List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed
### Dynamic statistical models to improve long-term volcanic hazard assessments

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- **CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW**
  - ☐ BEGINNING INVESTIGATOR (GPG I.G.2)
  - ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
  - ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
  - ☐ HISTORIC PLACES (GPG II.C.2.j)
  - ☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
  - ☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date
  - ☐ PHS Animal Welfare Assurance Number

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  - | Charles B Connor | PhD | 1987 | 813-974-0323 | cbconnor@usf.edu |
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  - | Rocco Malservisi | DPhil | 2002 | 813-974-5465 | rocco@usf.edu |

---

*EAGER* and **RAPID** are not used in this proposal.
Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG). Wilful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Conflict of Interest Certification

When the proposing organization employs more than fifty persons, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Conflict of Interest:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the organization has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Section IV.A.; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the organization’s expenditure of any funds under the award, in accordance with the organization’s conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, “Disclosure of Lobbying Activities,” in accordance with its instructions.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

(1) community in which that area is located participates in the national flood insurance program; and

(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:

(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and

(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)

(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.

The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.
Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations. By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:

(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

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* EAGER - EARly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research
PROJECT SUMMARY

Overview:
This project aims to develop a methodology to better understand long-term trends and hazards in distributed volcanic systems. Current hazard assessments for distributed volcanic fields rely on the timing and distribution of eruptions, using statistical estimates of spatial intensity (vents per unit area), volume intensity (erupted volume per unit area) and volume-flux intensity (erupted volume per unit time and area). To be most effective, these statistical models must be consistent with our process-level understanding of magma productivity, storage and transport, which arises from geochemical (e.g., thermal and mass budgets, evidence of storage and petrologic evolution) and geophysical (e.g., distribution of source and storage zones, strain accommodation) studies. Our challenge is to develop a modeling framework that assimilates multiple observations and so creates more reliable hazard models. The project involves three tasks that run simultaneously. In Task 1 we will gather and use existing data to develop nonparametric (kernel density) statistical models of the spatial intensity and volume intensity for six well-studied volcanic systems in the western U.S.A. These statistical models cast the discrete processes of dike injection, sill development, and eruption as continuous density functions. These functions will be used to compare and contrast the six volcanic systems. Task 2 will focus on assessment of uncertainties in these statistical models (e.g., uncertainty due to vent burial; uncertainty in geochronology). We will sample and map in the Caribou volcanic field to augment existing geochronology with new radiometric age determinations and collect additional volume data. These data are needed to test statistical models of field growth using stochastic recurrence rate and lava flow inundation models that we have previously developed. In Task 3, we will implement stochastic solutions to differential equations governing magma flux, relying on the assumption that, on average, volcanic systems can be described using a parameterized bulk conductivity, which responds to changes in magma productivity, storage, transport and deviatoric stress. The continuous and stochastic nature of these solutions allows a direct comparison of the surface observations typically used in hazard modeling (Tasks 1 and 2) with geochemical and geophysical models.

Intellectual Merit:
This approach will enable us to couple spatial intensity, volume intensity and volume-flux to observations of geochemical and geophysical changes that invariably occur in active volcanic systems. It is crucial for statistical hazard models of distributed volcanic systems to be sensitive to spatial and temporal petrologic trends associated with evolving plumbing systems, and to be consistent with geophysical and tectonic models of these areas. In contrast, current statistical models of distributed volcanic hazards are static (largely based on the distribution of past events, volume, magnitudes). These statistical models can become dynamic (responsive to variability in magma source and bulk conductivity) using our proposed methodology. For these six volcanic fields, we can systematically compare vent intensity, volume intensity and volume flux; test the uncertainty in these models using Monte Carlo simulations of recurrence rate that are sensitive to gaps in the stratigraphic record, and spatial uncertainty inevitably stemming from burial of vents. The result will be an improved understanding of hazard models, and an improved understanding of the significance of trends and episodes of volcanism.

Broader Impacts:
This project brings together a multidisciplinary team to improve the understanding of how volcanic fields evolve in space and time relative to the underlying source to surface magma processes. It will support one graduate student and two undergraduates, who will be trained in computational methods, laboratory analyses and field work. Project results and models will be distributed on the VHub volcanology cyberinfrastructure site, and educational materials will be developed on VHub to convey volcanological concepts (lava flow models, development of volcanic systems) and quantitative literacy concepts (spatial intensity, Monte Carlo simulation, flow inundation modeling) at a variety of levels, including introductory geology courses. This project supports an early-career female scientist and a Hispanic female graduate student.
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*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.
Project Description: Dynamic statistical models to improve long-term volcanic hazard assessments

Overview

Long-term volcanic hazard assessments are designed to increase awareness of the possible destructive effects of future volcanic activity (e.g., Bebbington and Lai, 1996; Turner et al., 2008; Marzocchi and Bebbington, 2012; Connor and Hill, 1995; Hill et al., 1998; Martin et al., 2004; Weller et al., 2006; Mahony et al., 2009; Bebbington and Cronin, 2011; Sandri et al., 2012). Long-term forecasts usually depend on statistical modeling of the distribution of past volcanic events, the timing of these events, and their volume or magnitude. On any time scale, it is imperative that volcanic hazard assessments be consistent with the geochemical, physical volcanological, and geophysical models of volcanic systems (e.g., Reid et al., 2001; Connor et al., 2000; Power et al., 2002). Otherwise, the risk is that long-term hazard models will be static, depending too strongly on past patterns of activity and not accounting sufficiently for the evolving nature of volcanic systems.

A challenge in volcanology is to improve the way we use hard-won geological insights to better account for the dynamic nature of volcanic systems in hazard models. The long term behavior of volcanic systems is revealed in multi-faceted data and models, such as: detailed field mapping, chronology and tectonics of specific volcanic systems (Sherrod and Smith, 1990; Fierstein et al., 2011; Schmidt and Grunder, 2011; Ford et al., 2013), analysis of the petrologic/geochemical evolution of these systems (Cashman, 1992; Hildreth et al., 2012; Germa et al., 2010; Martin et al., 2011) and geophysical data, such as magnetotelluric soundings (Bertrand et al., 2012; Park and Ostos, 2013), gravity surveys (Finn and Williams, 1982; Blakely et al., 1997; Connor et al., 2000; Tamura et al., 2002) and seismic studies (Durrani et al., 1999). How do we assimilate such diverse data-types in hazard assessments? One approach is to use Bayesian models, in which geological data and/or models are used as prior functions to modify likelihood functions based on past patterns of activity (Connor et al., 2000; Martin et al., 2004; Sandri et al., 2012; Marzocchi and Bebbington, 2012). A problem, however, is that there is significant uncertainty about how to recast the geologic data as a probability density function. Making this link requires a methodology that allows us to test statistical models against a variety of geochemical and geophysical models and results.

We propose to construct such a modeling framework that focuses on long-term trends and hazards in distributed volcanic systems. The goal of this modeling framework is to relate statistical models of spatial intensity (vents per unit area), volume intensity (erupted volume per unit area) and volume-flux (erupted volume per unit time and area) to geological models of subsurface processes of magma generation, storage and transport. As described in subsequent sections, these statistical models are continuous (differentiable) surfaces that describe the spatial intensity of volcanism, recurrence rate, and volume flux. Note that statistical models recast discrete volcanic events (e.g., dike intrusion and eruption) as continuous probability density functions. This result allows us to study the evolution of volcanic systems using a bulk continuum formulation. In such models, volcanoes and magma migration are not studied in terms of the complexities of dike injection, sill development and transient processes operating on multiple scales. Rather, these processes are considered as a bulk behavior averaged over geological time. Using the ergodic hypothesis, a statistical equivalent of the behavior of the volcanic system averaged on geological time can be approximated by the flow of a viscous fluid within a homogeneous porous medium (Bonafede and Cenni, 1998; Bonafede and Boschi, 1992). This approach, to our knowledge pioneered by Bonafede and colleagues in volcanology, is widely used in hydrogeology to
characterize systems of complex fracture systems (Lee, 1999; Dewandel et al., 2005; Zobak, 2010). The unique aspect of our proposal lies in the direct evaluation of the current generation of statistical models used in hazard assessment with a model based upon the ergodic hypothesis.

We will use our methodology on two scales. First, on a broad scale, existing data and models will be used to assess current long-term volcanic hazards/forecasts within six volcanic systems in the western United States: Mt. Adams (WA), Three Sisters (OR), Caribou (CA), Clear Lake (CA), San Francisco (AZ), and Springerville (AZ). These targets will test our methodology in a variety of volcanic systems, which transition from distributed- to central-vent-dominated activity. Each of these volcanic systems is well-studied in terms of mapped volcanic units, the timing of eruptions, geochemical changes attributed to the evolution of the plumbing system, and geophysical anomalies that may correlate with magma reservoirs. The type and quality of available data are variable among the volcanic fields, but cumulatively they are among the best studied and documented on Earth. Second, on a more detailed scale, we plan to gather additional radiometric age determination and volume data in the Caribou volcanic field (Lassen region) to uncover the uncertainties in our methods, building on considerable earlier work in this area (Clynne, 1990; 1993; Clynne and Muffler 1990; Bullen and Clynne, 1990; Guffanti et al., 1996; Muffler et al., 2010; 2011). Our workplan covers a range of activities over a three-year task schedule.

**Task 1.** One major task is to gather existing geological data in a consistent way that can be used for statistical model development and testing. The distribution of mapped vents will be used to develop nonparametric (kernel density) statistical models for the six volcanic systems. The volumes of magma erupted from these vents will be estimated using field measurements of lava flows, as other products such as pyroclastic deposits are easily eroded. The timing of eruptive events (linked to specific vents by mapping) will be characterized using existing radiometric age determinations and known stratigraphic relationships. For each of the six volcanic fields, the results of Task 1 will include: (i) a catalog of vent locations, volumes of lava flows associated with each vent, existing radiometric age determinations and reported analytical uncertainties in age determinations for each known vent; and (ii) statistical models of the spatial intensity and volume intensity of volcanism.

**Task 2.** The ages and distribution of vents are incompletely known. This uncertainty must be quantified in order to confidently relate statistical and conceptual models of specific volcanic systems. For example, although the 50 km³ Caribou volcanic field is spatially related to the greater Lassen region it is characterized by less evolved magmas that rose rapidly from the mantle, and has a different, episodic, recurrence rate compared with nearby clusters of volcanoes (Guffanti et al., 1996; Muffler et al., 2011). Task 2 will focus on an assessment of uncertainty related to both the timing of eruptions and the distribution of vents, and the influence of this uncertainty on recurrence rate estimates. Although this uncertainty cannot be entirely eliminated and often cannot be reduced, it is critical to know the magnitude of the uncertainty.

We have previously written a computer code to estimate the uncertainty in recurrence rate of volcanism using a Monte Carlo approach. The code systematically samples distribution functions for undated stratigraphic units and accounts for radiometric age determinations and stratigraphic correlations (Kiyosugi et al., 2012). We plan to revise and improve this code using experience gained in Task 1, then test (validate) this code by gathering additional samples and making radiometric age determinations on key units in the Caribou volcanic field. Estimates of the recurrence rate of volcanism made with and without the new data will be compared. The significance of this comparison will be quantified using Monte Carlo simulation. Even if every mapped vent and flow were radiometrically dated, uncertainty in vent distribution, eruption timing, and volumes (e.g., associated with vent burial by subsequent eruptions)
would still need to be assessed through simulation. We plan to use the spatial intensity models constructed in Task 1, and lava flow simulations, described in the following, to model vent burial and bias in recurrence rate estimates. To our knowledge, this systematic approach has not been previously attempted for these or other volcanic systems. The Caribou volcanic field is an excellent place to test this model, given the large number of age determinations already made (Muffler et al., 2011) and the potential for refinement gained by additional age determinations in adjacent parts of the field.

**Task 3.** In the third task we will apply the ergodic assumption to develop a conceptual model describing magma production and transport through a simple set of differential equations. This simple model will allow us to obtain a continuous description of magma migration in order to validate the spatial intensity, volume flux, and their respective uncertainties, the outputs of Tasks 1 and 2. Using this continuous formulation, additional complexities that influence magma migration, can be implemented through a study of bulk average behavior by changing parameters in a few differential equations. The advantage of this approach is that the magma outputs from Tasks 1 and 2, expressed as continuous density functions, can be directly compared to the output of the numerical modeling solutions. In this way we can explore physical processes that may give rise to heterogeneous flux in numerical models and relate these processes to observed vent distributions and volume flux at the surface. For example, thermal and mass balance estimates have already been made to model the magmatic evolution of the Caribou volcanic field (Guffanti et al., 1996). This 1D heat and mass balance model provides needed parameter estimates for a 3D model to relate the depth, area, and productivity of the magma source region to the observed 2D spatial intensity and volume-flux. Numerical modeling offers a means of linking the geochemical model of the system with observed spatio-temporal patterns of volcanism. This problem is highly under-determined (there are many unknowns), but the continuum approach allows us to explore this underdetermined problem by parameterizing source productivity and bulk conductivity and to analyze the output sensitivity to different assumptions.

This project requires a range of skills, tools and, above all, relies on the availability of a large volume of data from the six volcanic systems. This project team comprises A. Germa (volcanologist/geochronologist), C. Connor (volcanologist), L. Connor (computer scientist) and R. Malservisi (tectonophysicist/model developer) at the University of South Florida (USF). Currently, we have executable computer codes for the determination of spatial intensity, lava flow simulation, Monte Carlo simulation for recurrence rates, and the basic numerical model described in Task 3. These codes will require moderate revision to accommodate the unique aspects of this project. X. Quidelleur at Université Paris-Sud 11 and A. Calvert at USGS will work with A. Germa on precise radiometric determinations, using the complementary K-Ar and $^{40}$Ar/$^{39}$Ar techniques to more accurately constrain the timing of eruptive episodes in the Caribou volcanic field. We have initiated a collaboration with volcanologists from the USGS (J. Donnelly-Nolan, M. Clyne, and D. Ramsey) for sharing vent locations, ages, petrology, and geochemistry. These scientists will also participate in field work for obtaining volume estimates and additional age determinations and the interpretation of results. This concerted effort and multidisciplinary approach provides an excellent starting point for completing this project in three years.

**Conceptual models of distributed volcanism**

Figures 1a and 1b illustrate two conceptual models of volcanism. A distributed volcanic field (Figure 1a) is composed of 10s to 100s of dispersed small-volume ($<1$ km$^3$) monogenetic volcanoes, such as scoria cones, maars, and tuff rings. These distributed volcanic fields have a huge range in average output
rate but a limited range in spatial intensity. Spatial distribution and time-volume relationships suggest that the dimensions of distributed volcanic fields reflect a lateral extent of the magma source region (Valentine and Perry, 2007; Wetmore et al., 2009). A central-vent dominated system comprises a polygenetic volcano, often related to a central silicic system, numerous monogenetic vents (Hildreth and Lanphere, 1994; Guffanti et al., 1996; Hildreth, 2007) (Figure 1b). These systems are characterized by frequent eruptions, generally from vents on the upper flanks of a polygenetic edifice, and persistent high average flux rates (Davidson and de Silva, 2000). Their magma flux is focused (Davidson and de Silva, 2000; Ida, 2009; Annen, 2009) and facilitated by a thermally and mechanically favorable pathway toward the surface that is maintained by frequent eruptions (Fedotov, 1981; Wadge et al., 1982; Walker, 1993; Annen, 2011) and favorable stress conditions (Takada, 1994; Muller and Martel, 2001; Meriaux and Lister, 2002; Gudmundsson, 2002; Rivalta et al., 2005; Karlstrom et al., 2009; Paulson and Wilson, 2010; Maccaferri et al., 2010; Gudmundsson, 2011, Muffler et al., 2011).

![Figure 1](image)

**Figure 1.** Conceptual models of (a) a distributed volcanic field and (b) a central-vent dominated system. For both models, it is assumed that partial melting generated magma in the lithospheric mantle. After migration, basaltic magmas accumulate at the MOHO, creating a deep crustal hot zone (Annen and Sparks, 2002; Solano et al., 2012). Magmas ascend through the crust from this zone. (a) Low conductivity and productivity do not allow magma focusing. Basaltic magmas ascend rapidly through the crust to erupt at monogenetic vents. (b) High productivity of the source region results in high conductivity and magma focusing (Hildreth, 1981; Muffler et al., 1989; Brophy and Dreher, 2000; Hill et al., 2009). The silicic reservoir is impermeable to basaltic magmas that consequently erupt laterally.

For polygenetic volcanic systems, geochemical and petrologic studies have demonstrated that deep crustal hot zones create a mush of crystals plus interstitial melts (Figure 1b), which sometimes evolve into short-lived (20 – 200 yr) reservoirs of melt with suspended crystals (Eppich et al., 2012; Solano et al., 2012). Hildreth and Moorbath (1988) suggested that persistent mafic magma percolation within the mantle allows melts at the base of the crust to aggregate into diapirs or channels. This process produces thermal and mechanical changes in the crust that enhance mantle upwelling and magma focusing (Figure 1b). Modeling suggests that these zones, 10 - 30 km across, are present where the intensity of successive batches of magma is sufficient to maintain aggregation, magma focusing and the development of shallow
reservoirs where differentiation takes place (Annen and Sparks 2002; Hildreth 2007). In contrast, distributed systems appear to lack such features (e.g., Muffler et al., 2011).

We suggest that volume-flux and spatial intensity can be effectively simulated by parameterizing magma transport using bulk conductivity. The conductivity is a function of flow rate (thermally and mechanically favorable pathways), is anisotropic (responds to deviatoric stress and load), and can evolve magma reservoirs at intermediate levels, leading to geochemically distinct batches. This type of model yields a continuous distribution of volume-flux, or potential for volcanism, at the surface. These models can be altered to reflect geochemical models (e.g., deep crustal hot zones or not) and geophysical models (e.g., seismic tomographic anomalies) by changing the bulk conductivity appropriately. Magma migration is complex (predicting the path of an individual batch of magma is a difficult problem!), but over millions of years and on a regional scale the probability of volcanism can be estimated at the surface by modeling the average flow of magma. In other words, a simple parameterization of conductivity can explain varying patterns of spatial intensity observed in volcanic fields.

**Figure 2.** 2D Darcy law simulations treat distributed eruptions as a stochastic process. Three conductivity models are shown: (A) Homogeneous and isotropic constant conductivity. The broad normalized volumetric flow (black curves) at the surface suggests diffuse volcanism. (B) Homogeneous, isotropic constant conductivity with imposed crustal hot zones of higher conductivity centered at 15, 7.5 and 2.5 km depth (black rectangles). Note the flow focusing effects. (C) Same as (B) but with conductivity slightly flow dependent. The flow dependency of the conductivity associated with the presence of the hot zone leads to a highly localized steady state flow at the surface suggesting the presence of central vent volcanism. The model output (black curves) can be compared directly with spatial intensity, volume intensity, and volume-flux statistical models.

Data from different volcanic fields are necessary to correlate the conductivity parameterization with observable geologic rates and processes. Decades of previous work on these US volcanic fields have resulted in a remarkable body of maps, volcanological, geochemical, and geophysical data. The following six volcanic systems represent a spectrum of activity, from central-vent dominated to distributed systems, each exhibiting varying rates of eruptive activity and diverse tectonic settings (Figure 3).
Mt Adams (~1,150 km²) lies along the Cascade Range. It is a ~210 km³ polygenetic volcano surrounded by ~121 individual monogenetic edifices (Hildreth and Lanphere 1994; Hildreth 2007). About 75% of the volcanic units have been dated by high-precision K-Ar dating, geochemical analyses have been performed and eruptive volumes have been estimated for 124 mapped eruptive units (Hildreth and Lanphere 1994; Hildreth and Fierstein 1995; 1997). Origins of melts have been inferred, from Sr, Nd, Pb, Hf, Os and O isotopes (Jicha et al. 2009a) coupled with U-Th isotope disequilibria and Os-Th isotope variation (Jicha et al. 2009b), to be from an intraplate mantle source with a small subduction component, and then interact with young mafic crust. Melt zones beneath Mt St Helens and Mt Adams has been inferred from 3D modeling of magnetotelluric soundings to be located at the Moho and in reservoirs at several levels in the crust (Hill et al. 2009).

**Figure 3.** Location of the chosen volcanic fields (VF)/systems: (1) Mt Adams, (2) Three Sisters, (3) Caribou VF, (4) Clear LakeVF, (5) San Francisco VF and (6) Springerville VF. Triangles locate central-vent dominated volcanoes, circles represent distributed volcanic fields, and diamonds represent transitional fields. Dark grey area shows late Cenozoic volcanic rocks of the Cascade Range. Light grey area limits the Colorado Plateau.

Three Sisters is located 35 km west of Bend, Oregon, and includes five Quaternary stratovolcanoes (North, Middle and South Sister, Broken Top and Mount Bachelor) that were constructed more or less contemporaneously between 120 and 14 ka. They form a central silicic (andesite to rhyolite) 20x25-km area within which ~50 eruptive vents have been mapped (Taylor 1990; Hildreth 2007; Hildreth et al. 2012). These are surrounded by ~20 mafic centers generally younger than 50 ka (Hildreth et al. 2012). Magmas originate from small degrees of partial melting (<10%) of an asthenospheric source (Reiners et al. 2000; Mitchell and Asmerom 2011; Schmidt and Grunder 2011), and crustal reservoirs have been successively emplaced at different levels, evolving from basalt to rhyolite (72 – 77 % SiO₂) (Brophy and Dreher 2000; Stelten and Cooper 2012). Recent uplift, recorded between 1996 and 2009, has been attributed to an intrusion of magma at ~6.5 km depth (Wicks et al. 2002; Zurek et al. 2012). About 90% of the volcanic units have been dated, geochemical analyses have been acquired, and the eruptive chronology is established and published (Hildreth et al. 2012). Thus, no additional age determinations are required.

Clear Lake Volcanic Field is located within a pull-apart basin with a total erupted volume of ~100 km³. This volcanic field comprises > 100 basalt to rhyolite volcanic units (Hearn et al. 1995). About 160 eruptive vents built lava domes, scoria cones and maars, and two larger silicic volcanoes, Cobb Mountain and Mt Konocti (Hearn et al. 1981; Hearn et al. 1995). Volcanic rocks decrease in age northward, from 2 Ma in the south to about 10,000 years in the north, and four eruptive periods have been individualized (Donnelly-Nolan et al. 1981). Volcanism is thought to be related to a slab window and controlled by tectonic extension within the San Andreas transform fault system (Furlong and Schwartz, 2004). A
Individual erupted volumes can be calculated using existing map data.

The San Francisco Volcanic Field (SFVF), located near the southern margin of the Colorado plateau, consists of ~500 km³ of Pliocene to Pleistocene (~6 Ma to < 1 ka) lava flows and tephra deposits covering an area of 5000 km² (Moore and Wolfe 1987; Newhall et al. 1987; Ulrich and Bailey 1987; Wolfe et al. 1987a; 1987b; Holm 1988; Conway et al. 1997; 1998; Fenton et al., 2013). The field contains ~600 monogenetic vents, basalt flows, eight large intermediate to silicic centers and several silicic domes. The mafic monogenetic centers range in composition from alkali to transitional basalts (Arculus and Gust 1995), and the presence of intermediate to silicic centers in this mafic field suggest a bimodal magmatic system (Tanaka et al. 1986; Chen and Arculus 1995). Radiometric ages (mainly K-Ar and 40Ar/39Ar) and paleomagnetic polarity determinations constrain the migration of volcanism in the SFVF (Tanaka et al. 1986; Conway et al. 1998; McKee et al. 1998). High velocity zones have been imaged at upper crustal levels beneath the SFVF (Stauber 1982; Durrani et al. 1999; Bailey et al. 2012). Also, a recent study has revealed that young melts beneath the Colorado plateau were extracted from the base of the lithosphere while shallower melts reveal higher degrees of partial melting (Reid et al. 2012). We do not plan to collect additional samples in the SFVF.

The Springerville Volcanic Field (SVF) is the southernmost marginal Colorado Plateau volcanic field. It comprises more than 400 monogenetic eruptive vents (maars, scoria cones and domes) and lava flows that have erupted between 2.1 and 0.3 Ma (Condit et al. 1989; Connor et al. 1992) at a rate of $1.5 \times 10^{-4}$ km³/yr (Crumpler et al. 1994). In terms of areal extent, eruptive and petrological style, SVF is similar to the SFVF, but it does not include a coeval large silicic central volcano. In that sense, SVF is a distributed volcanic system. Models of magma conduits and reservoirs beneath this field suggest that SVF magmas ascended through magma mush columns with a multitude of sills within two intervals of magmatic differentiation (0-12 and 23-30 km) (Putirka and Condit, 2003). Eruptive history of the field has been constrained through chemical analyses of lava flows, K-Ar ages, paleomagnetic and stratigraphic relationships determined from mapping of every flow unit (Condit et al. 1993; Crumpler et al. 1994). We do not plan to collect additional samples in the SVF.

The area we plan to concentrate on in greatest detail is the Caribou Volcanic Field (CVF) located within a cluster of volcanoes, broadly termed the Lassen segment, in Northern California. The Lassen segment includes approximately 476 calc-alkaline vents younger than 2 Ma and 121 vents erupted 2 – 7 Ma (Hildreth 2007). Located about 20-30 km east of Lassen Peak, CVF (425 - 0 ka) contains ~140 basaltic to andesitic cones and their lavas. Several features of the Caribou volcanic field make it ideal for developing and testing our methodology. First, portions of the field are already extremely well dated and mapped in great detail. The Poison Lake Chain in the NE part of the field actually formed in nine episodes between approximately 100-110 ka (Muffler et al., 2011). This not only helps us constrain recurrence rate, but helps us identify volcanic episodes/events, rather than vents, which in turn impacts spatio-temporal models. Second, the petrogenesis of this field is well-constrained and comparatively simple (lacking a deep crustal hot zone). Third, the thermal and mass budget has already been estimated in a 1D model (Guffanti at al., 1996). Fourth, NW alignments of vents represent a Basin and Range overprint (Muffler et al., 2011), allowing us to test the sensitivity of bulk conductivity to anisotropy (deviatoric stress/strain). Fifth, we can compare detailed study of the CVF with spatial intensity, volume intensity and volume flux and numerical modeling of the Lassen region as a whole. Sixth, the region as a whole represents a significant volcanic hazard (Scott et al., 1995). For these reasons we plan to
concentrate on the CVF and fill gaps in the geochronology by gathering additional age determinations in the central and SW parts of the field (see Task 2).

**Research Design and Methods**

**Task 1.** For each volcanic system, the objectives of Task 1 include: (i) locating past events, (ii) acquiring volume data on volcanic units, and (iii) estimating the spatial intensity of volcanism and volume intensity.

**Locating past events.** Determining the location of past eruptive events is a crucial first step in estimating the spatial intensity of volcanism. Geographic coordinates of the eruptive vents from SVF (Condit and Connor 1996; Conway et al. 1998; Condit 2010), and SFVF (Moore and Wolfe 1987; Newhall et al. 1987; Ulrich and Bailey 1987; Wolfe et al. 1987a; 1987b) are already available. Eruptive vent locations from the Quaternary Cascade fields will be provided by USGS colleagues, based on geologic studies by numerous investigators.

**Estimating erupted volumes.** The total volumetric output of erupted volcanic material is often unknown and uncertainties in estimations can be large. Frequently, mapped contours of older lava flows, now partially or totally covered by younger flows, do not reflect their original morphology. Our goal is to estimate the eruptive volume, with uncertainty, for each mapped lava flow in the CVF and adjacent areas to the extent possible, and use existing data for the other fields. We will refine published volume estimates by gathering data on lava flow morphology (e.g. flow thickness, flow length, area of inundation), in the field, using a Tru-pulse laser rangefinder and RTK differential GPS, to rapidly obtain accurate field measurements, augmented by geological maps, digital elevation models, and imagery. Lava flow measurements will involve mapping of the flow boundaries, length measurement, flow thickness at different locations along the flow, identification of morphological features indicative of rheological properties and vent location. Our plan is to obtain volumes erupted from individual vents and eruptive events in order to later estimate volume-flux intensity. Afterwards, ArcGIS tools will assist us in solving morphology issues reconstructing paleotopographies of past eruptive stages (Lahitte et al. 2012), and estimating volumes and uncertainties.

**Estimating spatial intensity.** Kernel density estimation is a statistical method defining the spatial intensity (the number of events per unit area) and is a simple way to identify vent clustering and tectonic control on the distribution of vents (e.g. clusters orientation) within a volcanic field based on vent location. We will estimate the spatial intensity of volcanism in the six target areas using a nonparametric kernel density function based on the mapped spatial distribution of identified eruptive vents (Connor and Hill, 1995; Connor and Connor, 2009; Kiyosugi et al., 2010, 2012; Bebbington and Cronin, 2011). Spatial intensity maps will be used to define a boundary for each volcanic field that encloses all of the eruptive vents within which past eruptive activity has taken place. This boundary implies the magma footprint of a volcanic field and may reflect the extent of the thermal anomaly at depth (Valentine and Perry, 2007; Kiyosugi et al. 2010). For example, by using the area enclosed by the 95th percentile isoline of spatial intensity (Connor and Connor, 2009), the area of each volcanic system can be quantified and compared.
Our statistical analysis will be based on a bivariate, Gaussian kernel function and a directional, 2D smoothing bandwidth to account for the unique directional distribution of vents within each field. The intensity has its maximum centered at the vent location and decreases with distance from this point. The 2D smoothing parameter, or bandwidth, controls how local intensity varies with distance from the vent and is unique for each field. Bandwidth selection is a key feature of kernel density estimation (Connor et al., 2000; Jaquet et al., 2008), and is particularly relevant to investigating the controls of vent density on volcano morphology. Each volcanic field’s unique smoothing bandwidth represents an optimal smoothing for that field that is based on a mean integrated squared error (MISE) approach (Wand and Jones, 1995) and is calculated from the locations of all known vents (Figure 4). This optimal bandwidth selection method (Duong and Hazelton 2005a, b; Duong 2007; Chacon and Duong 2011; Chacon et al 2011; Chacon and Duong 2013) is preferred since it objectively determines a reasonable smoothing for each field. The bandwidth matrix is estimated using the SAMSE (smoothed asymptotic mean integrated squared error) method for multivariate kernel smoothing (Duong, 2007). The code is from the software package ks, kernel smoothers for univariate and multivariate data (Wand and Jones, 1994, 1995; Sheather and Jones, 1991; Duong and Hazelton, 2003, Chacon and Duong, 2010), and is part of R, a free software environment for statistical computing and graphics (Hornik, 2009). Bivariate bandwidth selectors like the SAMSE method are extremely useful because, although they are mathematically complex, they remove subjectivity from the process, which is essential for comparing the spatial intensity of volcanic systems.

**Figure 4.** (Left) Unique bandwidths calculated for 8 volcanic fields on the Baja California peninsula in Mexico, using the SAMSE bandwidth selection method (Duong, 2007). Each bandwidth is shown as a set of 3, 2D ellipses (representing 1, 2 and 3 standard deviations) indicating how local intensity varies with distance from the vent. (Right) Resulting composite model for the spatial intensity of volcanism. Note the orientation and elongation of the kernels, parallel to the strike of subduction.
The contoured surface of spatial intensity for each of the six fields will serve several purposes. First, spatial intensity maps of volcanism will be compared, contrasting the area, spatial intensity and distribution of central vents in each volcanic field. Second, we will weigh the spatial intensity by volume of mappable units (Martin et al., 2004) to look at spatial variations in productivity and relate these to geochemistry and age. Third, the shape of the optimized bandwidth can be compared among the target areas. For example, the bandwidths shown in Figure 4 for eight volcanic fields in Baja California are highly elliptical and oriented parallel to the strike of the subducted slab and normal faulting in the region (Germa et al, under review). Importantly, the shape and area of each volcanic field, and the shape and area of the bandwidth kernel are related to the geometry of the source region and the parameterization of conductivity.

**Task 2.** Spatial intensity and volume intensity maps provide a well-constrained, albeit static model of the distribution of volcanism in these fields. In Task 2 we plan to develop a model of the recurrence rate and spatio-temporal models of volcanism in these fields. These models will rely on existing radiometric age determinations, as well as new age determinations on key units in the CVF.

**Recurrence rate models.** In most volcanic fields, only a fraction of units have radiometric age determinations, and sometimes analytical uncertainty associated with these age determinations is large. Stratigraphic relationships and paleomagnetic stratigraphy, and sometimes morphologic data are used to further constrain the sequence of some eruptive events. Often many units have no age constraint, other than being inferred to be Quaternary in age based on morphology. We have developed a hierarchical model for modeling the recurrence rate of volcanism using incomplete datasets (Kiyosugi, 2012). Briefly, in this model each eruptive unit is assigned a cumulative number \(1,2,3,\ldots N(S,T)\) in a viable stratigraphic sequence, where \(N\) is the total number of units sorted by age, between maximum \((S)\) and minimum \((T)\) age. For radiometrically dated units, the age is sampled accounting for uncertainty; for stratigraphically constrained units, the age is sampled from a uniform random distribution between the bounding units, and so on. For undated units with no additional stratigraphic constraints, the age is sampled between \(S\) and \(T\) (e.g., the Quaternary). In practice, the permutations become complex but our code extracts a viable sequence of ages. Recurrence rate at each time period of interest between \(S\) and \(T\) is calculated. Of course, many alternative age distributions may be sampled, especially in cases with few age determinations. By sampling the stratigraphic sequence many times (e.g., 10000) using Monte Carlo methods, we are able to estimate the uncertainty in the model recurrence rate. After applying this algorithm to other volcanic fields (Abu, Yucca Mountain, Izu-Tobu) we have been able to evaluate the significant of episodes or phases or eruptive activity, and to identify key units that can constrain recurrence rates if more radiometric age determinations are made. We plan to modify this code to run more efficiently for the six volcanic fields and identify key units that, if dated, can improve recurrence rate estimates significantly. We will then collect new samples that need age determinations in Caribou volcanic field, as described in the following, and refine the recurrence rate estimates.

**Radiometric age determinations.** Many age determinations are available, but gaps in the record exist and often dates are not accurate enough to estimate recurrence rates or identify stages of volcanic activity. Consequently, we will date about 50 volcanic units, using the two complementary K-Ar (20 samples) and \(^{40}\text{Ar}^{39}\text{Ar}\) (30 samples) dating techniques. These methods allow comparatively rapid and accurate dating of both ancient and young lavas, even with low radiogenic Ar content (Quidelleur et al. 2001; Gillot et al.
2006, Germa et al., 2011a) and very low potassic mineral phases (Germa et al. 2010). For young basaltic and andesitic products, the reactor-induced production of interfering argon isotopes from Ca can limit the $^{40}\text{Ar}/^{39}\text{Ar}$ while K-Ar ages remain unaffected. On the other-hand, the $^{40}\text{Ar}/^{39}\text{Ar}$ technique will allow us to check that excess $^{40}\text{Ar}$ does not affect the K-Ar determinations of differentiated minerals, such as K-feldspars, when present. For inter-laboratory comparison, key units will be dated by both techniques. K-Ar geochronology will be completed in the Laboratoire IDES (Orsay, France). A total relative age uncertainty of about 1.4% for samples with relatively high radiogenic yield, such as those selected for the project, is routinely achieved in this laboratory (Chenet et al. 2007; Germa et al. 2011b; Al Kwatli et al. 2012; Gertisser et al. 2012; Hildenbrand et al. 2012; Boulesteix et al. 2013). Germa has dated about 150 samples using this facility, which will reduce the time required for analyses. Project collaborators from the USGS (A. Calvert, J. Donnelly-Nolan and M. Clynne) will work with the USF team to select samples for $^{40}\text{Ar}/^{39}\text{Ar}$ dating from the Caribou volcanic field. Most of the $^{40}\text{Ar}/^{39}\text{Ar}$ age determinations for the Cascades volcanic fields have been obtained from the Volcano Science Center, USGS, Menlo Park, so it is important that additional dating follow the same procedure.

Because the Caribou volcanic field has received detailed study, the chances of dating many units and getting accurate volume estimates is high, and will allow us to test the reliability of our models. Sampling strategy for K-Ar and $^{40}\text{Ar}/^{36}\text{Ar}$ dating is to collect non-weathered, hand-sized blocks of massive (not loose) lava flows or domes. For age determinations, we will first make thin sections of the collected samples to select candidates for $^{40}\text{Ar}/^{39}\text{Ar}$ dating and K-Ar dating. Jaw crushing and sieving within an appropriate size fraction (typically 63 to 250 microns) will be followed by mineral separations, using heavy liquids and magnetic separators. This preparation is compulsory to obtain homogeneous groundmass concentrates or mineral separates such as plagioclases, and to avoid excess Ar from xenocrysts. Rock preparation will be done at University of South Florida, and independent K and Ar measurements will be performed at the Orsay, facility for K-Ar dating, whereas $^{40}\text{Ar}/^{39}\text{Ar}$ dating will be performed at the USGS facility.

**Spatio-temporal uncertainty.** Over time, older eruptive vents are buried by subsequent volcanic eruptions. Using lava flow volume data we will systematically investigate the average number of lava flows needed to bury older units because this affects the spatial intensity estimate. Initially, the model spatial intensity (described in Task 3) will be used to run Monte Carlo simulations of lava flows by sampling potential vent locations from the surface, and then simulating the construction of topography. Connor et al. (2012) have created a lava flow model, written in PERL, that is similar in principle to other inundation models but treats vent location and lava parameters probabilistically. We will use the code to model the burial of older lavas, given an effusive eruption at a particular location estimated using the model spatial intensity. The model assumes that each cell of a digital elevation model (DEM) inundated by lava retains or accumulates a residual amount of lava. This residual corresponds to the modal thickness of the lava flow, calibrated by field measurements of flow thickness. One advantage of this model is that it fully utilizes lava flow morphologic data (length, volume, thickness, area) that can be measured in the field and gathered from the literature. As flow thickness varies between lava flows, the residual value chosen for the flow model also varies between simulations. The measured properties of various lava flows are fit to a statistical distribution and a residual value is randomly chosen to represent the modal thickness of each simulated flow based on the fit distribution. A second advantage of this approach to modeling topography development is that the code is quite fast and flexible, so additional rules (e.g., rheological) can be implemented to illustrate the effects of varying model assumptions.
To illustrate the impact of additional age determinations on the model development and uncertainty estimates, consider the spatial intensity map for the Caribou volcanic field (Figure 5). The vents included in the field is based on the geochemistry of the basalts and andesites, using the grouping by Guffanti at al. (1996) to differentiate the Caribou vents from Lassen and Basin and Range magmas. The spatial intensity map mimics the NW-trend of individual alignments reaches peak intensity in the 39-vent Poison Lake chain in the NE part of the field. Detailed geochronology has already indicated that the Poison Lake Chain is best modeled as nine episodes of activity in a narrow time range (Muffler et al., 2011). Further geochronology in the central part of the field will allow us to determine the total number and distribution of episodes and refine this spatial intensity map accordingly. Volume will allow us to recast the map as volume intensity or volume flux. Lava flow modeling using lava flow morphology data will allow us to estimate the number and distribution of buried events. Thus, the field is an ideal area to test the sensitivity of the hazard model using both existing data and additional data gathered in the timeframe of the project.

**Figure 5.** Spatial intensity map of the Caribou Volcanic Field (CVF) using vent location data from the USGS (Muffler et al, 2010). The CVF footprint is defined petrologically (white circles) from Guffanti et al., 1996). Note the NW-trend of alignments, including the highest intensity zone (red) delineating the Poisson Lake Chain. Other volcanoes (black dots) are part of the Lassen segment. Uncertainty in this spatial intensity estimate can be assessed by: (a) additional radiometric age determinations to define events and uncertainty in recurrence rate, and (b) volume estimates of the units and episodes, (c) modeling buried vent locations. Output of the numerical model in Task 3 will be compared to these maps, to determine the anisotropy in conductivity and related features. Magma source region will be defined by the 95th (or 99th percentile) on the spatial maps, and productivity estimated using data from Guffanti et al. (1996) and Muffler et al. (2011).

**Task 3.** In Task 3 we will compare statistical models of spatial intensity and volume-flux with a bulk continuum model formulation. Spatial intensity and volume-flux models represent bulk output from the magma source region plus complex factors that affect magma ascent. By expressing magma output as a bulk continuum formulation, we are able to explore the physical processes that give rise to observed spatial intensities using partial differential equations. In these models, volcanoes and magma migration
are not studied in terms of the complexities of dike injection, sill development and transient processes operating on multiple scales. Rather, these processes together represent a bulk behavior averaged over a regional scale and geological time. This behavior can be statistically approximated by modeling the flow of a viscous fluid within a homogeneous porous medium using Darcy’s law with variable conductivity dependent on flow rate and lithospheric stresses (Bonafede and Boschi, 1992; Bonafede and Cenni, 1998). Using this continuous formulation, additional complexities that influence magma migration such as complex sources, magma generation, magma rheology, tectonic stresses, and/or anisotropic/heterogeneous behavior of the porous medium, can be simply implemented by varying the choice of source and conductivity parameters. In other words, conductivity is the filter describing how the magmatic source manifests as volcanism at the surface.

In order to test the idea that a relatively simple numerical model can improve the link between statistical models of spatial intensity and geophysical/geochemical models of volcanism, and temporal trends in volcanic systems, we will construct a 3D finite difference model representing a flow controlled by magma overpressure within a porous material (Darcy’s Law). Although flow through a porous material does not directly reflect the motion of a single batch of fluid (magma) through the crust, it does reflect, in a statistical way, its bulk migration. On the other hand, variability in conductivity of the medium represents multiple pathways due to the presence of fractures, varying lithology, thermal state, and/or regional stresses. This ergodic approximation of magma flow, magma accumulation (e.g. magma chamber), or the preferential path of magma migration, could lead to heterogeneity of the local effective conductivity, and thus to an evolution of the volcanic system. The resulting, normalized, surface volumetric flow could be interpreted as a distribution of the probability of magma reaching the surface, and thus of volcanic eruption (Bonafede and Boschi, 1992; Bonafede and Cenni, 1998).

Figure 2 shows 2D examples of this approach. Case A, employs a uniform and stationary source and constant, isotropic conductivity. In this homogeneous case, variability in vent distribution is only a function of random sampling on the model output. Case B keeps the uniform and stationary source but allows hot zones of high conductivity imposed by geochemical and geophysical models. The normalized, surface volumetric flow is plotted above each model. A random sampling of this curve produces possible vent distributions that can be compared with the observed spatial and volume intensities. The K-S test will measure goodness-of-fit between the model and the spatial intensity and is expected to indicate any significant deviations.

To simulate the creation of a preferred path due to fracturing and thermal weakening from repeated magmatic batches, the conductivity is allowed to be flow dependent to study the eventual development of crustal hot zones. A critical point in this analysis is the relaxation time, that is, the amount of time a region remains the preferred pathway after the bulk passage of magmatic batches. A further step will include the investigation of anisotropic conductivity related to both preferred flow path and the evolution of tectonic stress regimes. Once we are able to simulate realistic scenarios of the migration pattern, the stationarity of the source will be relaxed, allowing us to analyze how different sources might affect the spatial intensity of volcanism observed at the surface for a given crustal behavior.

Next, we will combine Darcy’s law of magma migration with the enthalpy approximation describe by Katz (2008) to model source/sink (solidification and magma generation) in order to more fully simulate the complex range of conductivity behavior necessary to simulate realistic magma migration. The enthalpy approximation accounts for heat transfer from a two-phase magma (crystal and melt) to host rock, latent heat, diffusion, and adiabatic temperature change. It includes a temperature dependent viscosity law and requires the specification of porosity, the geotherm, and composition of magma and
host rock throughout the model domain. This model will test the variation in volume-flux and spatial intensity given depth, area, and productivity of uniform magma source regions. If distributed volcano clusters are related to uniform source regions, then change and rate of change in spatial intensity within vent clusters should reflect the scale of thermal diffusion along the magma ascent path (e.g., McKenzie, 1984; Katz et al., 2007; Katz, 2008).

**Expected Outcomes**

Overall, the numerical model results should link statistical models of volcano distribution with the processes governing magma production and ascent, and thus improve our understanding of the evolution of volcanic fields. This research will improve methods for long-term volcanic hazard assessments. This method will enable us to forecast how spatial intensity, volume intensity and volume-flux change in response to geochemical and geophysical changes that invariably occur in an active volcanic system. In contrast, the current generation of statistical models are static (based on the distribution of past events). We can make these statistical models dynamic (responsive to changes in magma source term and bulk conductivity) through implementation and testing of the proposed model.

**Broader Impacts**

This proposal will support Aurélie Gerra, a young female scientist establishing her career in geochronology and volcanology. Undergraduate and graduate students will participate in field work, geochronological analyses, numerical model development, and data analysis and visualization using state-of-the-art computing tools. Graduate students will work part time as teaching assistants in Physical Volcanology at USF, and bring research and computational experience to the classroom. We plan to run a physical volcanology field trip for undergraduates in the Caribou volcanic field as part of this experience. New age determinations, volume estimates, spatial density maps and related products will complement the growing database of scientific knowledge describing the development and eruptive history of US volcanic fields. This knowledge is needed for development of volcanic hazard models for US cities and populations located near these fields. These results will augment our approach in the funded USAID PEER proposal to collaborate on evaluation of volcanic hazards in the Ararat valley (Armenia), which is also related to distributed volcanism. Unique computer codes will be made available for download and/or online use via VHub, the NSF-sponsored cyberinfrastructure site for volcanology. Documentation and an example manual will be developed and added to the VHub site to introduce students, researchers, and educators to our unique approach. Previous experience indicates that online participation greatly expands when exercises (see our volcanology modules hosted on VHub and the SERC website) are developed to teach volcanology and quantitative literacy topics using VHub resources. We will develop such exercises using the project codes to convey volcanological concepts (lava flow models, vent density, development of composite volcanic systems) and quantitative literacy concepts (spatial density, Monte Carlo simulation, flow inundation modeling) at a variety of levels. The PIs and undergraduates will participate in preparation of these resources. If warranted, the education and outreach portion of the project will be written up for Journal of Geoscience Education. Conclusions will be disseminated at conferences (Fall AGU) and the results will be published in high impact journals.
Workplan

This project will be completed in three years. One main advantage is the fact that much of the needed data and required computer codes are already in hand. Additional required data can be gathered in one field season and tasks can be run in parallel. Germa will lead field work efforts in Year 1 to locate eruptive centers and volcanic deposits and measure length, thickness, and morphology of lava flows. Sample selection and radiometric dating with A. Germa, X. Quidelleur and A. Calvert will proceed in Years 2 and 3. Simultaneously, C. Connor, L. Connor and R. Malservisi, will develop the structure for statistical and numerical analyses. This framework will enable us to perform analyses in a cooperative and modular fashion. A meeting is planned in Menlo Park at the end of Year 1 (during the AGU Fall Meeting in San Francisco) to jointly review results across the entire project. Interpretation of data and dissemination of results will occur at regular intervals during the length of the project.

Previous NSF Support

DRL 0940839 CDI-Type II Proposal: VHub: Collaborative Research: Cyberinfrastructure for Volcano Eruption and Hazards Modeling and Simulation ($136,217 USF portion). USF’s role in this cyberinfrastructure project is to port the Tephra2 tephra dispersion model to the VHub site and to provide supporting materials for code development and use. This has been extremely successful. Tephra2 and the student version we created are the most heavily used simulation tools on VHub, with real-time simulation access through a GUI and online manuals in English and Spanish. This funding supports graduate student Leah Courtland, who has published one volcanology paper and one numeracy paper from the VHub project [Courtland et al., 2012a; 2012b]; she has a third VHub paper accepted to Bulletin of Volcanology and has received an NSF post-doctoral fellowship to take her studies in a new direction at Georgia Tech. Workshops have occurred at AGU, IUGG, COV, PASI.

EAR 0910696 Estimating Eruption Model Input Parameters From Direct Observations of Deeply Eroded Basalt Conduits, San Rafael, UT ($178,775). Infield work in the San Rafael we have discovered numerous deeply eroded conduits and mapped these using conventional techniques and LiDAR (through additional support from UNAVCO). The LiDAR data are allowing us to construct 3D models of volcano conduits. Sampling of conduits for a suite of geochemical analyses is completed indicating that conduits are zoned with progressive mixing with wallrock. In total, there is a compelling case for conduit development through erosion as magma ascent velocities increase in the bubbly flow region. This work has supported graduate students Koji Kiyosugi and Brian Ferwerda (Ferwerda et al., 2011; Kiyosugi et al., 2011). Numerous undergraduates have participated in LiDAR work and will again in a second survey in May 2012. An airborne LiDAR survey will be flown in 2013 to knit together the TLS data (funded by NCALM to graduate student J. Richardson). One publication appeared in Geology (Kiyosugi et al., 2012) and another in Lithosphere (Diez et al., 2009). Additional abstracts: Diez et al. (2009); Connor and Connor (2010); Wetmore et al. (2010).
REFERENCES


Annen, C 2011, Implications of incremental emplacement of magma bodies for magma differentiation, thermal aureole dimensions and plutonism–volcanism relationships. Tectonophysics, vol 500, pp. 3 - 10

Annen, C. and R. S. J. Sparks (2002). Effects of repetitive emplacement of basaltic intrusions on thermal evolution and melt generation in the crust. Earth and Planetary Science Letters 203: 937-955.


Fenton, C.R., et al., 40Ar/39Ar dating of the SP and Bar Ten lava flows AZ, USA: Laying the foundation for the SPICE cosmogenic nuclide production-rate calibration project, Quaternary Geochronology (2013), http://dx.doi.org/10.1016/j.quageo.2013.01.007


a. Professional Preparation
Ph.D. in Geology, University Paris-Sud 11, Orsay, France, December, 2008.
M.Sc. in Geology, University Paris-Sud 11, Orsay, France, June, 2005.
B.Sc. in Geology, University Blaise Pascal, Clermont-Ferrand, France, June, 2004.
B.A. in Geology, University Blaise Pascal, Clermont-Ferrand, France, June, 2003.

b. Appointments
Visiting Research Assistant Professor, Department of Geology, University of South Florida, Tampa (2013-2014)
Post-doctorate fellow, Department of Geology, University of South Florida, Tampa (2012-2013)
Voluntary Research Assistant, Department of Geology, University of South Florida, Tampa (March 2011- July 2012)
Post-doctorate Fellow, CICESE, Ensenada, Baja California, Mexico (November 2010 – February 2011).
Teaching and Research Assistant, Earth Sciences Department, Lab. IDES, University Paris-Sud 11, Orsay, France (September 2008 – August 2010).

c. Publications
c1. Five Selected publications relevant to this proposal

c2. Five other recent publications


d. Synergistic Activities
- Convener EGU General Assembly 2012 session GMPV4.10/GM2.7 Spatio-temporal perspectives on volcanological processes and volcanic landforms.
- 2011- present: member of IAVCEI Commission on Monogenetic Volcanism
- 2007 – present: member of AGU
- 2008 – present: member of IAVCEI

e. Collaborators & Other Affiliations

e.1. List of Collaborators
Xavier Quidelleur, University Paris-Sud 11, Orsay, France.
Edgardo Canon-Tapia, CICESE, Ensenada, Mexico.
Catherine Chauvel, University Joseph Fourier, Grenoble, France.
Ralf Gertisser, Keele University, U.K.
Pierre-Yves Gilliot, University Paris-Sud 11, Orsay, France.
Pierre Lahitte, University Paris-Sud 11, Orsay, France.
Shasa Labanieh, University of Bretagne Occidentale, Brest, France.

e.2. Graduate advisors
PhD and M.Sc. advisor: Xavier Quidelleur, Lab. IDES, University Paris-Sud 11, Orsay, France.
M.Sc. advisor: Pierre-Yves Gilliot, Lab. IDES, University Paris-Sud 11, Orsay, France.
B.Sc. advisor: Philippe Labazuy, Lab. Magmas et Volcans, University Blaise Pascal, Clermont-Ferrand, France.
Biography: Charles B. Connor

Professional Education:
PHD in Geology, Dartmouth College, Hanover, NH, USA, 1988.
MS in Geology, Dartmouth College, Hanover, NH, USA, 1984.
BS in Geology, University of Illinois, Urbana, IL, USA, 1982.
BA in Anthropology, University of Illinois, Urbana, IL, USA, 1982.

Professional Appointments:
Professor, University of South Florida, 2001–
Principal Scientist, Southwest Research Institute, 1998–2001
Senior Research Scientist, Southwest Research Institute, 1992–1998
Associate Professor, Florida International University, 1991–1992
Assistant Professor, Florida International University, 1987–1991

Honors and Awards
Sigma Xi Award, Dartmouth College, 1985
Master’s of Innovation Award, Zenith Data Systems, 1988
Leverhulme Fellow, University of Bristol, 2002

Products: Related Publications

Products: Other Publications


**Synergistic Activities**

Associate Dean of Research, College of Arts and Sciences, University of South Florida, 2012–

Chair, Committee to develop safety guidelines for assessing volcanic hazards to nuclear facilities, International Atomic Energy Agency, resulting in first global standard on safe siting of nuclear power plants with respect to volcanic hazards, 2004–2011

Chair, Department of Geology, University of South Florida, 2001–2009


Development of Tephra2, an open-source and web-available code-

**List of Collaborators**

Collaborators and Co-Editors: Mark Bebbington (Massey, NZ), O. Bokhove (Twente U, Netherlands), Costanza Bonadonna (U Geneva), Laura Connor (USF), Arkady Karakhanian (Armenia National Academy), Sarah Kruse (USF), Rocco Malservisi (USF), Abani Patra (U Buffalo), K. Meliksetian (Armenia National Academy), Ivan Savov (Leeds Univ, UK), R.S.J. Sparks (Bristol, UK), G. Swindles (Leeds U, UK), G. A. Valentine (U Buffalo), Paul Wetmore (USF)

Thesis Advisors: R. E. Stoiber (deceased), Noye Johnson (deceased), Chuck Drake (deceased)

**Thesis Advisor and Postgraduate-Scholar Sponsor** Aurelie Germa (Post-Doc), Sylvain Charbonnier (Post-Doc), Jennifer Lewicki (Post-Doc), Michael Conway (Post-Doc), Samantha Tavarez (Ph.D.), Jacob Richardson (PhD), Ophelia George (PhD), Leah Courtland (PhD), Koji Kiyosugi (PhD), Jose Armando Saballos (PhD), Sophie Pearson (PhD), Alain Volentik (PhD), Mikel Diez (PhD), Catie Carter (MS), Amanda Hintz (MS), John Petriello (MS), Heather Lehto, (MS), Mark Byrne (MS), Rick MacNeil (MS), Jennifer Weller (MS), Kristin Martin (MS), John Arifstrom (MS), Sammantha Lane-Magsino (MS), Ali Malek (MS), Xiao Dan Song (MS)

Total number of doctoral students advised: 9
Total number of Post-doctoral Fellows sponsored: 4
BIOGRAPHICAL SKETCH

NSF Format Vitae: Laura Connor

**Education**
M.S. in Computer Science, University of Texas at San Antonio, Fall, 1999.
BS in Biology, Univ. of Illinois, Urbana IL, January, 1982.

**Professional Appointments**
Associate Research Scientist, Computer Scientist in Department of Geology, University of South Florida, (August, 2010 – present)
Co-owner and Vice-President, Desperate Measures Worldwide, Inc. (2003–present)
Courtesy Research Scientist, Department of Geology, University of South Florida (2001–2010)
Software Engineer, Cyberlog LTD., San Antonio, Texas (2000-2001)
Programmer/Systems Analyst, Support Office for Aerogeophysical Research (SOAR), University of Texas Institute for Geophysics, Austin, Texas (1998-2000)

**Products: Related Publications**


**Products: Other Publications**


**Synergistic Activities**


Founder of advanced computing in the geosciences research group, University of South Florida

Development of volcanic hazard methods for tephra dispersion and hazard using parallel computing and run short courses on the topic (open source of these codes)

Developed code for volcanic hazard assessment for the Armenia nuclear power plant, for Ministry of Energy, Armenia

**List of Collaborators**

Collaborators and Co-Editors: Onno Bokhove, Twente Univ; Costanza Bonadonna, University of Geneva; E. Canon-Tapia; Univ. Ensenada; C. B. Connor (University of South Florida); Tim Dixon, University of Miami; Jackie Dixon, University of Miami; Toshi Hasenaka, Kunamoto Univ; Britt Hill, US Nuclear Regulatory Commission; Sarah Kruse, University of South Florida; Arlene Laing, NCAR; Peter LaFemina, Penn State University; N. Le Corvec, UNAM; Abani Patra, University at Buffalo; David Pyle, Oxford University; Jeff Ryan, University of South Florida; Ivan Savov, Leeds Univ.; Steven Sparks, Univ. of Bristol; Greg Valentine, Univ at Buffalo; Paul Wetmore, University of South Florida;

Thesis Advisors: Kay Robbins, University of Texas at San Antonio; Steve Robbins, University of Texas at San Antonio; Samir Das, University of Texas at San Antonio; Donald Blankenship, University of Texas at Austin

**Thesis Advisor and Postgraduate-Scholar Sponsor** NA

Total number of doctoral students advised: 0

Total number of Post-doctoral Fellows sponsored: 0
Biographical Sketch: Rocco Malservisi

a. Professional Preparation
Ph.D. in Geosciences, The Pennsylvania State University, University Park, PA, December, 2002.
Laurea in Physics, University of Bologna, Bologna Italy, March, 1996.

b. Appointments
Assistant Professor of Geology, University of South Florida, Tampa (November, 2009- present)
Junior Professor (W1) of geodynamics, Ludwig Maximilians University, Munich, Germany (2004-2009)
Adjunct Professor, University of Miami, FL (2006- 2010)
Post-doctoral associate, University of Miami, FL (2002-2004)
Laureateo frequentatore (visiting researcher), University of Bologna, Bologna, Italy (1996-1997)

c1. 5 Selected publications relevant to this proposal


c2. Five other recent publications


LaFemina, P.C., T.H. Dixon, R. Malservisi, T. Arnadottir, E. Sturkel, F. Sigmundsson,

d. Synergistic Activities
- Co-Teacher of the course Lithosphere Applications of Finite Element Method, University of Utrecht, NL, September 2013.
- Convener EGU General assembly 2012 and 2013 session TS9.5 Crustal faulting and deformation processes observed by InSAR, GPS and modeling techniques.
- Member of the UNESCO Project IGCP 601 “Seismotectonics and seismic hazards of Africa”.
- Convener Fall AGU 2011 session T21A. Birth, Growth, and Maturity of a Continental Margin: Modeling, Observing, and Interpreting the Evolution of a Margin.
- Candidate for the UNAVCO Board of directors 2010.

e.1. List of Collaborators
Valerian Bachtadse, LMU, Munich (D); Chuck Connor, USF; Paul Wetmore, USF; John Fletcher, CICESE (MX); Kevin Furlong, PSU; Rob Govers, University of Utrecht (NL); Urs Hugentobler, TUM (D); Peter LaFemina, PSU; Christina Plattner, LMU (D); Francisco Suarez-Vidal, CICESE, Ensenada (MX); Paul Umhoefer, NAU; Shimon Wdowinsky, UM; Richard Wonnacott, NGI (ZA), Francesco Zucca, University of Pavia (I); Giorgio Spada, University of Urbino (I).

e.2. Graduate Advisors
K.P. Furlong The Pennsylvania State University; R. Sabadini, University of Milan, Italy.

e.3. Theses Advised
Current students:
Mary Njorge (MSc, USF), Anita Marshall (PhD, USF), Makan Abdollahzadeh (PhD, USF), Ophelia George (PhD, USF), Hao Zhang (Coadvisor, TUM Munich, Germany).
Past students:
Matthias Hackl (PhD, LMU), Jose Armando Saballos (PhD, USF)
Christina Plattner (PhD,LMU), Robin Chacko (MSc,TUM), Stephan Eder (German Diploma, LMU), Matthias Hackl (German Diploma, LMU), Kathrin Schaber (German Diploma, LMU).
**SUMMARY PROPOSAL BUDGET**

**FOR NSF USE ONLY**

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<td>Aurelie Germa</td>
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<td>1. Aurelie Germa - Asst. Res. Prof.</td>
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**FOR NSF USE ONLY**

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<tr>
<td>ORG. REP. NAME*</td>
<td>Heather Morr</td>
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1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET
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FOR NSF USE ONLY

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<tbody>
<tr>
<td>PI/PD NAME</td>
</tr>
<tr>
<td>INDIRECT COST RATE VERIFICATION</td>
</tr>
<tr>
<td>ORG. REP. NAME*</td>
</tr>
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</table>

2 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET
<table>
<thead>
<tr>
<th>ORGANIZATION</th>
<th>University of South Florida</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR</td>
<td>Aurelie Germa</td>
</tr>
<tr>
<td>A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates</td>
<td></td>
</tr>
<tr>
<td>1. Aurelie Germa - Asst. Res. Prof.</td>
<td>0.80 0.00 0.00 4,310</td>
</tr>
<tr>
<td>2. Laura Connor - Asso. Research Sci</td>
<td>0.00 0.00 0.30 1,959</td>
</tr>
<tr>
<td>3. Rocco Malservisi - Asso. Professor</td>
<td>0.00 0.00 0.30 1,837</td>
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<tr>
<td>4.</td>
<td></td>
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<tr>
<td>5.</td>
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<tr>
<td>6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)</td>
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<tr>
<td>7. (3) TOTAL SENIOR PERSONNEL (1 - 6)</td>
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<td>B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)</td>
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</tr>
<tr>
<td>1. (0) POST DOCTORAL SCHOLARS</td>
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<td>5. SUBAWARDS</td>
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<td>TOTAL OTHER DIRECT COSTS</td>
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<td>H. TOTAL DIRECT COSTS (A THROUGH G)</td>
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<td>I. INDIRECT COSTS (F&amp;A)(SPECIFY RATE AND BASE)</td>
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<td>MTDC (Rate: 49.5000, Base: 41857)</td>
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<td>K. RESIDUAL FUNDS</td>
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<td>L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)</td>
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<tr>
<td>M. COST SHARING PROPOSED LEVEL $</td>
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</tr>
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</table>

<table>
<thead>
<tr>
<th>PI/PD NAME</th>
<th>Aurelie Germa</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOR NSF USE ONLY</td>
<td></td>
</tr>
<tr>
<td>ORG. REP. NAME*</td>
<td>Heather Morr</td>
</tr>
<tr>
<td>Date Checked</td>
<td></td>
</tr>
<tr>
<td>Date Of Rate Sheet</td>
<td></td>
</tr>
<tr>
<td>Initials - ORG</td>
<td></td>
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</tbody>
</table>

3 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET
### SUMMARY PROPOSAL BUDGET

#### University of South Florida

**Principal Investigator / Project Director**

**Aurelie Germa**

<table>
<thead>
<tr>
<th>A. Senior Personnel: PI/PD, Co-PI’s, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Aurelie Germa - Asst. Res. Prof.</strong></td>
</tr>
<tr>
<td><strong>2. Laura Connor - Asso. Research Sci</strong></td>
</tr>
<tr>
<td><strong>3. Rocco Malservisi - Asso. Professor</strong></td>
</tr>
<tr>
<td><strong>4.</strong></td>
</tr>
<tr>
<td><strong>5.</strong></td>
</tr>
<tr>
<td><strong>6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)</strong></td>
</tr>
<tr>
<td><strong>7. ( ) TOTAL SENIOR PERSONNEL (1 - 6)</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. Other Personnel (Show numbers in brackets)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. ( ) POST DOCTORAL SCHOLARS</strong></td>
</tr>
<tr>
<td><strong>2. ( ) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)</strong></td>
</tr>
<tr>
<td><strong>3. ( ) GRADUATE STUDENTS</strong></td>
</tr>
<tr>
<td><strong>4. ( ) UNDERGRADUATE STUDENTS</strong></td>
</tr>
<tr>
<td><strong>5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)</strong></td>
</tr>
<tr>
<td><strong>6. ( ) OTHER</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C. Fringe Benefits (If charged as direct costs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL SALARIES AND WAGES (A + B)</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>D. Equipment (List item and dollar amount for each item exceeding $5,000.)</th>
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</thead>
<tbody>
<tr>
<td><strong>TOTAL EQUIPMENT</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>E. Travel</th>
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</thead>
<tbody>
<tr>
<td><strong>1. Domestic (incl. Canada, Mexico and U.S. Possessions)</strong></td>
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<tr>
<td><strong>2. Foreign</strong></td>
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</table>

<table>
<thead>
<tr>
<th>F. Participant Support Costs</th>
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</thead>
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<tr>
<td><strong>1. Stipends</strong></td>
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<tr>
<td><strong>2. Travel</strong></td>
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<tr>
<td><strong>3. Subsistence</strong></td>
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<tr>
<td><strong>4. Other</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G. Other Direct Costs</th>
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</thead>
<tbody>
<tr>
<td><strong>1. Materials and Supplies</strong></td>
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<tr>
<td><strong>2. Publication Costs/Documentation/Dissemination</strong></td>
</tr>
<tr>
<td><strong>3. Consultant Services</strong></td>
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<tr>
<td><strong>4. Computer Services</strong></td>
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<tr>
<td><strong>5. Subawards</strong></td>
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<tr>
<td><strong>6. Other</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>H. Total Direct Costs (A through G)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL OTHER DIRECT COSTS</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I. Indirect Costs (F&amp;A) (Specify Rate and Base)</th>
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</thead>
<tbody>
<tr>
<td><strong>TOTAL INDIRECT COSTS (F&amp;A)</strong></td>
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</table>

<table>
<thead>
<tr>
<th>J. Total Direct and Indirect Costs (H + I)</th>
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</thead>
<tbody>
<tr>
<td><strong>Residual Funds</strong></td>
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<thead>
<tr>
<th>K. Amount of this Request (J) OR (J Minus K)</th>
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</thead>
<tbody>
<tr>
<td><strong>Cost Sharing Proposed Level $</strong></td>
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<tr>
<td><strong>Agreed Level If Different $</strong></td>
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</tbody>
</table>

#### FOR NSF USE ONLY

**Pi/PD Name**

**Aurelie Germa**

**Org. Rep. Name**

**Heather Morr**

**Indirect Cost Rate Verification**

**Date Checked**

**Date of Rate Sheet**

**Initials - ORG**

__C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET__
Budget Justification

All senior personnel are fully committed to the project. PI Germa is Assistant Research Professor. Participation of international senior personnel (X. Quidelleur) and USGS personnel (A. Calvert, J. Donnelly-Nolan, M. Clynne, and D. Ramsey) represents significant leveraging of the NSF budget. The main costs in this proposal are field expenses, and analytical costs associated with K-Ar and Ar-Ar radiometric age determinations, including travel to Orsay and Menlo Park for Germa, and the analytical costs associated with the Orsay lab ($500 per sample - reduced rate for this project). We feel this cost is justified for two reasons. First, the plan is for Germa to emerge from the project with a high degree of competence in analytical methods for K-Ar and Ar-Ar age determinations. Her goal is to be able to set up such a lab in a university environment and this project helps her achieve the required level of experience. Second, we propose to obtain around 50 K-Ar and Ar-Ar age determinations, a requirement for improving temporal trends in volcanism in the selected fields. This number of age determinations is achievable if Germa directly participates in the analyses.

YEAR 1

Senior Personnel: A total of 0.8 months is requested for Germa in Year 1, which reflects her actual time in the field and at Menlo Park as discussed in the following. Malservisi and L. Connor request one week summer salary to work with the graduate student on numerical and statistical model development, and with the undergraduate on database development.

Graduate student: The PhD student, Sammy Tavarez (Hispanic female), will work with Malservisi and C and L Connor on numerical and statistical model development in Spring and Summer 2014). Stipend and tuition are only requested for Spring and Summer. In Fall 2014 she will TA Physical volcanology in order to gain this classroom experience.

Undergraduate salary (2 students in first year): One student will participate in field work and sample preparation under the supervision of A. Germa (200 hr x $12.5 per hour = $2500). A second student will participate in database work for six volcanic fields (200 x 12.5 = $2500). These students will be selected from participants in field related classes.

Fringe Benefit. A total of $3358 Fringe benefits are requested for Senior Personnel and the graduate student fringe benefits.

Domestic travel.

Support is requested for field work in the Lassen-Caribou area. Germa and one undergraduate field assistant will conduct 3 weeks (~25 days) field work in year 1, coordinating the visit with USGS personnel (possible window due to weather conditions: May to October 2014). Direct field expenses associated with field work total $4,753, including airfare ($700x 2 = $1400). The USF 4WD Expedition will be used for this project at $0.25 per mile, 2100 miles (including roundtrip form SLC where the vehicle resides) = $525. The team will camp most of the time in the field. Consequently, field expenses are minimal. During field work: hotel (4 room nights at $50 per night per room = $200); gasoline (2100 miles at $4.5 per gallon, consumption of about 25mpg = $378) and per diem (2 persons at $45 per day, 25 days = $2,250).

Support is requested for A. Germa to travel to Menlo Park and visit USGS collaborators at the end of year 1 for a project meeting. This meeting is planned to take place during AGU fall meeting 2014 in order to reduce costs for travel. Only part of the expenses of the total trip are requested. Airfare $600; per diem = $40; 1 hotel night = $100. Total = $740.

Total domestic travel budget for year 1: $5,493

International Travel: No International travel is required in Year 1.

Material and supplies.

Material necessary for field work is estimated at $100.
Shipping of samples from western US to USF is estimated at $1,000.
Total material and supplies: $1,100.

Other costs: We request tuition support for one graduate student. Tuition is calculated from the present USF rate of $431 per credit hour for assuming a full time status at 9 credits per semester for Spring and 6 credit hours during summer.

Indirect Cost: USF indirect rate is charged is 49.5% excluding graduate student tuition.

YEAR 2

Senior Personnel: A total of 0.8 months is requested for Germa in Year 2, which reflects her time commitment for radiometric dating and related activities. Malservisi and L. Connor request two weeks summer salary to work with the graduate student on numerical and statistical model development, and with the undergraduate model application.

Graduate student: The PhD student, Sammy Tavarez (Hispanic female), will work with Malservisi and C and L Connor on numerical and statistical model development in Fall and Summer. Stipend and tuition are only requested for Fall and Summer. In Spring she will TA Natural Hazards in order to gain this classroom experience.

Undergraduate salary (2 students in first year): One student will participate in sample preparation under the supervision of A. Germa (200 hr x $12.5 per hour = $2500). A second student will work on running simulations for the six volcanic fields (200 x 12.5 = $2500). These students will be selected from participants in field related classes.

Fringe Benefit. A total of $4033 Fringe benefits are requested for Senior Personnel and the graduate student fringe benefits.

Domestic travel. Support is demanded for Germa to participate in the Ar-Ar analyses at Menlo Park. It is expected that 15 samples will be analyzed in year 2. One visit of 3 weeks will be necessary. Details for the trip: Airfare (Tampa-San Francisco) = $700. Hotel: 20 nights $100 = $2,000. Per diem 20 days at $42 = $840. Total = $3,540.
Total domestic travel budget for year 2 is $3,540.

Foreign travel. Support is requested for Germa to perform K-Ar analyses at Orsay (France). It is expected that 20 samples will be analyzed in year 2. Analytical work requires approximately 3 days per sample (including replicates) and the lab facility supports numerous projects that may extend the analyses schedule. Therefore, a visit of 60 days at Orsay will be necessary between January and December 2015. Foreign airfare (Tampa-Paris) at $1,000 round trip. Hotel: 60 nights $50 = $3,000. Per Diem 60 days $50 = $3,000. Total = $7,000. Note that the per diem quoted here is far less than normal government rate, and reflects actual expenses anticipated for Germa’s visit.
Total foreign travel budget for year 2 is $7,000.

Materials and Supplies. Analytical costs for year two include 50 samples for thin sections ($1,400), 20 K-Ar radiometric age determinations at $500 each ($10,000), and analytical supplies (diiodomethane, filters, masks, sieves = $3,000). Total: $14,400. No cost for Ar-Ar analyses is required for samples from the Cascades because of our agreement with the USGS.

Other costs: We request tuition support for one graduate student. Tuition is calculated from the present USF rate of $431 per credit hour for assuming a full time status at 9 credits per semester for Spring and 6 credit hours during summer.
YEAR 3

**Senior Personnel:** A total of 0.8 months is requested for Germa in Year 2, which reflects her time commitment to field work, radiometric dating and related activities. Malservisi and L. Connor request one week summer salary to refine models, to work with the graduate student on numerical and statistical model development, and with the undergraduate on model application.

**Graduate student:** The PhD student, Sammy Tavarez (Hispanic female), will work with Malservisi and C and L Connor on numerical and statistical model development in Fall and Summer. Stipend and tuition are only requested for Fall and Summer. In Spring she will TA Natural Hazards in order to gain this classroom experience.

**Undergraduate salary (2 students in first year):** One student will participate in sample preparation and field work under the supervision of A. Germa (200 hr x $12.5 per hour = $2500). A second student will work on running simulations for the six volcanic fields (200 x 12.5 = $2500). These students will be selected from participants in field related classes.

**Fringe Benefit.** A total of $3560 Fringe benefits are requested for Senior Personnel and the graduate student fringe benefits.

**Domestic travel. $8366**
We anticipate that additional field work should be planned in Year 3, after dating and modeling results have been obtained in Year 2 to verify stratigraphic relationships, collect additional samples for dating if necessary (before final round of dating in Menlo Park) and volume estimates. Support is requested for field work in the Lassen-Caribou area. Germa and one undergraduate field assistant will conduct 10 days field work in year 3, again coordinating the visit with USGS personnel (possible window due to weather conditions: May to October). Direct field expenses associated with field work total $3,231, including airfare ($700x 2 = $1400). The USF 4WD Expedition will be used for this project at $0.25 per mile, 1700 miles (including roundtrip form SLC where the vehicle resides) = $425. The team will camp most of the time in the field. Consequently, field expenses are minimal. During field work: hotel (4 room nights at $50 per night per room = $200); gasoline (1700 miles at $4.5 per gallon, consumption of about 25mpg = $306) and per diem (2 persons at $45 per day, 10 days = $900).

Support is required for Germa to participate in the Ar-Ar analyses at Menlo Park. These samples will be used to both verify year 2 sampling results and to date additional key units as necessary. It is expected that 15 samples will be analyzed in year 3. One visit of 3 weeks will be necessary. Details for one trip: Airfare (Tampa-San Francisco) = $700. Hotel: 20 nights $100 = $2,000. Per diem 20 days at $42 = $840. Total = $3,540.

**Total domestic travel budget for year 2 is $3,540.**

Funding is requested to send the graduate student to AGU in Year 3. Airfare (Tampa-San Francisco) = $700. Hotel: 6 nights $50 = $300. Per diem 7 days at $35 = $245, Registration ($350). Total = $1,595

**Publication cost.** Funds are requested to defray page charges (Geology, JGR). $2,400 is requested.

**Other costs:** We request tuition support for one graduate student. Tuition is calculated from the present USF rate of $431 per credit hour for assuming a full time status at 9 credits per semester for Spring and 6 credit hours during summer.

**Indirect Cost:** USF indirect rate is charged is 49.5% excluding graduate student tuition.
The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

<table>
<thead>
<tr>
<th>Investigator:</th>
<th>Other agencies (including NSF) to which this proposal has been/will be submitted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurelie Germa</td>
<td></td>
</tr>
</tbody>
</table>

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

**Project/Proposal Title:** Examining the along arc variation of fluid mobile element in the Lesser Antilles: characterization and inferences on sediment subduction.

**Source of Support:** National Science Foundation (NSF)

**Total Award Amount:** $137,283 **Total Award Period Covered:** 06/01/14 - 05/30/16

**Location of Project:** University of South Florida

**Person-Months Per Year Committed to the Project.** Cal:2.20  Acad: 0.00  Sumr: 0.00

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

**Project/Proposal Title:** Dynamic statistical models to improve long-term volcanic hazard assessments

**Source of Support:** NSF

**Total Award Amount:** $229,352 **Total Award Period Covered:** 01/02/14 - 12/31/16

**Location of Project:** University of South Florida

**Person-Months Per Year Committed to the Project.** Cal:2.00  Acad: 0.00  Sumr: 0.00

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

**Project/Proposal Title:**

**Source of Support:**

**Total Award Amount:** $  **Total Award Period Covered:**

**Location of Project:**

**Person-Months Per Year Committed to the Project.** Cal:  Acad:  Sumr:

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

**Project/Proposal Title:**

**Source of Support:**

**Total Award Amount:** $  **Total Award Period Covered:**

**Location of Project:**

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

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

(See GPG Section II.D.8 for guidance on information to include on this form.)

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

<table>
<thead>
<tr>
<th>Investigator: Charles Connor</th>
<th>Other agencies (including NSF) to which this proposal has been/will be submitted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support:</td>
<td>Current</td>
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</tbody>
</table>

**Project/Proposal Title:**

**Collaborative Research: Vhub cyberinfrastructure and virtual community for volcano research and hazard mitigation**

Source of Support: NSF

- Total Award Amount: $339,583
- Total Award Period Covered: 01/01/2014 – 12/31/2016 (36 mos.)

Location of Project: University of South Florida

Person-Months Per Year Committed to the Project: Cal: 1.0  Acad: 1.0  Sumr: 1.0

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

**Project/Proposal Title:**

**S12-SSI: Collaborative Research: Building Sustainable Tools and Collaboration for Volcanic and Related Hazards**

Source of Support: NSF

- Total Award Amount: $190,000
- Total Award Period Covered: 07/01/2013 – 06/30/2017

Location of Project: University of South Florida

Person-Months Per Year Committed to the Project: Cal: 1.0  Acad: 1.0  Sumr: 1.0

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

**Project/Proposal Title:**

**MRI Acquisition: Nicaragua Integrated Study of Eruptions (NISE): Integrated study of five volcanoes using seismic, GPS, infrasound, and lightning detection instruments**

Source of Support: NSF

- Total Award Amount: $1,246,345
- Total Award Period Covered: 09/01/2013 – 08/30/2017

Location of Project: University of South Florida

Person-Months Per Year Committed to the Project: Cal: 1.0  Acad: 1.0  Sumr: 1.0

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

**Project/Proposal Title:**

**CDI-Type II Proposal: VHub: Collaborative Research: Cyberinfrastructure for Volcanic Eruption and Hazards Modeling and Simulation**

Source of Support: NSF

- Total Award Amount: $134,000
- Total Award Period Covered: 01/01/2010 – 12/31/2013

Location of Project: University of South Florida

Person-Months Per Year Committed to the Project: Cal: 1.0  Acad: 1.0  Sumr: 1.0

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

**Project/Proposal Title:**

**Dynamic statistical models to improve long-term volcanic hazard assessments**

Source of Support: NSF

- Total Award Amount: $229,352
- Total Award Period Covered: 01/02/2014-12/31/2016

Location of Project: University of South Florida

Person-Months Per Year Committed to the Project: Cal: 1  Acad: 1  Sumr: 1

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.*
The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

<table>
<thead>
<tr>
<th>Investigator: Laura Connor</th>
<th>Other agencies (including NSF) to which this proposal has been/will be submitted: none</th>
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<td><strong>Support:</strong></td>
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<td>Project/Proposal Title:</td>
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<tr>
<td><strong>Collaborative Research: Vhub cyberinfrastructure and virtual community for volcano research and hazard mitigation</strong></td>
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<td>Source of Support: NSF</td>
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<tr>
<td>Total Award Amount: $339,583</td>
<td>Total Award Period Covered: 01/01/2014 – 12/31/2017 (36 mos.)</td>
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<tr>
<td>Person-Months Per Year Committed to the Project.</td>
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<td>Source of Support: NSF</td>
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<td>Total Award Amount: 229352</td>
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*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.*

NSF Form 1239 (10/99)
## Current and Pending Support

*(See GPG Section II.D.8 for guidance on information to include on this form.)*

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

<table>
<thead>
<tr>
<th>Rocco Malservisi</th>
<th>Other agencies (including NSF) to which this proposal has been/will be submitted.</th>
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<td><strong>Investigator:</strong> Co-I</td>
<td>DOE</td>
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### Advanced Technologies for Monitoring Carbon Dioxide (CO2) in Geologic Storage and Utilization Operations

- **Project/Proposal Title:** Advanced Technologies for Monitoring Carbon Dioxide (CO2) in Geologic Storage and Utilization Operations
- **Support:** Pending
- **Source of Support:** Funding Opportunity Number DE-FOA-000798
- **Total Award Amount:** $1,211,544.00
- **Total Award Period Covered:** 2013-2016
- **Location of Project:** USF Tampa, FL
- **Person-Months Per Year Committed to the Project:** Cal: 1.0 Acad: Sumr: 1.0


- **Project/Proposal Title:** MRI Acquisition: Nicaragua Integrated Study of Eruptions (NISE): Integrated Study of Five Volcanoes in Nicaragua using Seismic, GPS, Infrasound, and Lightning Detection
- **Source of Support:** NSF
- **Total Award Amount:** $1,752,500.00
- **Total Award Period Covered:** 09/01/2013 – 08/30/2016
- **Location of Project:** USF Tampa, FL
- **Person-Months Per Year Committed to the Project:** Cal: 1.0 Acad: Sumr:

### Collaborative Research: Vhub cyberinfrastructure and virtual community for volcano research and hazard mitigation

- **Project/Proposal Title:** Collaborative Research: Vhub cyberinfrastructure and virtual community for volcano research and hazard mitigation
- **Source of Support:** NSF
- **Total Award Amount:** $339,583
- **Total Award Period Covered:** 01/01/2014 – 12/31/2017
- **Location of Project:** USF Tampa, FL
- **Person-Months Per Year Committed to the Project:** Cal: 1.0 Acad: Sumr:

### Dynamic statistical models to improve long-term volcanic hazard assessments

- **Project/Proposal Title:** Dynamic statistical models to improve long-term volcanic hazard assessments
- **Source of Support:** NSF
- **Total Award Amount:** $229,352
- **Total Award Period Covered:** 01/02/2014 - 12/31/2016
- **Location of Project:** USF, Tampa, FL
- **Person-Months Per Year Committed to the Project:** Cal: 1 Acad: Sumr:

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

Analytical Facilities at USF
USF has a full sedimentological lab for support of rock crushing and sample preparation. These include thin section fabrication and polishing, rock crushing and grinding facilities, and sieving material. Also, a safe laboratory for heavy liquid mineral separation has been set-up, and the Department of Geology possesses a Frantz magnetic separator.

We maintain two analytical "wet labs": one for the routine dissolution of rock samples for compositional study, via classical fluxed-fusion methods; and another "clean" laboratory maintained as a B, Li and Be-free space, which we use to prepare samples for light element analysis, for ultra-trace element determinations by ICP-MS. We are well equipped with research grade petrographic microscopes with both transmitted and studies; an automated system for thin section photography; and several modern binocular microscopes with photographic capabilities. The most recent innovation in the USF analytical arsenal is a remotely-operated Electron Microprobe/Scanning Electron Microscope (EMPA/SEM) system. The instruments, a state-of-the-art JEOL SuperProbe, and a JEOL 5900-series SEM, are housed at Florida International University in the Florida Center for Analytical Electron Microscopy (FCAEM), and were obtained via a collaborative NSF grant for the use of geoscience faculty at all the major Florida universities. The system is run from desktop computers via an Internet 2 high data density connection, and provides full, real-time optical and backscatter graphics, as well as the full spectrum of quantitative micro-analysis options.

We are currently establishing a sample preparation lab for probe-SEM work in the Geology Department. These facilities are currently maintained by a full time technician.

Major computational resources are available at the University of South Florida. For this project, data processing will take place on PC clusters. Currently, two PC clusters are in operation at USF. One consists of thirteen dual 64-bit AMD processors. Each machine is equipped with Gbit ethernet. The cluster runs the Linux operating system (SuSe 11.0) and the Message Passing Interface (MPI) for parallel work. This cluster, maintained by L. Connor (Research Associate) will be dedicated to the project. In addition, the USF academic computing has a 258 node cluster (CIRCE) with similar specifications. This cluster is also available for use in the project. USF has full incense for the use of COMSOL.

Analytical Facilities at University Paris-Sud 11
An analytical "wet lab" and an Agilent AA-240 spectrometer (ICP-AAS) are used for routine dissolution of rock samples for compositional study and K measurement. An argon extraction line is maintained and used every day to date Archean to zero-age volcanic rocks as well as internal and international standards (e.g., GL-O, MMHb-1, HD-B1, MDO-G, ISH-G). The facility design allows in-line extraction, purification, calibration and isotopic measurement of argon from a mineral phase. A pressure below 10^-9 Torr (1.3µPa) is achieved by using three turbomolecular pumping units. Gas extraction is performed using a 3000 W radio-frequency induction furnace. Temperatures above 1600 °C (1873 K), sufficient to melt any silicate mineral phase, are routinely reached with this furnace. The 180° magnetic sector geometry mass spectrometer used for Ar measurement is constituted of a Nier-type source, similar to the one described by Gillot and Cornette [1986], and a multi-collector consisting of an assembly of three independent Faraday cups mounted in a silica block. The system is run from desktop computers using home-made programs using Labview (National Instruments) software.
Analytical Facilities at USGS-Menlo Park

USGS laboratories in Menlo Park are fully equipped for high-precision geochronology of Pleistocene to Holocene volcanic rocks, including full mineral separation facilities and two independent $^{40}\text{Ar}/^{39}\text{Ar}$ analysis systems with spectrometers attached to argon extraction lines utilizing Staudacher-type resistance furnaces and infrared lasers. One system uses a Baur-Signer source (MAP 216) for optimal linearity and is used for routine incremental heating experiments; the other utilizes a Nier-type source (Nu Instruments Noblesse) and offers higher resolution which is most useful for higher precision on critical samples and identifying contamination on difficult samples. Argon extraction lines are highly customized and include SAES getters, hot filaments and 125K cold traps for purifying gas. Samples for $^{40}\text{Ar}/^{39}\text{Ar}$ work are irradiated at the USGS-Denver TRIGA reactor. A third system is used for K-Ar dating and includes offline argon extraction lines with gas splits analyzed on a different Baur-Signer source instrument. The K-Ar system is reserved for very fine-grained materials that are impossible to analyze using $^{40}\text{Ar}/^{39}\text{Ar}$ techniques due to $^{37}\text{Ar}$ and $^{39}\text{Ar}$ recoil. K determinations are made by ID-TIMS.

Computer Facilities at USF for this project

Advanced Visualization Center and High Performance Computing. The Advanced Visualization Center (AVC) at the University of South Florida will support the development of VHub modules outlined in this proposal. The AVC facilitates the use and development of data analysis and representation for university students and researchers. The staff at the AVC, utilizes multiple 2d and 3d graphics software packages and develops in-house applications using various programming languages to build visualizations. The AVC also engineered an ultra-high resolution visualization display wall, that is capable of rendering 20 million pixels in both 2D and stereoscopic 3D. The visualization wall's unique setup processes data through a single workstation that utilizes two, six core Xeon processors and an array of NVIDIA graphics processors that send the pixel dense images and real-time 3d models to a tiled screen consisting of sixteen, ultra-thin bezel, LCD panels. The visualization system is also integrated with the university's high performance computing infrastructure. Which includes, a 64 core Beowulf Compute Cluster was purchased in 2007 and is available for research use. There are 2 Beowulf clusters of 49 and 42 processors of Pentium 4, 2+Ghz machines available for University-wide use. They can be used for distributed/parallel computing experiments; they have 2-4GB of memory per processor. We also have a 4-node Beowulf cluster with each node having 2GB of memory. In addition to the above, there are currently several Sunblade 100s, a Linux/Windows PC and 4 Linux machines (2ghz/2GB), 1 Linux machine (3ghz) with 4GB of memory are also available.

Volcanology Computer Infrastructure. USF Department of Geology currently has a computational facility dedicated to volcanology that includes a small diskless cluster of 10 nodes with a total of 80 processors of 3.6 GHz, 16 Mb total cache each, running Warewulf 3.3.2. Aggregate memory on this cluster is 384 Gb. This cluster is sufficient for all USF project tasks. Three workstations are located in the USF volcanology lab. One of these workstations is equipped with an NVIDIA Tesla card (C1060) for GPU computing (with CUDA installed). The other two workstations have 8 processors, 32 Gbit memory, and large dual screen space, each running SuSe 12.3. These three work stations will be available to project personnel (graduate students and undergraduates) to work on this project.
USF Data Management Plan

Stakeholders

- Participants, domestic and international partners,
- Other researchers in volcanology and related fields of geology, geography and computer sciences.
- Lay audiences with a need for and/or interest in these models and volcanic fields.

The data and sharing needs of each one of these stakeholders has been considered and is discussed in the following.

Resources and Plans

The USF data management involves the management and digital curation of the volcanic field data, including vent locations, volume estimates, radiometric age determinations, other map data, results from computer models, and the models themselves. The PI (A. Germa) and co-PI (C. Connor) are responsible for execution of the data management plan for the duration of the project and any extensions. The PI will delegate project tasks to other members of the USF team as appropriate. We anticipate that each investigator will spend about 5% of their commitment to this project on activities related to data management and storage. Data storage and maintenance (including upgrades) will be built into the schedules for the investigators and students engaged in this effort.

This project will be facilitated by using VHub resources, a cyberinfrastructure platform for the volcanological community. VHub has extensive hardware and software resources and multiple methodologies to facilitate storage and access for a range of users with both secured and unsecured access. We note that VHub enables not just passive access but also actual execution of shared software and tools. Subsequent to the project completion we will rely primarily on the University of South Florida repository supported and managed by the university library and information technology services. A detailed inventory of data to be stored, metadata and a memorandum of understanding will be executed and included in the final report of the project. The expertise and resources of the USF librarians in long term curation and archiving of physical (papers, reports etc.) and digital resources will be used here. Incremental costs of assimilating and maintaining these data will be borne by the university. In addition, we will share all data in this project with colleagues at the US Geological Survey and they will no doubt undertake similar curation of the data generated by this project.

Expected Data

The expected data generated by this project include:

- Digital files of volcano locations (UTM / Lat / Long coordinates)
- Volume estimates for mapped volcanic units (m$^3$)
- Age determinations and analytical uncertainties, including data previously gathered and reported, and new age determinations done as part of this project.
- Spatial density maps, volume intensity maps and related model output
- Computer codes and analyses generated by this project

In addition, papers and reports will be in the PDF format and open source software will be stored in simple downloadable archives. The educational materials will include supporting
materials developed by the PIs for presentations at major meetings and classes taught to disseminate research results.

**Access Policies and Intellectual Property Issues**

Full access will be provided to all finished products (research papers, data and simulations used in papers and computer software developed) as they are completed with at most a 90 day delay post completion. Papers will be regarded as complete when they are accepted. Intermediate data and products will be stored in secured (password protected) areas of VHub and access provided to all investigators and other stakeholders through an application process. The university and investigators will retain intellectual property (copyright and patent rights) as applicable to all NSF funded research.
July 4, 2013

Aurélie Germa Charbonnier, PhD  
Department of Geology  
University of South Florida  
4202 E. Fowler Ave., SCA 214  
Tampa, FL 33620  
(813) 974-2838

Dear Aurélie,

I am writing in support of your recent proposal to the National Science Foundation Petrology and Geochemistry Program, titled "Dynamic statistical models to improve long-term volcanic hazard assessments". The United States Geological Survey has been conducting detailed research into volcanism in the western U.S. for over the past approximately fifty years and has published extensively on the geochronological and geochemical variability of U.S. volcanoes, typically in a geospatial (map) context.

Using these spatial data to better understand the processes and timing of past events has important implications for the hazards posed by potential future volcanic eruptions. I look forward to collaborating with you on the geospatial investigations involved in this project and on publications as appropriate.

Sincerely,

David W. Ramsey  
Geologist  
U.S. Geological Survey  
Cascades Volcano Observatory  
1300 SE Cardinal Ct, Bldg 10, Suite 100  
Vancouver, WA 98683  
(360)993-8978
Dr. Aurélie GERMA
Department of Geology
University of South Florida
Tampa FL, USA

Support Letter
July 3rd, 2013

Dear Aurélie,

With this letter, I confirm that I offer full support and collaboration with regard to your NSF proposal «*Dynamic statistical models to improve long-term volcanic hazard assessments*».

Your project is timely and represents the opportunity for the community to better understand the relationship between magma production rates and distribution of eruption vents through time. This remains an important issue for our understanding of magma storage and ascent conditions, which have large impacts on risk assessments for many volcanic complexes.

I will be pleased to participate to this project and to provide you with full access to our equipments. Our geochronology laboratory has several decades experience for dating young volcanic systems, even in the Holocene. Together, we already have a nice record of successful collaboration leading to five publications including K-Ar ages. Among them, we have initiated the study of the Payun-Matru volcanic complex (Argentina), which turns out to be a very favorable setting for K-Ar dating, and a throughout investigation of all stages of volcanism from the Martinique Island (Lesser Antilles). I am convinced that many new well-constrained age data will be obtained during this collaboration.

I look forward working with you in the frame of this international project in order to constrain the timing of volcanic processes in order to better understand how volcanic fields evolve.

Pr. Xavier QUIDELLEUR
Dept. of Earth Sciences
Université Paris-Sud, Orsay (France)
xavier.quidelleur@u-psud.fr
United States Department of the Interior

U.S. GEOLOGICAL SURVEY
Volcano Science Center
Mailstop 910
345 Middlefield Road
Menlo Park, CA 94025

Dr. Aurélie Germa
Department of Geology
University of South Florida
4202 E. Fowler Ave., SCA 214
Tampa, FL 33620

July 2, 2013

Dear Aurélie:

We are writing to offer our support for your proposed NSF Project "Modeling the role played by magma focusing on the distribution, productivity, and longevity of volcanic fields" that you are submitting to the NSF Petrology and Geochemistry Program. Working to understand timescales of volcanic eruptions is central to the mission of the Volcano Hazards Program and developing reliable models of their long-term behavior would be extremely helpful. The USGS has long studied Western U.S. volcanoes to constrain potential hazards to nearby populations and infrastructure.

Our roles will be to provide access to the USGS $^{40}\text{Ar}^{39}\text{Ar}$ lab in Menlo Park, and its supporting facilities (TRIGA reactor, sample preparation labs and data reduction programs), where you will constrain and refine eruptive histories for selected volcanoes. Since the geochronology is programmatic, it can be accomplished with no cost to the NSF, provided you spearhead the sample preparation. We will provide access to samples, chemical analyses, and geologic mapping, and will work with you to develop improved time-volume-composition information on volcanic products. As needed, we will advise on field collection of additional samples. Where appropriate, we will participate in publishing results.

Sincerely,

[Signatures]

Dr. Andrew T. Calvert   Dr. Julie Donnelly-Nolan   Dr. Michael A. Clynne