# PROPOSAL FOR DOCTOR OF PHILOSOPHY DEGREE PROGRAM IN EARTH SCIENCES AT MONTANA STATE UNIVERSITY-BOZEMAN

**Department of Earth Sciences**
**Montana State University**

**Implementation Date: January 2003**

**PURPOSE:** To establish a Doctor of Philosophy degree program in Earth Sciences in the Department of Earth Sciences at Montana State University-Bozeman

**VISION:** The vision behind developing a Doctor of Philosophy degree program in Earth Sciences parallels the Montana State University-Bozeman vision statement, and is founded upon: 1) presence of a faculty cohort in earth sciences dedicated to research and experiential learning in graduate education, 2) a geographical and geological setting amidst world-class geological and paleontological resources, mountain to intermontane basin terrains, and the Yellowstone ecosystem, and 3) allied institutional resources for analysis of earth materials and systems. We seek to ensure that:

*"Montana State University-Bozeman will be the university of choice for those seeking doctoral level education and research expertise in a student-centered learning environment distinguished by innovation and discovery in a Rocky Mountain setting."*

The objective of this program is to provide doctoral level training to students in areas of faculty, resource, and geographical strengths unique to Montana State University-Bozeman including geographic information systems science, snow and avalanche science, earth surface systems, paleontology, geobiology, and geoscience education.

**RATIONALE:** The Department of Earth Sciences is well positioned for a variety of reasons to provide doctoral level education and training to graduate students interested in pursuing advanced learning in the earth sciences in the Northern Rocky Mountains. Currently, the Department has a vibrant undergraduate program with more than 240 total majors in Geology, Geohydrology, and Geography Bachelor of Science degree options. In addition, more than 30 graduate students are presently enrolled in the Master of Science degree program in Earth Sciences. These enrollments represent the largest undergraduate and graduate student cohorts in the history of the Department and are indicative of increasing student interest in earth science education and careers.

The Department's teaching, research, and service programs have historically fulfilled the primary goals of Montana State University's mission as a land grant institution. The spectrum of curricular and research activities focus on providing a better understanding of Montana's unique environmental, mineral, petroleum, hydrologic, paleontologic, and human resources, and the complex relations that exist between these resources across space (geography) and through time (geology). Given the Northern Rocky Mountain setting of the MSU campus proximal to such unique features as the Greater Yellowstone ecosystem and its underlying volcanic center, world famous paleontological resources such as Egg Mountain and the Hell Creek badlands, snow-capped mountains and such associated recreational sites as the Big Sky ski area, Intermountain Earthquake Zone, western Montana Overthrust Belt petroleum province, and coal resources of the Powder River Basin to name a few, the Department is well-positioned to take advantage of these unique geographic attributes to train doctoral students in all emphasis areas. In addition, the Department has established strong relations with the U.S. Geological Survey Northern Rocky Mountain Science Center at MSU and Gallatin National Forest Avalanche Forecasting Center to provide internship and research opportunities for doctoral students.

Fifteen tenure-track professors holding Ph.D. degrees, augmented by six adjunct faculty, will participate in delivering this program. The Department of Earth Sciences has recently been given permission to recruit new faculty in the fields of biogeography, molecular paleontology, and geobiology/biogeochemistry. At present 7 non-degree status graduate students at MSU are ready to enter this proposed doctoral program. In addition, because of the Department's international reputation for excellence in the fields of geographic information science, paleontology, and snow and avalanche science, the Department received in the past year 27 unsolicited inquiries from national and international students seeking to attend MSU for doctoral training in Earth Sciences.

**OBJECTIVES AND NEEDS:**

**Centrality to the Montana State University Mission**

Furthering the public's knowledge of the geological and geographic resources of the state of Montana has been and will continue to be a primary objective of the Department of Earth Sciences contribution to the land-grant mission of the University. The Department has fulfilled this objective through education of undergraduate and Master's level graduate students who have subsequently been employed in Montana by federal, state, or local government agencies, or the private sector. The Department faculty have strived to provide a challenging and interactive learning environment emphasizing development of field-based expertise and personal technical skills, fostering of a learning environment that promotes research and discovery at both the undergraduate and graduate levels, integrating classroom learning with research experience, and development of student skills in ways of disseminating information to the public through better communication and outreach activities.

This same philosophical approach to inquiry and information sharing will govern development of the doctoral degree program in Earth Sciences. Classroom and field-based instruction, research, outreach activities, and communication strategies will be integrated in student education to produce graduates who are capable not only of discovery through research, but sharing the excitement of that new information with and communicating its relevance for the public.

**Goals and Objectives of the Program**

The objective of this program is to offer doctoral level education to graduate students in the Earth Sciences (geology, paleontology, and geography) interested in pursuing classroom learning and both laboratory and field research in emphasis areas that reflect faculty, resource, and geographical strengths of Montana State University. These emphasis areas include geographic information science, snow and avalanche science, earth surface systems, paleontology, geobiology, and geoscience education. Each one of these areas has attracted the interest of Master's degree students as well as of graduate students across the country interested in pursuing doctoral work in these areas at MSU.

*Geographic information science* (GI science) involves the use of geographic information systems (GIS) to examine the complex relations between physical, biological, hydrologic, and geologic attributes across landscapes. The power of GIS lies in keeping track of complex spatially variable data sets, but also in providing a tool to model interactions between landscape attributes and predict the effects of natural or human change on the landscape. As such, geographic information science involves not only data management skills, but also mathematical and statistical modeling across three dimensions. The Department of Earth Sciences serves as home for the Geographic Information and Analysis Center (GIAC), a GIS research and classroom education center, that will provide the hardware and software foundation for the GI science emphasis area.

*Snow and avalanche science* incorporates investigation of the climatic and geomorphologic controls on the accumulation and distribution of snow, particularly in mountainous regions, as well as the study of the controls on the initiation and mechanics of snow avalanches. The Department has a long history of internationally recognized excellence in avalanche studies initiated in the 1950's at MSU by Dr. John Montagne, Emeritus Professor of Geology, who pioneered this field of study. In addition, the Department has established strong collaborative ties with the U.S. Forest Service Southwest Montana Avalanche Forecasting Center. The Center's Director, Dr. Karl Birkeland, is Adjunct Professor in the Department of Earth Sciences and a Department alumnus (M.S. 1992).

*Earth surface systems* analysis encompasses investigation of geological processes that operate at or near the surface of the earth and their relations to the lithosphere (solid earth), hydrosphere, biosphere, and atmosphere. In addition, this includes the formation of such geologic resources as coal, hydrocarbons, and precious metals. The Department of Earth Sciences possesses faculty and research strengths in particular in the areas of geomorphology and glacial geology, volcanology, surface water hydrology, sediment transport, human interactions with the landscape, biogeography, paleoclimatology, and earthquake analysis. Presently, the Department houses the MSU/U.S. Geological Survey Earthquake Laboratory with complete access to real-time seismic data for earthquakes across the entire earth.

*Paleontology* research in the Department of Earth Sciences is done in close association with the Museum of the Rockies. The Department and Museum have a world-renown reputation for excellence in both undergraduate and Master's level graduate education and research in the area of vertebrate paleontology. Given the long history of producing ground-breaking research in paleontology, and the resources of both the Museum of the Rockies and abundant fossil sites across the state of Montana, a doctoral program in Earth Sciences offering the opportunity for training in the paleontology emphasis area will undoubtedly be able to attract the very best students from not only North America, but the entire world.

*Geobiology* is a newly emerging field in the earth sciences that investigates the relationships between microbes and their role in controlling the growth of minerals. This field of study stands at the forefront of understanding how microorganisms live in extreme environments, and what the role of these single-celled organisms has been in the development of life on Earth and on other planets. In addition, geobiologic investigations have the power to produce better understanding of the role of microbes in such fields as biological remediation of environmental contaminants, evaluation of surface and groundwater resources for human use, and in the preservation of fossils. The Department of Earth Sciences at MSU is uniquely situated as the University in closest proximity to the geothermal features of the Yellowstone region, the first place on earth where extremophile organisms were recognized. In addition, the presence of the MSU Thermal Biology Institute (TBI) on campus has already allowed Master's students and faculty to work collaboratively with microbiologists in interdisciplinary research on microbes and minerals in Yellowstone. This interaction will undoubtedly expand with the additional opportunities provided for doctoral level educational and research in this area of study.

*Geoscience education* involves training of graduate students in the various pedagogical approaches to educating the public, ranging from K through 12 education, college and university instruction, and communication in public forums, to use of the media to educate and inform the citizenry. This field of study involves research into how students best learn in terms not only of teaching methods, but also in terms of the use of electronic forms of information to convey important concepts. Department of Earth Sciences faculty have collectively won numerous on-campus and national awards for excellence in education as well as for their work in developing new pedagogical approaches in educating students and the public about the geosciences. In addition, several faculty have extensive experience with scientific documentary production, and are involved working with students in the newly formed Master of Fine Arts in Natural History and Science Film-making at MSU.

Doctoral candidates entering the degree program will select one of these areas of emphasis in which they will pursue their dissertation research and take the appropriate coursework. All students will receive a Doctor of Philosophy degree in Earth Sciences, regardless of their chosen area of emphasis.

**Intellectual Basis for the Curriculum**

The curricular rationale of the Doctor of Philosophy in Earth Sciences degree program is to provide the students with a broad foundation of coursework upon which they can build their expertise in their chosen area of research emphasis. This parallels the emerging knowledge in the earth sciences that components of the lithosphere, atmosphere, biosphere, and hydrosphere all interact over space and time at multiple scales. Because this earth systems science approach is driving discovery in the earth sciences today, our plan is to ensure that students expose themselves to coursework not only in the Earth Sciences, but also in other academic Departments as well. Because the Earth Sciences is a wide-ranging disciplinary, synthetic, and synergistic field of inquiry, we will strive to produce students who are capable of seeing and understanding broad connections between seemingly disparate variables of the earth system over multiple scales of space and time. Not only must students have expertise in a given area of study, they must also be able to think synthetically and communicate that knowledge. For that reason, students studying in each research area will be expected to take courses in Earth Systems Science and Methods of Geoscience Education in addition to coursework in their specific field of study.

**Course of Study**

The Doctor of Philosophy in Earth Sciences course requirements follow the guidelines of the College of Graduate Studies, and is based upon selection of an area of specialization in research and intensive course

work that would normally require three years of full-time work beyond the Master of Science degree. The general course requirements include:

1) A Master of Science degree in Earth Sciences, Geology, Geography, Paleontology, or a closely related field.
2) A minimum of 50 hours of coursework beyond the Bachelor of Science degree. Thesis research credits may not be counted in this total. Course work completed as a part of the student's Master of Science degree may be counted toward this total. The 50 credits must include:
    a. 1 credit of ESCI 501.
    b. 9 credits in a supporting area. The supporting area must be outside the major in the sense of subject matter and content. A supporting area of study within the major department may be acceptable.
    c. 3 credits of ESCI 5XX – Earth Systems Science
    d. 3 credits of ESCI 5XX – Methods of Geoscience Education
3) A minimum of 18 credits of ESCI 690 – Doctoral Thesis.
4) A minimum of 30 credits must be taken through the regular registration process, on the campus of MSU after admission to the Ph.D. program.
5) The major professor and student's graduate committee will determine additional specific course requirements for completion of the Doctor of Philosophy degree. These courses will be relevant to the student's selected area of emphasis.
6) As per College of Graduate Studies requirements, all doctoral candidates will be required to successfully pass a Qualifying Examination during their first year in residence, a Comprehensive Examination by the end of their second year in residence, and a Dissertation Defense prior to receiving their Doctor of Philosophy degree.

**Course Descriptions:**

ESCI 500 – Seminar (1 credit)
Topics offered at the graduate level not covered in regular courses. Students participate in preparing and presenting discussion material.

ESCI 501 – Dissertation/Thesis Design (1 credit)
Instruction in preparation of research proposals and project design.

ESCI 502 – Fluvial Geomorphology (3 credits)
Processes controlling surface water run off and erosion at watershed scales and their linkages to river systems, transport of sediment, and contaminant transport.

ESCI 5XX – Earth Systems Science (3 credits)
Investigation of the links between the atmosphere, hydrosphere, biosphere and lithosphere.

ESCI 5XX – Methods in Geoscience Education (3 credits)
Pedagogical advances in understanding ways of student learning and effective styles of communication of information to facilitate optimal learning.

ESCI 5XX – Avalanche Science (3 credits)
Analysis of the controls on and dynamics of snow avalanches in mountainous regions.

ESCI 5XX – Snow Dynamics (3 credits)
Study of the climatologic, geomorphologic, and hydrologic factors influencing the distribution of snow pack and associated run off.

ESCI 690 – Doctoral Thesis (1-10 credits)

GEOG 501 – GIS and Environmental Modeling (3 credits)
GIS methods for managing and describing error links with modeling and spatial and statistical analysis. Operational and management issues arising from scientific application of GIS to resource management.

GEOG 503 - Settlement Geography (3 credits)

Settlement history and contemporary land use in the trans-Mississippi west. Evolution of cultural landscapes in the mountainous west.

GEOG 505 – Biogeography (3 credits)
The distribution of plants, as controlled by climate, geologic history, and geographic location. Changes over time in distribution patterns as related to climate change and other human activities.

GEOG 520 – Land Use Planning (3 credits)
History and philosophy of land use planning; application of geographical skills to contemporary land use issues.

GEOG 551 – Geography Instruction (3 credits)
Practicum in classroom instruction in geography.

GEOG 5XX – Paleoclimatology
The record of climate change through time as recorded in sediments, ice, and isotopic signatures in minerals.

GEOL 503 – Paleobiology
Study of the physiological attributes of ancient organisms as recorded in their fossilized remains.

GEOL 508 – Sedimentology
Facies models for terrestrial and marine depositional environments and their application to interpreting the stratigraphic record.

GEOL 510 – Igneous Geochemistry
Major element, trace element, and isotopic distribution in igneous rocks obtained from natural and experimental systems. Emphasis on models describing the origin of compositional diversity in rock suites.

GEOL 5XX – Geomicrobiology
Relationships between the precipitation of minerals and the world of microbial organisms.

GEOL 5XX – Molecular Paleontology
Investigation of the preservation of endogenous biomolecules in the fossil record and the role of microorganisms in facilitating preservation.

GEOL 5XX – Paleoecology
Relationships between ancient environments and the organisms that inhabited them.

GEOL 5XX – Vertebrate Taphonomy
The processes that influence fossilization of organisms from the time of death until final entombment in the rock record.

GEOL 515 – Structural Geology
Advanced topics in aspects of the deformation of rocks.

GEOL 551 – Geology Instruction (3 credits)
Practicum in classroom instruction in geology.

GEOL 537 – Tectonophysics
Development of tectonic theory, fundamentals of geophysics, earth's interior; global tectonics, active tectonics, orogenic belts.

GEOL 581 – Quaternary Environments
The last two million years of earth history as interpreted from geologic, biologic, and pedologic proxy data. Includes both global and regional analyses of changing climates and their effects on earth surface processes and landforms.

GEOL 583 – Applied Geological Hydrology
Application of ground-water principles to ground-water resource, contamination, and remediation problems.

**Need for the Program**

Given many of the aforementioned geographic and resource attributes of Montana State University and rising national enrollment trends in graduate student interest in the earth sciences, we believe the time is right to develop a doctoral program in Earth Sciences that can attract students to Montana for a world-class academic learning experience. Already, Montana State University is already a well-known leader in graduate education in snow science, paleontology, geographic information science, and geoscience education. Few universities have the faculty, analytical, or field resources available to students interested in pursuing research in these areas. Earth surface process science stands at the forefront of investigating how humans interact with the lithosphere, hydrosphere, biosphere, and atmosphere components of the earth system, and as such represents the hard science interface of environmental studies. The field of geobiology has the power to attract students interested in melding biological and geologic areas of expertise to create graduates with a truly unique ability to investigate the interface between microbes and minerals. In simple terms, all of these areas represent interdisciplinary and rapidly evolving areas of inquiry in the earth sciences. As such, they will undoubtedly prove attractive to graduate students in an increasingly complex and technological world in which the ability to possess skills and think across multiple disciplines in understanding the earth system is advantageous for employment. In addition, this program will attract students because our philosophy is not to train a new generation of university faculty to populate universities, but to train doctoral students to become a new generation of earth scientists capable for thinking across disciplinary boundaries and communicating the excitement and import of the earth sciences to the tax-paying public.

With continually expanding populations of undergraduate majors and Master's graduate students to historically highest levels in both geology and geography, the Earth Sciences are seeing an expansion of student interest across all of its subdisciplines. Career growth in geography has been driven by the development of geographic information systems as a powerful, widely used tool for managing spatially variable and distributed data. Our geography graduate students at the Master's level of education have been employed, many in Montana, as county or city planners, natural resource specialists, hydrologic modelers, or GIS technicians. During the last 5 years, approximately 75 percent of our geography Master's level graduates have been employed in their field of study, with 55 percent employed in Montana.

Geology Master's level graduate students during this same 5-year period have been employed at comparable rates in the fields of mining geology, geohydrology, environmental assessment and management, geotechnical assessment, and most recently, petroleum geology. Presently, ExxonMobil, Phillips Petroleum, and ChevronTexaco interview our Master's level graduates for employment opportunities in the petroleum industry, and numerous mining companies and hydrologic consulting firms hire our graduates.

During the past year, the Department of Earth Sciences has received a total of 27 unsolicited inquiries from Master's level graduate students across the country and world interested in pursuing doctoral level research in one of the emphasis areas designated for the Earth Sciences doctoral degree program. In addition, there are already 7 potential doctoral candidates already living in Bozeman who have expressed serious interest in obtaining a Doctor of Philosophy degree in Earth Sciences at MSU should this proposal receive Board of Regents approval. Because of their location, most of these students would require minimal tuition or other financial support, and yet could form a coherent critical mass to initiate the program in January 2003, with subsequent recruitment and addition of new students for the 2003-2004 academic year. Support for recruited doctoral students would come from conversion of some teaching assistant support to the Department from Master's to Doctoral candidates, and research grants. Presently, 2 doctoral students could be supported on research grants beginning Fall 2003. We anticipate developing a program within 3 years with approximately 7-10 doctoral candidates on average. With continued successful faculty recruitment, this number could stabilize at about 10-13 within 5 years.

Moreover, a doctoral degree program in Earth Sciences has the potential to increase the number of graduate students attending Montana State University, increase the research profile and reputation of MSU nationally in this field, and serve to raise the level of excellence in inquiry and learning in both the undergraduate and Master's level degree programs in Earth Sciences.

**ADEQUACY, ACCREDITATION AND ASSESSMENT ISSUES:**

**Adequacy of Present Faculty**

The 15 tenure-track faculty who will be involved in delivering the doctoral degree program in Earth Sciences include the following:

James Schmitt, Head (Ph.D. Wyoming)
David Lageson, Assistant Head (Ph.D Wyoming)
David Mogk (Ph.D. Washington)
William Locke (Ph.D. Colorado)
Steven Custer (Ph.D. Montana)
Todd Feeley (Ph.D. UCLA)
Mary Schweitzer (Ph.D. Montana State)
Open Geobiology Position
William Wyckoff (Ph.D. Syracuse)
Jian-yi Liu (Ph.D. Minnesota)
Kathy Hansen (Ph.D. Colorado)
Joe Ashley (Ph.D. Colorado)
Richard Aspinall (Ph.D. Hull)
Open Biogeography/Climatology Position
John R. Horner (Hon. Ph.D. Montana)

The College of Letters and Science at Montana State University has supported development of this program with approval to fill three faculty positions in molecular paleontology (Mary Schweitzer), biogeography/climatology, and geobiology.

In addition, the following adjunct faculty members are also already active in advising Earth Sciences Master's degree graduate students and in teaching courses in their areas of specialty:

Jack Fisher (Ph. D. California) – MSU Department of Sociology and Anthropology
Kenneth Pierce (Ph,D. Yale)– U.S. Geological Survey
Karl Birkeland (Ph.D. Arizona State) – U.S. Forest Service
David Bowen (Ph.D. Colorado) – Bowen Exploration
Kurt Constenius (Ph.D. Arizona) – Bowen Exploration
Russell Stands (Ph.D. Colorado School of Mines) – Amoco
Tom Kalakay (Ph.D. Wyoming)

**Adequacy of Present Facilities, Equipment, and Library Holdings**

Our present facilities for delivering this doctoral degree program are adequate and include the extensive paleontological collections and analytical equipment of the Museum of the Rockies, analytical equipment of the Imaging and Chemical Analysis Laboratory (ICAL), and combined research and teaching collections of the Museum of the Rockies and Department of Earth Sciences. The Geographic Information and Analysis Center (GIAC) provides computer hardware and software in both research laboratory and classroom settings for instruction and research use in GI science. The Department also houses the joint U.S. Geological Survey//Montana State University Earthquake Laboratory, and has recently expanded its student computer labs for upper division and graduate student use.

**Assessment Plan**

Admission requirements for the doctoral program in Earth Sciences will be predicated upon completion of a Master's degree in Earth Sciences, Geology, Geography, Paleontology, or a closely related field, or equivalent experience, a minimum graduate GPA of 3.00, and clear interest in pursuing research in one of the designated Degree program emphasis areas. The Earth Sciences Graduate Committee will assess undergraduate and graduate achievement, GRE scores, and letters of recommendation in selecting applicants for admission.

Intermediate assessment of student progress will be made by the graduate advisor and evaluated through period committee meetings, and successful performance in coursework and on qualifying and comprehensive examinations. Final student assessment will rely on the preparation of the dissertation and its successful defense.

Assessment of the overall effectiveness and success of the program will be monitored by the Department through the collection of data concerning student placement and success following graduation. This will include information on employment, salary, publication success, and student awards.

**IMPACT ON FACULTY, FACILITIES, COSTS, STUDENTS AND OTHER DEPARTMENTS ON CAMPUS:**

**Additional Faculty Requirements**

With College of Letters and Science approval to fill Department faculty vacancies in geobiology, molecular paleontology, and biogeography/paleoclimatology, the short-term (< 5 years) faculty needs to develop this program have been met. During the course of the next 5 years, it is anticipated that 2-3 faculty retirements will take place and it is hoped that these positions may be retained to provide continuity to the program. Need for new faculty additions beyond 5 years will be predicated upon the number of students enrolled and evidence of growth in research funding.

**Impact on Facilities**

It is anticipated that impact of this doctoral degree program on research facilities will be minimal. Because this proposed doctoral program is predicated on a solid foundation of research facilities already in existence at MSU, it is anticipated that augmentation of research facilities rather than acquisition of entirely new facilities or equipment will be required. Most of these needs can be met through funding from external grant and foundation sources.

As the program grows, space will likely be the major issue facing the Department. Currently, Department facilities are housed primarily in Traphagen Hall, with the Geographic Information and Analysis Center (GIAC) housed in AJM Johnson. As it grows, the Program will require development of more space primarily for graduate student and faculty offices as well as research labs.

Library resources are already adequate for program delivery because of the growing emphasis on electronic access to journals. Equipment for classroom lecture delivery such as computer projectors are already in place in the Department of Earth Sciences. Classroom space is adequate

**Costs**

This program will be phased in beginning with enrollment of approximately 5 students already present at MSU who would transfer from Non-Degree status to Degree Status in the Earth Sciences Doctoral degree program, augmented with an additional 1-2 newly recruited students per year.

| | 2003-2004<br>First year | 2004-2005<br>Second year | 2005-2006<br>Third year |
|---|---|---|---|
| I. Planned Student Enrollment | | | |
| Shifting Enrollment | 5 | 1 | 1 |
| New Student Enrollment | 2 | 2 | 2 |
| TOTAL | 7 | 10 | 13 |
| II. Expenditures | | | |
| Personnel Costs | | | |
| GRA(@$9,000/.5FTE) | $56,000 | $90,000 | $102,000 |
| Operating Costs | | | |
| Materials and Supplies | $500 | $800 | $1,000 |
| GRAND TOTAL EXPENDITURES | $56,500 | $90,800 | $103,000 |

| III. Revenues | | | |
|---|---|---|---|
| Sources of Funds | | | |
| Appropriated Funds Reallocation | $38,500 | $54,800 | $63,000 |
| Grant Support | $18,000 | $36,000 | $40,000 |
| GRAND TOTAL REVENUES | $56,500 | $90,800 | $103,000 |

**Impact on Enrollment**

As described above, we anticipate being able to begin this doctoral program with a minimum of 5-7 students. It is conservatively anticipated that enrollments will reach from 7-10 by the second year of the program with successful recruitment of students, and with successful faculty and student recruitment, from 10-13 students within 3 years. We also anticipate a slight drop in enrollment in the Earth Sciences Master's degree program initially as some resources are re-allocated to the Doctoral degree program.

**Relationship to Other Programs on Campus**

The proposed Doctor of Philosophy degree program in Earth Sciences will be housed in and served primarily by faculty in the Department of Earth Sciences. However, given the synthetic aspect of the earth sciences as a discipline, we believe this program will serve as a catalyst for expanded interaction between Earth Sciences doctoral students and faculty and peers in the Departments of Ecology, Land Resources and Environmental Sciences, and Microbiology. There will undoubtedly be increased student credit hour generation for these programs as Earth Sciences doctoral students enroll in courses outside of their own subject area.

In addition, given the analytical needs we anticipate in adding doctoral level student research to the Department's educational mission, we anticipate strengthening our collaborative research ties with the Imaging and Chemical Analysis Laboratory (ICAL), Museum of the Rockies, Thermal Biology Institute (TBI), and U.S. Geological Survey Northern Rocky Mountain Science Center.

**Relationship to Other Institutions**

Currently, no Doctor of Philosophy degree program in Earth Sciences exists in Montana or the surrounding region. The University of Montana has a Doctor of Philosophy degree program in Geology, and an accompanying emphasis in Applied Geology. These doctoral programs are focused in traditional areas of research and education in the geological sciences. There is little or no overlap in the Paleontology, Geobiology, Snow Science, Geographic Information Science, and Geoscience Education emphasis areas within the proposed Earth Sciences degree option. In fact, there is no doctoral program providing training in the major subdiscipline of geography at any institution in the state of Montana.