Shell growth increments Proposal

Rollins
Harbert
1994

NATIONAL SCIENCE FOUNDATION
4201 Wilson Boulevard • Arlington, VA 22230

July 29, 1994

Dr. Richard J. Neves
Fisheries & Wildlife Sciences
Virginia Polytechnic Institute &
State University
Blacksburg, VA 24061

Ref: IBN-9419967
Harold B. Rollins
U of Pittsburgh

Dear Dr. Neves:

The quality of the National Science Foundation's awards for research projects depends on the critical judgements of experts. For this reason, we are asking you to help us by reviewing the enclosed proposal.

The "Information for Reviewers" on the form's reverse side explains the evaluation criteria, with guidelines to avoid conflicts of interest and to protect the confidentiality of both the proposal and reviewer. Please note the policy of providing anonymous verbatim copies of reviews to investigators. You may limit your comments to those parts of the proposal in your area of expertise and/or recommend other reviewers.

Reviews with substantive and detailed information are more useful than those with only general statements. Review content is a major factor in reaching a decision regarding NSF support and provides important feedback to Principal Investigators. We are especially interested in your evaluation of (a) the scientific importance and originality of the research; (b) the quality of the proposed techniques; and (c) the capability of the investigator. If the application contains "Results of Prior NSF Support," please comment briefly on the quality of the prior work.

Please comment if you have any concerns regarding the violation of animal welfare laws or guidelines, the exposure of animals to unnecessary pain or mistreatment, or the use of excessive numbers of animals. If the species being used is not the most appropriate or if alternative or adjunct methods could be used to eliminate or reduce the need for animal experimentation, please comment in your review.

If possible please return the review by the date shown on the form. However, we would rather receive your review late, than not at all. Return the signed form and one copy in the enclosed envelope. If you use other paper to print your review, attach two copies of the forms. If it is more convenient, you may send your review by electronic mail or Fax: (703)-306-0349.

Thank you for assisting the National Science Foundation in the support of science. Your help is vital in assuring that each proposal is evaluated fairly, critically, and promptly.

Sincerely yours,

Sharon B. Emerson
Program Director,
Ecological and Evolutionary
Physiology

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e., program, division, etc.) Ecological Studies - Division of Environmental Biology	FOR NSF USE ONLY NSF PROPOSAL NUMBER 94-19967
PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE	

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	FILE LOCATION

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS:	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY?
25-0965591	☐ A RENEWAL OR ☐ AN ACCOMPLISHMENT-BASED RENEWAL	YES ___ NO X IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE: University of Pittsburgh	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING ZIP CODE: Office of Research 350 Thackery Hall Pittsburgh, PA 15260
AWARDEE ORGANIZATION CODE (IF KNOWN): 0033795000	
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING ZIP CODE:
PERFORMING ORGANIZATION CODE (IF KNOWN):	

IS AWARDEE ORGANIZATION (Check All That Apply): (See GPG For Definitions) ☐ FOR PROFIT ORGANIZATION ☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ WOMAN-OWNED BUSINESS

TITLE OF PROPOSED PROJECT:
Discovery and Analysis of Small-Scale (Subannual) Growth Increments in Freshwater Mussels by means of Digital Image Enhancement.

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE:
$ 143,538	24 months	September 01, 1994

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW:

- ☐ VERTEBRATE ANIMALS
- ☐ HUMAN SUBJECTS
- ☐ HISTORICAL PLACES
- ☐ BEGINNING INVESTIGATOR (See GPG SECTION I)
- ☐ GROUP PROPOSAL
- ☐ SMALL GRANT FOR EXPLORATORY RESEARCH (SGER) (SEE GPG SECTION II. C. 12)
- ☐ NATIONAL ENVIRONMENTAL POLICY ACT
- ☐ PROPRIETARY AND PRIVILEGED INFORMATION
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES
- ☐ FACILITATION FOR SCIENTISTS/ENGINEERS WITH DISABILITIES
- ☐ RESEARCH OPPORTUNITY AWARD
- ☐ INTERNATIONAL COOPERATIVE ACTIVITY: ________ Country/countries

PI/PD DEPARTMENT Geology & Planetary Sci.	PI/PD POSTAL ADDRESS 321 Engineering Hall University of Pittsburgh Pittsburgh, PA 15260
PI/PD FAX NUMBER (412) 624-3914	

NAMES (TYPED)	Social Security No.*	High Degree, Yr	Telephone Number	Electronic Mail Address
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CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

NOTE: THE FULLY SIGNED CERTIFICATION PAGE MUST BE SUBMITTED IMMEDIATELY FOLLOWING THIS COVER SHEET.

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE NSF INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

NSF FORM 1207 (1/94)

DISCOVERY AND ANALYSIS OF SMALL-SCALE (SUBANNUAL) GROWTH INCREMENTS IN FRESHWATER MUSSELS BY MEANS OF DIGITAL IMAGE ENHANCEMENT

PROJECT SUMMARY

Preliminary study has demonstrated that subannual growth increments can be recognized in the shells of both temperate and tropical unionoideans (= unionaceans), and these increments are amenable to enhancement and pattern analysis via application of ER Mapper, an image analysis program used in remote sensing. To our knowledge, rhythmically-deposited, small-scale shell growth increments have never been previously noted in freshwater mussels. We propose to study the environmental and physiological controls upon subannual growth increment deposition in freshwater mussels and, in addition, refine the computer enhancement of growth increments discernible in acetate peels and thin sections of mussel shells. We believe that the proposed research will (1.) extend the widely appreciated utility of marine bivalve shells as micro-environmental recorders to freshwater mussels, (2.) demonstrate how computer enhancement can extend "macro" remote sensing technology to a scale of "micro" remote sensing, (3.) assess the degree to which anaerobiosis and re-solution of deposited shell affect the fidelity of the shell microgrowth record, and (4.) explore the latitudinal distribution and controls upon formation of microgrowth increments in freshwater mussels.

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For font size and page formatting specifications, see GPG Section II. C.

*Proposers may select any numbering mechanism for the proposal.

PROJECT DESCRIPTION

Results of Prior NSF Funding - Harold Rollins

Earlier NSF support (not in last five years) to H.B. Rollins has resulted in the following publications (published abstracts/conference presentations are not included):

1. Donahue, J., H. B. Rollins and G. D. Shaak, 1972. Asymmetrical community succession in a transgressive-regressive sequence. 24th I.G.C., Section 7, Montreal, p. 74-81.

2. Rollins, H. B. and J. Donahue, 1972. Transgression and regression: Relative rates based on faunal communities. First Ann. Mtg. Eastern Sect. A.A.P.G., Columbus, Ohio, Guidebook p.V-1--V-8.

3. Donahue, J. and H. B. Rollins, 1974. Conemaugh (Glenshaw) marine events. Field Trip Guidebook, A.A.P.G.- S.E.P.M., Eastern Section, 3rd Ann. mtg., 47p.

4. Donahue, J. and H. B. Rollins, 1974. Paleoecological anatomy of a Conemaugh (Pennsylvanian) marine event. Geol. Soc. America, Spec. Paper 148, p. 153-170.

5. Rollins, H. B. and J. Donahue, 1975. Towards a theoretical basis of paleoecology: Community dynamics and the fossil record. Lethaia, v.8 (4), p.255-270.

6. Rollins, H. B., M. Carothers, and J. Donahue, 1979. Transgression, regression and fossil community succession. Lethaia, v.12(1), p. 89-104.

7. Donahue, J. and H. B. Rollins, 1979. Coal geology of Northern Appalachians. 9th Int. Congress of Carboniferous Stratigraphy and Geology, Guidebook, 50p.

8. Cain, B., M.A. Payne, S. Shulik, J. Donahue, H. B. Rollins, and V. A. Schmidt, 1979. The recovery of paleomagnetic polarities from cyclothemic sediments in the Carboniferous Appalachian Basin, U.S.A. Geophys. Res. Letters, v.6, p. 261-264.

9. Payne, M.A., S. Shulik, J. Donahue, H. B. Rollins, and V. A. Schmidt, 1981. Paleomagnetic poles for Brush Creek Limestone and Buffalo siltstone units from southwestern Pennsylvania. Physics of Earth and Plan. Interiors, v.25., p. 113-118.

10. Rollins, H. B., J. B. Richardson III and D. H. Sandweiss, 1986. The birth of El Nino: Geoarchaeological evidence and implications. Geoarchaeology 1 (1): 3-15.

11. Rollins, H. B., D. H. Sandweiss, U. Brand, and J.C. Rollins, 1987. Growth increment and stable isotope analysis of marine bivalves: Implications for the geoarchaeological record of El Nino. Geoarchaeology 2 (3): 181-197.

Results of Prior NSF Funding - William Harbert

EAR 82-182476, EAR82-182961 $64,263 6/1/83-6/31/85

Northward Displacement of the Aleutian Arc: A paleomagnetic test.

Summary of the results of the completed work.

It is now recognized the southern Alaska represents a collage of accreted terranes. At least 50 terranes, blocks and fragments have been recognized in central and southern Alaska (Jones and Silberling, 1979). Stevenson et al. (1983) had suggested that since the early Oligocene the Aleutian arc and Alaska Peninsula may have been displaced poleward over 1000 km. To test this hypothesis and determine the paleolatitude of deposition of early Oligocene units in the Aleutian arc, we have completed a paleomagnetic sampling of (from 170°E to 195°E) Shemya, Attu, Adak, Amlia, Umnak and Unalaska Islands.

Fine- to medium-grained siltstones, limestones, cherts and nearby dikes or small igneous bodies were sampled paleomagnetically. In total 140 sites, 1300 oriented cores were collected, as well as fossil and radiometrically datable material. On Adak, Amlia, Umnak and Unalaska Islands a characteristic magnetic vector was identified. The best constrained study on Umnak Island suggests 0 to 321 km of poleward motion of this portion of the Aleutian arc has occurred since the early Oligocene. This suggests that the Aleutian arc and Alaska Peninsula has not moved significantly since the middle Tertiary. Recent work on the Alaska Peninsula (Thrupp and Coe, 1986) supports this conclusion.

The declinations of the magnetic vectors, when corrected for the gentle tilt of the strata, show a consistent clockwise deflection away from the expected pole position for the North America plate. Since deposition of the sampled units in the early Oligocene, the study localities have been rotated in a clockwise sense. After the major change in Pacific plate motion reflected by the bend in the Hawaiian-Emperor seamount chain at 43 Ma the convergence vector between the Pacific and North America plates has had a significant right lateral oblique component. The consistent clockwise rotation of declinations probably occurred in response to oblique Pacific-North America motion.

Publication Citations:

Vallier, T.L., O'Connor, R.M., and Harbert, W., 1983, Gabbro and amphibolite on Attu Island, Aleutian Island Arc, Alaska: Transactions American Geophysical Union, v. 64, no. 45, p. 870-871.

Harbert, W.P., Cox, Allan, McLean, Hugh, 1984, Preliminary paleomagnetic results from Umnak Island, Aleutian Ridge: in Abstracts with Programs, 80th Annual Meeting Cordilleran Section, GSA, p. 288..IP 3.

McLean, Hugh, Harbert, W.P., and Douglass, S.P., 1984, Flysch, pillow lava, and diorite sills: A well exposed Tertiary assemblage on Unalaska Island is widespread in the Aleutian Islands: in Abstracts with Programs, 97th Annual Meeting, Geological Society of America, p. 590.

Harbert, W.P., Cox, Allan, and McLean, H., 1984, Paleomagnetism of Starr Point and Driftwood Bay, Umnak Island, Alaska: Transactions American Geophysical Union, v. 65, no. 45, p. 869.

Harbert, W.P., Cox, Allan, and McLean, H., 1985, Paleomagnetism of Eocene Sediments of Amlia and Adak Islands, Aleutian Islands, Alaska: Transactions American Geophysical Union, v. 66, no. 46, p. 864.

Harbert, W.P., Frei, L.S., Cox, Allan, and Engebretson, D.C., 1987, Relative motions between Eurasia and North America in the Bering Sea region: Tectonophysics, v. 134, p. 239-261.

Harbert, William, 1987, New paleomagnetic data from the Aleutian Islands: Implications for terrane migration and depositions of the Zodiac fan: Tectonics, v. 6, p. 585-602.

OCE85-10657 $39,153 1/1/86-1/30/87

Determination of Plate Tectonic Evolution of the Pacific Plate 9.8-3 Ma.

Summary of the results of the completed work.

The starting point of the study is the analysis of Pacific-Antarctic spreading by using older isochrons and fracture zones of Stock and Molnar (1982) who found stage poles from chron 5 (9.8 Ma) and chron 6 (19.0 Ma). They noted that the PA-AN poles for chron 5 (9.8 to 0 Ma). The question of when within the interval 9.8-3 Ma the change of motion occurred was left unresolved.

We examined ship-board magnetic and bathymetric data and SEASAT altimeter data in the region of the Pacific-Antarctic spreading center to determine the timing and style of this latest change in Pacific plate motion. The total amount of ship data available for the region of the Pacific-Antarctic spreading center is approximately 350,000 km. Approximately 51,500 km of new ship data has become available from NGDC (National Geophysical Data Center) since the data were last summarized for the publication of Molnar et al. (1975).

PA-AN rotation poles for times younger than chron 5 and 6 provided an opportunity to calculate an independent set of PA-HS poles from the PA-AN-HS circuit. AN-HS motion has not been measured directly from hotspot tracks on Antarctica, but several observations suggest that it was slow during the period of interest. The present rate of AN-HS motion (Minster and Jordon, 1978) is very slow (.054°/m.y. versus .964°/m.y. for PA-AN motion). Moreover during the Neogene the Antarctica plate was bounded mainly by a set of ridges, as it is today, and plates surrounded by ridges generally have low absolute velocities (Forsyth and Uyeda, 1975).

Publication Citations:

Harbert, William and Cox, Allan, 1986, Late Neogene motion of the Pacific plate: Transactions American Geophysical Union, v. 67, p. 1225.

Harbert, William and Cox, Allan, 1987, Late Neogene motion of the Pacific plate determined using stage of estimates of velocity: Transactions American Geophysical Union, v. 68, p. 290.

Harbert, William and Cox, Allan, 1988, Late Neogene motion of the Pacific Plate: Implications for coastal California: 84th Annual meeting, Cordilleran Section, Geological Society of America, v. 20, p. 166.

Harbert, William, and Cox, Allan, 1989, Late Neogene motion of the Pacific plate: Journal of Geophysical Research: Journal of Geophysical Research, v. 94, p. 3052-3064.

Harbert, William, 1990, Correlation to "Late Neogene motion of the Pacific plate:": Journal of Geophysical Research, Journal of Geophysical Research, v. 95, p. 5171.

Harbert, William, 1991, Late Neogene Relative Motions of the Pacific and North America Plates: Tectonics, v. 10, p. 1-15.

EAR89-15840: Requested $137,450: Received $16,750 9/1/89-9/1/90

Upgrading the Paleomagnetic Research Facility at the University of Pittsburgh

Summary of the results of the completed work.

Paleomagnetic research has played an increasingly important role in the earth sciences over the last two decades. In this proposal we asked for funds to upgrade our paleomagnetic laboratory by purchasing, 1) a new superconducting rock magnetometer (SRM), 2) sample transport, 3) alternating field demagnetizing system and 4) a computer controller, printer and hard disk. In designing this system we have been led by the desire to automate much of the measurement and alternating field demagnetization process, thereby upgrading the paleomagnetic research facility at the University of Pittsburgh and greatly increasing the usefulness of this laboratory to our ongoing research and to other researchers in our region. We received $16,450 in matching funds and purchased a new 2G AF demagnetizer and Macintosh computer controller. After delivery, a slight problem with ARM was found, 2G was contacted and with the on-site help of an engineer the performance of the alternating field demagnetizer was considerably improved. The system is up and running.

EAR91-04752: Requested $132,100: Received $88,510: 6/1/91-9/1/92

Upgrading the Paleomagnetic Research Facility at the University of Pittsburgh

Summary of the results of the completed work.

Paleomagnetic research has played an increasingly important role in the earth sciences over the last two decades. In this proposal we asked for funds to upgrade our paleomagnetic laboratory by purchasing, 1) a new superconducting rock magnetometer (SRM), 2) a sample transport system, 3) a 48 sample oven. In designing this instrument we have been led by the desire to automate much of the measurement and alternating field demagnetization process, thereby upgrading the paleomagnetic research facility at the University of Pittsburgh and greatly increasing the usefulness of this laboratory to our ongoing research and to other researchers in our region. With University of Pittsburgh matching funds we are presently purchasing this equipment. We expect everything to be up and running by June 1992. A Graphical User Interface (GUI) built around an Apple computer and complete GUI-based paleomagnetic analysis software has also been completed as part of this upgrade.

EAR-8916442: Requested $32,420: Received $32,420: 9/1/89-9/1/90

Paleomagnetism of the Olutorsky Peninsula and Kuyul Suture Zone, Northeastern USSR

Summary of the results of the completed work.

In the former northeastern USSR (now the Russian Republic), within the Koryak region, the region bordering the northwestern Bering Sea, the horizontal motion of the tectonostratigraphic terranes that comprise this region have been quantitatively interpreted by various authors in different ways. Previous tectonic models calculated for the Koryak superterrane and based on either purely geological data or of kilometers to many thousands of kilometers are required. At the time this proposal was made all suggested models were tentative because of the lack of the paleomagnetic studies from the terranes of the Koryak region.

The University of Pittsburgh signed a joint research exchange agreement and provided funds to allow the visit to our paleomagnetic laboratory of three young Soviet scientists (Alexander Heiphetz, Alexei Didenko, and Serge Dril) to work with the PI. Both A. Heiphetz and A. Didenko brought collections from the Koryak regions and completed more than 2,000 paleomagnetic measurements in our laboratory. Using funds from the University of Pittsburgh, two other Soviet scientists, Vadim Kravchinsky (Ministry of Geology, Siberian Branch) and Maxim Aleksutin (Moscow State University) completed paleomagnetic pilot studies at the Paleomagnetic Laboratory at the University of Pittsburgh.

After stepwise thermal demagnetization, component analysis, and the application of both Fisher and Bingham statistics to the observed characteristic remanent magnetic components, their results showed significant poleward transport of units in the Olyutorsky, Khatyrian and Maynisky terranes of the Koryak region. The rate of poleward transport of these terranes matched well the rate predicted by models of the past motions of oceanic plates in the Pacific basin. Results have been published in abstract form, in both English and Russian-languages, and two completed manuscripts have been submitted to the international journal Tectonophysics for publication. Funding of this proposal allowed a complete field season of paleomagnetic collection to be completed by the PI in the northern Kamchatka peninsula. In addition to publications a computer animation of a model of the plate tectonic development of this region was completed.

Publication Citations:

Harbert, William, 1989, Paleomagnetic data from Alaska: Reliability, interpretation and a plate tectonics movie: Sixth Scientific Assembly, IAGA Bulletin No. 53, Part B, p. 194.

Harbert, William, 1990, Paleomagnetic Data from Alaska: Reliability, Interpretation and Terrane Trajectories: Transactions American Geophysical Union, v. 71, p. 493-494.

Harbert, William, 1990, Paelomagnetic Data from Alaska: Reliability, interpretation and terrane trajectories: Tectonophysics, v. 184, p. 111-135.

Didenko, Alexi, Harbert, William, and Stavsky, Anatoly, 1990, Paleomagnetism of Cenomanian sedimentary rocks from the Koryakian Highlands, northeast USSR: in, Abstracts with program Geological Society of America Annual Meeting, v. 22, p. 57.

Heiphetz, A., Savostin. L., and Harbert. W., 1990, Paleomagnetism of the Olutosky terrane, northeast USSR: Transactions American Geophysical Union, v. 71, p. 1992.

Heiphetz, Alexander, and Harbert, William, 1992, Complex paleomagnetic features of the Jurassic ophiolites from NE Eurasia, EOS Trans. AGU, v. 73, Spring Meeting Suppl., p. 96.

Computer Animation:

Harbert, William, 1988, Tectonic History of the Northern Pacific Basin: 30 seconds (Exposure test): Copies at University of Pittsburgh, Shirshov Institute (Moscow).

Harbert, William, Zonenshain, L., and Kononov, M., 1989, History of the Pacific Basin: 12 minutes, captions in both English and Russian: Copies at more than 15 US Universities, including, University of Pittsburgh, Stanford University, University of California, Yale University, Alaska Branch USGS, Shirshov Institute, Geological Institute (Moscow), Geochemical Institute of the Academy of Sciences of the USSR (Irkutsk), Geophysics and Tectonics Institute (Khabarovsk), Yellowstone National Park, SAGE Teacher education program, Geological Society of America.

Introduction

Reconaissance study of shells of the temperate mussel Lampsilis ovata from French Creek, Crawford County, Pennsylvania and the tropical mussel Anodontites trapesialis from the Amazon River demonstrated subannual growth increments for the first time in freshwater mussels. Although disturbance marks (pseudoannuli) have been described in the literature, to our knowledge, rhythmically deposited, small-scale (subannual) shell growth increments have never been previously noted in freshwater mussels. Subannual growth increments in nonmarine bivalves have previously been described only in the Asian clam Corbicula fluminea (Fritz and Lutz, 1986) Our preliminary results suggest that not only can subannual increments be recognized in the shells of unionoideans (=Unionacea), they are also amenable to enhancement and pattern analysis via application of ER Mapper, an image analysis program used in remote sensing. We propose to further explore these preliminary results in terms of the significance and controls of subannual growth increment deposition in freshwater bivalves and, in addition, refine the computer enhancement of growth increments in acetate peels and thin sections of bivalve shells. We are convinced that this proposed research is worthy of NSF funding for three major reasons: 1.) It will extend the widely appreciated utility of marine bivalve shells as micro-environmental recorders to freshwater mussels, 2.) it will use computer enhancement of acetate peels and thin sections to demonstrate how "macro" remote sensing technology can be utilized in growth increment analysis - in effect, extend a technology heretofore only used for analysis of images of large scale features, such as landsat photos, to a type of, "micro-" remote sensing, and 3.) it will explore the distribution and causation of micro-growth increments in freshwater mussels. Questions posed by our preliminary study include: Do the smallest scale increments represent diel patterns of shell formation? Does the packaging of these smallest increments into "bundles" of 12-14 have any significance (e.g. lunar coupling)? Do both epibenthic and endobenthic mussels display these subannual increments? Are they present in lentic as well as lotic forms (some freshwater mussel species occur in both lacustrine and riverine habitats)? Do the subannual increments have the same interpretations in temperate and tropical mussels? What are the inter- and intraspecific differences in formation of subannual shell increments? Does winter cessation of growth in freshwater mussels lead to destruction by solution (perhaps via anaerobiosis) of previously deposited small-scale increments, and, if so, how might this affect the use of these mussels as high-resolution environmental recorders?

Formation of Growth Increments:

Although the subannual microgrowth increments of marine bivalve shells have received a great deal of attention, those of freshwater bivalve shells have not. Yearly "breaks" in shell deposition (annuli) have long been recognized in temperate freshwater species of unionoideans, however (LeFevre and Curtis, 1912; Isley, 1914, p. 17-18; Coker et al., 1921; Grier, 1922; Chamberlain, 1931; Tevesz and Carter, 1980; Stansbery, 1961; Hendelberg, 1960; Bjork, 1962; Ray, 1978; McCuaig and Green, 1983; Neves and Moyer, 1988; Haukioja and Hakala, 1978; Negus, 1966; Hinch et al., 1986; Payne and Miller, 1989). Annuli have also been noted in tropical freshwater bivalves, although the causes of "growth band" formation in the latter case are not known (McMichael, 1952; Tevesz and Carter, 1980). The annuli are generally discernible both on the valve surfaces and in cross-section (internal), but only the external surfaces have been used in most attempts to confirm annual formation of the shell "breaks".(Isley,1914, Chamberlain, 1931, Negus, 1966; Haukioja and Hakala, 1978). The internal annuli are easily confused with "pseudoannuli" which are caused by short-term disturbances of growth, sometimes due to dislodgement from the substrate or inadvertant incorporation of irritating sediment grains between the mantle and shell.. Neves and Moyer (1988) have provided criteria for distinguishing annuli and pseudoannuli in acetate peels and thin sections, and in the process provided the most conclusive "groundtruthing" of yearly periodicity of annuli. The physiological explanation for development of annuli (or, for that matter, any scale growth line created by interruption of shell deposition) is still debated, both in marine and freshwater bivalves. Anaerobiosis at the time of valve closure has been suggested by Lutz and Rhoads (1977) for marine bivalves, the result of a buildup of such metabolic products as succinic acid in the extrapallial fluid of the bivalve resulting in the dissolution of already deposited calcium carbonate, accompanied by a proportional relative increase in the amount of organic shell matrix. Although debatable and not conclusively demonstrated, facultative alternation of aerobic and anaerobic metabolic pathways are expected adaptive strategies for intertidal bivalves subjected to frequent immersion and emersion, especially those species incapable of adopting aerial respiration during hypoxic conditions (Vial et al., 1992). Theoretically, anaerobiosis can result in a scale-independent interruption of shell growth, explaining patterns of growth lines ranging from tidal to yearly, as well as those lines indicative of episodic cessation of growth, such as spawning cycles, storm disturbances, thermal shocks, etc. As noted by Lutz and Rhoads (1977) alternative explanations for growth line formation exist, specifically, that the mollusk, during valve closure, facultatively and periodically deposits concentrated organic matter at the growing margin of the shell, or that valve closure juxtaposes the organic rich periostracum against the growth surface relatively enriching the deposition of organic material. Virtually all researchers agree that growth lines are formed during times of valve closure, however. One significant implication of the anaerobiosis model is that it can lead to the under-representation of deposited growth increments, through dissolution and/or non-deposition. Conceivably this might result in "negative" shell growth due to ontogenetic loss of shell (Downing and Downing, 1993). There appears to be no theoretical problem with adopting anaerobiosis as a mechanism for growth line formation in freshwater mussels, as well as marine bivalves, although the causes of subannual growth increment rhythms should be less apparent given the presumed lack of tidal periodicities. Resolution of the physiological basis of growth line formation is not necessary for the successful completion of our proposed research, in view of the universal agreement that growth line formation accompanies valve closure. We should be able to assess the relative significance of anaerobiosis in the preservation of small-scale increments, however, as we will be able to contrast the patterns and frequencies of increments across latitude - in effect, contrast long-term winter growth cessation with more continuous tropical growth. Preliminary results from L. ovata suggest that spacing of small-scale, perhaps diel, increments gradually diminishes with the slow onset of winter and gradually increases with the coming of spring. This appears inconsistent with extensive anaerobiosis during the winter months (fig. 3).

Rhymically-deposited, subannual shell gowth increments have never been mentioned in the literature dealing with unionoideans, although Fritz and Lutz (1986) recognized daily increments in the freshwater Asiatic clam, Corbicula fluminea, from the non-tidally impacted portion of the Raritan River, New Jersey. In North America, C. fluminea is an introduced exotic, belongs to the superfamily Corbiculoidea (=Corbiculacea), and is therefore not closely related to native unionoidean mussels. Unionoideans invariably possess a nacreous prismatic shell whereas the corbiculoideans have crossed-lamellar shell structure (Prezant and Tan-Tiu, 1985). As such, the unionoideans appear to be descendants of the Trigonoidea, a superfamily currently restricted to Indo-Pacific estuarine and marine habitats (Newell and Boyd, 1975; Tevesz and Carter, 1980). South American unionoideans are only distantly related to the North American species, and are conventionally placed in a separate family (Parodiz, 1969; Ortmann, 1921).

Documentation of Subannual Increments in Unionoideans:

Acetate peel replicas of the unionoideans Lampsilis ovata, from French Creek, Crawford Co., Pennsylvania and Anodontites trapesialis, from the upper Amazon River clearly show regularly spaced small scale growth lines in the outer prismatic shell layer (Fig.1,2). Specimens of A. trapesialis were field collected in the summer of 1993 by Roman Kyshakevych, supported by a University of Pittsburgh Latin American Studies research grant to Kyshakevych and Rollins. .Acetate peels were prepared in the conventional manner (Ropes, 1985; Neves and Moyer, 1988; and other references contained in Rollins et al., 1990). Both L. ovata and A. trapesialis are large and thick-shelled, and did not require imbedding in epoxy resin prior to sawing. The differential etching of the outer prismatic layer apparently enhanced the small scale growth lines where they crossed the margins of the larger microstructural aragonite prisms, by creating a sort of bas-relief amplification. We have similarly examined other species of unionoideans (e.g. Amblema plicata, Elliptio complanata, and even other lampsilid species) and have not noted such high resolution replication of small-scale growth lines. Although visible under plane transmitted light the small-scale growth lines were difficult to trace laterally.

Using a petrographic microscope and a high-resolution IKONIX digitizing camera we scanned transmitted light images of the acetate peels. These data were digitally enhanced using a commercial software package called "ER Mapper". Within this package we converted the image to a Hue-Saturation-Intensity color look-up-table and digitally shaded the image (Richards, 1986). As a second step, we also applied a 12 X 12 edge enhancement convolution filter to sharpen the digital image. When computer-enhanced in this manner, the growth line patterns became very obvious (see Figs. 1-2). Over two hundred small growth increments are countable between annuli, and the small increments are bundled in packages of 12 to 14., which are bounded by slightly wider growth lines. If this were a marine bivalve there would be little hesitation to hypothesize daily and perhaps fortnightly (?lunar) periodicity for such a growth increment pattern, although the freshwater mussel growth increments are not grouped in cycles of narrow and wide spacing (spring/neap tidal signatures) as is the case in some studies of marine bivalves. Of course, such an interpretation poses a real problem when dealing with a riverine mussel and, in addition, represents an unwarranted ad hoc presumption of pattern and cause.

The "discovery" of small-scale growth increments in unionoideans demands, we feel, further investigation, especially in view of the fact that only yearly growth bands have been previously noted in these freshwater mollusks. The use of remote sensing image processing technology opens new horizons for the study of microgrowth increments.

Proposed Study:

We propose to utilize remote sensing software to analyze and interpret subannual shell increment periodicity in freshwater mussels. French Creek, a tributary to the Allegheny River will be the primary focus of the study as it harbors a high diversity unionoidean fauna. A recent census by Bogan (1992) documented 27 mussel species in the French Creek Basin, although several are currently listed as endangered. NOAA weather and stream gauge data are available from the Meadville station along French Creek, only a few miles downstream from the primary collecting sites.(Note: Pa. Fish and Game Commission is aware of our study, but due to the sensitive nature of endangered species sites we have not included precise field locations in this proposal. Such data will be furnished, however, upon specific request). The high diversity of unionoideans at French Creek will permit comparison of interspecific differences in subannual growth increments, while minimizing differences in general environmental parameters that inevitably accompany samples taken from greatly disparate localities. Extrinsic environmental parameters such as water and air temperatures, river level, flooding periodicity, etc. can be held constant permitting assessment of micro-habitat differences upon growth increment formation. On the other hand, Lampsilis ovata has a longevity in excess of 30 years, based upon annuli counts, and the historical weather and stream gauge station data can be turned to advantage, when correlated with the chronology of live-collected specimens, as a method of ground-truthing the controls of growth line formation. Temperature shocks, both shorter term summer heat perturbations and longer-term winter growth retardation, can be analyzed in real time. Relative rates of seasonal growth can be potentially correlated with real environmental parameters, etc. Although comparable water parameter data are not available for our Amazon River mussel collection, we have several Amazon R. species available for increment comparison with the temperate French Creek species. Specimens from both collections will be subjected to oxygen isotope analysis for independent corroboration of increment pattern and ambient water temperature. Channel-sampling of cross-sectioned shells parallel to growth lines provides adequate samples for such isotopic analyses and will minimally permit bi-weekly to monthly resolution of encoded water temperature information.

We are acutely aware of the controversy surrounding the analysis of marine bivalve growth increments, and will do our utmost to avoid the pitfalls of the past. Bourget et al. (1991) have critiqued previous studies regarding evidence supporting short-term growth controls in marine bivalves (daily, tidal, endogenous, etc). Whether such increments are tracking daily or tidal rhythms have been debated for many years (Pannella and MacClintock, 1968; House and Farrow, 1968; Farrow, 1972; Richardson, 1988a; 1988b; Richardson et al., 1979; 1980a; 1980b 1980; 1981; Crisp, 1989; Evans, 1972, 1975; Rollins et al., 1990; Whyte, 1975; Ohno, 1985; Clark, 1968, Koike, 1973; Deith, 1985; among others). Bourget et al (1991) have attempted to impose some order on the chaos of measuring and interpreting micro-growth increments in marine bivalves by suggesting that the null hypothesis (no significant departure from expected frequency) only be rejected if missing growth increments can be accounted for. To assume that growth increments are either too few or too many is, they maintain, basically an ad hoc presumption of periodicity and an a priori rejection of the null hypothesis. They assert that avoidance of this presumption demands careful correlation of micro-growth increments among individuals, using carefully prepared peels or thin sections, and accountability of observor (counting) error. Considering the wide variation of micro-growth patterns among individual marine bivalves of the same species (due to variation in microhabitat, locality, age of individual, etc.) Bourget et al (1991) state that a "reasonable number of individuals (5 or 10) should be examined". However, as they state, variation among individuals may, for the many reasons listed, commonly mask any rhythmic patterns. For that reason, "there is only one option for testing the hypothesis: each animal must be considered an individual test of the hypothesis". We will consider following or amending the protocol of Bourget et al. (1991). This will be particularly imperative in year #2 of our research, when we intend to interpret the patterns of the microgrowth patterns discerned in year #1.

Methodology and Implementation of Research:

Year #1

The first year of our proposed research will be devoted to (1). refinement of the application of image processing techniques (e.g. ER Mapper) to enhancement of micro-growth increment recognition in acetate peels and thin sections, (2) sampling of freshwater mussel specimens from French Creek, and (3) measurement and assembly of water parameter data from French Creek (including NOAA data over last ten years, flood frequency, water level, water temperature, and microhabitat descriptions of collected mussel species, (4) preparation of peels and sections of freshwater mussels from French Creek and the Amazon River.

We anticipate, based upon our preliminary study, that best results will be obtained from computer enhancement of acetate peels, rather than thin sections. Although Clark (1980) and Neves and Moyer (1988) have demonstrated that thin sections are more useful than acetate peels for determination of seasonal or annular periodicities in shell deposition of marine and freshwater bivalves, respectively, smaller scale increments are generally more traceable via the acetate peel technology. Differences in color or opacity of the shells are discernable in thin section, and this commonly correlates with seasonal changes in rate of shell deposition. However, the differential etching by dilute hydrochloric acid amplifies the relative strength of the smaller-scale increments, especially in the prismatic outer layer of unionoideans. Acetate peels will be prepared in the conventional manner (e.g. Ropes, 1982;1985; Rhoads and Lutz, 1980; Rollins et al., 1987; 1990). The peels will be taken from carefully oriented radial shell sections, as variation in section orientation leads to technological bias in spacing of increments (Bourget et al., 1991). Acetate peels will be mounted between thin plexiglas slides for direct scanning via a IKONIX digitizing camera mounted to a petrographic microscope. Scanned portions of acetate peels will be digitally enhanced using "ER Mapper." Image processing is labor intensive and will be the primary responsibility of the GSR (Roman Kyshakevych), under the supervision of Dr. Harbert. Five to ten specimens of Lampsilis ovata and 5-10 specimens each of an estimated 5 other French Creek species will be analyzed. In order to digitally enchance this large number of images we require a Sun SPARC 10/GX/30 workstation. We can provide the ER Mapper software, which retails for $19,500, at no cost to NSF. This workstation will supply us with the computer processing power and disk storage required for this project.

Species will be selected from the non-endangered list and will be chosen, following field reconnaissance, to optimize the variation in habitat at the French Creek sites. This will provide control upon the intra- and interspecific, and microhabitat variation in growth increment formation. If any of the species also occurs in nearby Conneaut and Pymatuning Lakes, comparable samples will be taken for comparison of lotic and lentic growth increment patterns. All analyzed specimens will be live-collected to optimize the use of available NOAA climatic data. For each species, an additional two live specimens will be collected, cold-shocked to provide a baseline growth check, and removed to an aquarium ("Living Stream") housed in the Geology Department, at the University of Pittsburgh. These individuals will be sacrificed near the end of the study to provide direct evidence of increment addition over a period of 1.5 years. We have previously maintained living mussel specimens for extended times in this aquarium and anticipate no problem in this endeavor. However, we will try to maintain only younger, rapidly growing individuals for we have experienced difficulty (as have others) in measuring the very slow growth in many adult freshwater mussels. As noted by Downing and Downing (1993) adult mussels may even experience net shell loss. We have not employed a field mark/recapture strategy in this proposed research because of the difficulty of recovery of replaced riverine specimens following flooding events.

Year #2

Year #2 will be devoted to analysis of computer-enhanced images of acetate peels and thin sections, hypothesizing and testing the cause(s) of microgrowth increment deposition in freshwater mussels, assessing the future utility of the technique and the results, and the presentation of results at a national GSA meeting.

Patterns of spacing and strength (opacity, in thin section) of growth lines will be automatically digitized and analyzed by spectral analysis (Chatfield, 1980; Trump and Bourget, 1980; Berard et al., 1992). Within- and among- individual variation in growth patterns will be examined, as will interspecific and interhabitat variation. Corroboration of growth increment periodicity, if discerned by statistical analysis, will involve: 1.) attempt to recognize subannual increments deposited by specimens maintained in the aquarium, (2.) correlation of growth increment pattern with NOAA climatic data for the French Creek Basin. Disturbance marks that result from flooding events and dislodgement or from abnormally cool or hot periods may be recognizable and correlatable among specimens. If so, they can serve as landmarks for pattern analysis of growth increments, (3.) attempt to integrate growth increment patterns with natural history data of the studied species. In this regard, relatively little is known about the details of the natural history (e.g. spawning times, host fish, seasonal growth, preferred microhabitat, etc) of most species of unionoideans. Ortmann (1919) provides some details for

Pennsylvania unionoideans, and select species have been monographically studied (Chamberlain, 1930; Coker et al., 1921, among others), (4.) A total of five shells (from French Creek and from the Amazon River) will be submitted to Dr. U. Brand at Brock University for oxygen isotopic analyses (Mook, 1971; Yapp, 1979; Abell, 1985). The techniques of oxygen isotope analysis used by Brand are reported in Rollins et al., 1989; Brand et al., 1987). He requires at least 16 milligrams of shell material for each analysis. This limits the resolution of the record of temperature and/or precipitation encoded in the shell (using the $^{18}O/^{16}O$ ratio) to about a month (perhaps two weeks if channel-drilled) in rapidly growing thicker-shelled mussels. A transect of at least three samples will be taken on each analyzed shell to provide a range of temperature variation from summer to winter and back to summer. Even this will, however, provide an independent check on seasonal changes that can be correlated with the NOAA data and both can be used to test hypotheses of cause of microgrowth increment patterns.

Education and Human Resources:

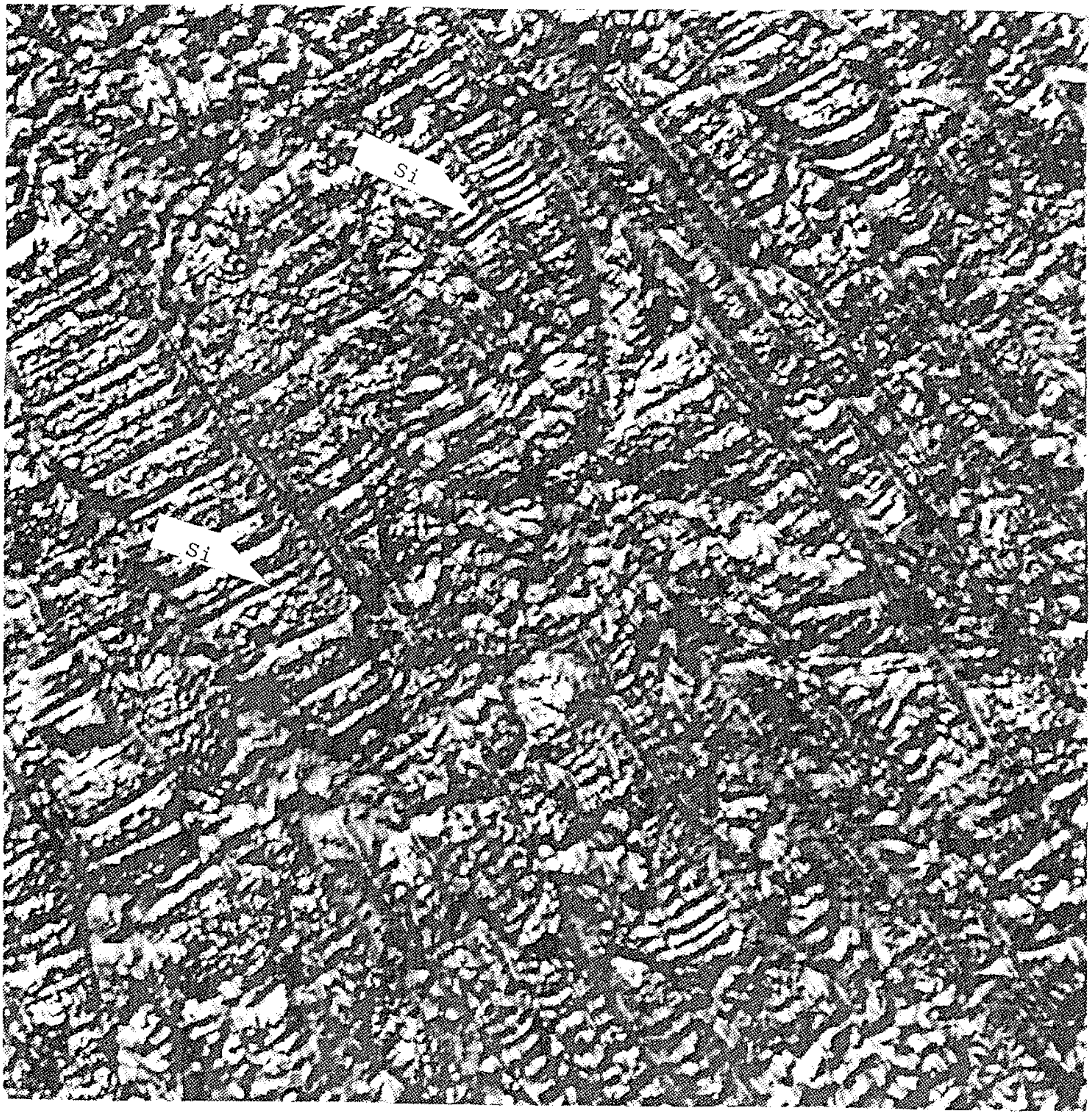
The budget for this project includes funding for the academic year and summer over two years for a PhD student (Roman Kyshakevych). This student will gain valuable experience in image processing, laboratory technique, and field ecology. In addition, we plan to involve one or more undergraduate students in the project; in the laboratory, in the field, and in computer processing of data.

Significance of Anticipated Results:

New applications of remote sensing software currently used in image processing of regional landforms, etc. will be adapted for the computer enhancement of acetate peels and thin sections. This is virtually guaranteed from the proposed research, on the basis of our preliminary work. These techniques will permit us to document for the first time, subannual (small-scale) growth increments in freshwater mussels. This, too, is virtually guaranteed, based on the results of our preliminary study. By comparing high and low latitude mussel species we should be able to assess the extent to which anaerobiosis and re-solution of deposited shell material confounds the use of shell growth increments as environmental recorders. The riskiest aspect of the proposed research involves the interpretation of the small-scale growth increment patterns. Can we unambiguously ascribe these patterns to known forcing mechanisms, or not?

.1 mm

Figure 1 Shell of *Anodontites trapesialis*. Sun angle from southeast, 30° above horizon. Shows " macro" (Ai) and "micro" (Si) growth interruptions.



.1 mm

Figure 2. Digitized image of *L. ovata*. Sun-angle from southeast 30° above horizon. Enhancement of subannual accretions (Si).

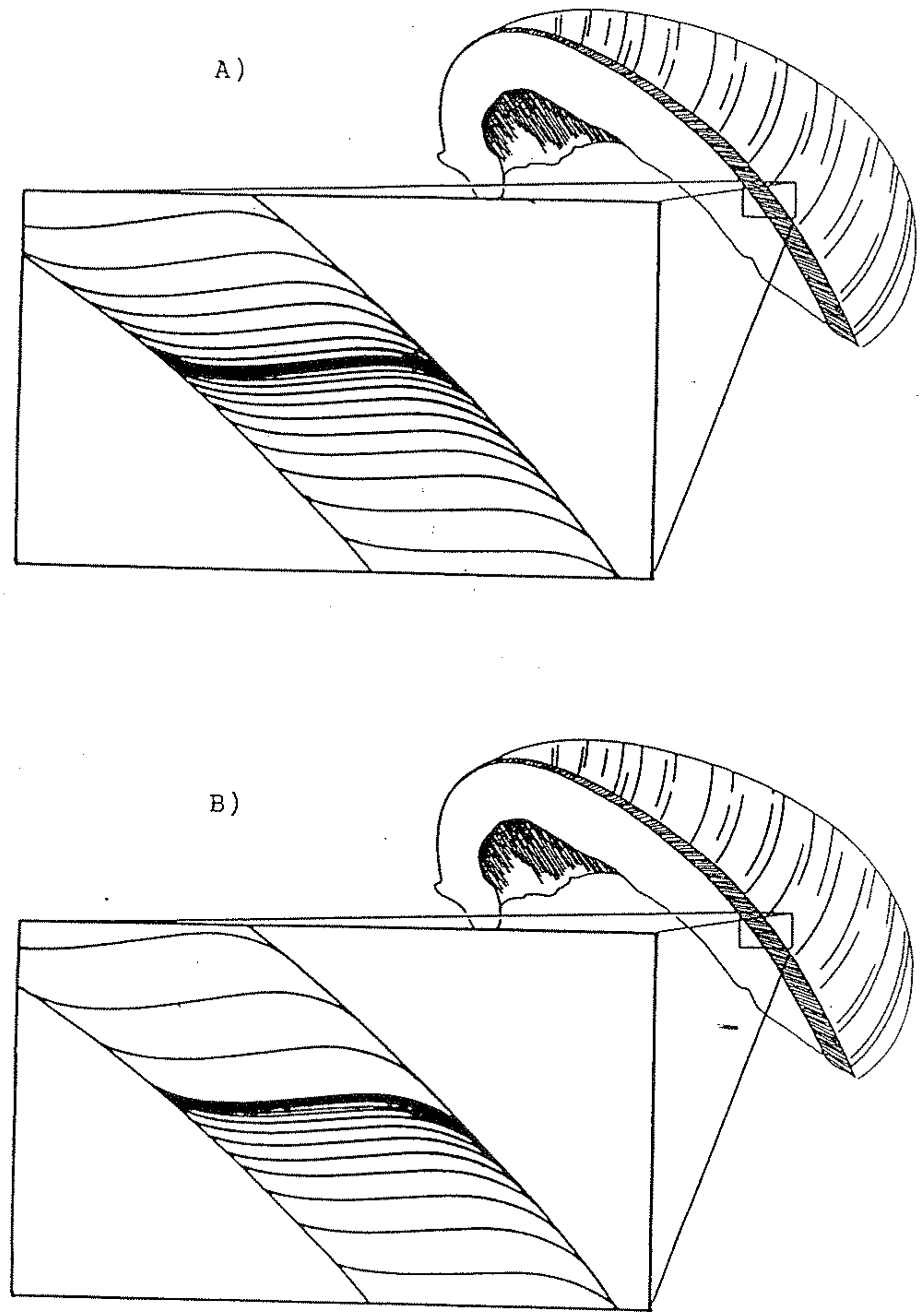


Figure 3. A) "Bunching" model if dissolution is limited or non-existent during winter break. Not to scale.
B) "Bunching" model if dissolution occurs during winter break.

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Supervision of Students

Li Yufeng (completed MS degree 1991: Paleomagnetism of Wind River basin, Wyoming)
Alexander Heiphetz (in progress for Ph.D. degree, expected finish, 10/1994)
Xi Xu (in progress for MS degree, expected finish, 9/1994)
Jianyang Zhemeng (in progress for Ph.D. degree, expected finish 9/1995)

List of Collaborators during the last 4 years

John Hillhouse, United States Geological Survey
Tracy Vallier, United States Geological Survey
Jon Hagstrum, United States Geological Survey
Alexander Heiphtz, Laboratory of Regional Geodynamics, Moscow
Alexi Didenko, Institute of Physics of the Earth, Moscow
Sergi Dril, Institute of Geochemistry, Moscow
Mikhail Kononov, Institute of Oceanography, Moscow
Vadim Kravchsinsky, Research Branch, Ministry of Geology, Irkutsk
Lev Zonenshain, Institute of Oceanography, Moscow

Five Significant References

Harbert, William, Frei, Leah, Jarrard, Richard, Halgedahl, Susan and Engebretson, Dave, 1990, Paleomagnetic and Plate Tectonic Constraints on the Evolution of the Alaskan-Eastern Siberian Arctic: in Grantz, A, Johnson, L., and Sweeney J. F. eds., The Arctic Ocean region: Boulder, Colorado, Geological Society of America, The Geology of North America, v. L, chapter 30, p. 567-592.

Harbert, William, 1990, Paleomagnetic Data from Alaska: Reliability, interpretation and terrane trajectories: Tectonophysics, v. 184, p. 111-135.

Harbert, William, 1991, Late Neogene Relative Motions of the Pacific and North America Plates: Tectonics, v. 10, p. 1-15.

Hagstrum, J.T., and Harbert, W., 1991, Paleomagnetism and microplate tectonics: United States National Report to International Union of Geodesy and Geophysics 1987-1990, Reviews of Geophysics, Supplement, p. 395-404.

Harbert, William and Heiphetz, Alexander, 1992, Geological Interpretation of north Kamchatka, Russia: Constraints from Digital Residual Magnetics, Synthetic Aperture Radar, and Digital Elevation Models, AGU, vol. 73, supplement Fall Meeting, p. 137.

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†Deceased

SUMMARY PROPOSAL BUDGET

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Pittsburgh

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Harold B. Rollins

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted By NSF (If Different)
1. Harold B. Rollins/Professor	4			$ 21476	$
2. William Harbert/Assistant Professor			4	19248	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (2) TOTAL SENIOR PERSONNEL (1-6)	4		4	40724	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. (1) GRADUATE STUDENTS ($1,000/mo x 24 months)				24000	
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				64724	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) (33% of A.7.)				13438	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				78162	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.) Sun SPARC workstation 10/GX/30/32-P46 @$13,086					
TOTAL PERMANENT EQUIPMENT				13086	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				2000	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER					
( ) TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				2000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER (tuition remission 34% of B.3.($8,160)/Prof.Services($600)				8760	
TOTAL OTHER DIRECT COSTS				10760	
H. TOTAL DIRECT COSTS (A THROUGH G)				104008	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 47.5% of $39,081($55,567 excl.equip.($13,086)and tuit.rem.($3,400)) 48% of $43,681 ($48,441 excl.tuition remission ($4,760))					
TOTAL INDIRECT COSTS				39530	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				143538	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$143538	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT $		
PI/PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY — INDIRECT COST RATE VERIFICATION	
INST. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date of Rate Sheet	Initials-ORG

NSF Form 1030 (1/94) *Supersedes All Previous Editions*

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

SUMMARY PROPOSAL BUDGET

ORGANIZATION University of Pittsburgh	FOR NSF USE ONLY PROPOSAL NO.	DURATION (MONTHS) Proposed / Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Harold B. Rollins	AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted By NSF (If Different)
1. Harold B. Rollins/Professor/P.I.	2			$10738	$
2. William Harbert/Assoc. Professor/Co-P.I.			2	9624	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (2) TOTAL SENIOR PERSONNEL (1-6)	2		2	20362	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. (1) GRADUATE STUDENTS (12 months @$1,000/mo)				12000	
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				32362	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) (33% of A.7.)				6719	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				39081	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.) Sun SPARC workstation 10/GX/30/32-P46 @ $13,086					
TOTAL PERMANENT EQUIPMENT				13086	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				500	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ ____ 2. TRAVEL ____ 3. SUBSISTENCE ____ 4. OTHER ____					
( ) TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				1500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER (tuition remission 34% of B.3. ($4080)				4080	
TOTAL OTHER DIRECT COSTS				5580	
H. TOTAL DIRECT COSTS (A THROUGH G)				58247	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 47.5% of $39,081 ($55,567 excluding equip.($13,086)+(tuit rem($3400)) 48% of $2,000 ($2,680 exluding tuit.rem. ($680)).					
TOTAL INDIRECT COSTS				19523	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				77770	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$77770	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT $	
PI/PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION
INST. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked / Date of Rate Sheet / Initials-ORG

NSF Form 1030 (1/94) *Supersedes All Previous Editions*

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

Year Two: 1996

SUMMARY PROPOSAL BUDGET

ORGANIZATION University of Pittsburgh				FOR NSF USE ONLY PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Harold B. Rollins				AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-mos. CAL	ACAD	SUMR	Funds Requested By Proposer	Funds Granted By NSF (If Different)
1. Harold B. Rollins/Professor/P.I.	2			$ 10738	$
2. William Harbert/Assoc Professor/co.P.I.			2	9624	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (2) TOTAL SENIOR PERSONNEL (1-6)	2		2	20362	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)					
3. (1) GRADUATE STUDENTS (12 months @ $1,000 month)				12000	
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				32362	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) (33% of A.7)				6719	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				39081	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000.)					
TOTAL PERMANENT EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				1500	
2. FOREIGN					
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ ______ 2. TRAVEL ______ 3. SUBSISTENCE ______ 4. OTHER ______					
( ) TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER (ADPE) SERVICES					
5. SUBCONTRACTS					
6. OTHER tuition remission 34% of B.3.($4080)/Prof.Services ($600)				4680	
TOTAL OTHER DIRECT COSTS				5180	
H. TOTAL DIRECT COSTS (A THROUGH G)				45761	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) 48% of $41,681($45,761 excluding tuition remission ($4080))					
TOTAL INDIRECT COSTS				20007	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				65768	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$65768	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT $			
PI/PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

NSF Form 1030 (1/94) *Supersedes All Previous Editions*

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

Budget Explanation Page
Harold B. Rollins

	Year One			Year Two			
	FY95** 09/01/94-06/30/95	FY96*** 07/01/95-08/31/95	TOTAL YEAR 1	FY96*** 09/01/95-06/30/96	FY97**** 07/01/96-08/31/96	TOTAL YEAR 2	GRAND TOTAL
A. Personnel:							
1. H.B. Rollins (2 person-months)	10738	0	10738	10738	0	10738	21476
2. W. Harbert (2 person-months)	9624	0	9624	9624	0	9624	19248
B. 3. GSR (12 mo @ $1000/mo)	10000	2000	12000	10000	2000	12000	24000
Total Salaries:	30362	2000	32362	30362	2000	32362	64724
C. Fringe (33% of A.1 & 2.)	6719	0	6719	6719	0	6719	13438
Total Wages & Salaries:	37081	2000	39081	37081	2000	39081	78162
D. Equipment							
1. Sun SPARC 10/GX/30/32-P46	13086	0	13086	0	0	0	13086
E. Travel							
1. Field Work, NW PA	500	0	500	500	0	500	1000
2. Mtg - GSA national	0	0	0	1000	0	1000	1000
	500	0	500	1500	0	1500	2000
G. Other							
1. Materials & Supplies							
a. lab supplies	500	0	500	0	0	0	500
b. Lapidary (thin sect & peel preparation)	500	0	500	0	0	0	500
c. Other (color images & printer costs)	500	0	500	500	0	500	1000
3. Professional Services:	0	0	0	600	0	600	600
a. oxygen & carbon isotopic analysis, 15 x $40 (Brock U.)							
6. tuition remission (34% of B.3.)	3400	680	4080	3400	680	4080	8160
Total Other:	4900	680	5580	4500	680	5180	10760
H. Direct Costs	55567	2680	58247	43081	2680	45761	104008
I. IDC* (47.5% excl. G.6 & D.)	18563		18563				18563
IDC* (48% excl. G.6 & D.)		960	960	19047	960	20007	20967
J. Total	74130	3640	77770	62128	3640	65768	143538

*Pitt IDC FY95=47.5%, FY96&97=48%)
**Pitt FY95=7/1/94-6/30/95
***Pitt FY96=7/1/95-6/30/96
****Pitt FY97=7/1/96-6/30/97

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Harold B. Rollins

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Population Dynamics of Hard Clam (MERCENARIA Mercenaria) in Tidal Creek Point Bar Habitats, St. Catherines Island, Georgia.

Source of Support: American Museum of Natural History

Award Amount (or Annual Rate): $6,000 Period Covered: 08/01/92 - 07/31/94

Location of Project: St. Catherines Island, GA and U. of Pittsburgh

Person-Months Committed to the Project. Cal: 0 Acad: Summ:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Discovery and Analysis of Small-Scale (Subannual) Growth Increments in Freshwater Mussels by Means of Digital Image Enhancement.

Source of Support: NSF

Award Amount (or Annual Rate): $ 143,538 Period Covered: 09/01/94-08/31/96

Location of Project: University of Pittsburgh

Person-Months Committed to the Project. Cal: 4 Acad: Summ: 4

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $ Period Covered:

Location of Project:

Person-Months Committed to the Project. Cal: Acad: Summ:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $ Period Covered:

Location of Project:

Person-Months Committed to the Project. Cal: Acad: Summ:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $ Period Covered:

Location of Project:

Person-Months Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: William Harbert

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Tectonics and Paleomagnetism of the Kamenskoye - Penzhinskaga Guba Regions, Korya Superterrane, Northeastern Russia.

Source of Support: NSF EAR 9219271

Award Amount (or Annual Rate): $ 75,000 Period Covered: 01/01/93 - 06/30/95

Location of Project: University of Pittsburgh, Northeastern Russia

Person-Months Committed to the Project. Cal: Acad: Summ:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Discovery and Analysis of small-scale (Subannual) Growth Increments in Freshwater Mussels by means of Digital Image Enhancement.

Source of Support: NSF

Award Amount (or Annual Rate): $ 143,538 Period Covered: 09/01/94-08/31/96

Location of Project: University of Pittsburgh

Person-Months Committed to the Project. Cal: 4 Acad: Summ: 4

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $ Period Covered:

Location of Project:

Person-Months Committed to the Project. Cal: Acad: Summ:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $ Period Covered:

Location of Project:

Person-Months Committed to the Project. Cal: Acad: Summ:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Award Amount (or Annual Rate): $ Period Covered:

Location of Project:

Person-Months Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages if necessary.

Laboratory:

Fully equipped Geology Lab at the University of Pittsburgh for making thin sections and acetate peels. Unlimited availability.

Clinical:

n/a

Animal:

n/a

Computer:

Fully equipped computer graphics and image processing facility at the University of Pittsburgh. Unlimited availability.

Office:

University of Pittsburgh Department of Geology and Planetary Science, office and secretarial assistance. Unlimited availability.

Other: Computer-interfaced, fully equipped stable isotope facility at Brock University. Unlimited availability. Field sampling equipment available at Pymatuning Ecology Laboratory (University of Pittsburgh), a few miles from French Creek Field Sampling Site.

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

Computer graphic laboratory and image processing software (University of Pittsburgh). Stable isotope lab (Brock University).

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

Computer consultant (University of Pittsburgh). Unlimited availability. Secretary assistance, Department of Geology and Planetary Science, University of Pittsburgh. Unlimited availability.