**MidLife Review Committee Report on the NSF GEOPRISMS program**

## I. Executive Summary

The GeoPRISMS Midlife Review Committee met on August 31 and September 1, 2015 at NSF headquarters to evaluate program progress and to provide recommendations for the second half of the ten-year program. GeoPRISMS is an outstanding amphibious and interdisciplinary research program that brings together investigators with very different approaches and backgrounds to solve important geoscience problems. GeoPRISMS fills a unique role by building broad research and education communities that cross-cut traditional boundaries between Earth and ocean sciences, different research platforms and scientific cultures, and structural divisions within the NSF to enable problems to be approached in new ways.

The two GeoPRISMS research initiatives, Subduction Cycles and Deformation (SCD), and Rift Initiation and Evolution (RIE), focus research at community identified primary sites to achieve their goals. For the SCD science questions, the community chose to focus studies at Cascadia, Alaska-Aleutians, and the New Zealand convergent margins. Excellent progress has been made at the more mature Cascadia focus site, particularly in geodetic and faulting process studies, and data for ambitious seismic imaging projects have been collected Field studies in Alaska-Aleutians have recently begun with amphibious field programs made possible by the GeoPRISMS approach, and field studies have not yet begun in New Zealand. In addition, experimental and modeling studies have produced important results. The committee raised concerns about the degree to which SCD can fully realize its goals given the current phased funding schedule, particularly as questions about the development of arc crust and the seismogenic zone require further projects in Alaska-Aleutians.

The RIE initiative selected the Eastern North America passive margin (ENAM) site to study rift evolution and architecture in an ancient rift setting and the East Africa Rift System(EARS) to study the initiation and early development of rifts. Because of the phased funding approach, the RIE initiative is not yet as advanced as the SCD initiative. Geophysical data has been acquired for one of three proposed ENAM sites, and data processing and interpretation are still to be accomplished through future projects. Consequently, science efforts and potentially additional data collection will need to be funded to achieve the stated science objectives at this focus site. The ENAM site also benefits from synergy with EarthScope data collection and research. Data acquisition and interpretation for the EARS focus site are still under development. To date no large-scale interdisciplinary project has been funded here. This committee encourages the EARS community to concentrate their efforts within a selected area of EARS where rift initiation, and mechanisms and consequences of fluid exchange can be studied in a multi-disciplinary approach.

The restriction of GeoPRISMS funding by sequester has had a major impact on achieving the science goals outlined in the planning and implementation documents.

The committee recommends that current budget levels be augmented to the extent that funds become available within the NSF Geosciences. Limited funding has raised questions about whether the number of focus sites should be reduced. The focus sites were well chosen at community workshops in order to answer the science questions, and the implementation plans are well underway. The committee recommends that all focus sites be retained and that proposal pressure and quality drive funding decisions. The phased approach to major data collection projects was necessary at the beginning of the program, but the committee recommends that it be removed for the remainder of the program, to allow important gaps that have developed in the portfolio of funded proposals to be filled. Major field proposals should be allowed for all sites with the exception of the mature Cascadia site in FY17-FY19. Thematic studies, including important experimental and modeling studies that are vital for connecting field observations to physical processes, should continue during the remaining funding period and that thematic and synthesis projects be emphasized in FY20 –FY21.

The management functions provided by the GeoPRISMS Office are essential to the success of the program. The office is effectively staffed and managed and should be commended for its crucial role in building and maintaining the community of scientists engaged in GeoPRISMS research. Activities supported by the office have been particularly effective at growing the GeoPRISMS community, engaging new scientists in GeoPRISMS research and entraining the next generation of geoscientists in cutting-edge interdisciplinary research. GeoPRISMS Steering and Oversight Committee (GSOC) advice on how best to leverage the resources available to achieve science goals has been valuable and remains critical for the future development. The theoretical & experimental institutes are essential for integration and synthesis and should proceed. Additional synthesis workshops should be scheduled during FY20 and FY21. Overall, the Geoprisms program is on course to be an extremely successful decadal program, and should proceed with its implementation plan over the next five years with the minor strategic modifications noted here.

## II. Background

GeoPRISMS is a multidisciplinary decadal research program that is jointly funded by the National Science Foundation (NSF) Divisions of Ocean and Earth Sciences. It was established following the 2009 Watts Committee decadal review of the Margins program (2000-2010) which recommended the establishment of a new amphibious decadal research program. Subsequent community workshops in 2010-2011 followed these recommendations and established the Subduction Cycles and Deformation (SCD) and Rift Initiation and Evolution (RIE) science plans. The corresponding research implementation plans formulated at community workshops in 2011-2013 adopted a focus site approach, with large-scale data collection activities concentrated at sites chosen to allow progress on the important scientific questions. The SCD community chose to focus in the Cascadia, Alaska-Aleutians, and the New Zealand convergent margins. The RIE initiative selected the Eastern North America passive margin (ENAM) site to study rift evolution and architecture in an ancient rift setting and the East Africa Rift System (EARS) to study the initiation and early development of rifts.

The GeoPRISMS Midlife Review Committee met on August 31 and September 1, 2015 at NSF headquarters to evaluate progress and provide recommendation for the second half of the ten-year program. The review committee was composed of six scientists with a variety of interests and disciplines related to GeoPRISMS science, but with no direct involvement with or funding from GeoPRISMS. The evaluation given here is based primarily on examination of the GeoPRISMS review documents provided by the GeoPRISMS Steering and Oversight Committee (GSOC), GeoPRISMS science "nuggets" contributed by the researchers themselves, past review documents such as the 2009 Watts report, oral presentations given by members of the GeoPRISMS steering committee, and other information such as statistics on funded proposals provided by NSF program managers. The evaluation is focused on the questions provided in the charge to the review committee by NSF.

The review meeting began with a welcome by NSF program manager Bilal Haq and with strong words of encouragement by the NSF head of Ocean Sciences Rick Murray and head of Earth Sciences Carol Frost, who both pointed out the unique multidisciplinary and cross-program aspects of GeoPRISMS. The current GeoPRISMS chair Peter van Keken presented an overview of the GeoPRISMS program, after which former GeoPRISMS chair Julia Morgan presented a review of the SCD research theme, and GeoPRISMS steering committee member Maureen Long presented an outline of the RIE initiative. Program Director Jennifer Wade made a presentation on the effectiveness of amphibious ship-helicopter data collection strategies being employed in the Aleutians during the 2015 field season and additional information on proposal numbers and statistics for the various initiatives and sites.

Van Keken, Morgan, and Long departed after the morning presentations. The afternoon was devoted to enthusiastic and frank discussions among the committee members and NSF administrators Bilal Haq, Jennifer Wade, Maurice Tivey, Barbara

Ransom, and Donald Rice. The day ended with an approximately one-hour session involving only the committee members. The second day was focused mainly on report writing but also included additional discussions among committee members and NSF personnel.

## III. Subduction Cycles and Deformation

The main goals of the SCD initiative are to study the strain buildup and release along the plate interface; the transport and release of volatiles and magma in subduction systems; linkages among surficial processes, fault behavior and magmatism; and the long-term growth and evolution of arc crust and lithosphere. Numerous individual accomplishments towards these goals include primarily data collection and synthesis from the Cascadia Initiative, and to a much lesser extent from the Alaska-Aleutians due to the phased funding approach. Data collection proposals for the New Zealand focus site are currently being evaluated and it is highly likely that some studies will commence during 2016.

**The committee applauds the many SCD accomplishments which include new constraints on tectonic processes and fluid pathways obtained through new heat flow, seismic, geochemical and petrological datasets at the Cascadia plate boundary.** Results on episodic tremor and slip, together with seismic imaging are defining characteristics of slow earthquakes and seismic structure of the subduction zone. Mineral physics constraints on rupture conditions are being provided by new laboratory experimental data. The observational studies are complemented by geodynamic modeling results that are providing constraints on the dynamics and thermal structure of subduction zones. Use of the new wave glider technology to record seafloor geodetic observations appears to be an exciting new method to obtain data on strain buildup in Cascadia that may have future applications to other subduction zones. The iMUSH project has just completed acquisition of impressive seismic, magnetotelluric, and geochemical datasets at Mount St. Helens in order to provide constraints on pathways of magmas below the active volcano.

In spite of numerous excellent results that have come out of the Cascadia Initiative to date, there remain gaps with respect to overarching GeoPRISMS and main SCD science goals. One gap consists of integrating results of studies that focus on individual tectonic structures or geographic locations into a larger 3D subduction zone context. With iMUSH, for which imaging and analysis results are not yet released, it is not yet possible to assess how those results will fit into overall SCD science goals. In general for SCD, the committee recommends a more intensive focus on synthesis of individual datasets or experiments, and integration together with relevant modeling and thematic studies to address the overarching project architecture.

GeoPRISMS studies are just now getting underway in Alaska-Aleutians, with strong contributions anticipated from petrology and geochemistry. The multidisciplinary amphibious fieldwork campaign carried out during summer 2015 is an outstanding example of how the GeoPRISMS program facilitates research that

would be difficult otherwise, and important results are expected. However, it seems that very little has been funded to address some important, relevant science goals, such as the development of arc crust. This goal must be addressed in the Aleutians, as the presence of pre-existing continental crust in Cascadia and New Zealand compromise the ability to study arc crust growth in those sites. Since Alaska-Aleutians is not currently slated for further data collection proposals under the phased funding plan, it is not clear how such goals can be addressed unless the phased funding plan is altered.

The restriction of GeoPRISMS funding by sequester has had a major impact on achieving the science goals outlined in the planning and implementation documents. In particular, the imposition of phased funding has limited the funding of major data collection projects to two proposal rounds for each site, with severe budget limitations on each round. As a result, important major studies in some cases have not been funded due to deficiencies in the submitted proposals or lack of funding in particular years. In response, the question of whether to reduce the number of focus sites has been raised, in order to increase the amount of funding available for the remaining sites. However, **the committee recommends that all focus sites be continued, despite the funding limitations.** The focus sites were well chosen at community workshops in order to answer the science questions, and the implementation plans are well underway. Therefore eliminating focus sites would essentially waste resources spent in the planning stage and halt the community momentum and collaborations that have been generated for each site.

In order to overcome the funding restrictions that have limited the implementation of the program, **the committee recommends that that current budget levels be augmented to the extent that funds become available within the NSF Geosciences.** As an additional step, and independent of the exact budget level, **the committee recommends that funding for major data collection efforts be opened to all the sites, with the exception of the mature Cascadia site, for the FY17, FY18, and FY19 proposal rounds.** This is to allow gaps that have developed in the portfolio of funded projects additional opportunities to be selected and carried out. The phased approach to major data collection projects was necessary at the beginning of the program to prevent all the major proposals from competing head-to-head every year, but now that much has been accomplished, the restrictions should be removed for the remainder of the program. Thus funding decisions should be made throughout the rest of the program based on the quality of the proposals as well as their value to meeting the Geoprisms science goals.

Overall for the Alaska-Aleutians focus region, the main science questions should be addressed with further experiment(s) that include large-scale collection of geophysical data to answer the SCD science questions. New comprehensive experiments encompassing the entire Aleutian chain would likely be too ambitious for GeoPRISMS considering the time and funds available; nonetheless, carefully selected studies and transect(s) will yield invaluable insights into the growth and evolution of arc systems and the continental crust.

The committee recommends no new major data collection efforts in Cascadia, but encourages further submission of proposals for analysis and synthesis of Cascadia datasets and thematic studies during the next five years. Cascadia, and GeoPRISMS work in general, show very effective multidisciplinary, collaborative efforts.

In addition, the GeoPRISMS science plan has as one its overarching goals to "develop comprehensive systems-based models to understand margin evolution and dynamics, the construction of stratigraphic architecture, and the implications for the accumulation of economic resources, associated geologic hazards, climate change and environmental management." Studies toward development of these comprehensive models, as relevant to SCD, constitute another gap. If work on these topics has been carried out, it needs to be better articulated and integrated into the project outcomes. If studies toward these goals are needed, the research community should be encouraged to propose them.

**The committee strongly recommends that integrative thematic and synthesis studies continue until the end of the program.** These can provide connections within and between focus sites that would be difficult to achieve otherwise, and help to address some of the gaps noted above. Thematic studies will help to broaden the reach of GeoPRISMS to improve our understanding of subduction processes worldwide beyond the geographic areas of the focus sites. SCD thematic studies have also proven critical in leveraging entirely new international collaborations. For example, GeoPRISMS has supported the ExTerra group working on exhumed subduction zone terranes that offer novel perspectives on several overarching SCD questions, including the transport and release of volatiles and the evolution of arc systems. Working together via GeoPRISMS sponsored Field Institutes and other initiatives, ExTerra team members have proposed a large (~$4 M) international investigation of key exhumed complexes to the NSF PIRE program (Partnerships for International Research and Education) that has now been recommended for funding. This example highlights how thematic studies can fundamentally enhance GeoPRISMS scientific goals and community building.

**The committee recommends that proposals during the last two years of GeoPRISMS (FY20 and FY21) be restricted to thematic and synthesis projects, as large-scale data collection efforts begun at that time will be too late to be adequately analyzed and synthesized. A synthesis workshop should be held near the end of the program to facilitate data interpretation and synthesis between results from the different sites.**

The subduction community has recently become excited the possibilities for the Amphibious Array deployments and Subduction Zone Observatory, which are mid or large-scale science initiatives focused on subduction zones. The committee encourages the SCD community to work with the proponents of these activities so that SCD science objectives can be included in these programs, which have the potential of being realized towards the end of the GeoPRISMS program.

## IV. Rift Initiation and Evolution

The RIE initiative is an ambitious program to address some of the most fundamental questions about the formation and causes of continental break-up and the influences of rifting on larger scale processes in the solid earth, hydrosphere and atmosphere. In order to develop predictive models of continental rifts the community organized its efforts in four research questions: 1) timing and causes of rifting; 2) temporal and spatial evolution; 3) controls on rifted architecture during and after breakup and 4) the mechanisms and consequences of fluid exchange between the solid earth, hydrosphere and atmosphere. Through community workshops that included numerous international and early-career participants, two focus sites were chosen that have characteristics where these questions can be best addressed through interdisciplinary data acquisition, interpretation and modeling. The two sites are the Eastern North American Margin (ENAM) and specific sections in the East African Rift System (EARS). In addition to questions that can be addressed at these focus sites, several thematic questions were identified for targeted work at other continental rifts. These are: 1) rift obliquity, 2) rift processes as functions of strain rate, 3) volatiles in rift zone processes, 4) sediment production, routing and transport during and after rifting and 5) discrete events at rifted margins.

Geophysical data has been acquired for the central portion of the ENAM site through the ENAM Community Seismic Experiment (CSE), a multi institutional and multi-disciplinary geophysical data collection effort, designed to acquire critical new data using ocean bottom and on-land seismic stations. A second large-scale collaborative geophysical project (Mid-Atlantic Geophysical Integrative Collaboration; MAGIC) benefitted from collaboration and joint funding from EarthScope and the EAR geomorphology program. This project aims to understand the structure and dynamics of the mid-Atlantic Applachians and the evolution of the margin through orogenic cycles. The interpretation of the data from the CSE project is expected to be achieved through future proposals to GeoPRISMS and the EAR/OCE core programs. Geodynamic 3-D time-dependent modeling efforts are currently underway to characterize the mantle flow under the Eastern US and results will be compared to data acquired through the CSE. While large-scale geophysical and modeling projects are well underway at ENAM, geochemical and geochronologic investigations have so far only focused on Eocene magmatic events in Virginia with the objective to better constrain the sources of these magmas and provide geochemical constraints on the geophysical and modeling results.

**The committee feels that progress to date at ENAM is on track to achieve new and significant insights into the controls on rifted architecture during and after breakup.** Another large-scale geophysical transect in the northern section of ENAM may be necessary to address the question of the temporal evolution of rifting, however, given budgetary constraints and priorities at other GeoPRISMS focus sites, such a project may not be realized in the time-frame and budgetary landscape of the current program. The committee commends the program for the real community effort at ENAM and the amphibious nature of the data collection efforts that involve

numerous early-career PIs from a several academic institutions.

The EARS investigations currently lag behind progress made at ENAM. This is in part due to the staged funding model for large research projects but also appears to be related to the challenges the community has faced with regards to putting forward compelling, focused, multi-disciplinary projects. As at ENAM, community workshops were charged with the selection of focus areas within EARS; however, while participants identified the Eastern Rift from Turkana to the Tanzania Divergence as a main focus area, the entire rift including the Afar, and the Western and Southern Branches were also identified as areas for collaborative research. The lack of focus is reflected in funded studies on different regions of the entire rift. A seismo-tectonic study is investigating the relationship between the locations of earthquakes and known faults in the Malawi region. A one-year project includes the deployment of new GPS stations across the actively spreading region of the Turkana Depression. This project also aims to compile existing geodetic data from all over East Africa to develop a community velocity model. The committee recognizes the value of this project which will form an important framework for understanding rift initiation and evolution. The third GeoPRISMS funded project is a purely modeling and experimental study without any field or analytical component. This project is funding a post-doc to investigate the relationships between faults, and the distribution of active volcanoes and melt extraction processes along all three actively spreading branches of EARS.

Given that the EARS focus site is the best location to address the fundamental questions of the causes of rift initiation, the temporal evolution of rifting and mechanisms of fluid exchange between the solid Earth, the atmosphere and hydrosphere, as well as investigations related to the connections of solid earth processes and climate, **the committee advises the community to concentrate their efforts within a selected area of the Eastern Rift to address these important questions in a multi-disciplinary approach.** A community effort to constrain crustal and lithospheric mantle architecture through a seismic study, collect and analyze xenoliths for mantle composition, constrain magma and volatile sources and fluxes through geochemistry and geochronology, constrain depths of melting through geobarometry as well as perform structural geology and seismotectonics for characterizing faults and depth of brittle deformation are potential approaches that would significantly advance progress towards answering some of the key identified questions. Results from these field and analytical studies could then be tested against the 3-D time-dependent model predictions as is currently underway at ENAM. Broader representation of the EARS community on the GSOC and a focused EARS TEI in the very near future could help in effective proposal development. Close collaboration with international partners should be encouraged to leverage infrastructure and logistics in the focus area.

**The committee makes a similar recommendation for RIE as it does for SCD in terms of the discontinuation of the phased funding strategy.** It seems likely that there will be important data collection efforts remaining for both EARS and ENAM following their final proposal years in the original strategy. Therefore, both

EARS and ENAM should be open for new data collection proposals during FY17, FY18, and FY19.

The thematic questions listed above appear not to have been addressed through ongoing or proposed work. For ENAM, this is in part because the early stages of the project focused primarily on data collection, to be followed up by new proposals focused on the science and overarching syntheses. Overall, the committee recommends that some of the thematic questions, for example rift processes as a function of strain rate, volatiles in rift zone processes, discrete events and sediment transport during rifting can likely be also addressed at the identified focus sites. Such an approach would further encourage community building, take advantage of on-going work at the focus sites and provide important connections to climate processes and geohazards at these sites.

Synthesis studies may be particularly important for the RIE initiative, since the focus sites are studying an ancient rift in one case (ENAM) and an active rift in the other (EARS). As for SCD, the committee recommends that FY20 and FY21 funding be reserved for synthesis and thematic studies. **The RIE theoretical and experimental institute (TEI) should be held as soon as possible after the new GeoPRISMS office is established,** as a successful TEI can facilitate rapid progress in community building and synthesis.

## V. GeoPRISMS Management

**The GeoPRISMS Office plays a critical role in building and facilitating interactions among a broad diverse community of scientists** spanning a range of geoscience disciplines (geophysics, petrology and geochemistry, surface processes, hydrology, etc.), the traditionally separate earth and ocean sciences, and individuals at a variety of career stages (students, early career, and established). The community aspects of the GeoPRISMS program are the core of its successes to date and will remain at the core in the future. The coordination, communication, and continuity provided by the office are essential to the success of the GeoPRISMS program and to maintaining and growing the community. The office (both leadership and staff) has been particularly effective at engaging and entraining new scientists into the program, broadening the number of scientists and range of disciplines, and increasing the percentage of participants from traditionally under-represented groups (e.g., women).

The GeoPRISMS office also plays an essential role in providing effective management, communication, and coordination between scientists and allied facilities (IT, SAGE, GAGE, EarthScope), and between the community and the NSF. In addition, the office facilitates dissemination of GeoPRISMS results to the geoscience community and coordinates outreach to the general public. The committee was asked to comment on whether the 12% of the annual program budget currently being spent to operate the office, the workshops and the GSOC, was appropriate in the context of the total program budget. **The office is efficient and effectively run. It's hard to see how it could do more at the current staffing levels or how it could do all of**

**its important activities for less money**. In considering the value and cost effectiveness of the office, it is important to realize that the office is essential to maintaining and growing the community and the community is essential to the success of the GeoPRISMS program. At the same time, the office and community-building activities should not expand beyond their current levels, unless additional funding external to the OCE and EAR research budgets can be found.

The GSOC plays an important role in advising the office and the NSF on programmatic issues. GSOC advice on how best to leverage the resources available to achieve science goals is critical, particularly with constrained budgets. The structure and composition of the GSOC is effective and appropriate.

The GeoPRISMS website is well organized and clear; the content is appropriate and useful. Listservs and social media presence are essential and the GeoPRISMS office does both well. The newsletter is beautifully produced and contains great content but the audience and purpose is unclear, as the mailing list seems to target GeoPRISMS researchers but the technical content level is a bit lower. Changing the mode of the newsletter publishing to an electronic format could be considered to save money and to more effectively target one or more particular audiences. Planning workshops and AGU mini-workshops are well attended and an important mechanism to establish community consensus and grow the community. The distinguished lectureship program is an effective mechanism to disseminate results to a broader audience including 4-year colleges. The explicit creation of student forums, awards, and mentorship program have a proven record of success in promoting professional development and transition between career stages (student to post-doctoral research to research scientists and tenure track faculty). One area where the GeoPRISMS Office could play a larger role is in helping to secure additional resources (REU, NSF Research Traineeship (NRT) training grants), either by directly submitting proposals, or by providing a forum and encouraging community members to collaboratively submit proposals. The interdisciplinary nature of GeoPRISMS is fertile ground for these types of programs.

Leveraging larger data archiving efforts like IEDA makes sense, and there are excellent tools such as *GeoMapApp* that work well for those familiar with the datasets. The interdisciplinary aspects of GeoPRISMS make it essential that all data types are easily discoverable and accessible from the Geoprisms data portal web link. Linkages to other data sources such as petrology (PetDB), geochemistry (EARTHCHEM), seismic (IRIS), geodetic (UNAVCO), as well as experimental and modeling data should be made clearer. The GeoPRISMS data portal should undergo a usability study to assess and improve functionality with the goal of insuring that those not already intimately familiar with the interface can easily discover and access data and data products relevant to and created by GeoPRISMS research. If not already in place, DOIs should be generated for GeoPRISMS data and data products. The extent to which GeoPRISMS is engaged with Earth Cube is not clear. Effective multidisciplinary data integration remains a challenge for the geosciences. GeoPRISMS research is a great test case for developing the tools and technologies needed to address these challenges.

## VI. Concluding Remarks

**The committee commends the GeoPRISMS community and leadership on a strong, and still evolving, body of work that is helping to solve important, long-standing questions in the geosciences**. With adequate funding and the few minor strategic modifications of the plan noted here, the GeoPrisms program will be successful at meeting its research goals as stated in the science plan, and make great strides forward in important areas. If the program advances as envisioned, the GeoPRISMS research model may well become a long-term template used by other science communities both within and outside of earth sciences. GeoPRISMS is in an important and timely position for influencing the way in which large-scale problems can be most effectively addressed, given the multidisciplinary nature of the work and a rapidly changing funding environment.

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