Report of the Committee of Visitors for Deep Earth Processes Section - Earth Sciences Division Research Programs, 2002-2004

The Committee of Visitors (COV) met on August 29 – 31, 2005 at the NSF Headquarters in Arlington, Virginia to review the Deep Earth Processes Section of the Earth Sciences Division. The programs that are part of this Section are: Geophysics, Petrology and Geochemistry, Tectonics, Continental Dynamics and EarthScope.

The 2005 COV members are: Sharon Mosher, Chair (University of Texas at Austin), Cynthia Dusel-Bacon (USGS at Menlo Park), Gabriel Gwanmesia (Delaware State University), Robert Hamilton (retired; formerly National Research Council), James Jackson (Cambridge University), Louise Kellogg (UCAL Davis), Joaquin Ruiz (University of Arizona), Carl Sondergeld (University of Oklahoma), Manfred Strecker (Universitat Potsdam), and Donna Whitney (University of Minnesota).

The charge to the COV was to review action taken by the programs during the last three fiscal years (2002-2004), evaluate the products and contributions supported and overseen by the programs over the last three years, and to review and comment on the effectiveness of the programs, areas needing improvement, and recommend future courses for the programs. For the review of the proposal actions, the COV was to examine the integrity and efficiency of the processes used to solicit, review, recommend, and document proposal evaluation and actions, including the effectiveness of the program's use of NSF's two merit review criteria and the relationship between decisions and program goals.

The staff did an excellent job of providing the COV a wealth of information to help with the review, including tables and graphs showing a wide variety of statistics for the three completed fiscal years that were pertinent for answering questions on the COV template and information on outcomes and awards. In addition, Program Directors made helpful presentations to the COV on their programs. The COV would like to thank the staff for all of their help. We also were provided the 2002 COV report (COV chaired by Gail Ashley) that covered the same programs plus others. We had access to all proposal jackets for one disciplinary panel for each program, generally for a panel in 2004. We looked at the ranking and scores of all proposals provided for each disciplinary panel, and then carefully evaluated 20 to 35 proposals per program. We selected for careful review all proposals that were reviewed with mixed results, either between reviewers or between the panel and mail reviewers, some funded and some not, plus examples of unanimously good proposals and unanimously poor proposals.

The COV formed subgroups to consider each program in detail, with one person responsible for writing up a specific program and another as their backup. The subgroups were:

Geophysics: Louise Kellogg – lead reviewer, Gabriel Gwanmesia – back up, James Jackson, Robert Hamilton, Carl Sondergeld

Petrology & Geochemistry: Joaquin Ruiz – lead reviewer, Cynthia Dusel-Bacon – back up, Gabriel Gwanmesia, Louise Kellogg, Donna Whitney

Tectonics: Donna Whitney – lead reviewer, Manfred Strecker – back up, Cynthia Dusel-Bacon, Sharon Mosher, Joaquin Ruiz

Continental Dynamics: Robert Hamilton – lead reviewer, Carl Sondergeld – back up; entire committee

EarthScope: James Jackson – lead reviewer, Carl Sondergeld – back up, Sharon Mosher, Manfred Strecker, Robert Hamilton

General Observations of the COV

Overall Program

The COV was very impressed overall with the proposal review process, program management, interactions and collaboration among Program Directors, and external collaboration with other Directorates and Divisions in GEO. Based on our review and evaluation of proposal jackets and the material provided to us, we made the following observations:

- Universally Program Directors provide fair and well documented decisions that weigh both mail and panel input.
- Interaction and cooperation between Program Directors appears to be better than ever before, and we strongly encourage this interaction to continue.
- The Deep Earth Processes Section does a very good job of balancing individual investigator projects and larger scale collaborative projects. By its very nature, many of these projects are multidisciplinary and/or interdisciplinary.
- The work funded by the Deep Earth Processes Section programs is generally excellent. The quality of the science with NSF funding has been superb and the increase in our knowledge of deep Earth processes and the evolution of the deep Earth is outstanding. The quality of the science is well documented by the outcomes.
- The Program Directors are a model of pro-activity in terms of working with other Directorates and Divisions within GEO.

The COV noted the large overlap between individual programs within the Deep Earth Processes Section. We believe that Program Directors are essential in keeping boundaries fluid between the somewhat arbitrary program boundaries.

- Current Program Directors are excellent and work well together sharing proposals, funding and ideas. It is critical to maintain and encourage this interaction.
- Such interactions with new Surface Earth Processes Section need to be developed if not already in place; we see a number of areas of overlap, particularly in the Tectonics and Petrology and Geochemistry programs. As the two new Sections evolve, we caution that the somewhat arbitrary boundary between deep and shallow Earth processes should not become a barrier to integrated and multi/interdisciplinary research.
- We recommend that new Program Directors emulate the practices of the current Program Directors, particularly those in Geophysics, Petrology and Geochemistry, and Tectonics. Also, the current Program Directors need to be fostered so that they maintain their high level of dedication.

The COV strongly supports the current review process that consists of a combination of mail and panels reviews. The two provide an excellent balanced review process. Program Directors work extremely hard to get appropriate assessment of proposals via both mail and panel reviews, and these provide appropriate checks and balances to ensure fair evaluation of proposals**.**

- External reviewers are selected with the appropriate expertise to judge the specific proposal and provide insights into the proposal – goals, techniques, etc. – that are critical to its assessment. Panels do not have the range of expertise needed to adequately evaluate each proposal. Without mail reviews flawed proposals could well be funded (i.e. they sound good to a knowledgeable non-expert but have fundamental flaws or are not feasible).
- The panel on the other hand sees all the reviews and can evaluate whether specific reviewer comments are generally held by others. They also see the range of proposals in that round and can consider the relative merits.
- We found many instances where mail reviews were critical in deciding funding and others where the panel's input was instrumental. The program directors carefully

weighed both and used whichever provided the best information. We saw no bias towards either panel or mail reviewers.

Additional recommendations with regards to the current processes and management we wish to highlight are:

- The Program Director workload is very high relative to rest of the GEO Directorate, although the staff is extremely efficient and maintains very good dwell time statistics. We note the increase in personnel since the last COV but stress the need for even more personnel to make the workload comparable with the rest of the Division. Such heavy commitments cut into their ability to interact with community and other programs plus can cause burn out. Given the high quality of the Program Directors at this time, it is critical to alleviate some of the workload to prevent a return to the problems observed by the last two COVs.
- We strongly encourage the continuation of two deadlines and panels per year for Geophysics, Petrology and Geochemistry, and Tectonics. EarthScope may need to go to two deadlines and panels per year if and/or when proposal pressure increases sufficiently.
- We recommend increasing the size of the Tectonics and Geophysics panels by one or more to increase the discipline diversity. We would like to encourage the continuation of the practice of having a younger person serve on a panel for one round. This practice provides an opportunity to increase the breadth and diversity of panels while providing an excellent learning experience for new potential PIs.
- We recommend EAR encourage more CAREER proposals; we believe such proposals will be beneficial to the health of the Earth sciences. CAREER awards are a prerequisite for the prestigious Presidential Early Career Awards for Scientists and Engineers (PECASE).
- The COV supports the goals and favors continued support of ISES (Integrated Solid Earth Sciences) and other similar forums and workshops. They provide an important mechanism allowing the EAR community to discuss future directions, fundamental problems and potential avenues of addressing them. Such discussions are likely to lead to more collaboration and coordinated efforts at answering larger scale problems. Our science tends to be very individualistic and many major advances require a more coordinated effort; these forums and workshops are one way of encouraging cooperation.
- Recognizing the need to interest individuals from underrepresented groups in Earth science at the earliest possible age, we suggest one possible avenue to do this might be through installing EarthScope instruments on K-12 school grounds and integrating the big picture science and data collection with the school's science curriculum. Perhaps minority "magnet" schools could be given a high priority in site selection.

Although we found a striking similarity in the performance of each program, some specific observations relate only to individual programs. We also note that EarthScope is a new program since the last COV, and the last two COVs noted serious problems with the Tectonics program which were starting to be addressed at the time of the last COV. We focused on the future of the EarthScope program in our review and paid particular attention to the Tectonics program to ensure that the previous problems had been rectified. A short summary from each subgroup reviewing individual programs is given below that highlights observations most pertinent to the individual program

Geophysics Program

The Geophysics program supports a diverse spectrum of science addressing a range of important questions in the Earth's interior. This diversity is a significant strength of the program, and allows

the Program Directors to respond rapidly to the evolving needs of the scientific community and to take advantage of emerging scientific opportunities.

The COV commends the Program Directors on the high quality of their work. They work extremely hard to get appropriate assessment of proposals via both mail and panel reviews, and they provide appropriate checks and balances to ensure fair evaluation of proposals, especially when referees disagree in their assessment. The Geophysics Program Directors are also flexible and creative in working with other Programs Directors to co-review and co-fund proposals with other programs when appropriate. This pro-active approach has provided encouragement to interdisciplinary projects.

During the time period covered by this review, Robin Reichlin was the permanent Program Director and was assisted by two rotators, Kaye Shedlock (2003-2004) and David Fountain (2002), who are now permanent program directors of other Deep Earth Processes programs. Both commented on the high quality mentoring they received from Robin Reichlin while they were rotators. She is an enthusiastic, insightful, and effective individual who clearly puts enormous energy into the successful Geophysics program. Since the time period of our review, an additional permanent program director has been added as well as a new rotator. We view this as essential with the number of proposal submissions reaching over 400 in 2004.

The previous COV noted that the panel reports were sometimes not as complete as they might be. We find that this issue has largely been addressed. Adjustments in the way panel reports are written, and combined with the adoption of the Electronic Jacket system, have resulted in panel summaries that are clear and provide appropriate justifications for the panel recommendation and feedback to PIs.

The organizational excellence of this program has resulted in excellent science, with interesting and high-impact discovery at the frontiers of science, development of a diverse and talented scientific workforce, and state-of-the-art scientific tools for discovery and learning. This is one of the few programs in any agency that funds research in deep Earth. These results are discussed in more detail below in the COV template.

Because of the workload and the topical diversity of the program, the COV felt that the program could benefit from a larger panel. This would be a cost-effective way to help manage the workload and would allow the appropriate expertise for the wide range of proposals this program handles.

Petrology and Geochemistry

The Petrology-Geochemistry program funds research related to the chemical evolution of the whole Earth. The program accepts proposals that include fundamental geochemical and petrological questions and application of geochemistry and petrology to the physical evolution of the Earth. Research appropriate for this program includes experimental, field and analytical work. Petrology and geochemistry is a highly interdisciplinary area of research and includes collaborations and fieldwork around the world.

The Petrology and Geochemistry program has been consistently well run for some time. The last COV did not find major problems with the program. The Program Directors for the time of this review are Sonia Esperanca as the permanent Program Director and Thomas Wagner (2003-2004) and Glen Mattioli (2002) as rotators. Currently the program has two permanent Program Directors – Sonia Esperanca and William Leeman - reflecting the very high load of proposals in this program.

In 2004 the program received an unprecedented number of proposals, close to 400, with success rates dropping as the budget decreased and the number of proposals increased. From 2002 to 2004 the success rate for the program dropped from about 35% to 30%. The average award in 2004 was about $210,000 and the average duration was 2.76 years. The committee of visitors focused on proposals evaluated by the March 2004 panel. We evaluated carefully how ~30 proposals were treated. These proposals were taken as examples of unanimously good proposals, unanimously poor proposals and examples of proposals that were reviewed with mixed results, some funded and some not.

Each proposal typically gets more than three mail reviews even though more are requested. From 2002 to 2004, about 74% of mail reviewers responded positively for a request for a review. This percentage of review response has not changed during the three years that we are evaluating. The second review of the proposals is by a panel, which is now seven members strong, with a one-year rotating junior scientist invited for one panel. The review process seems very good, and we recommend that it remains as is with both mail and panel reviews and two panel meetings a year instead of one, as was suggested as a possibility.

The Petrology and Geochemistry program is a model for a well-run program. Sonia Esperanca, who was the lead program officer for the period of the evaluation, is clearly an energetic, dedicated and innovative manager that leverages her funds with other NSF funds. She is interested in diversity and international collaborations and is clearly fair in the way she handles the review process. The summaries that she wrote for all the grants we reviewed were carefully documented and her summaries accurate. The dwell time for response is good even though the proposal load is high. The program manager also communicates with PIs very well.

There is no question that the quality of the science that has been done by the geochemistry and petrology community with NSF funding has been superb and that the rate of increase in our knowledge of the Earth's geochemical makeup and evolution is outstanding. The subgroup is concerned, however, that the field of geochemistry and petrology will soon have leadership in other countries if the budget of this program does not increase in the future. In mineralogy, Germany has taken great strides by funding important science and in geochemistry France and the UK also are making major advances.

Tectonics Program

The Tectonics program funds research related to the structural modification of the lithosphere through time, with an emphasis on continental tectonics. Research supported includes field, analytical, modeling, and theoretical studies at various time and spatial scales. Tectonic research is highly multidisciplinary by definition and can involve both physical and chemical characteristics and processes in Earth dynamics. Tectonics is the underlying framework of most Earth processes, from the surface to the base of the lithosphere.

The last COV (2002) identified major problems in management of this program, but noted that 2001-2002 was a time of major transition in personnel. In the 2002-2004 review period, we found that all significant management problems have been solved by the permanent Program Director David Fountain and temporary Program Directors Arthur Goldstein (2002-2003) and Stephen Harlan (2003-present). Evaluation of all aspects of this program related to proposal review, decision, and outcomes strongly shows that this is a superbly managed program. The outstanding management of this program can be seen in the statistics related to proposal dwell time, number of mail reviews received/proposal, the selection of reviewers and panel members, the wide range

of high-quality, innovative projects funded, the meticulous Program Director comments and review analysis, and the strong interactions with other Program Directors.

The COV subgroup focused on proposals evaluated by the March 2004 Tectonics panel. Of approximately 100 proposals, the subgroup examined approximately 35 in detail. We examined a few proposals in the groups with very high and very low rankings by both mail and panel reviews to 'calibrate' ourselves and assess whether certain groups or types of research were favored or not. In all cases, we strongly concurred with the Program Director's decision on these examined proposals. We focused mostly on proposals for which there were discrepancies between mail and panel ratings, and proposals in the 'gray zone' in which the correlation between ranking and award/declination can not be discerned from inspection of the rating data. With one exception, all proposals had sufficient mail reviews (> 3). In all cases examined, the path to the decision could be traced easily in the mail reviews, panel summary (although in some cases this was the weak link), and the program officer summary. Again, we were impressed by the thoroughness of the program officers' evaluation, the amount of feedback given to PI's, and the fairness of the decisions.

The panel review process appears to be highly efficient and fairly effective. Panel members and mail reviewers reflect a good balance in terms of expertise, geographic base, gender, and career track. COV subgroup members emphasized the importance of having a panel member with expertise in field-based active tectonics/neotectonics or paleoseismicity, given the number of proposals submitted in these fields. Nevertheless, we saw no negative effect on the range of proposals funded when the panel has lacked such a person on the panel.

Panel responsibilities for individual proposals are outlined in advance, and each proposal is read by at least 4 panelists, with one panelist designated as a discussion leader and another as the scribe for the panel summary. This procedure allows for advance evaluation of the proposals (before the panel meeting) and thorough evaluation at the panel meeting, and should lead to thoughtful and informative panel summaries. In most cases, panel summaries are short but sufficiently informative, but in several cases within the small subset of proposals that we examined, the summaries were too terse and appeared to repeat mail review comments without enough context for these comments to be useful.

Proposals submitted by active panel members are not considered by the panel, but are assessed by the program officers based only on mail reviews. We echo the comment made by the 2002 COV that it is important that these proposals receive as many mail reviews as possible (>>3).

The program officers do an excellent job of balancing mail reviews, panel recommendations, and funding priorities (e.g., support for early career investigators, support for high risk and innovative projects, and support for a range of research approaches and activities). This is all the more impressive given the high work load of the program officers and their level of involvement with cross-disciplinary activities (e.g., workshops and other GEO/NSF workshops and initiatives).

The COV subgroup noted that a number of proposals examined contained international field work but no international collaboration (or incompletely documented international collaboration). This absence did not affect the outcome of otherwise strong proposals. Even in these cases, however, it would be beneficial to the projects and to NSF's mission of fostering global scientific research if the PI's could be encouraged to establish formal international collaboration. Although it is ultimately the responsibility of PI's to make these ties, program officers could encourage these activities and facilitate co-funding of international proposals.

Continental Dynamics Program

This unique program supports large, multidisciplinary projects that address major problems related to geodynamics requiring long-term planning, substantial funding and collaborative effort. Continental Dynamics has a unique strength in addressing complex questions which require diverse expertise. For example, such questions include: the causes of horizontal extension in active convergent boundaries; the retreat of subduction zones exemplified by the Apennine-Adriatic system; the causes of upper mantle velocity variations under the Rocky Mountains and the magnitudes of fluctuations in paleo-sea level.

Many of these projects are conducted internationally, adding complexity to the planning and execution and a potential ambassadorial role for scientists. For example, Continental Dynamics demonstrated agility in responding and participating in a multinational study of the collapse of the dome of the Montserrat Volcano. A particularly precious consequence of the global scope of Continental Dynamics is the story of the development of a strong cultural exchange between people in Northern California and a small town Nepal. These opportunities are priceless in displaying Americans at their best to the world.

The subgroup noted cases of international projects where mail reviews by international scientists familiar with the area were not requested. Such reviews would provide valuable, perhaps essential, perspectives. The high visibility of many Continental Dynamics projects in international areas necessitates that scientists from those areas be informed of the work, as a matter of good diplomacy, if not scientific courtesy.

This program encourages a pre-proposal for project planning prior to submission of a proposal. The COV endorses this approach as it avoids wasted effort on the part of potential investigators. Although the Program Director communicates with the PIs by phone, response letters are form letters; a more personal response would undoubtedly be welcomed by PIs. We found the panel summaries very good; they could serve as a model for other programs.

As this program is complex and typically multidisciplinary, it could create the impression that young PIs need not apply; therefore, inter-disciplinary teams should engage young PIs. As geodynamic studies can include tectonics, geophysics, petrology, and other disciplines, it is essential that the Program Directors effectively manage the boundaries between EarthScope, Continental Dynamics, and other programs. As EarthScope grows so should the CD involvement. Good tectonic, geochemical and geodynamic problems have no borders.

We considered the large overlap with the new EarthScope program, but agreed that some of the best locations to address the types of questions covered by the Continental Dynamics program lie outside North America and thus outside the scope of EarthScope. We advise a close working relationship between the two programs and anticipate that shared funding of proposals will increase as the EarthScope facilities are further developed.

Because of the multidisciplinary nature and large number of PIs on CD projects and the need for panelists with experience with such projects, we noted that panelists often have proposals or pre-proposals under consideration by the panel. We recommend that this situation be avoided and a small pool of back up panelists be established that can take a panelist's place for a specific panel meeting during their term of service if the panelist submits a proposal or pre-proposal for that panel meeting. We do not think that either excusing the panelist or relying solely on mail reviews would solve the conflict of interest problem. We also encourage 3 year panel terms.

Continental Dynamics has sponsored a number of planning and other workshops on diverse topics. The international flavor promotes global cooperation among scientists and facilitates communication among and across disciplines.

Continental Dynamics funds projects that capture the imagination and thus can play an important role in reaching out to the nonscientific community. The program has sponsored films on scientific drilling and on field work in Tibet (Nanga Parbat – Naked Mountain). Continental Dynamics has many showcase projects and is appropriately documenting these for public support and awareness. The superb IMAX movie "Forces of Nature" sponsored by NSF highlights science funded by Continental Dynamics and other programs in the Deep Earth Processes Section.

EarthScope Program

The COV period of EarthScope differed from that of the other programs reviewed here. There was only one proposal round (in 2004) in this period, so there were no precedents or trends to examine. Furthermore, during this period there was no full-time Program Director to manage the program or handle the proposals. The management job was particularly demanding, because it required someone to interact and be involved with the numerous groups concerned with managing and developing the EarthScope facilities, as well as with the NSF side of proposal processing and other incidental activities concerned with EarthScope science. These tasks were carried out by a temporary Program Director who was performing these duties in addition to other assignments elsewhere in the EAR. In the circumstances, they were carried out well, with difficult decisions being made through a combination of mail and panel reviews moderated by the part-time Program Director. The process demonstrated the effectiveness of this flexible, combined assessment approach, which we fully support.

This first EarthScope round was also unusual in that it contained several proposals that are best described as 'service' activities, necessary to develop the software and data handling procedures that must be in place when the main EarthScope data become available, if they are to be used effectively. Other unusual proposals were for work that had urgent time requirements, for example analysis of initial SAFOD pilot-hole cores that would guide future data sampling or core retrieval, or analysis of geophysical data that would guide future SAFOD drilling activity. It was important to give such proposals priority, at least in consideration, and sometimes the panel or Program Director had to weigh the priority more than the scientific merits in the overall ranking. The final Program Director and/or panel decision appeared to be based on evidence that such proposals had been discussed by the EarthScope community and that a consensus had been reached that the endeavor was appropriate and being carried out by the right people for the job. These decisions were properly documented and, in our opinion, justified. We anticipate that future EarthScope rounds will change in emphasis, with most proposals being concerned with data analysis and interpretation, allowing them to be evaluated in the more usual manner.

This COV subgroup thought the panel membership was very good. There is a good distribution of expertise, and the panel is not biased by members with a strong involvement in EarthScope.

EarthScope will be very good for promoting the scientific careers of young professionals; the data will be available to everyone regardless of whether or not they have a funded proposal. It will also be important for education and outreach as the data can be used in education at all levels.

Because EarthScope is a new program we also considered its future direction. EarthScope represents an unprecedented opportunity within EAR as well as many challenges.

- In terms of funding, as the facility becomes more fully operational and the science budget for EarthScope increases, it is important that the portion devoted to operations and maintenance decrease and be small relative to that for science. Also it is important that science funding become more focused on solving significant problems rather than more immediate "service-oriented" activities as seen in the first round.
- It is critical to increase the overall EAR science budget to make the most of the opportunities available because of the EarthScope facility. Many investigators currently supported by other programs in Deep Earth will be conducting research using EarthScope data, especially younger researchers, which will help take some of the pressure off these programs by focusing research in these directions.
- Success of EarthScope depends on positive interaction between it and other related programs in the Deep Earth Processes Section. It is important for Program Directors in other programs to view the advent of EarthScope as a benefit for researchers in their area – an exciting time where major, fundamental questions can be addressed using new facilities that could not be considered in individual investigator and small collaborative projects.

It is rather early to highlight achievements of EarthScope, which is currently in the phase of developing facilities. Nonetheless, two achievements already stand out:

1. SAFOD. It is undoubtedly an achievement to have drilled a hole through an active fault to earthquake-generating depths. While the oil industry is used to having to hit targets of 10m in size that are a few kilometers distant, what distinguishes the SAFOD project is the uncertainty in knowing where the target itself actually is. The intention is to drill through a patch of fault that has repeating earthquakes which may only be a few tens of meters in size. Although it is known that such patches exist, it is very difficult to locate them accurately in space. Thus work is currently underway to improve the locations of these earthquakes to the necessary extent, and is stretching seismological capabilities to the limit.

2. EDUCATION AND OUTREACH. E&O is a major component and opportunity for EarthScope. This part of the program has already produced startling visual images, for example movies of the deforming velocity field in California that will attract widespread attention. Other software development is underway to allow real-time access to EarthScope earthquake data, including seismograms, in high schools as well as research institutions, which should greatly increase awareness of earthquakes and seismic hazard issues. Another program involves the making of a broadcast-quality video that demonstrates the breadth of the EarthScope vision and ambition and its context in the study of how our planet works.

Agency Wide Issues

The COV noted three agency wide issues:

1) Better cyberinfrastructure is needed - i.e. more funding for cyberinfrastructure and for more permanent, stable platforms (homes) for databases, software, etc. that are being developed as part of Geoinformatics and other NSF ITR and cyberinfrastructure programs.
2) The difficulty in meeting science budget needs for MREs such as EarthScope in times of flat or declining budgets. It would be a shame to not take the full advantage of the MRE facilities, but it should not be at the expense of core programs where the innovation and ideas are generated that advance the science and lead to MRE proposals.
3) The connection between CAREER proposals and Presidential Early Career Awards for Scientists and Engineers (PECASE) awards. CAREER awards require excellent science and a well developed education and/or outreach component. They are a prerequisite for

receiving a PECASE award which is given for showing exceptional potential for leadership at the frontiers of knowledge. Many exceptional young scientific leaders are concentrating on pushing scientific frontiers, not integrating such research with education and outreach. Thus many deserving PECASE awardees are overlooked, and we question the reason for the prerequisite.

FY 2005 REPORT TEMPLATE FOR NSF COMMITTEES OF VISITORS (COVs)

Date of COV: August 29 – 31, 2005
Program/Cluster: Deep Earth Processes Section
Division: EAR
Directorate: GEO
Number of actions reviewed by COV[1]: Awards: 49 **Declinations: 74 Other:** 10
Total number of actions within Program/Cluster/Division during period being reviewed by COV[2]: Awards: 1200 **Declinations:** 1900 **Other:** 110
Manner in which reviewed actions were selected: We looked at the ranking and scores of all proposals provided for each disciplinary panel, and then carefully evaluated 20 to 35 proposals per program. We examined a couple proposals in the groups with very high and very low rankings by both mail and panel reviews to 'calibrate' ourselves and assess whether certain groups or types of research were favored or not. Then we focused mostly on proposals for which there were discrepancies between mail and panel ratings, and proposals in the 'gray zone' in which the correlation between ranking and award/declination can not be discerned from inspection of the rating data.

PART A. INTEGRITY AND EFFICIENCY OF THE PROGRAM'S PROCESSES AND MANAGEMENT

Briefly discuss and provide comments for *each* relevant aspect of the program's review process and management. Comments should be based on a review of proposal actions (awards, declinations, and withdrawals) that were *completed within the past three fiscal years*. Provide comments for *each* program being reviewed and for those questions that are relevant to the program under review. Quantitative information may be required for some questions. Constructive comments noting areas in need of improvement are encouraged.

A.1 Questions about the quality and effectiveness of the program's use of merit review procedures. **Provide comments in the space below the question**. **Discuss areas of concern in the space provided.**

[1] To be provided by NSF staff.
[2] To be provided by NSF staff.

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCEDURES	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE[3]
1. Is the review mechanism appropriate? (panels, ad hoc reviews, site visits) Comments: The COV strongly supports the current review process that consists of a combination of mail reviews and panels. The two provide an excellent balanced review process. Program Directors work extremely hard to get appropriate assessment of proposals via both mail reviews and panel reviews, and these provide appropriate checks and balances to ensure fair evaluation of proposals**.** The Continental Dynamics Program is unique to this Section in that it encourages pre-proposals. The COV endorses this practice for Continental Dynamics and considers it especially appropriate considering the scale and scope of proposals. For international projects in this program, reviewers who are knowledgeable from those areas would add an important perspective.	Yes
2. Is the review process efficient and effective? Comments: The process is effective although not the most efficient. However to make it more efficient, you would need to go to either just mail reviews or just panel reviews. Based on our review of the program and Program Director decisions, we think that the fairness and effectiveness would suffer in that case. Effectiveness should not be lost in support of efficiency. That said, however, the current process does well overall if a sufficient number of reviews is received, and the dwell times are low. Thus for a review process using both mail and panel reviews, it is very efficient. Tectonics: we support the new policy of 2-year terms for panel members, as this will increase the likelihood of individuals agreeing to serve on the panel and will reduce panelist 'burnout'. We also support the involvement of an early career scientist as 1-time visitors to each panel for several of the programs.	Yes
3. Are reviews consistent with priorities and criteria stated in the program's solicitations, announcements, and guidelines? Comments: Most proposals are in response to general solicitations, but when specific solicitations are involved (i.e. CAREER, RUI, etc.) the reviewers respond appropriately for the most part. For the new program, EarthScope, the call for proposals particularly emphasized the E&O component, which was reflected and in the proposals received and funded.	Yes

[3] If "Not Applicable" please explain why in the "Comments" section.

4. Do the individual reviews (either mail or panel) provide sufficient information for the principal investigator(s) to understand the basis for the reviewer's recommendation? Comments: Mail reviews are variable but are generally informative. The majority contain detailed and thorough analyses of the proposals and were done carefully, thoroughly and following the stated criteria. In some cases there is a disconnect between the comments and the rating, and a wide range of opinions corresponds to similar ratings. In contrast the panel reviews were sometimes minimalist and not very useful – see answer to #5 below for specifics. In addition, the comments of the Program Director are very useful in explaining how decisions were made when mail and panel reviews disagree, for example and explaining reviewer and panel comments to proponents in case of rejection.	Yes
5. Do the panel summaries provide sufficient information for the principal investigator(s) to understand the basis for the panel recommendation? Comments: The quality varied by program. Geophysics: The panel summaries seem to have improved considerably since the last COV. Panel summaries are generally clear and provide useful feedback to the principal investigators. Petrology and Geochemistry: The panel summaries were sometimes minimalist and not very useful to the PI. Tectonics: In some cases panel summaries should be more informative. This applies to those panel summaries that were very terse and did not reflect well major proposal aspects that led to the proposal's success or rejection. This comment, however, does not extend to the program directors' evaluations, which are superb and make up for deficiencies in panel summaries. Continental Dynamics: The panel reviews for Continental Dynamics are exceptionally thorough and would make an excellent model for the other programs. EarthScope: The panel summaries were particularly good explaining the unusual circumstances and decision-making that was necessary in this first EarthScope round.	**Yes**
6. Is the documentation for recommendations complete, and does the program officer provide sufficient information and justification for her/his recommendation? Comments: Geophysics: The Program Director Robin Reichlin's comments in particular are very well articulated, and provided excellent justification for the decisions, especially where	Yes

either the panel or the mail reviews disagreed. Petrology and Geochemistry: The program director, Sonia Esperanca, does an excellent job at summarizing the panel's view, the mail review's comments and justifying her actions Tectonics: The Program Directors have done an excellent job documenting decisions. The major deficiencies from the 2002 COV have been addressed. Documentation is complete and thorough now, all correspondence between the Program Directors and PI's can be traced and evaluated. Dave Fountain's meticulous summaries are more informative than the panel summaries – he weighs proposals, panel summaries, and other considerations and makes fair, well articulated, and informed decisions. Reviews by rotators Goldstein and Harlan are similarly excellent. Continental Dynamics: The Program Director, Leonard, Johnson, is particularly effective in communicating, including personal contacts by phone. EarthScope: The Program Director, Kaye Shedlock, did a particularly good job here in circumstances that were difficult because of (a) the unusual circumstances of the first EarthScope round and (b) the work was being done by a part-time Program Director on her own, under exceptional pressure. We congratulate her on her achievement; she made difficult decisions that were properly documented and, in our opinion, justified. Her reasons were clear and well-presented in this EarthScope round, justifying the unusual circumstances of some decisions. Some of the Program Director's feedback to PI's was a little terse and brief, which we attribute to the difficult circumstances in which the feedback was delivered under pressure of time. Now EarthScope has a full-time Program Director, we anticipate that the feedback will be rather fuller and will help the PIs understand the reasons for the decision and provide constructive advice. As this is a new program and PIs are still discovering what is fundable, these responses should be particularly diplomatic and helpful. We suggest using those of program directors in Tectonics, Geophysics, or Petrology and Geochemistry as a guide.	
7. Is the time to decision appropriate? Comments: Although the workload in these programs is extremely high, proposals are reviewed in a timely fashion. The proportion of proposals that were decided with a dwell time of < 6 months increased during 3 years under review from 60% to almost 87% in Geophysics. 84% to 90% in Petrology and Geochemistry, and 50% to 92% in Tectonics. The complexity of most Continental Dynamics proposals, both in the number of investigators, the location of the field work (internationally), and equipment availability, demands a more deliberate approach than in a typical program. So even though the current dwell time is higher than the other programs, the COV felt it was understandable. It also has decreased over the 3 years of the review; proposals that were decided with a dwell time of < 6 months rose from 14% to 50% and the average number of months to decision decreased from nearly 9 to about 6.5 months. For the new program EarthScope, in its first year, the average dwell time on this round was good but longer (6 months 7 days) than optimal. This lag was because the program	Yes

had no full-time Program Director and the work was being done by a part-time rotating Program Director. We anticipate this situation will improve with the new fulltime Program Director.	

8. Discuss any issues identified by the COV concerning the quality and effectiveness of the program's use of merit review procedures:

We evaluated the number of reviewers/proposal, the breadth of reviewers, composition of the panels, and the documentation of decisions, and we have no major concerns. Efforts should continue to obtain sufficient numbers of mail reviewers and to have a diverse panel in terms of expertise and background of panelists. This is clearly a very effective program.

The combination of panel and mail reviews works well to ensure a fair process. It is clear that the program director is key since he/she identifies the reviewers, the panel members and then takes all the advice of these folks and decides the fate of the proposal. For all programs, the Program Directors have sound judgment and thus the programs are fairly run. We believe that both panel and mail reviews are necessary.

A.2 Questions concerning the implementation of the NSF Merit Review Criteria (intellectual merit and broader impacts) by reviewers and program officers. **Provide comments in the space below the question. Discuss issues or concerns in the space provided.**

IMPLEMENTATION OF NSF MERIT REVIEW CRITERIA	**YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE[4]**
1. Have the individual reviews (either mail or panel) addressed both merit review criteria? Comments: Yes; the great majority of reviewers address both merit and review criteria, and the number of reviews that address both criteria is increasing with time. This is in great part owing to the organization of the review form on FastLane. It is now a rare proposal that does not address both review criteria, though the view on what constitutes a "broader impact" varies between reviewers.	Yes
2. Have the panel summaries addressed both merit review criteria? Comments: Panel summaries address both criteria.	Yes
3. Have the *review analyses* (Form 7s) addressed both merit review criteria?	Yes

[4] In "Not Applicable" please explain why in the "Comments" section.

Comments:	
The review analyses address both criteria, but Form 7 only lists reviewers and panel members. The review analyses are excellent, very well articulated, and provided excellent justification for the decisions, especially where the either the panel or the mail reviews disagreed	

4. Discuss any issues the COV has identified with respect to implementation of NSF's merit review criteria.

Implementation of the intellectual merit criterion is straightforward, but how is the broader impact criterion used? Is there a hierarchy among the possibilities? This comment is based on the observation that there are inconsistencies in emphasis on broader impacts among proposals and in how individual reviewers and panels perceive them. In some cases training of graduate students is seen as a sufficient broader impact whereas in others a lack of involvement of undergraduate students or some sort of outreach activity is seen as a negative. In each case we evaluated, the uses of the criteria are documented, and the committee agrees with decisions, but a better agreement on what constitutes appropriate "broader impact" would help. Another example particularly pertinent to EAR proposals is: in some cases the lack of an international collaborator for work in another country negatively impacts a proposal, and in other cases the same lack has little effect. We understand that the broader issues are used in the context of the overall proposal, but more clarity about this criterion would be useful (but not more emphasis). In this respect it should be emphasized to proponents who plan to work in other countries that collaboration with local scientists is an important aspect of doing research. Lack of respect for this important point has resulted in countries that have made the exportation of rock and soil samples very difficult. A formal collaboration would ease these problems and build strong international networks, which are especially useful for junior scientists, including students.

EarthScope: This was an unusual proposal round. A number of proposals were concerned with 'service' to the EarthScope initiative, involving setting-up of data handling procedures and software. Several of these were clearly necessary, even though the science involved may not have been particularly innovative or exciting, and therefore attracted mail reviews that were unenthusiastic. The panel sometimes recommended that these were nonetheless necessary and even urgent (timely), and should be funded. The Program Director generally supported the panel if (a) there was evidence the PI had discussed the intended data handling with the EarthScope community and gained their approval for the intended approach, and (b) there was general agreement that the PI(s) were the right people for this necessary job. We reviewed the Program Director's decisions in these cases and supported her choice. We anticipate that future proposal rounds will have less of these service proposals, as proposals shift towards an emphasis of using the data rather than acquiring and archiving it. In these future circumstances there should also be less of an impression that 'consensus' or 'approval' is needed from the EarthScope community before a project is funded. The experience of this 2004 round exhibited very well the advantages gained by the flexibility of NSF's system of combined mail and panel reviews moderated by the Program Director's discretion.

A.3 Questions concerning the selection of reviewers. **Provide comments in the space below the question. Discuss areas of concern in the space provided.**

SELECTION OF REVIEWERS	YES , NO, DATA NOT AVAILABLE, or NOT APPLICABLE[5]
1. Did the program make use of an adequate number of reviewers? Comments: ***Mail Reviewers*** <u>Geophysics, Petrology and Geochemistry, Tectonics:</u> The program makes a serious effort to get sufficient referees, although it apparently is sometimes difficult to get an appropriate number of responses (<u>≥4</u>). We recognize the difficulty here; we brainstormed a bit and only came up with ideas that have already been tried (such as asking younger reviewers who may respond at a higher rate than more senior scientists). In all cases the Program Director asks for enough reviews to ensure an adequate response, in addition to the panelists. The response for request of review seems to be greater than 50% and that is taken into account by the program manager, so all seems to work well. Only a few proposals had < 4 mail reviewers in 2004. The number of reviews/proposal has increased with time during 2002-2004; many proposals receive 5-6 mail reviews. <u>Continental Dynamics and EarthScope:</u> Continental Dynamics has generally had difficulty getting enough reviews (>3) although the number has increased in recent years. In 2004, many proposals had over 6 reviews. EarthScope has only had one round of proposals and also had difficulty getting enough reviews (>3) although over half had 5 or more. The Program Director certainly tried to get appropriate reviewers. Part of the problem was the timing as EarthScope was the last in the Deep Earth Processes Section cycle, and reviewers with appropriate expertise who were not already engaged by other programs were few. ***Panel Reviewers:*** For most panels the size is appropriate. Overall there is a good disciplinary balance on the panels and this should be maintained. We recommend that the program directors broaden the expertise of the Tectonics review panel by adding a field-oriented member of the active tectonics/paleoseismology community. For Geophysics we recommend that the program consider increasing the panel size to get sufficient disciplinary breadth..	**Yes**
2. Did the program make use of reviewers having appropriate expertise and/or qualifications?	**Yes**

[5] If "Not Applicable" please explain why in the "Comments" section.

Comments: The mail reviewers generally have appropriate expertise, and the majority were qualified to provide an in-depth assessment of proposals. As noted before, international reviewers with appropriate expertise should be used for international projects. Panels appear well balanced in terms of expertise and qualifications. For EarthScope, we thought the panel was particularly well-chosen for this first round, with a group that was diverse and not obviously dominated by any interest group.	
3. Did the program make appropriate use of reviewers to reflect balance among characteristics such as geography, type of institution, and underrepresented groups? Comments: The Program Directors are clearly making an effort to do so. In the data we were given, there was such a large number shown as "not given" for underrepresented groups (minorities & women), however, that it is very difficult to judge. Also, without knowing the overall diversity level in the various fields it would be hard to assess how representative these are even if the data was available. For Earth Sciences, in general, the number of minorities is very small and we interpret the low numbers of such reviewers to the absence of potential reviewers in this field. The Program Directors clearly make an effort to get good geographic distribution. It is somewhat concentrated in a few areas for many fields, however, this appears to simply represent the geographic distribution of expertise. We encourage a continued effort to broaden the base. We note that excellent checks and balances are provided by the Program Director. As mentioned before, Continental Dynamics should make a specific effort to include international reviewers for projects that are to be carried out internationally. It seems that the Program Director requests reviews from a balanced pool. However, because the response of reviewers is a bit unpredictable the final reviews may not represent a proper balance. This is unfortunate but we suggest that the Program Directors continue working as they are now.	**Yes**
4. Did the program recognize and resolve conflicts of interest when appropriate? Comments: The Program Directors take potential conflicts of interest very seriously and make a serious effort to identify and resolve them. There were instances where subtle conflicts that were not identified by the reviewers were identified by the program director resulting in a more fair overall review of a proposal. Because of the multidisciplinary nature and large number of PIs on Continental Dynamics projects and the need for panelists with experience with such projects, we noted that panelists often have proposals or pre-proposals under consideration by the panel. We were concerned that there could still be some bias in these cases even though the panelist left the room during the discussion. This is particularly true when the number of mail reviews is small. We do not think that either excusing the panelist or relying solely on mail reviews would solve the conflict of interest problem. We	**Yes**

recommend that this situation be avoided and a small pool of back up panelists be established that can take a panelists place for a specific panel meeting during their term of service if the panelist submits a proposal or pre-proposal for that panel meeting.	

4. Discuss any issues the COV has identified relevant to selection of reviewers.

none

A.4 Questions concerning the resulting portfolio of awards under review**. Provide comments in the space below the question. Discuss areas of concern in the space provided.**

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE[6], OR DATA NOT AVAILABLE
1. Overall quality of the research and/or education projects supported by the program. Comments: The work funded by the core programs, including Continental Dynamics, is generally excellent. There is no question that the quality of the science that has been done by the geophysics, geochemistry and petrology, and tectonics communities with NSF funding has been superb and that the rate of increase in our knowledge of deep Earth processes is outstanding. The very high quality of the research is evidenced by the large number of high-visibility papers resulting from projects funded by these programs. EarthScope and Continental Dynamics draw on the same communities as the core programs but support large-scale, integrated projects that are beyond the scope of other programs. As noted elsewhere, it is too early to effectively evaluate the science coming out of the EarthScope program. The facility is not fully functioning and we only had one round of proposals to review. By necessity, many proposals were more "service" oriented and related to background work needed for placing instruments, work on the pilot hole, etc.	Appropriate
2. Are awards appropriate in size and duration for the scope of the projects? Comments: The size and duration of awards are appropriate for the scope of the projects in most cases.	Appropriate

[6] If "Not Appropriate" please explain why in the "Comments" section.

In many cases, however, it is clear that budgets have been reduced to make it possible to fund the work, which then reduces the scope of the work. In one case, a reduced time frame was given to allow a trial period for data acquisition of a high-risk proposal. In other cases it is clear that the hypothesis tested will take longer than the duration of the proposal. The average amount and duration of awards has increased from 2002-2004. This is appropriate, because it is more expensive to do research, but these increases nevertheless do not keep pace with increases in research costs (particularly graduate salary + tuition and postdoc salaries).	
3. Does the program portfolio have an appropriate balance of: • High risk projects? Comments: Although risk is difficult to assess, the program has funded a number of what the COV would consider risky projects that have resulted in high-impact outcomes. In most cases, however, we didn't know which proposals are 'high risk' other than the ones identified as such by the Program Directors in the COV materials. However, sufficient examples are given to suggest that these are funded at an appropriate level. There should be some high-risk projects funded each year. The COV noted that nearly everything involved in EarthScope is high risk: such a project has not been attempted on this scale anywhere before.	Appropriate
4. Does the program portfolio have an appropriate balance of: • Multidisciplinary projects? Comments: By their very nature, deep Earth processes generally require a multidisciplinary (and interdisciplinary) approach. For example Tectonics easily lends itself to multidisciplinary research, as well documented by proposals funded. Researchers tend to team up with members of different fields in the geosciences. Petrology and Geochemistry has a portfolio with a fair amount of multidisciplinary projects that seem like a good and appropriate number. Geophysics program has funded a number of multi- and interdisciplinary proposals. Continental Dynamics proposals are almost all are multidisciplinary, and EarthScope is exceptional for its multidisciplinary range of activities. We commend the program directors who have gone out of their way to both solicit both multi- and interdisciplinary proposals and to identify appropriate cross-reviewing programs.	Appropriate
5. Does the program portfolio have an appropriate balance of: • Innovative projects? Comments: A large number of the funded projects in these programs are innovative. Plus, the great majority of the funded projects have some degree of innovation and are ranked	Appropriate

higher by the reviews than others with less innovation. As with high risk projects, we do not know which proposals are considered particularly "innovative", but the examples given refer to studies that we also consider very innovative and creative. The emphasis on outcomes should not negatively impact the awarding of high-quality innovative research, so we strongly support the continuation of funding projects of this type.	
6. Does the program portfolio have an appropriate balance of: • Funding for centers, groups and awards to individuals? Comments: There is a very good mix of groups/collaborative proposals and individual proposals. Awards in the core programs support both individuals and 2-3 part collaborative projects, and Continental Dynamics (and EarthScope) support larger collaborative efforts. Collaborative projects enhance multidisciplinary approaches and inter-university collaboration and use of resources. The resulting larger and more diverse research environment is beneficial to early career investigators and students. Nevertheless, it is also important for individual research projects to be supported, as is the case for this program.	Appropriate
7. Does the program portfolio have an appropriate balance of: • Awards to new investigators? Comments: There appears to be a good effort to fund new investigators. The program supports some new investigators with CAREER awards as well as with regular grants to early career investigators. The Program Directors have shown good judgment in awarding these in terms of numbers and awardees. We saw evidence of particular notice being taken of new investigators in the EarthScope funding, and some precedence being given them at the funded/not funded borderline.	Appropriate
8. Does the program portfolio have an appropriate balance of: • Geographical distribution of Principal Investigators? Comments: The distribution of PIs reflects the distribution of proposals received. Based on the maps provided, it appeared appropriate. But we found this difficult to assess, as we have no information about the distribution of people in the specific disciplines. Based on what we know, it seemed to be as well as can be achieved, with the distribution of awards being much more uniform than that of the submittals.	Appropriate
9. Does the program portfolio have an appropriate balance of: • Institutional types? Comments: The program funds projects at a range of institutions. Most awards are for investigators at top 100 research universities, and this is probably appropriate. There	Appropriate

is continued support for non-research intensive PhD institutions, and this furthers the education of graduate students and undergraduates who benefit from the research environment. We noted a broad range in EarthScope, partly due to the E&O emphasis.	
10. Does the program portfolio have an appropriate balance of: • Projects that integrate research and education? Comments: The program has funded RUI grants, REU supplements, and CAREER proposals, for example. But there is room for more to be supported. We particularly noted the need for more CAREER proposals. Projects combining research and education is a particularly strong feature of EarthScope.	Appropriate
11. Does the program portfolio have an appropriate balance: • Across disciplines and subdisciplines of the activity and of emerging opportunities? Comments: There is an appropriate balance in terms of methods, scales (temporal and spatial), and focus of research.	Appropriate
12. Does the program portfolio have appropriate participation of underrepresented groups? Comments: We note that these programs have a high proportion of successful women principal investigators. This can contribute to the development of a diverse scientific workforce. Because the representation of minorities in geosciences is so low, it is difficult to assess the statistics of any individual program as to appropriate representation. The very small number of minority group PIs renders the statistical treatment for this group meaningless (for example in Petrology and Geochemistry: 1 or 2 proposals awarded out of 5-8 submitted during 2002-2004). Given the extremely low percentage of minority Earth scientists, it seems especially important to encourage and provide specific and constructive feedback to PIs from underrepresented groups. We were not able to evaluate if this had been done through our e-jacket examination. It would be helpful for future COVs to have the underrepresented status information (where known) in the provided proposal spreadsheet for each program. Considering the low numbers of underrepresented groups, the level of participation is most likely appropriate. The Program Directors actively work to involve members of underrepresented groups in program activities, and this may increase participation over time. We recommend efforts to reach minority groups such as Blacks and Hispanics who are clearly underrepresented in this field. Recognizing the need to interest individuals from underrepresented groups in Earth	Appropriate

science at the earliest possible age (obviously far earlier than the NSF proposal writing stage!), one possible avenue to do this might be through installing EarthScope instruments on K-12 school grounds and integrating the big picture science and data collection with the school's science curriculum. Perhaps minority "magnet" schools could be given a high priority in site selection.	
13. Is the program relevant to national priorities, agency mission, relevant fields and other customer needs? Include citations of relevant external reports. Comments: The Board on Earth Sciences and Resources, National Research Council's 2001 Basic Research Opportunities in Earth Science Report identifies areas of high-priority research. Deep Earth Processes programs have embraced the spirit of this report and have made excellent use of 1) major improvements in techniques for measuring geologic processes from new dating techniques to vastly improved detection of geochemical and geophysical properties, 2) capabilities of observing geologic phenomenon and modern day processes through everything from geodetic experiments to drilling through the San Andreas fault (SAFOD), and 3) the computational technologies for simulating dynamic processes within the deep Earth (e.g. mantle tomography, Earth's core rotation, earthquake simulation, etc.). Of the six specific opportunity areas outlined in this report, the Deep Earth Processes Section has tackled four, plus has initiated the EarthScope project. The Section has also made the natural linkages between basic research and societal needs recommended by the report. For example: These programs fund research into investigations associated with hazard assessment and risk mitigation for earthquakes, volcanic eruptions, and related natural disasters (e.g. landslides). For example, the program supports investigations of tectonically active zones in North America and other regions (examples: San Andreas Fault, see Bennett et al., 2004, Science; Great Basin, see Wesnousky et al., 2005, J. Geophysical Research; blind thrusts in LA, see Dolan et al., 2003, Science; Dead Sea Fault, Syria, see Meghraoui et al., 2003, Earth and Planetary Science Letters). Furthermore, as indicated in Part B of this report, Deep Earth Processes programs fund and promote interdisciplinary and multidisciplinary investigations (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2004 Report: Facilitating Interdisciplinary Research). Projects in the Deep Earth Processes Section are making excellent use of large research facilities supported by NSF (National Research Council 2004 Report Setting Priorities for Large Research Facility Projects supported by NSF). This Section also has been heavily involved in Geoinformatics, supporting the drive for better cyberinfrastructure to revolutionize our science in the integration, distribution and use of large datasets (such as that which will come out of EarthScope), as recommended by the NSF Blue-Ribbon Advisory Panel on Cyberinfrastructure in 2003. In addition, most projects support an education and/or outreach component, furthering scientific literacy. Several projects involving research in other countries involve researchers and students from these countries, furthering international collaboration and cooperation.	Appropriate

14. Discuss any concerns relevant to the quality of the projects or the balance of the portfolio.

None. There appears to be a good balance of projects in terms of approach, scale, disciplines, and investigators (diversity, individual vs. collaboration).

EarthScope: At this 2004 round, roughly 50% of the money awarded was for Operation and Management costs of EarthScope facilities. We note that NSF anticipates that the EarthScope budget will rise from $6M in 2004 to $15-18M in the next few years. We recommend that the fraction of award money to O&M decreases, and certainly should not increase. Also see comment in A2 #4.

A.5 Management of the program under review**. Please comment on:**

1. Management of the program.
Comments:

Geophysics: The project management is excellent. There is clearly a good collaborative working relationship among the group of program directors and among the directors of this and other programs. Fastlane and the E-jacket system are significant and vital improvements. The resulting quality and timeliness of communication with principal investigators is outstanding. The geophysics program has an excellent track record of supporting women principal investigators

Petrology and Geochemistry: The leadership and management are impressive. The Program Director is fair, communicates well, looks hard for partnerships and seems eager to help the principal investigators do better. The number of successful grants from females is about the same as males, and the program director also looks at ways to promote international collaborations.

Tectonics: Excellent. Problems identified in previous years have been addressed. The Tectonics program is extremely well managed. Decisions are well documented and fair, and funded projects represent an outstanding range of research activities and investigators. The committee was impressed by the high level of interaction and collegiality among Program Directors of related fields. This is very beneficial to investigators and helps further the mission of the programs and NSF by fostering high-quality, multi-disciplinary science.

Continental Dynamics: The Project Director is experienced and enjoys the confidence and respect of the scientific community.

EarthScope: The management of this program is a big job, and includes an extra dimension because of the necessary liaison activities of the Program Director with various EarthScope facility management groups. This 2004 round was managed by a part-time Program Director, who did well under difficult, demanding circumstances. We note that the job is now full-time, which is certainly justified, and we have confidence that it will be carried out to a high standard.

2. Responsiveness of the program to emerging research and education opportunities.
Comments:

Geophysics: The program responds rapidly to emerging opportunities. For example, the Program

Directors responded rapidly to time-sensitive observational opportunities such as the 2002 Denali earthquake.

Petrology and Geochemistry: As mentioned above, the Program Director works hard at fostering partnerships within EAR and across NSF to increase the success of the applicants in Petrology and Geochemistry. The consequence of these partnerships is to be always looking at new initiatives in research and education.

Tectonics: Very responsive to new research directions (via SGER and other grants) and to providing support to study tectonically and seismically active environments.

Continental Dynamics is highly competitive, with a logical approach for developing new projects; therefore, outstanding science has consistently emerged.

EarthScope is a grass-roots movement, and is particularly responsive to research and E&O opportunities.

3. Program planning and prioritization process (internal and external) that guided the development of the portfolio.

Comments:

The Program Directors communicate readily with the larger scientific community to set priorities and plan projects and programs. Many of the programs funded or co-funded a number of community workshops that promoted a forward view of the science. Just as importantly, the Program Directors regularly attend these workshops, promoting communication between them and the scientists who create their portfolio.

We observed an excellent rapport among the personnel in these and related programs. We feel that this communication provides an excellent environment that facilitates interaction, interdisciplinary research, and appropriate management of proposals.

To a great extent, however, portfolio seems mostly guided by peer review as it should be.

For Continental Dynamics, planning is extensive, uniquely including a pre-proposal phase.

The 2004 EarthScope round was unusual because of the need to balance early service requirements with the usual scientific criteria. The prioritization was met through discussion between panel and Program Director, augmented by mail reviews. The resulting decisions were understandable and properly documented. In our opinion they were also justified.

4. Additional concerns relevant to the management of the program.

The Program Director workload is very high relative to rest of the GEO Directorate, although the staff is extremely efficient and has very good dwell time statistics. We note the increase in personnel since the last COV but stress the need for even more personnel to make the workload comparable with the rest of the Division. Such heavy commitments cut into their ability to interact with community and other programs plus can cause burn out. Given the high quality of the Program Directors at this time, it is critical to alleviate some of the workload to prevent a return to the problems observed by the last two COVs.

PART B. RESULTS OF NSF INVESTMENTS

NSF investments produce results that appear over time. The answers to the first three (People, Ideas and Tools) questions in this section are to be based on the COV's study of award results, which are direct and indirect accomplishments of projects supported by the program. These projects may be currently active or closed out during the previous three fiscal years. The COV review may also include consideration of significant impacts and advances that have developed since the previous COV review and are demonstrably linked to NSF investments, regardless of when the investments were made. Incremental progress made on results reported in prior fiscal years may also be considered.

The following questions are developed using the NSF outcome goals in the NSF Strategic Plan. The COV should look carefully at and comment on (1) noteworthy achievements of the year based on NSF awards; (2) the ways in which funded projects have collectively affected progress toward NSF's mission and strategic outcomes; and (3) expectations for future performance based on the current set of awards. NSF asks the COV to provide comments on the degree to which past investments in research and education have contributed to NSF's progress towards its annual strategic outcome goals and to its mission:

- To promote the progress of science.
- To advance national health, prosperity, and welfare.
- To secure the national defense.
- And for other purposes.

Excellence in managing NSF underpins all of the agency's activities. For the response to the Outcome Goal for Organizational Excellence, the COV should comment, where appropriate, on NSF providing an agile, innovative organization. Critical indicators in this area include (1) operation of a credible, efficient merit review system; (2) utilizing and sustaining broad access to new and emerging technologies for business application; (3) developing a diverse, capable, motivated staff that operates with efficiency and integrity; and (4) developing and using performance assessment tools and measures to provide an environment of continuous improvement in NSF's intellectual investments as well as its management effectiveness.

B. Please provide comments on the activity as it relates to NSF's Strategic Outcome Goals. Provide examples of outcomes (nuggets) as appropriate. Examples should reference the NSF award number, the Principal Investigator(s) names, and their institutions.

B.1 <u>OUTCOME GOAL for PEOPLE</u>: Developing "a diverse, competitive and globally engaged workforce of scientists, engineers, technologists and well-prepared citizens."

Comments:
The Deep Earth Processes Section has produced a scientifically diverse, highly competitive and globally

engaged workforce of scientists and has helped to prepare citizens for natural disasters and for understanding the natural world.

Geophysics:

The geophysicists funded by this program in general are globally engaged. The program makes a real effort to develop a diverse, competitive workforce. The Program Directors have funded and encouraged a number of interdisciplinary workshops and a workshop for young scientists. Such workshops are a good way to encourage the development of interdisciplinary projects; indeed, these workshops have been cited in publications. The Program Directors also attend many workshops as a means to be engaged with the scientific community.

Four CAREER proposals have been funded, and in general new PIs have been successful at an appropriate level. The program has supported RUI and REU projects that involve undergraduates in high quality research. For example, EAR 0106924 (Collaboration for Earthquake Research - PI Thomas Jordan, University of Southern California) has undergraduates at all grade levels participate in interdisciplinary, collaborative earthquake science and create movies, etc., to support the Southern California Earthquake Center communication, education and outreach efforts.

Petrology and Geochemistry:

There is no doubt that the program has been useful in promoting new science and in helping promote the careers of new scientists. This includes 15 sponsored and 6 co-sponsored workshops and 3 CAREER grants. The investment has been exceedingly well used and the results are evident with a new generation of vibrant scientists and the development of new fields in petrology and geochemistry. Some of the investments have even had a direct contribution to societal needs. Among the most obvious are studies in volcanology that have helped to accurately predict volcanic eruptions, studies in ore deposits that have aided exploration of new resources and studies in materials that have helped understand environmental issues. This program also encourages international collaborations, which certainly will promote better citizens. Regarding preparing "well prepared citizens", NSF should be commended or its efforts to properly broadcast some of the most interesting and accessible work done by researchers funded by the Foundation.

Tectonics:

This program supports many high-quality projects, including 1) those led by early career investigators (e.g. CAREER award EAR 0346816, Bradley Ritts, Indiana University: Giant nonmarine sedimentary basins of China and intracontinental tectonics – an integrated research and education plan in Asia and western North America.), 2) people from underrepresented groups in the physical sciences (e.g. award EAR 0349070, Michelle Cooke, University of Massachusetts (also a CAREER award): Response of fault systems to shifts in tectonic regime: implications for the evolution of present-day activity of fault systems in southern California), and 3) teams of international collaborators (e.g. collaborative awards EAR 0408978, 0409487, Pamela Jansma (University of Arkansas) and Eric Calais (Purdue University): GPS measurements and deformation modeling of oblique subduction and strain partitioning in the northeastern Caribbean (involves collaboration with researchers in Haiti).

The research and education components foster science literacy among citizens, and involvement of undergraduates and graduate students in research encourages their careers in science and related technical fields. This is an ongoing process, and the Tectonics program is on the right track.

The program also supports workshops that enhance communication and involvement of geoscientists in formulating emerging disciplines and questions and in developing new approaches to solving tectonic problems.

Continental Dynamics: This program has funded films, workshops, conferences and undergraduate programs to broaden exposure of the public, students and young scientists. For example, EAR 0228336 SGER: Scientific Drilling Film Project - PI Doug Prose of Earth Images Foundation, will show the drilling of the pilot

hole for SAFOD, and EAR 0310011 RUI/Collaborative Research: Batholiths: Generation and Evolution of Crust in Continental Magmatic Arcs - PI Margaret Rushmore is for research at Occidental College, an undergraduate institution. The nature of many Continental Dynamic projects also involves global cooperation among scientists.

EarthScope: EarthScope will certainly meet this criterion. Its data will be available to everyone from high school students to professional researchers, internationally. A measure of its success will be how many people use it.

B.2 OUTCOME GOAL for IDEAS: Enabling "discovery across the frontier of science and engineering, connected to learning, innovation, and service to society."

Comments:

The Deep Earth Processes Section has funded an abundance of projects that have enabled "discovery across the frontier of science" as shown by the large number of articles published in Science, Nature and other highly ranked disciplinary journals (including many that were, for example, Science editors choices), plus has made many advances that provide direct societal benefit.

Geophysics:

The program has generated a number of very important discoveries about the Earth's interior. For example, the discovery of inner core rotation by NSF-funded seismologists Paul Richards and Xiaodong Song (Lamont-Doherty Earth Observatory at Columbia University) has generated a great deal of excitement, both within the scientific community and in the popular press. This discovery has sparked much research aimed at explaining how the Earth's magnetic field is created, what causes the reversal of the Earth's magnetic field and when it may flip again, and temperatures and heat flow within the Earth's interior. A PBS special "Magnetic Storm" interviewed several PIs who were funded in 2002-2004 (EAR 0207789 PI Dan Lathrop, University of Maryland; EAR 0441788 PI Mike Fuller, University of Hawaii; EAR 0315714 PI Gary Glatzmier, University of California at Santa Cruz; EAR 0337579 PI Jeremy Bloxham, Harvard Univesity; and EAR 0310316 PI Rob Coe, University of California at Santa Cruz).

The discovery of the post-perovskite phase in 2001 has generated a great deal of excitement for its role in generating the D" layer. This discovery prompted numerous interdisciplinary projects funded by Geophysics to understand the phase transition and its implications. Post-pervoskite has now been generated from first principle calculations and has been studied by seismologists, geodynamicists, and mineral physicists. (See EAR 0230319 Collaborative Research: Quantum Mechanical Modeling of Major Mantle Materials - PI Renata Wentzcovitch, University of Minnesota).

The discovery of sharp sides to the African superplume provides insight into the structure of Earth's deep interior (EAR 0309298 Finites-Frequency Tomography of the Earth's Mantle; PI Guust Nolet, Princeton University).

The program responds rapidly to events such as the Denali earthquake and Sumatra earthquake by releasing funding for time-sensitive geophysical studies; for example 5 of 7 SGER grants were for such purposes.

Petrology and Geochemistry:

There is no question that the quality of the science that has been done by the geochemistry and petrology community has been superb and the rate of increase in our knowledge of the Earth's geochemical makeup and evolution is outstanding. For example, in a paper in Nature Schulze et al (2003) show that anomalously low oxygen isotope signatures preserved in high pressure SiO2 (coesite) inclusions within eclogite are typical of subduction zone metabasalts and accordingly provide strong support for the altered ocean floor origin of deeply subducted material (EAR 0207340 – Zircon are forever, PI John Valley, University of Wisconsin).

Among the noteworthy research that has been funded by this program is work demonstrates the link between new discoveries and societal needs. For example, studies of the nature of volcanic eruptions show that the previous volcano model was much too simple and how the volatile content of magmas play a key role during dangerous explosive eruptions. This is of particular societal value because half a billion people live around active volcanoes and the advances in this study improve our ability to mitigate the hazards they pose. This collaborative research was highlighted in the NY Times (EAR 0207362 – Physical properties of bubble and crystal bearing melts and their implications for eruption dynamics: integrated, theoretical, experimental and field-based investigations; PI Katherine Cashman, University of Oregon; and EAR 0308866 Experimental Investigation of H2O, Cl, CO2, and SO2 solubilities in rhyolite and andesite melts at shallow crustal conditions, PI James Webster, American Museum Natural History).

Tectonics:
As noted above, the Tectonics program funds creative research in a wide range of disciplines involving Earth dynamics through time and involving an array of new and proven technology and approaches. Multidisciplinary research is at the core of this program, which commonly also supports research shared with geophysics, petrology and geochemistry, surface processes, hydrogeology, and engineering (e.g., materials science). This research is of great service to society because tectonic processes profoundly influence how and where people live. Research such as EAR 0207520 (Collaborative Research: Co-evolution and dynamic interplay of the San Jacinto and southernmost San Andreas fault zones, PIs Kevin Furlong, Penn State and Richard Bennett, University of Arizona) addresses fundamental scientific questions but has significant societal impact. In addition, tectonic processes either provide land bridges, seaways and corridors that have, and will fundamentally influence biotic processes and the evolution of climate. There are thus further cross-disciplinary aspects of this program with regards to paleoclimate studies, climate modeling, evolution and migration of species, including man. Importantly, tectonics is also fundamental to physical sciences education and is the underlying theme of much of Earth science research (deep and shallow, modern and ancient). Examples of innovative science at the frontier (interface) of tectonics and climate/landscapes:
EAR 0126253, Robert Anderson (UC Santa Cruz and University of Colorado): Caves as recorders of river incision, tectonics, and landscape evolution in the Sierra Nevada, California. EAR 0412509, Christian Teyssier (University of Minnesota): A new method for determining the paleoelevation of orogens. EAR 0196449, Peter Reiners, Yale University: Collaborative research: Uplift of the Washington Cascades and climatic evolution of eastern Washington.

Continental Dynamics: This program funds numerous projects that serve this goal from those on asteroid impact areas (e.g. EAR 0207407 Chicxulub Scientific Drilling Project: Age and Environmental Consequences of the Chicxulub Impact Event; PI Gerta Keller, Princeton University, or EAR 0207658 Petrological and Geochemical Analyses of Impact Breccias and Melts Recovered by the Chicxulub Scientific Drilling Project; PI David Kring, Harvard University), greenhouse gases (e.g. EAR 0307112 Collaborative Research: NSF-NJGS Drilling of the Greenhouse World: The Cretaceous Transect; PI Kenneth Miller, Rutgers University), and potential volcanic eruption sites (e.g. EAR 0116826 Collaborative Research: Magma reservoir-Conduit Dynamics Revealed by Borehole Geophysical Observatory and Continuous GPS; PI Barry Voight, Penn State).

EarthScope: EarthScope is very diverse and ambitious, on a scale that has not been attempted before. It will provide information of a quantity and quality that is entirely new, and is almost certain to reveal new insights.

B.3 OUTCOME GOAL for TOOLS: Providing "broadly accessible, state-of-the-art S&E facilities, tools and other infrastructure that enable discovery, learning and innovation."

Comments:

Geophysics:
This program clearly produces many useful tools and facilities, and the development and deployment of these,

including the integration of high end computing and geosciences, has led to major advances in our understanding of the Earth's interior. An example is the recent funding of a computer initiative in geodynamics that has the potential to provide a large number of important tools to the community (EAR 042671 Computational Infrastructure for Geodynamics CIG; PI Michael Gurnis, Cal Tech).

A geophysics project won the Gordon Bell Computing Award for earthquake simulation on the Earth Simulator (EAR 0106666 Global Analysis of Body Wave Travel Times and Amplitudes: Whole-Mantle Tomography and Simulations of 3-D Wave Propagation; PI Jeroen Tromp, Cal Tech).

SCEC community models: The Southern California Earthquake Center has been a leader in the earthquake research community for taking advantage of high-end computing power including the TeraShake and CyberShake projects. They have made software, models and computational testbeds available through CME - Community Modeling Environment (SCEC is supported through EAR 0106924; PI Thomas Jordan, University of Southern California). Also, the advent of LIDAR has allowed airborne laser swath mapping of the southern San Andreas fault (EAR 0409045 Airborne Laser Swath Mapping of the Southern San Andreas Fault; PI Michael Bevis, University of Hawaii).

Research funded by this program also makes use of NSF sponsored facilities and equipment as well as tools used in such facilities. The *Consortium for Materials Properties Research in Earth Sciences* (COMPRES) is an excellent example of a community-based consortium that supports and advocates research in materials properties of Earth and planetary interiors with a particular emphasis on high-pressure science and technology and related fields. COMPRES is charged with the oversight and guidance of important high-pressure laboratories at several national facilities, such as synchrotrons and neutron sources that have become vital tools in Earth and Planetary science research. COMPRES promotes both research and education in the area of Earth Science materials properties.

Petrology and Geochemistry: The program provides the research money to either create or use the many facilities that exist in the country. Importantly, this program fosters the kinds of collaborations required for keeping the labs as "state-of-the art". Also some grants, for example (EAR 0408526 3He/4He thermochronometry and noble gas diffusion behavior via proton irradiation, PI Kenneth Farley, Cal Tech), collaborate with high energy physicists to understand the diffusive behavior of He. Another example (Nancy Ross, Virginia Tech) has a lab for crystallography that is an interdisciplinary facility for chemistry, physics and geosciences that attracts students from around the region, which is key for building a literate workforce.

Geophysicists have had a working model of the Earth based on data worldwide geophysical data. Geochemists have been hampered in global views if the Earth by the lack of databases that deal with fluxes and concentrations of elements in various reservoirs. The Geochemical Earth Reference Model (GERM) is an attempt at collecting and managing the large data sets already available in the literature, and convening a series of workshops to look into these global problems (EAR 0230121 Geochemical Earth Reference Model, PI Hubertus Staudigel, Scripps).

Tectonics: The need to address complex tectonic problems has spurred novel uses of new tools and technologies from other disciplines as well as the development of new technologies and tools. For example:

(1) Tools for understanding fault zone mechanics or the determination of deformation rates and the spatial evolution of deformation in high-risk zones, such as growing anticlines in blind-fault areas. This information is vital for hazard mitigation and urban planning. Example: EAR 0310357, Ramon Arrowsmith (Arizona State): Kilometer-scale fault zone structure and kinematics along the San Andreas Fault near Parkfield, California.

(2) Tools to determine paleo-elevation in orogenic belts: these techniques will provide tectonicists with uplift rates, climate modelers will find this information useful to realistically model the evolution of atmospheric

circulation patterns and its interference with topography. Some of these tools are novel and lead to new ways to understand continental dynamics.
Examples:
Use of the NSF funded high resolution X-ray CT scanning multi-user facility at the University of Texas at Austin to determine paleo-elevations using sizes of bubbles in lavas - EAR 0207818 Uplift history of the Colorado Plateau since the Late Miocene: Analysis using vesicular basalts as a paleo-altimeter, PI Alex Proussevitch, University of New Hampshire and Dork Sahagian, University of Chicago
(see also Christian Teyssier SGER project listed above, published in Geology, involving using the hydrogen isotopic composition of mica in extensional faults to as a tracer of meteoric fluid composition and therefore elevation 50 million years ago in the Cordillera.

Continental Dynamics: This program provides global opportunities in deep drilling for scientific purposes (e.g. EAR 0309707 PI Dennis Nielson, DOSECC, Inc).

EarthScope: Because of its scale and very nature, EarthScope is already triggering the development of innovative techniques and facilities.

B.4 OUTCOME GOAL for ORGANIZATIONAL EXCELLENCE: Providing "an agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices."
Comments:

Geophysics: The size and scope of the Geophysics program is a real plus, providing the program with the flexibility to respond rapidly to changing needs. The interpersonal interactions between the Program Directors stand out as an excellent practice. The Program Directors are also proactive in engaging with programs in other parts of EAR, GEO, and in other directorates. Two Program Director from other programs cited the mentoring they received from this program as a real advantage.

Petrology and Geochemistry: The Program Directors of Petrology and Geochemistry are very innovative in finding the funds to fund grants and they manage one of the highest workloads of NSF in a very efficient way. The teamwork that is evident in this group of program managers is truly vital in a successful business practice.

Tectonics: The data provided strongly support the conclusion that the Tectonics program is superbly managed: e.g., the time from proposal deadline to decision is low although the work load of the Program Directors is high, and decisions are meticulously documented by the Program Directors.

Continental Dynamics: The leadership in frontier research has been outstanding for studies involving deep drilling and tectonic opportunities in global locations. It has proven to be adaptable to a diverse spectrum of undertakings.

EarthScope: The organizational requirements of EarthScope are daunting, and involve handling and making available real-time data on a scale never-before attempted.

PART C. OTHER TOPICS

C.1 Please comment on any program areas in need of improvement or gaps (if any) within program areas.

None

C.2 Please provide comments as appropriate on the program's performance in meeting program-specific goals and objectives that are not covered by the above questions.

As the EarthScope program ramps up, there will be many opportunities for collaboration between Continental Dynamics and EarthScope.

C.3 Please identify agency-wide issues that should be addressed by NSF to help improve the program's performance.

The COV noted three agency wide issues:

4) Better cyberinfrastructure is needed - i.e. more funding for cyberinfrastructure and for more permanent, stable platforms (homes) for databases, software, etc. that are being developed as part of Geoinformatics and other NSF ITR and cyberinfrastructure programs.
5) The difficulty in meeting science budget needs for MREs such as EarthScope in times of flat or declining budgets. It would be a shame to not take the full advantage of the MRE facilities, but it should not be at the expense of core programs where the innovation and ideas are generated that advance the science and lead to MRE proposals.
6) The connection between CAREER proposals and Presidential Early Career Awards for Scientists and Engineers (PECASE) awards. CAREER awards require excellent science and a well developed education and/or outreach component. They are a prerequisite for receiving a PECASE award which is given for showing exceptional potential for leadership at the frontiers of knowledge. Many exceptional young scientific leaders are concentrating on pushing scientific frontiers, not integrating such research with education and outreach. Thus many deserving PECASE awardees are overlooked, and we question the reason for the prerequisite.

C.4 Please provide comments on any other issues the COV feels are relevant.

We also remain concerned that the workload in the Deep Earth Processes Section (and all of EAR) is excessively high compared to other programs in GEO. Also see overview at beginning of report.

C.5 NSF would appreciate your comments on how to improve the COV review process, format and report template.

For the Deep Earth Processes Section COV:
Sharon Mosher, Chair

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