Statement of Academic Activities and Goals

Edward J. Garnero

Overview

Here I summarize my most important research, teaching, and service activities since coming to ASU, particularly those relevant to my most fundamental goals. I was attracted to ASU because of the opportunity to be an integral part of building a geophysics emphasis in an already strong department. This relates to my first and foremost goal: to build and be immersed in an internationally successful *Earth and Planetary Interiors* research program. Secondly, I aim to build a mentoring system that consistently produces the most talented graduate students. Thirdly, I aspire to constantly improve my research, teaching and service abilities, so I have something useful to offer to my ASU, national, and international communities, as well as myself. I hope to clarify in this document how I am well on my way to meeting these goals.

Research Activities and Goals

Upon coming to ASU, my research primarily focused on Earth's deep interior, due to momentum of recent successes at that time. In a variety of studies, I worked on improving our understanding of the region in Earth where the solid rock mantle meets the much hotter and denser fluid outer. The primary motivation for this research is that it addresses long standing questions about how Earth operates as a whole, including, for example, the mode of internal mantle circulation (over millions of years, which relates to plate tectonics at the surface), the origin of mantle plumes that feed hot spot volcanoes (like Hawaii and Iceland), and important effects on heat flow out of the core, which can modulate the Earth's magnetic field behavior. This continues to be an active research area for me [See CV, Publications #27-36,38,39,41-50, Hereafter noted as "Pubs #"]. I now detail some specific successes of my Earth interior research, in a topic-by-topic fashion, and point to future activities as well. The first two topics focus on the deep mantle and core-mantle boundary (CMB), and are more thoroughly addressed, as they represent on-going research areas.

I. Ultra-low velocity zones (ULVZ) at Earth's core mantle boundary. I have worked extensively on discovering and better characterizing thin zones right at the base of Earth's mantle with significantly reduced seismic wave speeds. The most likely explanation for this intermittent sluggish veneer on the CMB is partial melting of mantle rock [Pubs #13,19,22,25,30,31]. Since coming to ASU, I have demonstrated additional possibilities for the origin of these observed seismic retardations, which include a slight blurring or mixing zone between the core and mantle, or even mushy material in the outermost core [Pubs #30-32, 34-36,46,48]. Each of these possibilities has far reaching consequences for the state and evolution of Earth's interior, as mentioned above. Thus this work has motivated (and benefited tremendously from) multidisciplinary collaborations between my research discipline of seismology, and the disciplines of mineral physics, geodynamics, and geodesy. This topic is emerging as an important deep Earth research area, with investigations and interpretations of ULVZ structure now being pursued by a number of groups internationally (including Caltech, MIT, and Berkeley). I have summarized these results for non-seismologists in two wide-readership encyclopedia articles (peer reviewed) [Pubs # 35,46]. Most recently, there have been 4 aspects to my (our) continuing ULVZ studies:

(a) Produce the most comprehensive global map of ULVZ structure (with ASU PhD student M. Thorne) [Pub# 48], and making all data/results available online (see http://ulvz.asu.edu).

(b) Pursue the highest possible resolution ULVZ modeling in localized zones (currently with ASU Postdoctoral Researcher S. Rost, and UC Santa Cruz colleague Q. Williams). This work is slated to be submitted to Science within the month (Hereafter, "Ms. # " refers to the manuscript number in the *Miscellaneous Manuscripts* section of my CV) [Ms. #11].

(c) Develop new tools and methods to improve our ability to extract finer details of these important mush zones (with ASU and UC Santa Cruz PhD students, and Dr. Rost) [see Pub #51, Ms.#4].

(d) Improve multidisciplinary investigations with geodynamics and mineral physics. We are developing new hypotheses for a planned proposal to be submitted to the National Science Foundation's (NSF) Cooperative Studies of Earth's Deep Interior (CSEDI), September 2004 (with UC Berkeley and Santa Cruz faculty Michael Manga and Quentin Williams, respectively).

<u>*II. Lower mantle structure and dynamics*</u>. The ULVZ work described above focuses on a few to 10's of km scales right at the CMB. However, important structural features have also been detected in the deepest mantle over 100-300 km (and larger) vertical scales. I have been quite active with my students and colleagues in pursuing key aspects of the broader deep mantle, such as the characterization of deep mantle seismic heterogeneity, anisotropy, and discontinuity structure [Pubs #28,30,33,38,39,41-45,47,49,50]. In a recent (invited) Science Perspective [Pub #43], I have argued that the spectrum of new discoveries of Earth's deep mantle are rivaled only by the outermost few 100 km of the surface. The top and bottom of the mantle are Earth's two largest boundary layers, with abrupt changes in properties and dynamical behavior, and display the strongest and most diverse heterogeneities within Earth, and are each intimately related to the chemistry, dynamics, and evolution of the interior. Two primary activities of my lower mantle structure and dynamics research are listed below, and currently focus on improving research methods, particularly when these improvements promise more rapid advances in the field. They are:

(a) *Better documentation of lower mantle seismic discontinuities*, that is, reflectors of seismic energy some 200-300 km above the CMB. Using powerful data stacking methods, we have one paper in press [Pub #50], one in review [Ms. #13], and one to be submitted soon [Ms. #9]. We are focusing on sorting out the trade offs present between topographic and volumetric heterogeneity, and also using more realistic 2- and 3D synthetic seismogram predictions to be compared with data [Ms. #7,12,13].

(b) *Improved characterization of deep mantle seismic anisotropy*. Seismic anisotropy is the dependence of seismic wave velocity on wave propagation direction, and is likely an important marker of important dynamic and rheological properties. It is inferred from time separation anomalies between waves of different polarizations. I have a variety of past [Pubs #15,20-22,24,26,28,39,41,42,49] and present studies [Ms. #3,8,9] focusing on improving our understanding of this topic. I am very excited about our recent work that demonstrates the need for a more complex form of anisotropy (azimuthal) in the deep mantle than in past work [Ms. #3,8], as it holds promise of more confidently mapping deep mantle dynamical motions.

<u>*III. Other core and mantle studies*</u>. As part of my goal of becoming a better researcher, I have put efforts in expanding my research targets to include Earth's deeper core and the upper mantle (this new research will be presented in July 2004 at the *Studies of Earth's Deep Interior* Conference in Germany). I am now actively studying Earth's inner core with ASU postdoc Sebastian Rost [Pubs #40,51], using array seismology – a method that utilizes large seismometer arrays. We have several studies underway that build on this earlier work. I am working with European colleagues in a study of Earth's outermost core, revisiting my older work [Pubs #7,9] with modern high quality data and methods [Ms. #2].

Shallower in the Earth, ASU PhD student N. Schmerr and I are investigating the nature of the upper mantle phase boundaries at 410 and 670 km depths – important depths where mantle rock compresses to denser structures. These boundaries are predicted to grow closer to each other in the presence of a hot plume conduit. We are studying this phenomena beneath Hawaii, a hot spot volcano predicted to have a deep mantle source. We are also utilizing 3D wave propagation predictions to compare with data. Mr. Schmerr received a 3 year NSF Graduate Student Fellowship for this project [Ms. #5].

<u>*IV. Improving research tools and methods.*</u> Since coming to ASU, I have worked hard at incorporating new research methods into my research. The two most significant are:

(a) *Seismic array methods and field seismology*. As mentioned previously, seismic array analyses are permitting us to extract detailed information at the shortest possible scale lengths, and we are pursuing these methods in all aspects of our work. Portable seismometer array installations have also become an important component of my work. In an NSF-funded experiment, we are currently installing 50 seismometers in NW Canada for Earth structure research from the crust to inner core. With ASU colleague Matt Fouch, we are similarly deploying seismometers around Arizona.

(b) *New analysis tool development* from collaboration with applied mathematicians (ASU Math faculty Rosie Renaut and Anne Gelb). This is an NSF-funded initiative, and currently focuses on two key advances: (i) improved signal restoration for more accurate seismic phase identification, characterization, and timing, and (ii) improved retention of short scale information in tomographic inversions through edge-detection and reconstruction approaches [Ms. #1]. Both math colleagues are experienced with these methods in other physical science disciplines – and we are excited to employ them in seismology.

Geophysics and seismology program building at ASU. My efforts to build and grow geophysics at ASU have been four fold: (a) Facilities development and support, (b) Curriculum development, (c) Research team building, and (d) Increased national/international exposure.

Facilities. Using combined start-up funds of myself and Matt Fouch, I co-built the Geophysics Computing Commons (PSF-412), which now serves 6 (soon to be 8) graduate students, and a variety of undergraduate and staff personnel. An NSF Instruments/Facilities grant helped to support a systems administrator of this lab. Along with Fouch, I co-built the Field Seismology Laboratory, which houses our field seismometry equipment, the Geophysics Reading Room, a collective geophysics student office, and the Seismic Museum Display in the PSF-wing lobby, an outreach device that displays latest earthquake information, and contains a "make your own earthquake" drum. Recently, we have begun building a Linux cluster supercomputer that will enable us to run necessary memory intensive calculations. These facilities are important for any successful program

Curriculum. I have spent considerable time working with the department on the best way to train the next generation of successful geophysicists. Several department course requirements were modified to help in this regard. My NSF *CAREER* grant has allowed me to put energy into developing a Structure Seismology emphasis in our department, that focuses on Earth interior research. Also, we are now 3 years running with our DEEP seminary series (http://deep.asu.edu), which serves a multidisciplinary, multi-departmental ASU community interested in Earth and planetary interior research.

Research Team. I have now been on 3 departmental search committees, with 2 geophysics hires secured (Matt Fouch, Allen McNamara). I regularly work with other department faculty at seeking ways to combine strengths to further build Earth interior geophysics at ASU. I have worked hard at building an international team of university collaborators that share the goal of a broad pool of graduate student mentorship. My students and I regularly collaborate with a broad spectrum of experts, worldwide.

Exposure. A most important element to any successful program is talented graduate students. Very early on (at ASU) I worked on a departmental web page overhaul, then along with Matt Fouch, put resources into putting our latest ideas, findings, results, data, etc., on our ASU web pages. This worked: my first year at ASU had 1 graduate student applicant out of 110 indicating interest in geophysics. In the year following our web page construction, 32 out of 130 applicants noted *geophysics* in their disciplinary interest. We are doubling our efforts at increased and improved open-source and data philosophy on our web pages.

Teaching Activities and Goals

My main teaching activities at ASU have centered on (a) supporting geophysics courses and curriculum development (I have taught Geophysics, Seismology, Computers in Geology, and a class on dynamics "Earth's ups and downs" and (b) teaching the 225 student GLG101 course (Introduction to Physical Geology, I've taught it 4 times). For the former, I have worked hard to include as many examples from recent research results as possible, and also to keep the quantitative bar high enough to serve graduate students that may never take further coursework on the topic(s). This is always a challenge in small classes (10-15) with mixed graduate/undergraduate student enrollment. I have worked harder to meet this challenge recently, with word processed lecture notes, in class examples, resource CDROMS of literature and data, and better homework sets aimed at key principles. I was nominated by a graduate student in my Seismology class to give an ASU *Last Lecture*, and subsequently selected.

For GLG101, I have developed a 10 CDROM set of PowerPoint lectures and materials (including movies, animations, images), and a full resource website for students (see http://garnero101.asu.edu). These materials have been freely distributed to over ½ of department faculty, as well as teachers at other institutions worldwide. I also employ modern teaching approaches in the large lecture (e.g., active learning, think-share-pairs, in-class group exercises). This class has gone quite well for me, as I now receive the highest GLG101 student evaluation ratings that have been recorded in our department.

An important goal for me as a teacher is to bring discovery into the classroom, through a variety of methods, and technology infusion, wherever possible. This is a theme in my CAREER grant, as I continue to develop seismology/geophysics curriculum. My upper division and graduate courses all have final projects; I work one-on-one with students to accomplish semester-long research goals, catered towards student interests. Graduate students from a variety of disciplines in our department have expressed enthusiasm for learning new skills that advance their primary research activities. I now utilize the 3D visualization device called *GeoWall* in small and large format lectures, which immediately facilitates student comprehension of often difficult to grasp data and model spatial relationships.

In addition to the classroom setting, I have one-on-one mentored a number of undergraduate researchers: 5 within our department, 1 in Mathematics, and ~8 honors projects in my GLG101 course. I have also supported several of these students from two different NSF *Research Experience for Undergraduates* grants. I have one completed MS student, Melissa Moore, who received a *Best Student Paper* award at the Spring Meeting for the American Geophysical Union Conference (in 2001). I currently have 4 graduate students (effective July 2004) and a postdoc. For graduate student mentoring, I stress vigilantly my expectation for them to become their best, that we are equals, and quickly immerse them in a team of international experts. My students have responded favorably to this, and are quickly establishing themselves as leaders in the global research community.

In the next 2-3 years, I would like to develop two additional courses in our department: (a) *Numerical Methods in the Earth Sciences* that addresses important training that a number of students have expressed desire in, and (b) *Advanced Seismology*. There are now enough seismology concentration graduate students to offer the latter, and is necessary for any future leader in the field.

Service Activities and Goals

At ASU, my service contributions have primarily centered on department activities. I was an undergraduate advisor to half of all department undergraduates, and created user-friendly web materials for degree planning and advising. Recently, I have been on the Graduate Committee, and have worked hard at improving prospective applicant file review. I designed and lead a Prospective Graduate Student Visitation Weekend in our department, which successfully attracted 3 top PhD recruits. I've been on three faculty search committees, as part of building geophysics at ASU (see CV for other ASU service).

National/International service roles include Associate Editor at the American Geophysical Union's (AGU) *Journal of Geophysical Research*, the Seismology Chair at AGU's summer meeting, a chair of AGU's *Studies of Earth's Deep Interior* Focus Group, member of the *Data Management System Steering Committee*, for the Incorporated Research Institutions for Seismology (IRIS), one-time panelist for the *NSF Geophysics Program* (reviewed 112 proposals), organizer of several international conference special sessions, including conceiving/developing AGU's first ever virtual session.

An important goal in all my service roles is to utilize technology where possible to facilitate sometimes lengthy processes, and support of open source philosophy whenever possible (and appropriate). I have recently been invited to apply to two Editorial posts (both AGU journals: *Geophysical Research Letters*, and *Reviews of Geophysics*). I applied for the latter, and have ideas I am excited about trying, should I be chosen. My future goals also include participation in graduate student mentoring in our department, since I already informally speak to 5-10 students a year (not from my group) on a number of topics that loosely fall under the umbrella of leadership training.

Summary

In closing, my first 2-3 years at ASU focused strongly on development of the geophysics discipline, important curriculum changes, and facilities development (along with their technical support and web representation). These were necessary activities to attract and support successful graduate students. In subsequent years I have focused on building an international research team and student mentoring system. These efforts have resulted in: 23 peer-reviewed co-authored publications (in press or print) since coming to ASU, over a dozen others anticipated to be published within the year, 50 co-authored conference presentations (16 invited, 6 of which were longer keynote lectures), 11 invited university colloquium lectures, over $1M research funding (predominantly from NSF programs), and most importantly, an emerging Earth interior research program at ASU that holds great promise for making the best possible future leaders, and competing with other top schools.