effort within the USGS was recently initiated to merge their mineral information database, the Mineral Resource Data System (MRDS), with the MAS/MILS. While each database contains unique mineral location data, some sites are present in both databases. Before merging the databases, the USGS will identify all those mineral locations found in both databases so that only unique information is contained within the final single database (Shield and others, 1996).

## LIMITATIONS OF THE MAS/MILS

The intended use of the MAS/MILS was to provide mining experts with a tool for quickly extracting information on mines and mineral deposits. It did not include serving as a relational database for mining-related GIS applications. However, a survey[1] of western U.S. mining and environmental agencies was conducted to determine potential mining-related environmental impacts on a

1. Unpublished survey conducted by Hagler Bailly personnel from January, 1997 to April, 1997.

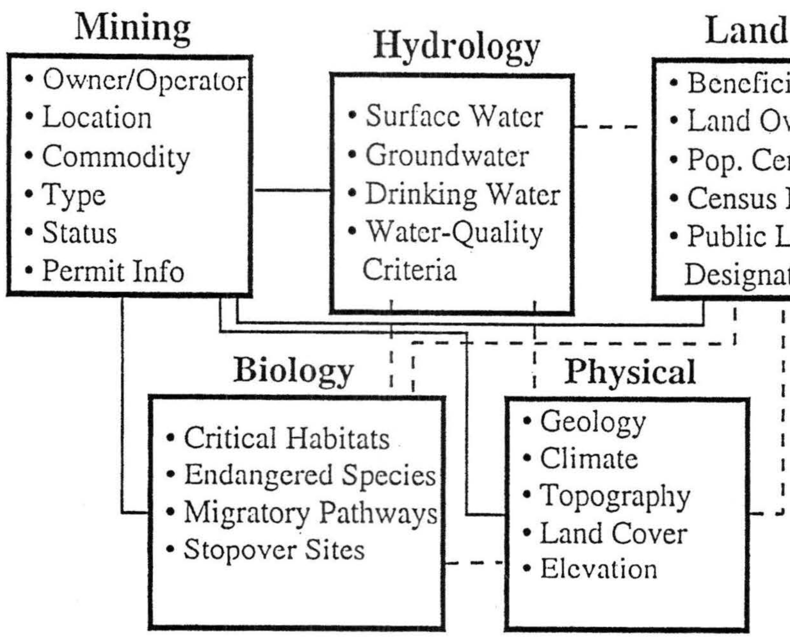


**Figure 4.** Contents of proposed environmental hard rock mining database.

regional scale. The database was evaluated with respect to the location, number, and existence of mines, the commodity mined, and the production status of mines. Through this survey, it was concluded that in addition to being out of date, the database contained duplicate and triplicate entries, treated minor byproducts as stand-alone producers, hence overestimating the total number of mines in the database, and contained a large number of "promotion" mines (mines that existed on paper only).

Spatial data in the MAS/MILS, limited to a digital latitude and longitude for each mine site, were evaluated through the use of ARC/INFO software which plotted the locations of all mines in the database by commodity. Maps containing these data were included in packets sent to survey participants for evaluation (Fig. 3). Participants reported numerous incorrect locations and commodities of mines on the map through comparison with state-generated maps and directories

## PROPOSED NATIONAL ENVIRONMENTAL HARD ROCK MINING DATABASE

### Contents

Large-scale (i.e., regional landscape) analyses of adverse mining-related effects on surface water, fisheries, and terrestrial resources and socioeconomic, regulatory impact, and policy studies would benefit from a database that could couple mining information such as location, commodity, mine type, and production status with biological, hydrological, land use, and physical data sets (Fig. 4). The information that might be included in the database is listed below. The rationale behind their choice follows.

*Mining*
- Owner/operator
- Location including digital latitude and longitude
- Commodity mined
- Type of mine
- Production status
- Federal and state permit information
- Deposit mineralogy

*Biology*
- Critical habitats
- Migratory pathways/stopover sites
- Documented biological effects associated with media or tissue contaminant concentrations

*Hydrology*
- Surface water/groundwater locations, chemistry, and flow data
- Aquifer characteristics (i.e., water table elevation, porosity, hydraulic conductivity)
- Federal and state water quality criteria

*Demographics/Land Use*

- Beneficial uses for surface water and groundwater
- Land ownership
- Public land designation (National Park, Nature Preserve, etc.)
- Census data

*Physical*

- Climate (evaporation, precipitation, etc.)
- Physical geology and geochemistry of local bedrock
- Land cover
- Topography/elevation

**Mining**

*Owner/operator, location, commodity mined, deposit mineralogy, type of mine, and production status*

These five parameters should be the basis of any mining database. A database that includes this information provides users with an immediate overview of the types of environmental problems which might be encountered at a particular mine site. For instance, if a user's query of the database shows that a mine located in Anytown, U.S.A., is extracting precious metals from a sulfide ore body, the user might decide that he/she should take a closer look at whether acid mine drainage (AMD) is a potential problem at that site.

*Federal and state permit information*

The Clean Water Act requires mining sites with discharges to surface water to have a permit that establishes pollution limits, and specifies monitoring and reporting requirements for wastewater discharges (U.S. Congress, 1973a). National Pollutant Discharge Elimination System (NPDES) permits regulate industrial wastes that are collected in sewers and treated at municipal wastewater treatment plants. Permits also regulate industrial point sources that discharge into other wastewater collection systems or directly into receiving waters. This information could be used to compare measured contaminant concentrations in a river downstream of a mine to reported contaminant concentrations in the mine's wastewater discharge.

**Biology**

*Critical habitats*

The Endangered Species Act defines the term "critical habitat" for a threatened or endangered species as "specific areas within the geographical area occupied by the species on which are found physical or biological features (1) essential to the conservation of the species and (2) which may require special management considerations or protection" (U.S. Congress, 1973b). The designation of endangered species and critical habitats allows natural resource managers to make informed decisions regarding land use. Hence, it is important that they be integrated into the database in order to assess or predict the potential impacts caused by mining to areas that are essential to the protection of fish and wildlife habitat.

*Migratory pathways/stopover sites*

The continued loss and degradation of stopover habitat for migratory birds is a major ecological problem in the United States. Hence, it is imperative that we identify and protect critical stopover sites. When and where a migratory bird makes a stopover, and the length of time spent at a particular stopover site, depends on several factors, including the availability of a suitable place to land and habitat quality. If appropiate habitat is not available for a needed stopover, birds must fly farther, even if a weakened condition lessens their chance of survival, or remain in poor habitat and risk starving or becoming easy prey for a predator. Loss and degradation of stopover habitat not only can result in more birds dying while on migration, but also can have serious repercussions on nesting success. Late arrival, or arrival in poor condition, at the breeding grounds because of inadequate food and rest en route is likely to jeopardize a bird's ability to reproduce (Evans and others, 1984).

Stopover areas will continue to be affected by land use policies, especially with regard to development, ranching, agriculture, forestry, oil exploration, and mining.

*Documented biological effects associated with media and tissue contaminant concentrations*

There is a broad range of biological effects caused by the presence of a particular chemical substance in the tissue of an organism, from the induction of particular enzymes or enzyme systems to whole-organism effects on survival, growth, or reproduction (Eisler, 1994; Eisler, 1987). A strong inferential link exists between whole-organism toxicological effects (e.g., reduced survival) and ecological impacts on populations, communities, and ecosystems. All chemical substances have the potential to produce adverse effects (i.e., toxicity), including such diverse compounds as cyanide and mercury (Eisler, 1991; Eisler, 1987). Because environmental contaminants vary so widely in their potential to produce toxicity, contaminant-specific information must be used to reach a determination regarding the potential for a contaminant to produce adverse effects.

**Hydrology**

*Surface water/groundwater locations, chemistry, and streamflow data*

The Environmental Protection Agency's Toxic Release Inventory for mining provides information on releases to water, air, and land from mining facilities. The availability of this type of basic information regarding water and sediment chemistry, coupled with streamflow data makes it significantly easier for state water-quality managers, scientists, and watershed groups to determine water-quality conditions and trends. The combination of the flow data and water-quality data is needed to determine how pollutants are moving through watersheds. This will help water planners evaluate the relative effects of various pollution sources in critically important watersheds and thus effectively target watershed protection and restoration efforts related to hard rock mining.

*Aquifer characteristics*

In the United States, groundwater is supplied to over 40 percent of the population served by public water utilities. Accounting for private systems, which are dominantly groundwater, over half of the population relies on groundwater for drinking water (Solley and others, 1988). Hence, protecting groundwater resources is of national importance.

The movement of chemical substances through groundwater is influenced not only by the properties of the substance (quantity, volatility, density), but also by the properties of the geologic material. Quantitative data on the porosity, hydraulic conductivity, and type of geologic material is necessary in order to determine contaminant transport in the subsurface.

*Federal and state water-quality criteria*

The purpose of using water quality criteria, methodologies, policies, and procedures in the environmental decision-making process is to establish consistent, enforceable regulations for the long-term protection of aquatic life, wildlife, and human health. Hence, the inclusion of federal and state water-quality criteria in the mining database would allow users to quickly determine whether contaminant concentrations within a specific mining-affected watershed might cause (or be causing) ecological impacts on populations, communities, and ecosystems.

**Demographics/Land Use**

*Beneficial uses for surface water and groundwater*

Environmental and water pollution control agencies usually establish beneficial uses for surface water and groundwater in each state. Beneficial uses include municipal water supply, industrial water supply, recreation, agricultural irrigation, power, navigation, and protection and enhancement of fish and wildlife. The beneficial use usually is based on the quality of the water body in question, existing and projected sources of pollution, acceptable alternate water resources, historical use patterns, and existing treatment systems for pollution abatement (Malina 1996). The beneficial use designation is important because it establishes water-quality criteria to protect the designated use. For example, the protection of public water supplies requires much higher water-quality criteria than the protection of water for navigation purposes. Hence, cleanup criteria at an AMD-polluting mine in a watershed designated for navigation purposes would be significantly lower than criteria established for a "protection of public water" designation. The cost of implementation would be significantly lower as well.

*Land ownership*

When determining potential injury to natural resources or evaluating potential risk posed by mining to ecosystems, it is crucial that land ownership be taken into consideration. For instance, mining reulations and remediation requirements vary between federal agencies responsible for landmanagement and stewardship. In many areas, land ownership can be a checkerboard of public and private interests.

*Public land designation*

Using the proposed mining database to cross-reference the boundaries of National Parks and Nature Preserves with the locations of proposed hard rock mines, existing hard rock mines, and inactive and abandoned mines would allow the accurate assessment of potential or real injuries and risks to natural resources on public lands. In turn, this information could be used to estimate tax dollars being spent on cleanup of these sites.

*Census data*

Population databases are forming the backbone of many important studies that model the interactions between population growth and environmental degradation, and assess the risks of various hazards associated with mining such as water pollution, air pollution, and radiation. Detailed information on population size, growth, and distribution (along with many other environmental parameters) is of fundamental importance to such efforts.

**Physical**

*Climate*

Climatic variables such as evaporation and precipitation can be the controlling factor in pollution generation and distribution at mine sites. Typically, hard rock mining operations leave behind large deposits of waste rock and

| Data Sets | Source | Internet Location (http://) | Description |
|---|---|---|---|
| Aquifers | Kansas Geol. Survey | gisdasc.kgs.ukans.edu | Extent and composition of Kansas aquifers |
| Climate Database | National Climatic Data Center | www.ncdc.noaa.gov/ol/climate/climateresources.html | surface temperature and pressure |
| Drainage Basin Database | USGS | grid2.cr.usgs.gov/data/download.html | drainage basin data generated from elevation model |
| Endangered species habitats and occurrences | Kansas Department of Wildlife and Parks | gisdasc.kgs.ukans.edu | digital data on critical habitats and occurrences |
| Environmental Residue - Effects Database | U.S. Army Corps of Engineers, U.S. EPA | www.wes.army.mil/el/ered/index.html#misc | biological effects (e.g., reduced survival, growth)associated with tissue contaminant concentrations |
| Geologic maps | USGS | geology.wr.usgs.gov/wgmt/digdata.html | geologic maps on local and regional scales |
| Global Land Information System (GLIS) | USGS | edcwww.cr.usgs.gov/webglis | land use, land cover, soils data, cultural and topographic data, remote-sensing/aircraft data |
| Major Land Uses (MLUs) in the U.S. | U.S. Department of Agriculture | www.mannlib.cornell.edu/usda/usda.html | acreage estimates of MLUs by region and state for each Census of Agriculture year |
| Mineralogy | Athena Mineralogy | un2sg4.unige.ch/athena/mineral/mineral.html | chemical compositions of minerals |
| Montana Natural Resource Info System | State of Montana | nris.mt.gov/nsdi/datadir/reg1.html | National Forest and Park boundaries; wilderness areas, wildlife refuges |
| National Water Information System | USGS | h2o-nwisw.er.usgs.gov/nwis-w/US/ | surface water locations, streamflow data (chemistry data in development) |
| Natural Wetlands Data | USGS | grid2.cr.usgs.gov/data/download.html | distribution and environmental characteristics of wetlands |
| Olson Vegetation data set | USGS | grid2.cr.usgs.gov/data/download.html | vegetation data for the United States |
| Population Distribution | CIESIN | www.ciesin.org | population distribution at several degrees of resolution |
| Population Distribution | U.S. Census Bureau | www.census.gov | population distribution at several degrees of resolution |
| Screening Benchmarks Ecol. Risk Assessment | Oak Ridge Nat'l Lab | www.hsrd.ornl.gov/ecorisk/ecorisk.html | tissue contaminant concentrations (thresholds) resulting in adverse biological effects |
| State mining databases | State agencies | n/a | includes mine owner/operator, location, commodity, etc. |

**Table 1.** Potential Data Sources on the Internet

tailings. In a wet climate with high precipitation rates, these waste materials often become unstable over time as they weather and deteriorate, forming high-acid, metal-rich waters that leach into surface water and groundwater. In contrast, the same waste material may have significantly lower pollution potential rates if located in a dry climate with high evaporation rates, thus decreasing the mining-related impacts to fish, wildlife, and human health. Hence, including climate data in the proposed database would allow pollution prevention managers to predict leachate/AMD problems that could occur at a mine site.

*Physical geology and geochemistry of local bedrock*

Physical geology and geochemistry of the local bedrock can influence the potential for environmental risk to fish, wildlife, and human health. For instance, if the neutralization capacity of the bedrock is low and the percentage of sulfide minerals in the mined ore body is high, problems with acid generation might occur. Similarly, the presence of fault systems,the aperture of faults, and the presence of other areas of structural weakness might increase contaminant transport rates to groundwater aquifers or surface water bodies. Hence, including geological and geochemical data of the local bedrock in the proposed database would allow environmental managers and industry leaders to make informed decisions regarding appropriate locations for new mines, as well as potential environmental risks associated with active mines and inactive and abandoned mines.

*Land cover*

Global coverage by remotely sensed images such as those provided by Advanced Very High Resolution Radiometry provides the opportunity to derive estimates of global- and continental-scale land cover. Land cover characterizations enable environmental managers to determine loss of land cover or changes in land cover due to mining.

*Topography/elevation*

Digital topographic information describing the shape of the Earth's surface is important for many human and Earth resource models. The most fundamental type of topographic information is elevation data. Elevation data can be modeled to yield derived topographic information such as aspect, slope, watershed, drainage, or landform information to more completely describe the Earth's surface. Each of the variables can have an effect on potential environmental risks at mine sites.

**Potential Data Sources**

There is a wealth of easily accessible digital- and metadata available on the internet that might be useful in developing a national environmental hard rock mining database (Table 1).

In particular, the USGS offers one of the most complete sets of digital land information in the country through the Global Land Information System (GLIS). It is an interactive computer system developed by the USGS for scientists seeking sources of information about the land use, land cover, and soils data; cultural and topographic data; and remotely sensed satellite and aircraft data. The GLIS website is at http://edcwww.cr.usgs.gov/webglis

## CONCLUSION

Recent advances in the development and application of GIS technology and the availability of demographic and environmental databases containing local, regional, and national information have created the opportunity to modernize the spatial analysis of environmental risks associated with mining. Mining databases, when coupled with demographic and environmental databases in a GIS framework, can facilitate large-scale (i.e. regional landscape) analyses of adverse mining-related effects on surface water, fisheries, and terrestrial resources, and aid in socioeconomic, regulatory impact, and policy studies.

However, the nation's major mining database, the BOM /USGS MAS/MILS, was not designed with GIS applications in mind and in some cases contains inaccurate and out-of-date information.

The creation of a new national environmental hard rock mining database that couples demographic and environmental data sets in a GIS framework could facilitate large-scale analyses of adverse mining-related effects. Environmental and demographic data sets that could be included in the mining database include biological, hydrological, physical, demographic, and land use information. Much of this information is available on the Internet or through state and federal agencies.

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# GEOLOGIC MAP DATABASE OF THE NEVADA TEST SITE AREA, NEVADA

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*Abstract*--In August 1996, the USGS National Geologic Map Database Project and the Association of American State Geologists (AASG) formed working groups to devise standards for defining and using geologic map data. One working group has been developing a geologic map data model. They produced a draft report in October 1997 that after public discussion, will be submitted to the Federal Geographic Data Committee (FGDC) for more public review and comment. At about the same time, the USGS decided to digitally compile traditionally collected geologic data from the Nevada Test Site (NTS) area, Nevada into a composite geologic map database. The current version of the digital geologic map database was built using a preliminary version of the data model. The proposed data model allows the easy extraction of different kinds of hierarchical geologic attribute data that can then be integrated with other geo-spatial data sets to help evaluate and possibly help ameliorate current environmental problems at the NTS. Queries against the NTS database have shown potential usefulness in interpreting geologic and hydrogeologic structure at the NTS.

## INTRODUCTION

The U.S. Geological Survey has studied various aspects of the geology of the Nevada Test Site, Nevada (NTS, figure 1) in cooperation with the Department of Energy (DOE) and its predecessor agencies for about forty years. Systematic geologic mapping of USGS 7½ minute quadrangles in and around the NTS was essentially completed in the time period from late 1960s to the early 1970s. Stratigraphic revisions and corrections were incorporated into special 1:48,000-scale quadrangle geologic map compilations published during the late 1970s. During the late 1980s and early 1990s, regional geologic map compilations at a 1:100,000 scale were initiated. These compilations summarized the then current state of geologic understanding; and they reflected the significant improvements that had been made in the stratigraphic framework, structural interpretations, and surficial geologic data that came from new geologic studies in and around the NTS. Most of the USGS geologic mapping in this area has been digitally compiled at 1:100,000 scale by Wahl and others (1997). The compiled database covers a contiguous area of nearly 11,000 km$^2$ or roughly the size of the state of Connecticut.

The interest of the DOE in digital geologic map databases arose from a need to understand the geologic framework of the NTS primarily to plan for weapons testing operations that continued until 1992. At the same time, the DOE was initiating a major on-going study of various kinds of environmental contamination that were a by-product of Department of Defense projects at the NTS. As a result, the DOE had need of a scientific and management tool to aid in protecting ground water resources in Southern Nevada. Geographic Information Systems (GIS) were becoming useful and more-widely applied tools to help answer land-management questions during this period.

As public and scientific awareness of environmental and land use issues grows, the ability to combine geologic data with other geo-spatial data sets is becoming critical. The capability to create geologic databases that are useful to any investigator is needed to help answer questions that arise from complex land management issues and to help understand the consequences of making difficult policy decisions from among various presented options.

A data model for geologic maps is needed to answer a fundamental question. What is a digital geologic map and how can it be used as an information resource? According to Rumbaugh, 1996, the development of a data model is the first step in a methodology that takes raw information and transforms that information into a database that can be easily shared by others. A data model can be likened to a vocabulary and a set of grammatical rules that relate words in the vocabulary. So then, digital geologic map data can be more easily distributed when an accepted description exists of the data structures and content that

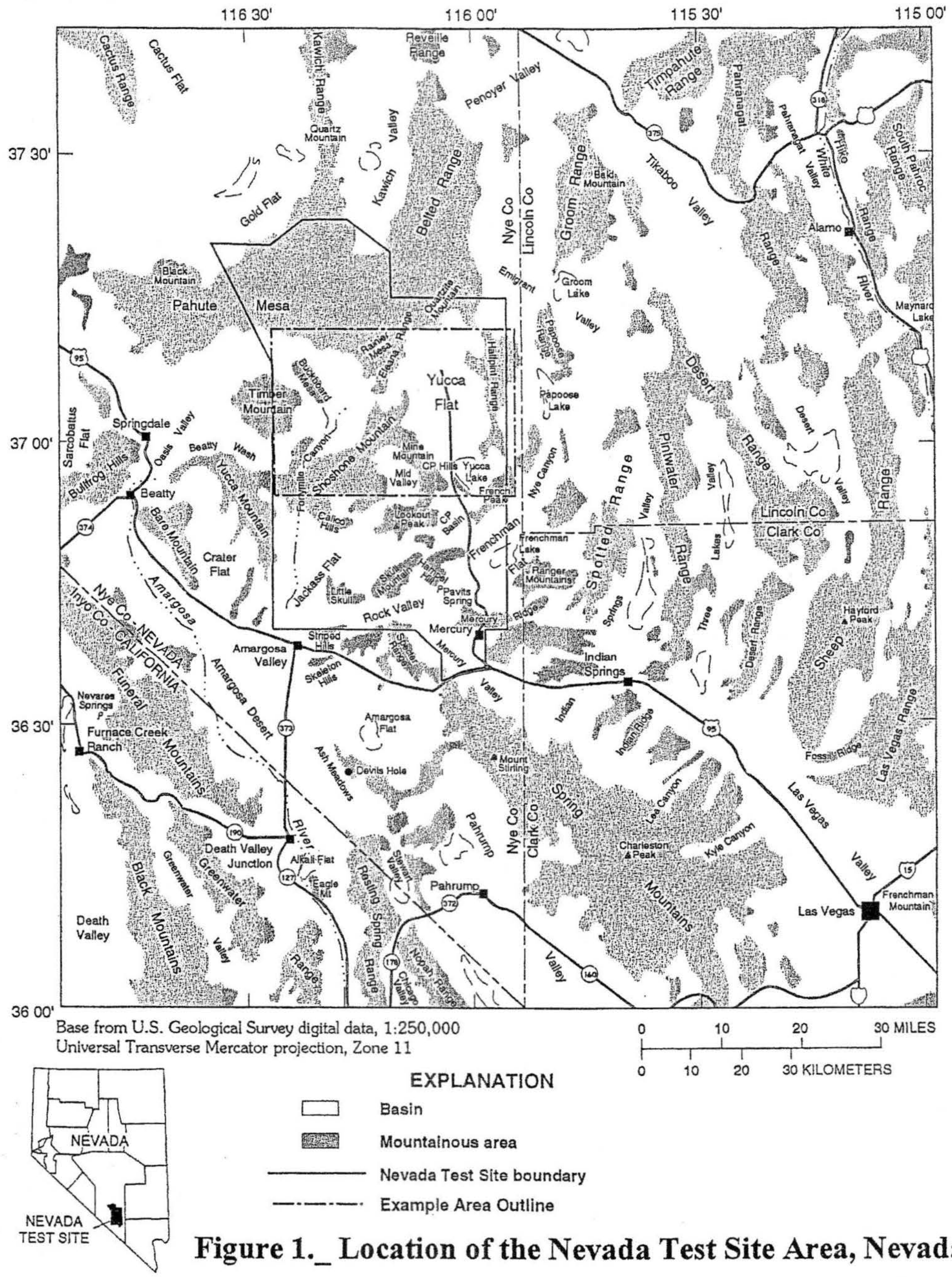


**Figure 1._ Location of the Nevada Test Site Area, Nevada**

constitute a digital geologic map product. The next step in the process is the implementation of the data model design in current geo-spatial software systems. The last major step in this sequence will be the development of a process to transform the database into a format that is sharable in agreed-upon exchange formats. For federal agencies the required distribution format standard is the Spatial Data Transfer Standard (SDTS). Additional USGS /AASG distribution formats for digital geologic maps have yet to be agreed upon.

## USGS/AASG WORKING GROUP DATA MODEL

In August 1996, the Digital Geologic Map Committee of the Association of American State Geologists (AASG) and the U.S. Geological Survey, National Geologic Map Database Project formed several working groups to devise standards and guidelines for various concepts that make up a geologic map in digital form. The first objective of the working group for creating a data model for digital geologic maps was to determine a working definition for a geologic map. The working group arrived at the definition graphically shown in figure 2.

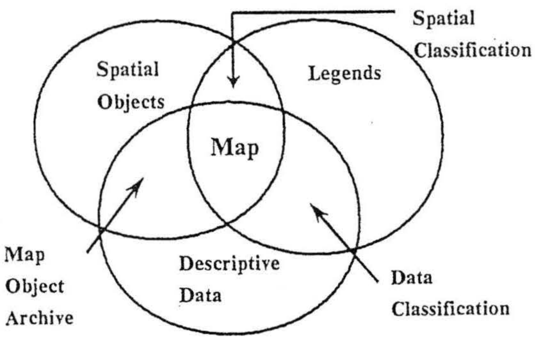


Figure 2._ A Geologic Map Definition
(After Raines, written communication, 1997)

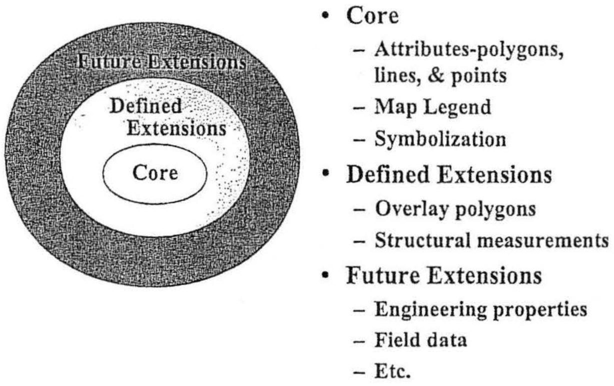


Figure 3._ Geologic Data Model Fundamental Concepts
(After Raines, written communication, 1997)

A digital geologic map consists of spatial objects: polygons, lines, and points; descriptive material, which includes sketches as well as text; and legend information which include symbols, and relationships. When the geologic map information is stored in the object archive in an agreed upon data model, a new legend definition created as a way to query the database can then be used to build a derivative map. The legend definition will also facilitate the display of that map in a way that shows the information in a useable manner.

## THE DATA MODEL FOR GEOLOGIC MAPS

### Fundamental Concepts

The data model is built around the concepts shown in figure 3. The core section describes those objects, descriptions, and legend materials that are fundamental to any geologic map. Special purpose geologic maps are considered as maps that can be constructed from a properly built geologic map database. Defined extensions are additions or changes to the data model that may become core requirements at a later date. Future extensions should allow the data model to grow and adapt to changing needs of the users of geologic map data.

A more detailed explanation of the concepts and terms used here can be found in the current working group committee report (Johnson, and others, 1997). This report can found on the World Wide Web at: http://ncgmp.usgs.gov/ngmdbproject/model41.pdf

### Geologic Map Legend

The geologic map legend as it applies to the digital geologic data model is a conceptual constraint with important practical implications. The legend, as described in the data model, expresses various relationships among map objects in ways that can be processed digitally. Most geologists are comfortable with line and point symbols, and colors and patterns used in map polygons that are used on geologic maps. However the storage of the information in unit descriptions, correlation charts and diagrams showing map unit relationships are difficult to store without agreed-upon word lists that will convey the information in such charts and diagrams. Relationships shown in diagrams on geologic maps are particularly difficult to translate into words (figure 4).

The words that capture information in the diagrams on the right side of figure 4 are in the column at the left. This list is not exhaustive but it is meant to give an idea of the type of words that can be used to store the relational information in the diagrams and charts in geologic map legends. Word lists for rock units, geologic time, and other geologic information are being developed along with the data model.

### Object Attribute Hierarchies

A critical part of the data model is the concept of hierarchical attributes (figure 5). When thinking about hierarchies of attributes for objects, the concept of inheritance is key. Simply put, the more specific an attribute is, the more inherited attributes of a more general nature become associated with it. For example, if a mapped geologic unit is classified as a member, it is also important to know the formation, group and super-group to which the member belongs. The attributes that define the super-group, group, and formation to which the member belongs, are inherited by the member map unit. In addition, a class in a hierarchy can have multiple descendants. However, a class may have different antecedents. For example, an ash-flow tuff (a type of erupted volcanic rank) can be a rhyolite (a chemical type of tuff) in addition to being a comendite (a particular chemical kind of rhyolite). But knowledge that a map unit is a comendite does not indicate that it was erupted as an ash flow tuff. It may, for example, been erupted as a lava flow. The above attribute list is from Wahl, et al., 1997. For more information about object hierarchies the reader may refer to Rumbaugh, and others, 1991, and Rumbaugh, 1996.

Examples of Words

- Contains
- Contemporaneous
- Correlates
- Equivalent
- Intrudes
- Overlies
- Above

Examples of Relations

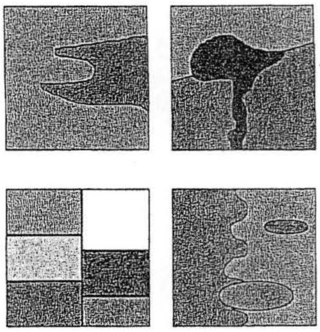

**Figure 4._ Relationships in Geologic Map Legends**

MAP UNITS

| Group | Formation | Member |
|---|---|---|
| Timber Mountain | Rainier Mesa | Fluorspar Canyon |

ROCK TYPE

| Volcanic | Mineral Sub Class | Extrusive Type |
|---|---|---|
| Rhyolite | Comendite | Ash Flow Tuff |

Figure 5._ Object Attribute Hierarchies

**Example of Database Query**

A query into the geologic database for the NTS (Wahl and others, 1997) might then require following two or more attribute hierarchies to satisfy it. For example, a request to select all Neogene rhyolites requires the selection of all rock units that are of Miocene and Pliocene age and a reselection based on rhyolitic composition.

## DATA MODEL IMPLEMENTATION

### Geographic Information System (GIS) Software

Current plans call for a prototype data model implementation using ArcView, from Environmental Systems Research Institute, Inc. (ESRI) and MicroSoft Access. Next an implementation will be constructed in ARC/INFO, also from ESRI. Other implementations of the data model will be developed as they are needed. As the geologic map databases grow, sophisticated database software systems will be adapted to the data model.

### Graphical User Interface Tools

Graphical user interface (GUI) tools are being developed so that a geologist does not need to know complexities of the data model to build digital geologic map databases. The current prototype tools use MicroSoft Access and the graphical tools available in ArcView. Future GUI tools will be developed in ARC/INFO and other software systems as needed. Additional GUI tools will be needed to help in the querying of geologic map databases and subsequent plotting of geologic map data.

## DATA DISTRIBUTION

### Spatial Data Transfer Standard

The Spatial Data Transfer Standard (SDTS) is a general expression of how spatial data can be exchanged. The implementation of this standard is by means of profiles. Profiles are a specific description of the content of spatial data computer files of the types that can be actually written. SDTS is now an American National Standards Institute (ANSI) standard which makes SDTS a national standard. This means that most GIS software vendors will have SDTS translators as a part of their software systems.

SDTS does have some deficiencies when used with a geologic map database. It doesn't handle multiple interrelated data sets. The metadata file (data about data) included with the current SDTS profiles does not match FGDC standards for metadata. In addition, if double precision data sets are put into SDTS, they come out only as single precision.

### Other Formats

Other exchange formats can be used in addition to SDTS. Among the broad spectrum of possible data formats, ASCII text files, AutoDesk-AutoCAD DXF files, and ARC/INFO export files have found general acceptance.

## DERIVATIVE MAP EXAMPLES USING THE NTS DIGITAL GEOLOGIC DATABASE

Because a data model for digital geologic maps is not yet approved as a national standard, the digital geologic data for the NTS were built into a database using a preliminary version of the data model. The collection and integration of these data into a usable database using a data model has been a formidable problem. The attribute data for the mapped units was difficult to compile, because such data were not part of the database at the start. The data sources for this compilation were many and varied. Data were taken from publications, publication materials, paper maps, green-line compilations, and direct from aerial photography.

Figure 6a is a map of a portion of the NTS database around Yucca Flat, Nevada. The data are represented as a traditional geologic map but without faults or strike-and-

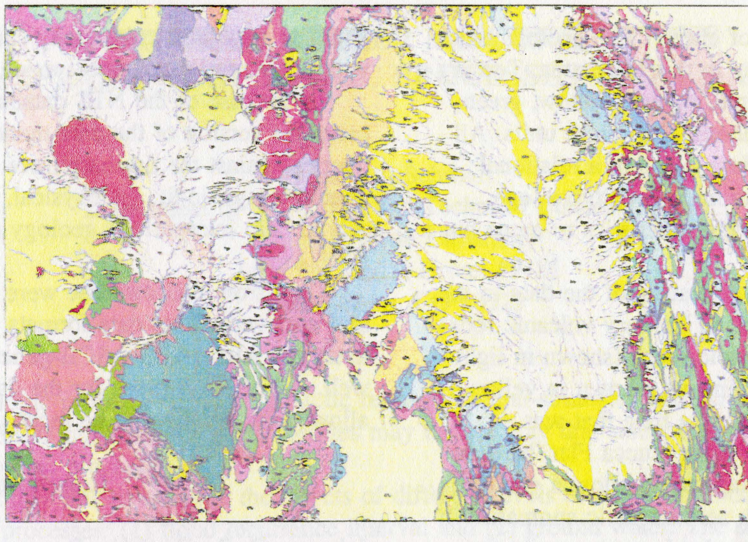

**Figure 6a._ Rock Outcrops in the Yucca Flat Area, Nevada**

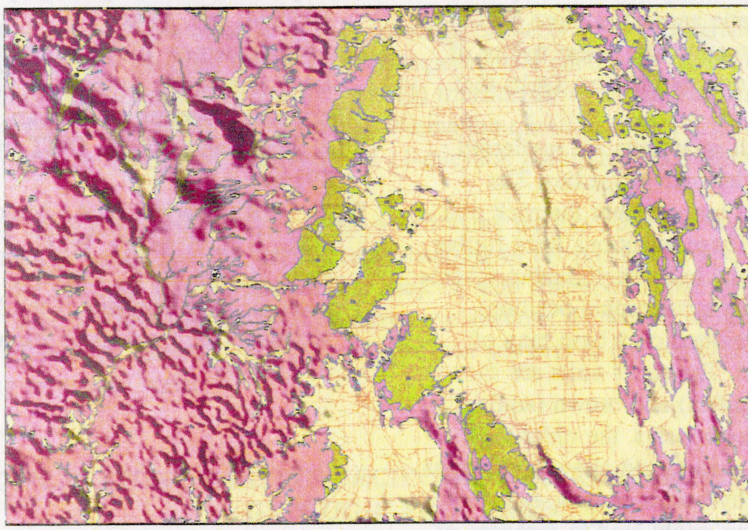

**Figure 6b._ Derived Map Showing Tertiary Volcanic Rocks, Quaternary Surficial Deposits, and Other Rock Units With Shaded Aeromagnetic Surface Yucca Flat Area, Nevada**

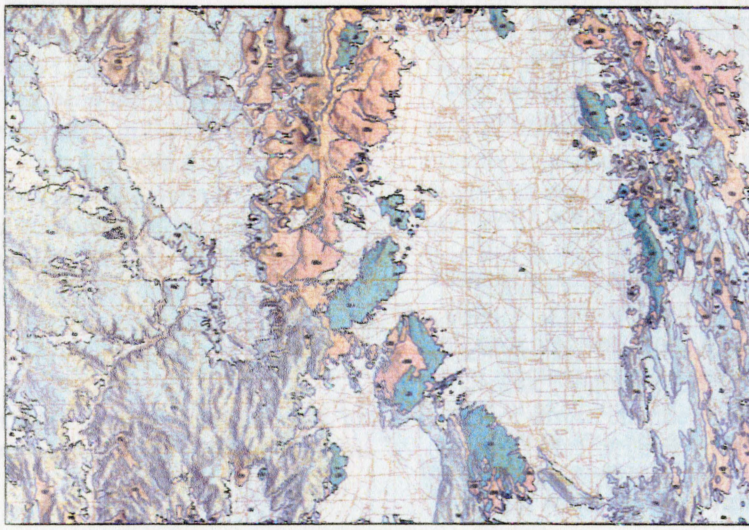

**Figure 6c._ Derived Map Showing General Hydrogeologic Units Yucca Flat Area, Nevada**

dip information for the sake of clarity. The geologic compilers identified 130 map units in this large area. Tertiary volcanic rocks are shades of red, orange, yellow, green, and violet. Figure 6a shows about 90 of these units. All 130 map units are linked to data tables in a relational database that contain information on rock types, age, chemistry, and hydrogeologic characteristics to name but a few of the data attributes.

The first example of an application of the data in the NTS database was a query for all Tertiary volcanic rocks (shown in pink), all pre-Cenozoic rocks (shown in light green), and all Quaternary sediments (shown in yellow). Those data were then overlain on a base that was a shaded-relief aeromagnetic map for Yucca Flat, Nevada (figure 6b). This derivative map would allow a geologist to see that the high frequency aeromagnetic anomalies in the west half of the map are probably responses to the highly variable terrain. The eastern part of the map shows that the sources of aeromagnetic anomalies there are buried under Quaternary sediments. The linear nature of these anomalies suggest that they result from faults that offset buried magnetic units.

In the second example, all rock units are reselected according to their general hydrologic properties. The primary attribute to be chosen was whether the rock unit is an aquifer or an aquitard. These selections were further classified according to a general hydrostratigraphic scheme based on rock type and age (or stratigraphic position). This data selection was then plotted on a base map of shaded topography (figure 6c). The rocks units are shown in various shades of blue (aquifers) and brown (aquitards). In general, the darker the color appears, the older the rocks unit is. This derivative map would allow a geologist or hydrologist evaluate what hydrostratigraphic units are in contact and where precipitation might lead to recharge of the aquifers.

The above illustrations are necessarily simple for the purpose and format of this paper. If the reader desires to see or get more detailed "PDF" versions of these illustrations, they can be found on the World Wide Web at: http://ncgmp.cr.usgs.gov/ncgmp/nts/geoldb/gsa.htm

## CONCLUSIONS

When the digital geologic map data model content standard in finally adopted, a geologist will be able to build a richly attributed geologic database from a number of geologic maps that will permit the derivation of many types of products in addition to a paper geologic map. In addition, a geologist who receives a digital geologic map built from the standard data model will not have to spend time reformatting and re-interpreting the data to use it. Work is proceeding to implement the proposed data model standard in current GIS software that will allow digital geologic map data to be easily shared and easily integrated with other spatial and non-spatial data.

In the case of the NTS database, where only the primitive version of the data model was used, preliminary queries against the database have shown great potential for combining geologic, geophysical, and hydrogeologic data sets to help interpret the geology and hydrogeology of the NTS Area.

Data from this database were put into SDTS format and retrieved. Other data formats including ASCII attribute data, and ARC/INFO ASCII-generate forms were tried as well. All of the formats for the data that were tried allowed the database to be reconstructed completely.

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# ADDRESSING READER MISCONCEPTIONS WHEN EXPLAINING GEOLOGIC PROCESSES TO LAY AUDIENCES

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*Abstract*--Explaining geologic processes to the lay public requires special strategies and skills. Addressing misconceptions and replacing them with more plausible scientific theories may be one way that science communicators can help lay audiences understand geologic processes.

The purpose of this study was to examine the effects of different levels of explanation on readers' ability to understand two geologic processes: (1) flood recurrence interval and (2) ground water. The study focused specifically on the usefulness of transformative explanations in correcting misconceptions that lay people often hold about these processes.

The stimuli consisted of two versions of each geologic process. Subjects were undergraduate students at Colorado State University and were randomly assigned to one of three experimental conditions for each process: (1) no explanation (comparison group), (2) non-transformative explanation, and (3) transformative explanation. After reading the explanation, subjects answered a questionnaire containing demographic information questions and questions designed to measure their level of expertise in earth science. Next, they completed an 11-question multiple choice test related to the explanation they read.

Because the processes being explained are ones about which many readers hold misconceptions, it was hypothesized that transformative explanations would promote greater understanding of the process by acknowledging and replacing the erroneous theory held by the subjects. Results showed that subjects who read transformative explanations did not score significantly higher than subjects who read non-transformative explanations. However, subjects who read transformative and non-transformative explanations scored significantly higher than subjects in the comparison group who did not read an explanation of flooding or ground water.

## THE EFFECT OF EXPLANATORY WRITING TECHNIQUES ON READER MISCONCEPTIONS ABOUT GEOLOGIC PROCESSES

### INTRODUCTION

#### Explanation in Science Writing

When James Wesley Powell returned from his first exploration of the Green and Colorado Rivers, he discovered that his journey had been the subject of much newspaper writing (Powell, 1895). In Powell's own words, "The exploration was not made for adventure, but purely for scientific geographic and geologic purposes, and I had no intention of writing an account of it, but only of recording the scientific results" (Powell, 1895). However, the American public was hungry for descriptions of an unknown land, and soon after his return Powell discovered that a "popular" account of his journey was in great demand.

Although Powell was most certainly unaware of it, his journal was an early example of a writer's attempt to accurately explain geological phenomena to a lay audience. Not only was he charged with describing the geography of the land, but also with explaining land forms and topography with which much of his audience was unfamiliar.

Low knowledge levels of basic scientific concepts may actually be traced to an inability of communicators to effectively explain scientific phenomena. Steinke (1995) found that readers had trouble understanding science articles that contained unfamiliar scientific terminology that was not adequately explained or defined.

Science communicators must take responsibility for adopting new writing strategies which encourage public understanding. However, understanding is more than just awareness. Simply exposing a reader to relevant content does not ensure that the information will be learned (Mayer, 1983). Science communicators must help the public as much by *explaining* scientific phenomena as they do by reporting their existence (Rowan, 1990a). According to Long (1991), "Many adults may not have the requisite background knowledge to understand relationships among scientific findings, ideas, and concepts unless these relationships are explained" (p. 168).

Research shows that much science reporting suffers not only from a lack of *effective* explanation, but from a lack of explanation altogether. In a content analysis study of scientific explanation in U.S. newspaper stories, Long (1995) found that while 70% of newspapers included in the study carried science articles, few of these stories contained scientific explanation. Of the 70 articles examined, 38 contained less than 11% explanation, and 23 contained less than 21% explanation (Long, 1995).

Researchers have explored the use of a variety of strategies to promote audience understanding of scientific information. Studies indicate that textual devices such as advance organizers (Williams & Butterfield, 1992), metaphors (Duit, 1991), analogies (Duit, 1991; Dowdey, 1987; Mayer, 1983), literary allusions (Dowdey, 1987), active verbal style (Bostian, 1984; Bostian, 1983), definitions of key terms (Mayer, Dyck, & Cook, 1984), and signals which highlight key relations among processes (Mayer, Dyck, & Cook, 1984) increase reader comprehension of science messages. Few studies, however, have investigated the effects of varying levels of explanation on reader comprehension and knowledge gain.

Myers et al. (1983) looked at the effect of explanation on students' ability to comprehend elementary probability. Subjects who had no previous exposure to probability or statistics read one of three texts that varied in the degree of explanation of basic probability concepts. Results showed that subjects in the low-explanatory and standard-text conditions performed better on formula problems than on story problems. Subjects in the high-explanatory text condition, however, performed equally well on both types of problems.

In another study, Long and Boiarsky (1993) examined the effect of scientific explanation on readers' responses to newspaper science stories. Specifically, they investigated the effect of elucidating explanations (definitions of key terms) and quasi-scientific explanations (explanations of relationships among terms or processes) on subjects' recall, comprehension, and inference-making. Controlling for the effects of interest and expertise, they found that both elucidating and quasi-scientific explanations affected readers' understanding of science stories. They also suggested that quasi-scientific explanations may have a stronger effect on understanding than do elucidating explanations.

**Explaining Geologic Processes**

Explaining geologic processes to the lay public in a way which encourages comprehension requires special strategies and skills. Many geologic phenomena involve processes which are counterintuitive. For example, the process by which glaciers carve mountain valleys is counterintuitive because glacial action cannot be seen. Similarly, the concept of continental drift is counterintuitive because continents appear to be stationary. Since the average person generally has few reasons to question his or her own implicit notion of how objects are seen (Rowan, 1988), the mechanisms that set these types of processes in motion are often difficult for readers to comprehend.

Jacobi, Bergeron, and Malvesy (1996) looked at how communicators present the concepts of plate tectonics and the geologic time scale. "One of the main problems (if not the crucial point) to be dealt with when writing a text on tectonics for the general public concerns the space and time scales of the phenomena at issue: geologic duration and the gigantic proportions of the surfaces in motion" (p. 91). Since continents appear to be immobile, most people find it difficult to imagine the sequence of events involved in plate tectonics.

## THEORETICAL PERSPECTIVE

### Theory of Explanatory Writing

Explanatory discourse has long been a topic of concern among those charged with the responsibility of explaining difficult concepts to lay audiences. However, unlike other forms of discourse, such as persuasive and literary, explanation is somewhat lacking in theoretical development. Kinneavy (1971) pioneered the research in this area. In his theory of discourse, he identified four types of discourse, based on different communication aims. *Self-expressive discourse* focuses on the self and includes personal journals and diaries. *Persuasive discourse* focuses on the reader and includes advertisements and public relations campaigns. *Literary discourse* focuses on language and includes poetic forms of writing. *Reference* discourse aims to represent some part of reality (Kinneavy, 1971).

Explanatory writing is included in the category of reference discourse. According to Kinneavy (1971), reference discourse excludes persuasive, literary, and expressive discourse, and comprises the following three sub-categories:

* Scientific discourse: goal is to furnish proof for some scientific claim,
* Exploratory discourse: goal is to raise questions about some scientific claim,

* Informatory discourse: goal is to make a claim accessible to readers.

Using Kinneavy's reference discourse category as a framework, Rowan (1988) developed a contemporary theory of explanatory writing. Basing her theory on the notion that explanatory discourse should be distinguishable from other discursive goals, Rowan (1988) proposed two subdivisions of Kinneavy's informatory discourse category: informatory and explanatory discourse. Informatory discourse aims primarily to represent reality by increasing the reader's *awareness* of some phenomenon. Explanatory discourse aims primarily to represent reality by enhancing the reader's *understanding* of some phenomenon (Rowan, 1988, p. 33).

According to Rowan (1990a), there are three reasons why readers fail to understand a complex or difficult idea: (1) they don't grasp the meaning or use of a term, (2) they struggle to represent mentally a structure or a process, and (3) they may have a pre-existing model that is an inaccurate representation of reality. She identified three specific types of explanation present in explanatory discourse:

*Elucidating explanations* are designed to overcome a reader's difficulty in understanding the meaning of a term and its use. They occur frequently in textbook glossaries where terms are defined. A definition of sedimentary rock based on its physical structure would be an example of an elucidating explanation.

*Quasi-scientific explanations* are designed to overcome a reader's difficulty in seeing how a group of processes are related to one another. They have easily discernible main points and clear connections among them (Rowan, 1990a). A description of the steps involved in the process of weathering would be an example of a quasi-scientific explanation.

*Transformative explanations* are designed to overcome readers' difficulties in rejecting and supplanting their own plausible, but erroneous, theories of familiar events in the everyday world (Rowan, 1988). For example, the belief that a 100-year flood will only occur once every 100 years is a widely-held, plausible, but erroneous, theory.

### Characteristics of Transformative Explanations

The classification of an explanation as transformative depends on knowing whether lay audiences generally have erroneous theories about the phenomenon being explained (Rowan, 1988). Transformative explanations can be useful in correcting misconceptions that the lay public holds about scientific processes and events. According to Rowan (1990a), "Good transformative explanations get attention by presenting surprising facts about the familiar. Rather than simply dismissing erroneous notions, they treat readers as thinkers who have plausible ideas" (p. 30). By acknowledging these plausible ideas, writers may be able to motivate readers to be more receptive to new information that will transform their erroneous beliefs.

There are five essential steps to composing an effective transformative explanation:

* State the lay theory,
* Acknowledge its plausibility,
* Demonstrate its inadequacy,
* State the more accepted theory,
* Demonstrate its greater adequacy.

(Rowan, 1988).

## METHODS

### Study Objectives

The purpose of this study was to examine the effects of different levels of explanation on readers' ability to understand a particular geologic process. The study focused specifically on the usefulness of transformative explanations in correcting misconceptions that lay people often hold about certain geologic processes. The study also examined what effect subjects' levels of expertise in geology had on their ability to comprehend the phenomena.

### Subjects

Subjects in the study were undergraduate and graduate students enrolled in JT 301 (Business Communication) at Colorado State University. Since this course is designed for non-journalism majors, participants in the study represented several majors and colleges within the university. Participation in the study was voluntary, and students were given the opportunity to work on another task if they did not wish to participate.

A total of 132 subjects participated in the study. Gender was fairly evenly spread, with 64 males and 68 females. The mean age was 24. The minimum age was 19, and the maximum age was 50. Of the 132 subjects, 76 percent were college seniors. College juniors made up 22 percent of the sample, and sophomores and graduate students made up the remaining 2 percent.

### Stimulus

The stimuli consisted of two scientific explanations. The topics of the explanations were two different geologic processes about which many people hold significant misconceptions. The processes were chosen based on consultations with professors in the Department of Earth Resources at Colorado State University. These professors provided insight into which geologic processes seem to be particularly prone to misconceptions by lay audiences.

The explanations had similar organizational structure and were written so that each was equally interesting to read. There were three story conditions: (1) no explanation, (2) elucidating and quasi-scientific explanations only, and (3) elucidating, quasi-scientific, and trans-formative explanations. Subjects in the comparison group (no explanation) read a text about an unrelated topic.

**Experimental Procedure**

Subjects were randomly assigned to one of the six experimental conditions. After reading the text, subjects participated in an activity unrelated to the subject of the text. This involved answering questions related to demographic data and information about their levels of interest and expertise in geology. Next, subjects completed an 11-question multiple-choice test that was designed to measure the absence/presence of misconceptions about the geologic process that they read about.

**Operationalization of Variables**

**Independent Variable**: *Explanation Type*

Rowan's theory of explanatory writing (1988) was the basis for operationalizations of scientific explanation in this study. Explanation was operationalized as text that provides elucidating, quasi-scientific, or transformative explanations. Elucidating explanations were operationalized as explanations that provide the definition of a key scientific term, concept, or phrase (Long & Boiarsky, 1993). The following is an example of an elucidating explanation of *seafloor spreading*:

> *Seafloor spreading is the pulling apart of the oceanic crust along the rift of the mid-oceanic ridge* (Strahler & Strahler, 1992, p. 611).

Quasi-scientific explanations were operationalized as explanations that show how or why certain scientific facts, ideas, terms, or processes are related (Long & Boiarksy, 1993). The following is an example of a quasi-scientific explanation of *seafloor spreading*:

*Extending around the world like the seams on a baseball is the mid-oceanic ridge, a giant undersea mountain range. The sea floor is moving like a conveyor belt away from the crest of the mid-oceanic ridge, down the flanks of the ridge and across the deep ocean basin, to disappear finally by plunging beneath a continent or island arc. The sea floor is generally moving at a rate of 1 to 6 centimeters per year. Although this may seem to be quite slow, it is rapid compared to most geologic processes* (McGeary & Plummer, 1992, p. 73).

Transformative explanations were operationalized as explanations that state an erroneous theory, acknowledge its plausibility, demonstrate its inadequacy, state the more accepted theory, and demonstrate its greater adequacy (Rowan, 1988). The following is an example of a transformative explanation of *seafloor spreading*:

> *People usually think of the seafloor as consisting of miles of stationary sand and sediment. This idea seems reasonable since there is no perceptible movement when we stand in the ocean. But in reality, the ocean floor is actually spreading at a rate of 1 to 6 centimeters per year. How is this possible? An undersea mountain range, known as the mid-oceanic ridge, extends around the world. Volcanic magma from the earth's interior seeps through cracks in this ridge, creating new ocean floor. This new sea floor moves like a conveyor belt away from the ridge, across the deep ocean basin, and disappears by diving beneath a continent or island.*

**Dependent Variable**: ***Misconceptions***

One of the biggest obstacles facing science writers is how to correct misconceptions that the public has about many scientific phenomena. Several researchers have recognized the need for acknowledging learner misconceptions. Giordan (1991) states that "Learners' conceptions need to be taken into account, or they will stand firm and be an obstacle to learning" (p. 321). Dee-Lucas and Larkin (1986) asserted that writers need to take into account the preconceptions of their audience and include signals that will enable readers to distinguish between important and less critical content in scientific material. According to Dowdey (1987), "One way of gaining the ence's interest is to explain why certain commonly held beliefs or ideas are in fact contrary to scientific evidence or assumptions" (p. 278). However, Dowdey asserts that writers must be careful to demonstrate that it is a widely held belief. By demonstrating the belief's pervasiveness and acceptance in society, the writer is able to involve the reader in the scientific argument and adapt their erroneous ideas to conform with scientific evidence (Dowdey, 1987).

Hewson and Hewson (1983) offered a comprehensive interpretation of the need to acknowledge misconceptions:

> "Students come to class with ideas, often ill-formed, hazy, and inappropriate, but ideas nevertheless. When the accepted scientific view is presented, it is to these same ideas that it must be reconciled if it is to be accepted. If no reconciliation is effected, then it is no small wonder that science is progressively viewed as abstruse, difficult, incomprehensible, and finally and most dangerously, irrational. In other words, alternative conceptions may on the one hand be counter productive if they are ignored. On the other hand,

they may be seen as the key to successful instruction if they are explicitly considered" (Hewson & Hewson, 1983, p. 742).

In an examination of the usefulness of analogies in explaining science, Duit (1991) stated that it is important to address misconceptions when using analogies to explain scientific concepts. "Analogies may transfer severe misconceptions from the analog concept to the target concept" (p. 662). For example, Anderson and Smith (1984) found that an analogy that compared light's reflection to the bouncing of a ball failed to overcome fifth graders' misconception that objects are visible simply because light shines on them. Rowan (1988) explained this as failure by the students to distinguish between their prior knowledge and the new knowledge being acquired. If inaccurate prior knowledge is drawn upon to understand the unfamiliar, analogical reasoning will not remedy students' misconceptions, but rather will support them (Duit, 1991). According to Rowan (1988), "Transformative explanations must begin with text features that are the stylistic opposites of analogies: They must highlight the *contrast* between naive theories and the more adequate theory being presented" (p. 49).

Teachers and textbook writers too often assume familiarity in areas where students quite often hold major misconceptions (Duit, 1991). Evidence of this is found in studies of high school students. In an investigation of biology textbooks, Cho, Kahle, and Nordland (1985) found that three widely used high school textbooks contained inadequacies in explaining genetics, which provided bases for misconceptions by students. The textbooks were inadequate in the following areas: (1) sequencing of topics, (2) showing relationships among concepts, (3) using terms, and (4) explaining mathematical elements (Cho, Kahle, & Nordland, 1985).

Students often hold conceptions which are at variance with scientifically acceptable conceptions, even after formal instruction (Hewson & Hewson, 1983). Millar (1994) conducted a study of 16-year-old students in Great Britain and found that many held a conception of the process of absorption of radiation that is significantly different from the accepted scientific view. His findings indicate that "a fundamental idea which educators have previously assumed was readily understood is in fact widely misunderstood and misinterpreted by learners" (p. 69).

A variety of terms are used to refer to learner misconceptions, including intuitive beliefs, preconceptions, naive beliefs, and misperceptions. For the purpose of this study, the term "misconception" was used to refer to erroneous beliefs held by the lay public about scientific phenomena. According to Cho, Kahle, and Nordland (1985), a misconception is "any conceptual idea whose mean ing deviates from the one commonly accepted by scientific consensus" (p. 707).

**Independent Variable: *Expertise***

One factor affecting students' ability to learn science is their existing knowledge prior to instruction (Hewson & Hewson, 1983). Myers et. al (1983) examined the role of explanation in learning elementary probability and suggested that "the effect of explanation may be greatest for high-aptitude subjects because they have the most adequate knowledge base to assimilate the explanation" (p. 380).

In their study of the effect of scientific explanation on readers' responses to newspaper science stories, Long and Boiarsky (1993) found that "subjects with higher scientific expertise had a better understanding of the relationships among scientific concepts" (p. 14). Funkhouser and Maccoby (1971) conducted a quasi-experimental study on textual variables in science writing and their effects on a lay audience. They found that science majors did significantly better on information tests than non-science majors. However, when scores were corrected for prior knowledge there was no significant difference between science and non-science majors.

To examine the effects of prior knowledge on subjects' scores on the knowledge test, *expertise* was employed as an independent variable. To determine a range for geologic *expertise*, a scale was created using subjects' responses to the following questions:

1. How many college level courses have you taken or are you currently taken in the following areas?

| | |
|---|---|
| Atmospheric Science | Geology |
| Ecology | Natural Hazards |
| Oceanography | Watershed Science |
| Geography | Statistics |
| Environmental health | |
| Environmental Conservation/Science | |

2. How knowledgeable would you say you are on the subject of flooding/ground water?
3. Have you participated in any field work related to earth science?
4. How familiar are you with the topic of the text you just read?

**Hypotheses**

**H1:** Subjects who read texts that have elucidating and quasi-scientific explanations will provide more accurate responses than will subjects who read texts without these explanations. The presence of these types of explanations in scientific text seems to increase the inference-making of subjects (Long & Boiarsky, 1993).

**H2:** Subjects who read texts that have transformative explanations in addition to elucidating and quasi-scientific explanations will provide more accurate responses than will subjects who read texts with only elucidating and quasi-scientific explanations. Because the geologic process explained will be one about which many people hold misconceptions, it is predicted that the transformative explanation will promote greater understanding of the process by acknowledging and replacing the erroneous theory held by the subjects.

**H3:** Across all text conditions, subjects who have high levels of expertise in geology will provide more accurate responses than will subjects with lower levels of expertise in geology. This prediction is based on the premise that subjects with higher levels of expertise will have more geology knowledge to draw on when answering the test questions.

## RESULTS

The main purpose of the study was to test the effectiveness of transformative explanations vs. the effectiveness of elucidating and quasi-scientific explanations. The results of the study showed that there was no significant difference in the effectiveness of the two types of explanation. The mean score for the subjects who read the elucidating/quasi-scientific explanation was 9.32, while the mean score for those who read the transformative explanation was 9.05.

However, there was a significant difference between the comparison group and the groups who read the two explanations. The mean score for subjects in the comparison group who read the unrelated text was 5.33.

## IMPLICATIONS FOR GEOSCIENCE COMMUNICATORS

* Readers who have a limited amount of knowledge/familiarity (low expertise) with a particular process do benefit from some type of explanation. Therefore, it is important to provide readers with explanations that define terms, show how processes are related, and/or identify and correct misconceptions. The comparison group, which read the text on an unrelated subject, had a mean test score that was significantly lower than the two groups that read the explanations. This lends some support to the usefulness of all three explanation types in explaining counterintuitive processes.
* It may not be any more useful to identify and correct misconceptions than it is to provide clear definitions and show how processes are related. Acknowledging the misconceptions may not add to the reader's level of understanding any more than simply explaining and defining the process.
* All of the subjects in the study were educated college students (76% seniors). It is possible that a group this educationally sophisticated has more of an ability to correct their own misconceptions one they are provided with a complete definitive explanation. However, audiences who have lower educational levels may be less able to correct their own misconceptions when presented with a simple definition. Future research should address whether transformative explanations are more effective in less-educated populations, or in lower age groups, such as elementary and junior high school students.

## LIMITATIONS

The study had two limitations. First, an assumption was made that the less expertise a subject had about earth science, the more likely he/she would be to hold a misconception about the processes explained. However, there was no way to be 100% certain that the subjects in the study all held misconceptions about the processes of flooding and ground water.

Second, the study did not have a **true** control group. A true control group would have consisted of a group of subjects who read a text on the **same** subject, but without any explanation. Since the processes that were explained were written in a textbook/reference book style, it would have been very difficult to write a version that contained no explanation. Nonetheless, a comparison group was used in the study. These subjects read an unrelated text, then completed the same multiple-choice tests on flooding and ground water.

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## APPENDIX A

(Text read by comparison group)

### The Vanishing Giant Panda*

The giant panda is one of the world's most endangered animals. One reason is that it is so specialized, getting 99% of its food from bamboo. Worse, its digestive system absorbs only about 17% of the food it eats, and its bamboo diet provides protein but very little energy. To survive, these animals must spend most of each day eating up to one-third of their body weight in bamboo.

Three million years ago giant pandas were widespread in China. But China's soaring population has pushed them into smaller and smaller areas in the remote, fog-shrouded western mountains. Today only about 800 giant pandas survive in the wild, in about 20 isolated "islands" of bamboo forest. These isolated populations of 10-50 animals are vulnerable to being wiped out and to inbreeding.

One serious threat is illegal hunting. Although killing a giant panda in China brings an automatic death penalty, poachers kill 40 or more pandas per year because their pelts bring $100,000 or more in Hong Kong and Japan. Giant pandas are also biologically vulnerable to extinction. Only about one cub per female survives every other year. Pandas are also quite finicky about picking mates, which becomes critical with their low numbers and isolated habitats.

Finally, bamboo dies off in cycles of 15-120 years, depending on the species. Then it takes several years for new bamboo sprouts to reach edible size. When bamboo was abundant, this was not a problem. The pandas simply moved to another area. Today, however, the few remaining pandas are confined to islands of forest dominated by a few bamboo species. When these plants die back, the pandas have no food source.

China has set aside 12 giant panda reserves, but in eight of them, the animals are threatened by poaching and by China's growing population. Fourteen new reserves have been proposed. Three of these would link existing reserves with migration corridors that would be planted with bamboo. This would help end the animals' isolation, but it remains to be seen whether it will actually happen.

About 220 giant pandas are found in zoos and research centers in China and elsewhere, but more captive pandas die than are born. Will this specialized species survive? Maybe in a few zoos, but within your lifetime it may disappear from the wild.

*From *Living in the Environment*, by G. Tyler Miller, Jr.

## APPENDIX B

(Explanations on Flood Recurrence Interval)

### 100-year floods

(Elucidating/Quasi-Scientific Explanation)

Flooding is a geology topic that is of great interest to the public because it directly affects human welfare. However, despite this interest, few people have a genuine understanding of the nature of flooding.

Flood frequency is described by recurrence interval, the average time interval between floods of a given size. Hydrologists use statistical methods to estimate the probability that a flood of a certain size will occur in a given year. These estimates are based on records of flooding in past years. Estimates of flood frequency do not tell us *when* floods will occur, but give us an idea of how *frequently* they might occur based on history.

A 100-year flood is one that occurs, on the average, every 100 years. This means that a 100-year flood has a 1-in-100 chance of occurring in any given year. Consider the following illustration: If a flood of a certain size has occurred on the Colorado River five times between the years 1500 - 2000, then it has occurred an *average* of once every 100 years and will be referred to as a 100-year flood. However, in reality the flood probably did not occur at evenly spaced time intervals. For example, it may have occurred in the years 1550, 1635, 1750, 1820, and 1950. While this represents an average of once every 100 years, the actual time intervals between floods were 85 years, 115 years, 70 years, and 130 years, respectively. Therefore, even though we refer to a flood of a certain size as a "100-year flood," it does not necessarily mean that it will only occur every 100 years. If a 100-year flood occurs this year on the river you live near, you should not assume that there will be a 99-year period of safety before the next one occurs. The same size flood could occur again within the next 10 years. In fact, it is possible to have two 100-year floods in two successive years, or even in the same year.

### 100-YEAR FLOODS

(Transformative Explanation)

Flooding is a geology topic that is of great interest to the public because it directly affects human welfare. However, despite this interest, few people have a genuine understanding of the nature of flooding. The randomness of flood occurrence is a difficult concept to perceive, and many people believe that flooding is cyclical and repeats itself at regular intervals.

For example, consider the idea of a "100-year flood." Many people believe that a 100-year flood can only occur one time every 100 years, and that they can feel "safe" during the 99-year intervals between them. This idea makes sense because the phrase "100-year flood" implies that the flood will only occur every 100$^{th}$ year. However, this notion fails to consider the fact that the number of years between floods has been *averaged* over a long period of time to come up with the flood frequency of 100 years. A 100-year flood is one that occurs, on the average, once every 100 years. This means that it has a 1-in-100 chance of occurring in any given year.

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## APPENDIX C
## (Explanations on Ground Water)

### Ground Water:
(Elucidating/Quasi-Scientific Explanation)

More than half of the rain and snow that falls to the earth's surface returns to the atmosphere through evaporation or transpiration from plants. The remainder of the precipitation trickles down into the ground to become ground water. Ground water is water that lies beneath the surface of the ground and fills the cracks, crevices, and pore spaces of rocks. Surface water, on the other hand, is water that is exposed on the surface of the earth and flows as rivers, streams, lakes, and ponds.

Surface water usually lies on the earth's surface in large quantities that can be readily seen, such as in a lake or river. Ground water is different, however, in that it is usually contained in underground rocks. The water fills cracks and pores in the rock, much like water is contained in a sponge. The measurement of a rock's ability to hold water is called its porosity. Although most rocks can hold some water, there is great variation in their ability to allow water to pass through them. Permeability refers to a rock's ability to allow water to flow through it. A mass of underground rock that has the ability to hold and transmit a large amount of water is called an aquifer.

Compared to the rapid flow of surface water in streams and rivers, ground water moves relatively slowly through underground rock. The rate at which ground water flows depends upon its level of permeability. If the spaces and pores in the rock are small and have poor connections between them, then ground water will move slowly. If the spaces are large and well connected, the ground water will move more rapidly.

Surprisingly, there is 30 to 40 times more ground water than surface water on the earth. Ground water is an important natural resource. It is a major economic resource, especially in the arid western regions of the United States and Canada where surface water is scarce. Many towns pump great quantities of ground water from wells, because ground water is often less polluted and more economical to use than surface water.

In its natural state, ground water tends to be relatively free of contaminants. However, because it is such a widely used source of drinking water, pollution of ground water can be a serious problem. Because ground water percolates into the ground through runoff, pesticides, herbicides, and fertilizers which are applied to agricultural crops, golf courses, and residential lawns often find their way into ground water.

### Ground Water
(Transformative Explanation)

More than half of the rain and snow that falls to the earth's surface returns to the atmosphere through evaporation or transpiration from plants. The remainder of the precipitation trickles down into the ground to become ground water. To some people, it seems likely that ground water exists in the form of large, underground lakes. Other people think that ground water exists in the form of rapid-flowing underground rivers. These notions of ground water make sense, because people often associ-ate the idea of ground water with surface water, which lies on the earth's surface in large quantities that can be readily seen, such as in lakes and rivers.

However, these ideas neglect the fact that ground water has distinct characteristics, which are quite different from those of surface water. Surface water is water that is exposed on the surface of the earth and flows as rivers, streams, lakes, and ponds. Ground water is different, however, in that it is contained in the cracks, crevices, and pore spaces of underground rocks. Permeability refers to an object's ability to allow water, or fluid, to pass through it. Since rock is a solid substance, most people do not think of it as being permeable. But when rain and snow percolate into the ground, the water fills cracks and pores in the rock, much like water is contained in a sponge. The measurement of a rock's ability to hold water is called its porosity. Although most rocks can hold some water, there is great variation in their ability to allow water to pass through them. A mass of underground rock that has the ability to hold and transmit a large amount of water is called an aquifer.

Compared to the rapid flow of surface water in streams and rivers, ground water moves relatively slowly through underground rock. The rate at which ground water flows depends upon its level of permeability. If the spaces and pores in the rock are small and have poor connections between them, then ground water will move slowly. If the spaces are large and well connected, the ground water will move more rapidly.

To many people, it seems likely that there is a far greater amount of surface water on the earth than ground water. But surprisingly, there is 30 to 40 times more ground water than surface water. Ground water is a tremendously important natural resource. It is a major economic resource, especially in the arid western regions of the United States and Canada where surface water is scarce. Many towns pump great quantities of ground water from wells, because ground water is often less polluted and more economical to use than surface water.

# VIRTUAL COLLABORATORY™, FRAC CITY™, FACILITATES GEOSCIENTIFIC COLLABORATION AND TECHNOLOGY TRANSFER

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*Abstract*--Projects involving collaboration across disciplinary, organizational and geographical boundaries can be facilitated through the use of appropriate internet technologies. By taking advantage of the Virtual Collaboratory™ secure, interactive website environment, geoscientists and others can communicate and share a variety of information resources more effectively and conveniently. This results in closer collaboration, faster progress, lower costs and more effective technology transfer to the private sector.

One example of a workgroup that will benefit from the wise use of a Virtual Collaboratory™ is the fracture research and application consortium (FRAC), a global consortium of energy and technology companies that support multidisciplinary studies of natural fractures in hydrocarbon reservoirs led by The University of Texas at Austin. Company representatives are located in different cities (or continents), and the team in Austin is also located in different buildings and on different campuses.

Traditionally, consortium members meet once or twice a year to review progress since the last meeting and to discuss future directions for the study. Limited resources, conflicting travel schedules and outside time constraints often mean that not all stakeholders are able to receive the full benefits of participation. With the implementation of the consortium's Virtual Collaboratory™, *Frac City*™ (http://www.frac-city.org), all consortium members have convenient access to current study data, technical assistance, archival materials and interactive discussion forums. *Frac City*™, was built by Geolectica, LLP using their Virtual Collaboratory™ template developed specifically for distributed collaborative workgroups. This technology allows the site to grow and change with the needs of the workgroup.

## INTRODUCTION

Cross organizational workgroups are not new in geoscientific research, but they are becoming increasingly important to the advancement of science and technology transfer. Progress on geoscientific research projects involving collaboration across disciplinary, organizational and geographical boundaries is greatly facilitated through the use of appropriate Internet technologies. However, the traditional Internet website, intranet and extranet approaches are not solutions to many of the challenges created by the distributed collaboratory environment. To address the special needs of such workgroups, the deployment of a customized Virtual Collaboratory™ (The term Virtual Collaboratory™ and its graphical repre-sentations are a trademark of Geolectica, LLP.)

One workgroup that will benefit from the wise use of a Virtual Collaboratory™ is the fracture research and application consortium (FRAC). This interdisciplinary approach to fracture study is supported by a global consortium of energy and scientific instrument companies and related research institutions.

Limited resources, conflicting travel schedules and outside time constraints often mean that not all stakeholders are able to receive the full benefits of participation. With the recent implementation of the group's website *Frac City*™ (The term Frac City™ and its graphical representations are a trademark of Geolectica, LLP.) All research study participants have daily access at their desktops to current study data, archived files and publications, and online forums in which members can privately discuss project-related issues at their convenience. *Frac City*™ was built using the Virtual Collaboratory™ template developed specifically for the geoscientific community by Geolectica, LLP. The Virtual Collaboratory™ template is a fully scalable, database-driven, interactive, secure website environment that can be easily customized for any work group. Major aspects of the *Frac City*™ website are presented here.

## FRACTURE RESEARCH AND APPLICATION CONSORTIUM (FRAC)

The fracture research and application consortium (FRAC) is a global consortium of energy and technology companies that support multidisciplinary studies of natural fractures in hydrocarbon reservoirs. The research is conducted by a team at The University of Texas at Austin in collaboration with scientists from the sponsor companies. Challenges to integrated research for such a group are formidable. Not only are the company representatives located in different cities (or continents), but the team in Austin is also separated. The leadership of the project is in the departments of Petroleum and Geosystems Engineering and Geological Sciences, which are across campus from each other, and in the Bureau of Economic Geology, which is on a satellite campus about 15 miles from the main UT campus. Thus, the project is faced with serious logistical hurdles to effective cooperation in addition to the challenge of communication across disciplinary boundaries between geology, mechanical modeling, geostatistics, and reservoir testing and simulation. A variety of new scientific approaches, tools and techniques are employed in the studies The project makes use of many large images that must be made available to all, and large databases to

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* Collaborators cross disciplinary, industry, organizational and geographic boundaries
* New technology development & testing demands high levels of interaction
* Proprietary, time-sensitive information demands rudence
* Data sharing among sub-groups requires coordination and access

**Table 1.** Characteristics of the fracture research and application consortium (FRAC)

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which all participants must have access. Organizational and operational characteristics of FRAC are outlined in Table 1.

In addition to enjoying the significant benefits derived from collaboration, FRAC also inherited a set of problems due to the cross-organizational, geographically distributed nature of the consortium membership. Table 2 outlines some of the major problems associated with distributed collaboration.

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* Timezone differences limit availability of collaborators
* Scheduling conflicts reduce participation
* Infrequent interaction inhibits synergy
* Traditional publication lead times too long
* Print-based materials limit usability
* Unfamiliar research technologies require time and guidance to master
* Participants use wide range of incompatible computers and software

**Table 2.** Problems Inherent in Distributed Collaboration

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Many of the problems created by distributed collaboration can be resolved by employing suitable Internet technologies. In recognition of this, *Frac City*™ is being developed to allow the project's participants to take full advantage of evolving Internet technologies to enhance collaboration. A website solution was selected because all of the participants already had the capability to connect to the Internet and use a Web browser. Special care was taken in designing Frac City™ so that participants would not be required to purchase any new hardware, software or learn any special skills.

## INTERNET TECHNOLOGIES AND VIRTUAL COLLABORATORIES™

Many organizations that participate in distributed collaborative activities already employ Internet technologies in a variety of ways. It has become common in the last several years for geoscientific organizations to publish and maintain Internet websites. Such websites however, typically provide a static, one-way flow of information to outsiders and rarely enable secure information transfer. A growing number of organizations are developing intranets to facilitate internal communications. An intranet can be characterized as an internal website accessible only to employees within an organization. Recognizing the importance of developing a more effective means of interactive communication with those on the outside, some organizations are deploying extranets. These hybrids allow selected outsiders to access some parts of an organization's intranet, but present serious security, resource and computer incompatibility concerns.

Although Internet websites, intranets and extranets are useful in addressing many communications and publication issues, they do not present optimal solutions for distributed collaborative workgroups made up of individuals from a variety of both private and public sector organizations. Typically, such workgroups have no dedicated computing resources, nor do they necessarily use the same types of computers or software. The short-term, continually changing nature of these project-based collaborations requires similarly flexible, quickly-deployed and easily retired approaches. The optimum solution for such workgroups is to utilize the facilities of a Virtual Collaboratory to facilitate internal discussion and publication of project-related items.

A Virtual Collaboratory™ is the database-driven, scalable, secure, interactive website template developed by Geolectica, LLP especially for distributed workgroups. Virtual Collaboratories™ can be easily used with any common computer operating system and Web browser. They are designed to support the entire range of interactive Internet technologies and digital transmission formats as they evolve. Virtual Collaboratories™ are hosted on a third-party webserver computer to free up the limited computing and human resources of the participating organizations. This third party hosting arrangement also eliminates any security risks to organizations that otherwise would expose their own networks to outsiders.

**FRAC CITY©**

Frac City™ is the Virtual Collaboratory™ that will support the work of the participants in the fracture research and application consortium (FRAC). It can be found on the World Wide Web at http://www.frac-city.org. It is designed to achieve three purposes: to facilitate collaboration and publication of proprietary information among the project's consortium members, to provide a forum for greater professional interaction among all fracture researchers, and to promote the research to the interested public.

**Design Considerations**

For a website solution to be effective in achieving its goals, good design principles must be followed. There are many factors to be considered in determining the structure, features and technologies employed in the website. Table 3 lists the factors that were considered in the design and implementation of Frac City™.

To address these issues and achieve the various goals, an interactive, database-driven Virtual Collaboratory™ is being deployed. The use of interactive databases allows the restriction of access to proprietary information and also allows the control of where and when content is displayed on the website. Based on the design factors stated above, a website with the characteristics outlined on Table 4 was developed and implemented.

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*Security*

* Proprietary data must be secured from access by non-members for specified periods of time
* Intellectual property rights must be protected
* Project-related discussions must remain private

*Management*

* Large volumes of a variety of digital data formats impose high storage and retrieval requirements
* Continual input from researchers requires consistent, skilled site management
* Member-driven nature of project demands flexibility and scalability
* Must allow for near real-time updating

*User-Friendliness*

* Must accommodate a variety of computer platforms, monitor sizes, modem speeds, and preferred browsers
* Must not impose additional hardware, software, skillset or time burdens on members
* Must be accessible at consortium members' convenience

*External Communication*

* Inform non-members about the research and new techniques
* Encourage prospective members to join consortium
* Promote lively scientific discussions on day-to-day basis

*Financial*

* Must not divert funds from research budget
* Must not demand major continued input of funds
* Self-supporting site preferable

**Table 3.** Considerations, Issues & Constraints

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To site visitors, Frac City™ appears to be one website, with access to the Members Only section restricted to FRAC participants only. For the purposes of discussion however, Frac City™ can be considered two separate websites: a public and a private. Each site, or side, of Frac City™ has its own sub-sections, content and distinct navigational scheme. Both sides are controlled by the backend databases running on Geolectica's Web servers from which the viewer downloads the pages on his or her browser.

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*Entire Site*

* Database-driven backend allows fast publishing and retrieval of all digital files
* Hyperlinkages allow quick, logical navigation
* Template-based architecture allows fully flexible site growth and management
* Developmental platform allows highly interactive functionality
* Digital watermarking of downloadable material protects authors
* Third-party site hosting protects intellectual property rights
* Third-party site hosting allows commercial involvement
* Third-party site hosting eliminates demand on collaborators' computer resources
* Third-party site maintenance and updates leave researchers free to concentrate on science
* Secure server environment protects data transmission

*Private Side*

* Three levels of security protect collaborators and content
* Members Only access controlled by independent database of pre-approved individuals
* Easy to use—register once, browse at will
* Discussion forums facilitate convenient, private interaction on a variety of project-related issues

*Public Side*

* Informs interested individuals about research
* Promotes and facilitates public discussion on a variety of scientific topics
* Online technical assistance for new technology users reduces downtime
* Different look & feel than private side eliminates possibility for confusion

**Table 4.** The Frac City© Solution

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**Sections Of Frac City©**

*--Public*

The public side of Frac City™ is open to anyone with a professional interest in natural fractures. Its purpose is to inform non-members about the research and new techniques, encourage prospective members to join the consortium and to promote lively, meaningful scientific discussions relating to fractures on a day-to-day basis. Appendix A shows the current site architecture of the public side. All content is submitted by members of the consortium. Content which does not arise from within the research consortium may be added to the site with the prior approval of the project's Principal Investigator.

The main features of the Public side architecture are "About this Project", "What's New", "Discussion Forums" and the "Site Map". Information about the project and the consortium members is featured in the "About this Project" section. "What's New" aquaints visitors with recent additions or changes to the site, as well as other news relevant to the project. The "Site Map" allows visitors a quick and easy method of gauging the depth and breadth of the site at a glance, and allows single-click access to any page.

The "Discussion Forums" allow interested individuals to participate in moderated, lively scientific discussions pertaining to a variety of aspects of fracture research. The main idea behind the threaded forums is to pick up where the discussions at professional meetings leave off. Specific topics of discussions are scheduled and guided by carefully selected moderators who are themselves active participants in a variety of disciplines within fracture research. Since the discussions occur within a private environment, any possible incidences of misuse can be controlled or prevented.

*--Private*

The private, Members Only side is accessible only to pre-approved members. One of the most important aspects of Frac City™ is that it allows members to publish and discuss research-related information which is then made available only to other members of the consortium. Appendix B shows the current site architecture of the private side. All content is submitted by members of the consortium.

The private side contains proprietary research data, with summaries and reports in a variety of digital formats. Consortium members also agree that this information is to be made available only to members of the consortium for a specified period of time. After that, the information may be made available to the public. Frac City™ uses an interactive database which controls when such proprietary content may be viewed on the public side of the site.

The main sections of the private side are the "Calendar of Events", "What's New", "Discussion Forums", "Studies", "Publications", "References" and a "Site Map". The "Calendar" displays dates and details of relevant conferences, seminars and deadlines for project-related activities which are submitted by project members. The "What's New" section informs members of recent additions or changes to the private side, as well as other news relevant to the project. The "Publications" section features reports and articles relating to the research which are still considered proprietary. "References" contains articles and links which are considered relevant to the research. A "Site Map" allows members to quickly and easily gauge the depth and breadth of the entire site at a glance, and allows single-click access to any page. Once access is granted to the private side, members may freely navigate between the public and private sides at will.

The "Discussion Forums" facilitate threaded discussions about research-related and logistical issues by allowing members to view contributions posted by all members and to reply at will. Unlike the public discussion forums, these forums are not moderated.

The "Studies" section is the most important section of the private side. "Studies" contains the proprietary research data, images, reports, presentations and other files directly related to all of the research areas. Very large photographic images must be made available to all and several large databases must be accessible to many of the participants.

## THE FUTURE OF FRAC CITY©

One of the main strengths of using the Internet is the ease and speed with which changes may be made to electronically published information and interactive features. Frac City™ takes advantage of this capability to continually make changes to the site. Members frequently send in new content to be added to the site. The project's Principal Investigator, Steve Laubach orders changes to the site's overall architecture based on the changing needs of the project. Participants on the forums may read and reply to posted messages more easily than sending e-mail.

### Expansion capabilities

The Virtual Collaboratory™ template allows Frac City™ to grow as large as required by the needs of the workgroup. Extremely large numbers and sizes of content files of various types may be stored on the Web servers. Very high levels of simultaneous online traffic on the site may be accommodated. The number of sections and pages that can be included in the website is unlimited. The number of members that may be added to the database is large enough to accommodate the expected growth of the consortium.

### New features

As the website continues to become a workaday part of the consortium members' routine, additional interactive features may be added. In addition to being able to scale into a very large website, Frac City™'s Virtual Collaboratory™ template also allows it to incorporate any new interactive capabilities the members wish to add. Table 5 outlines the features which are under consideration for incorporation into Frac City™ within the next year.

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*Public Side*
* Enhanced online technology use hotline/helpline
* Fracture-related links & calendar
* Online seminars and conferences

*Private Side*
* Online shared editing and image annotation
* Live chat & conferencing
* Flexible site search engine
* Enhanced online technology use hotline/helpline
* Online customized graphic manipulation of datasets

**Table 5.** What's Next for Frac City©

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## FINANCING FRAC CITY©

A major concern when planning the development of Frac City™ was the funding. As discussed above, all parties felt it was important that funds not be diverted from the research budget for development of the site. Additionally, there was some interest in exploring whether or not the site could be self-supporting. A funding model which incorporated a contribution by Oxford Instruments, and a contribution from the University of Texas to fund the initial development was established. Geolectica, the developer, underwrote part of the development and marketing costs of the site. In order to ensure financial self-sufficiency for the site, it was decided to solicit and display paid advertising banners on the public discussion forums and selected other pages.

Because the research undertaken by the FRAC workgroup is not commercial in nature, there are some limitations on appropriate financing for Frac City™. This funding model for the site is therefore similar to that of a professional technical journal that covers some of its publication costs through the sale of appropriate advertising. Income from the sale of advertising on the public side of Frac City™ goes to Geolectica (the "publisher") and is used to promote the goal of technology transfer (i.e. it is used to support the public side of Frac City™).

Other possible avenues of funding include paid membership to some portions of the public side of Frac City™. Table 6 highlights the major advantages to the Frac City™ funding model.

## CONCLUSION

Effective use of Frac City™ by workgroup members will result in many benefits. This type of web-based research support vehicle will be the standard for geoscientific collaboration in the future. Table 7 lists the major

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