C. Proposal Information Summary

1.	Regional Panel Destination:	SC
2.	Project Title:	Rupture History of the San Andreas Fault at Van Matre Ranch, Carrizo Plain, California: Collaborative Research with University of California, Irvine and Arizona State University
3.	Principal Investigator(s):	J Ramón Arrowsmith, Ph.D. Department of Geological Sciences Arizona State University Tempe, AZ 85287-1404 Office: 480-965-3541 Fax: 480-965-8102 ramon.Arrowsmith@asu.edu
4.	Authorized Institutional Representative:	Larry Fallis Office of Research and Sponsored Projects Arizona State University Tempe, AZ 85287 Office: 480-965-1413 Fax: 480-965-8102 larry.fallis@asu.edu
6.	Element Designation	Element III: Research on earthquake occurrence, physics and effects
7.	Key Words	Paleoseismology, Tectonic Geomorphology, Trench Investigations
8.	Amount Requested:	$22,663 (ASU portion)
9.	Proposed Start Date:	February 1, 2004
10.	Proposed Duration:	12 months
11.	New or Renewal Proposal;	New
12.	Active Earthquake-related Research	
13.	Has this proposal been submitted elsewhere?	No
14.	Proposal Abstract	(From this proposal on separate sheet)
15.	Proposal Budget Summary	(From this proposal on a separate sheet)

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Rupture History of the San Andreas Fault at Van Matre Ranch, Carrizo Plain, California: Collaborative Research with University of California, Irvine and Arizona State University

D. Table of Contents

E. Abstract

To evaluate seismic hazard in California, it is essential to understand the behavior and earthquake potential of the San Andreas fault (SAF). The SAF dominates seismic hazard assessments because of its high moment release (slip) rate and documented frequency of historic and prehistoric large magnitude earthquakes (WGCEP, 1988). In addition, data on the earthquake history of the SAF forms the basis of numerous general models of fault behavior and seismic hazard. These models range from simple, deterministic systems such as the time-predictable and slip predictable models of Shimazaki and Nakata (1980), to complex, non-linear, and/or chaotic systems that can be described as a group, but cannot be individually predicted (Liu, 2003). The high slip rate, short recurrence interval, great length and accessibility of the SAF make it the best target in the U.S. (and possibly the world) for observational testing of fault behavior models. These models form the basis for all estimates of seismic hazard, and in turn, seismic risk. Paleoseismic data are essential for such testing, because they are the only type of observations that span multiple earthquake cycles (Grant and Gould, in press).

The Carrizo Plain has been one of the most productive sections of the San Andreas fault for paleoseismic research, and we think it holds the potential, over the next decade, to reveal a paleoseismic record approaching Pallett Creek in number of earthquakes, and exceeding Pallett Creek in measurement of slip per event. Our long-term goal is to document this record, working as a team, and as part of a larger group of Carrizo researchers. We hope that over the next decade, a multi-investigator Carrizo Plain Working Group will develop to fulfill this expectation.

This proposal outlines our plans to begin work at the first site in a series of planned investigations. Our proposed research is a continuation of a successful 7-year collaborative investigation of the rupture history of the south central San Andreas fault between Cholame and the Carrizo Plain by P.I.s Ramón Arrowsmith and Lisa Grant. We have conducted individual field research programs in the area since graduate school, and have recently published 3 papers (Stone et al., 2002; Young et al., 2002; Runnerstrom et al., 2002) on the results of collaborative research in the northern Carrizo funded by SCEC. We request funding to extend preliminary research at the Van Matre Ranch in the southern Carrizo Plain.

The Van Matre Ranch site is 18 km southeast of previously developed and spatially clustered paleoseismic sites at Wallace Creek (Sieh and Jahns, 1984; Liu, 2003), Phelan Creeks (Sims, 1994), Phelan fan (Grant and Sieh, 1993) and Bidart fan (Grant and Sieh, 1994). Excavations at Van Matre Ranch will allow us to date previous ruptures and measure slip per event from the last few earthquakes, for comparison with other sites in the Carrizo and sites to the southeast such as Frazier Mountain and Pallett Creek. The results will help to constrain variability of rupture patterns in space and time, and provide better estimates of magnitude and dates for ruptures already documented in the Carrizo Plain. We have already 'ground-truthed' the Van Matre Ranch site with a series of excavations so that it will be cost-effective and relatively rapid to complete. We also have an outstanding opportunity to overcome some of the dating challenges by doing our own radiocarbon dating at UCI's new Keck AMS facility devoted to carbon isotopes, under the supervision of Dr. John Southon. Recent improvements in applications of radiocarbon dating to paleoseismology were made by Gordon Seitz (Fumal et al., 2002) while he was working under Dr. Southon at the LLNL C-AMS Lab. We will have a similar opportunity to improve the event record in the Carrizo Plain through long-term collaboration beginning with this project.

F. Proposal Budget

Budget summary

Project Title: Rupture History of the San Andreas Fault at Van Matre Ranch, Carrizo Plain, California: Collaborative Research with University of California, Irvine and Arizona State University

Principal Investigator(s): J. Ramón Arrowsmith

Proposed Start Date: February 1, 2004

Proposed Completion Date: January 31, 2005

COST CATEGORY	Federal First Year	Federal Second Year[2]	TOTAL Both years[2]
1. Salaries and Wages	$ 7,513	$ - 0 -	$ 7,513
Total Salaries and Wages	$ 7,513	$ - 0 -	$ 7,513
2. Fringe Benefits/Labor Overhead	$ 1,878	$ - 0 -	$ 1,878
3. Equipment	$ - 0 -	$ - 0 -	$ - 0 -
4. Supplies	$ 800	$ - 0 -	$ 800
5. Services or Consultants	$ 1,400	$ - 0 -	$ 1,400
6. Radiocarbon Dating Services	$ - 0 -	$ - 0 -	$ - 0 -
7. Travel	$ 2,895	$ - 0 -	$ 2,895
8. Publication Costs	$ - 0 -	$ - 0 -	$ - 0 -
9. Other Direct Costs	$ 3,500	$ - 0 -	$ 3,500
10. **Total Direct Costs (items 1-9)**	$17,986	$ - 0 -	$17,986
11. Indirect cost/General and Administrative (G&A) cost	$ 4,676	$ - 0 -	$ 4,676
12. Amount Proposed (items 10&11)	$22,663	$ - 0 -	$22,663
13. Total Project Cost (Total of Federal and non-Federal amounts)	$22,663	$ - 0 -	$22,663

DETAILED BUDGET

Project Title: Rupture History of the San Andreas Fault at Van Matre Ranch, Carrizo Plain, California: Collaborative Research with University of California, Irvine and Arizona State University

Principal Investigator: J Ramón Arrowsmith

Proposed Start Date: 02/01/04 Proposed Completion Date: 01/31/05

COST CATEGORIES:

1. SALARIES/WAGES TOTAL	$ 7,513
J Ramón Arrowsmith, Principal Investigator: 1 mo summer @ $7,513/mo (includes 4% cost of living allowance)	$ 7,513
2. FRINGE BENEFITS/Labor Overhead	$ 1,878
J Ramón Arrowsmith, Principal Investigator: 25% salaries/wages total	$ 1,878
3. PERMANENT EQUIPMENT	$ - 0 -
4. SUPPLIES	$ 800
Trench supplies (nails, paint, tools); Film and developing (includes film for Trench-o-matic)	
5. SERVICES OR CONSULTANTS	$ 1,400
Trench excavation and backfill ($75/hr*16 hours + mobilization $200); local contract	
6. RADIOCARBON DATING (N/A)	$ - 0 -
7. TRAVEL	$ 2,895
Site preparation, initial survey, National Monument staff briefing	
Perdiem $50/day x 5 days	$ 250
Personal vehicle	
(Toyota pickup truck) 0.35 x 1200 miles R/T + 10 miles per day average	$ 438
Lodging (3 nights, camping otherwise)	$ 150
Paleoseismic investigation	
Perdiem $50/day x 25 days	$ 1,250
Personal vehicle	
(Toyota pickup truck) 0.35 x 1200 miles R/T + 10 miles per day average	$ 508
Lodging (average every 4th day, camping otherwise)	$ 300
8. PUBLICATION, DISSEMINATION & FINAL REPORT	$ - 0 -
9. OTHER DIRECT COSTS	$ 3,500
Manual excavation assistance (100 hours @ $10/hour)	$ 1,000
Hydraulic shoring	$ 2,000
Laboratory expenses (drafting materials and computer software maintenance)	$ 500
10. TOTAL DIRECT COSTS	$17,986
11. INDIRECT COSTS	$ 4,676
Indirect totals: $4,497 MTDC Base: $17,986 Rate: 26 % (off campus)	
12. AMOUNT REQUESTED	**$ 22,663**

G. Proposal Body

Significance of project

Overview

The Carrizo Plain has been one of the most productive sections of the San Andreas fault for paleoseismic research, and we think it holds the potential, over the next decade, to reveal a paleoseismic record approaching Pallett Creek in number of earthquakes, and exceeding Pallett Creek in measurement of slip per event. Our long-term goal is to document this record, working as a team, and as part of a larger group of Carrizo researchers. We hope that over the next decade, a multi-investigator Carrizo Plain Working Group will develop to fulfill this expectation.

This proposal outlines our plans to begin work at the first site in a series of planned investigations. We request funding to extend preliminary research at the Van Matre Ranch in the Carrizo Plain (Figs. 1-3). The Van Matre Ranch site is in the southern Carrizo Plain, 18 km southeast of previously developed and spatially clustered paleoseismic sites at Wallace Creek (Sieh and Jahns, 1984; Liu, 2003), Phelan Creeks (Sims, 1994), Phelan fan (Grant and Sieh, 1993) and Bidart fan (Grant and Sieh, 1994). Excavations at Van Matre Ranch will allow us to date previous ruptures and measure slip per event from the last few earthquakes, for comparison with other sites in the Carrizo and sites to the southeast such as Frazier Mountain and Pallett Creek. The results will help to constrain variability of rupture patterns in space and time, and provide better estimates of magnitude and dates for ruptures already documented in the Carrizo Plain. We have already 'ground-truthed' the Van Matre Ranch site with a series of excavations (Fig. 4) so that it will be cost-effective and relatively rapid to complete. Therefore, this is a one-year proposal.

Our proposed research is a continuation of a successful 7-year collaborative investigation of the rupture history of the south central San Andreas fault between Cholame and the Carrizo Plain by P.I.s Ramón Arrowsmith and Lisa Grant. We have conducted individual field research programs in the area since graduate school, and have recently published 3 papers (Stone et al., 2002; Young et al., 2002; Runnerstrom et al., 2002) on the results of collaborative research in the northern Carrizo funded by SCEC. In this proposal, we describe an exciting new initiative by our team to refine radiocarbon dating methods for the Carrizo Plain by doing our own dating at UCI's new Keck AMS facility devoted to carbon isotopes, under the supervision of Dr. John Southon. Recent improvements in applications of radiocarbon dating to paleoseismology were made by Gordon Seitz (Fumal et al., 2002) while he was working under Dr. Southon at the LLNL C-AMS Lab. We will have a similar opportunity to improve the event record in the Carrizo Plain through long-term collaboration beginning with this project.

How expected results can be applied to reduce earthquake hazards in the US:

Because of its great length and high slip rate, the San Andreas fault is the largest source of seismic hazard in California. It's proximity to densely populated and economically vital regions makes the risk associated with this fault a major threat to the country, comparable in magnitude to the events of September 11, 2001 - or worse. Unlike terrorists, the threat from the San Andreas fault cannot be stopped. However, the past behavior of the fault is the best indicator of earthquake potential, including the location and magnitude of future earthquakes. The proposed research will provide additional insights on the magnitude and dates of past earthquakes in the Carrizo Plain

and thereby help to assess the potential magnitude, location, and date of future damaging earthquakes.

Significance of paleoseismic data from the San Andreas fault

To evaluate seismic hazard in California, it is essential to understand the behavior and earthquake potential of the San Andreas fault (SAF). Despite the tectonic complexity of southern California and the large number of active faults, the SAF dominates seismic hazard assessments because of its high moment release (slip) rate and documented frequency of historic and prehistoric large magnitude earthquakes (WGCEP, 1988). In addition, data on the earthquake history of the SAF forms the basis of numerous general models of fault behavior and seismic hazard. These models range from simple, deterministic systems such as the time-predictable and slip predictable models of Shimazaki and Nakata (1980), to complex, non-linear, and/or chaotic systems that can be described as a group, but cannot be individually predicted (Liu, 2003). The high slip rate, short recurrence interval, great length and accessibility of the San Andreas fault make it the best target in the U.S. (and possibly the world) for observational testing of fault behavior models. These models form the basis for all estimates of seismic hazard, and in turn, seismic risk. Paleoseismic data are essential for such testing, because they are the only type of observations that span multiple earthquake cycles (Grant and Gould, in press).

A special issue of *BSSA* on Paleoseismology of the San Andreas Fault System (Grant and Lettis, Eds., 2002) contains the longest documented multi-cycle earthquake sequence in North America (14 ruptures at Wrightwood) and unprecedented age control on individual earthquakes. Despite the relatively large amount of new data, questions remain about segmentation of the SAF, the rupture patterns of prehistoric earthquakes, and reasons for variation in earthquake characteristics. For example, as shown in **Table 1,** average recurrence intervals of San Andreas fault ruptures vary by more than a factor of two. Although this has been suspected, it is now well documented, and the pattern of variation is surprising. The most recent Working Group reports characterized the Cholame segment as having a relatively short recurrence interval, and the Carrizo segment as having one of the longest recurrence times (WGCEP 1988; SCECWG, 1994; Fig. 1). Neither characterization appears to be correct, as the most recently published paleoseismic data indicate that the LY4-Cholame site ruptures infrequently (Stone et al., 2002; Young et al., 2002; Runnerstrom et al., 2002) while the Bidart Fan site in the Carrizo Plain ruptures almost as frequently as Pallett Creek (Grant and Sieh, 1994; Sieh et al., 1989; Biasi et al., 2002; Fig. 3, and Table 1 below).

Table 1. Average recurrence intervals through AD 2000 for selected sites along the southern San Andreas fault. (Modified from Stone et al., 2002; with additions from Grant and Lettis, 2002).

Paleoseismic site	Number of ruptures	Average Recurrence (years)
Cholame LY4	4	236
Bidart Fan[1]	5	156
Frazier Mountain[2]	2	257-397
Pallett Creek[3]	10	135
Wrightwood[4]	14	105
Thousand Palms[4]	5	215
Indio[5]	4	238

References:[1]Grant and Sieh (1994) [2]Lindvall et al (2002) [3] Biasi et al., (2002) after Sieh et al. (1989)
[4] Fumal et al., (2002) [5] WGCEP (1988)

Significance of the Carrizo Plain and Previous Work

The Carrizo Plain is one of the best places to study the rupture history of the San Andreas fault. Although the Mojave section currently holds the record for the longest sequence of events (at Wrightwood, with Pallett Creek a close second), the Carrizo Plain is a close contender with a well-constrained slip rate (Sieh and Jahns, 1984) validated by geodetic studies (Lisowski et al., 1991), multiple measurements of slip per event (Sieh, 1978; Grant and Sieh, 1993; Grant and Donnellan, 1994; Liu 1993; Young et al., 2002) and event chronologies from several sites (Grant and Sieh, 1994; Sims, 1994; Stone et al., 2002; Liu, 2003). The geomorphology of the fault is well preserved, and the recent designation of the Carrizo National Monument ensures that the paleoseismic record will not be destroyed by development - unlike most other areas along the fault. Therefore, the Carrizo Plain is an important natural laboratory for probing the long-term rupture history of the San Andreas fault. The success of previous investigations in the Carrizo Plain suggests that future efforts will be productive, and worth the investment.

The Mojave section of the SAF has received much attention from researchers because it has several readily datable peat sites, and is close to populated metropolitan areas. However, the rupture pattern of the San Andreas fault cannot be understood from such a limited geographic area. Several sections of the fault must be well-characterized to understand the potential for the largest earthquakes. Rupture extent and slip variation remain essential fault-system parameters that cannot be answered without improved spatial coverage. Furthermore, the potential to correlate events diminishes with distance and slip observed at a given site (e.g., Biasi presentation at 2002 SCEC SAF workshop). The record along the Mojave segment as characterized at Wrightwood, Pallet Creek, and Pitman Canyon (>225 km southwest of the central Carrizo Plain) only poorly extrapolates to and correlates with the Carrizo-Cholame record. Work in progress by Liu, Sieh and others fills a spatial gap between the Wallace Creek slip rate site of Sieh and Jahns (1984) and the event chronology at the Bidart fan (Grant and Sieh, 1994). We seek to fill a much larger data gap to the south, between the Bidart fan and the Frazier Mountain site of Lindvall et al. (2002) (Figs. 1 and 3).

Previous work at the Van Matre Ranch site

Previous work at the Van Matre Ranch site (Sieh, 1977,1978, 1979; Sims et al. 1993; and our unpublished observations) indicates that it is likely to yield interesting results. Sieh (1977) documented sites along the SAF where slip from the 1857 earthquake was well preserved including the area of Van Matre Ranch (Figs. 1 and 2). His channels numbered 44-50 were used to document slip: the 1857 offset was 8 ± ½ m and two previous displacements were 7½ ± 1 m and 10 ± 1 m (Sieh, 1977 and 1979). In the early 1990s, two efforts gathered more data at the site. In 1991, Sieh had large scale aerial photography flown and a topographic map produced photogrammetrically for the site (Grant worked with the data as part of her Carrizo Plain Ph.D. research). In 1993, Arrowsmith worked with John D. Sims and his group (USGS) at the site (Fig. 2c and 4). Our effort there was to establish the quality of the stratigraphy and to test models for channel responses to earthquake offset (Sims, et al., 1993). We produced a topographic map (Fig. 2c) and excavated and logged 7 trenches (Fig. 4). Soon after, Sims became head of USGS EHRP and was unable to pursue research at the site. Arrowsmith archived the original data with the goal of returning to the site when time and funding would allow.

The 1993 study exposed a stratigraphy that included local "bedrock" comprised of massive pebbly sands and silts that showed strong soil development and bioturbation. Overlying these units were colluvial and fluvial packages of sediment associated with the southwest-flowing channel systems. The colluvial units tended to be grey-brown pebbly silts with some laminae. The fluvial units included fine, well bedded silts, clast-supported gravels, laminated and upward fiing pebbly silty sands and even cross-bedded pebbly sands. These units were often cut into the underlying units (especially in the lower stratigraphically and topographically located trenches); so well defined channels could be followed (Figs. 4B and D). In addition, in higher stratigraphic levels and in positions where the offsets had caused damming and the deposition of more tabular units, evidence for rupture was clearly preserved (Fig. 4C). The elevation at the Van Matre Ranch site is 200' higher than the central Carrizo Plain sites and thus the vegetation a bit more vigorous there. Numerous shrubs and heavy grass cover the slopes. These are important sources for charcoal and dateable organic materials for the site.

Significance of the Van Matre Ranch site

Since 1993, we have gained a lot of experience identifying and developing Carrizo Plain sites with the potential to answer questions about slip per event and earthquake timing. Our previous work at the Van Matre Ranch indicates that it is an excellent place to make this investigation for several reasons: 1) the geomorphic manifestation of repeated ground rupture is clear, 2) the stratigraphy is not heavily bioturbated and relatable to the geomorphic history of the site (it is as good as other good sites in the region; e.g., Bidart Fan and Phelan Creeks), and 3) offset stream channels and their backfilled stratigraphy offer the potential for quantification of earthquake slip and timing (Figs. 2 and 4).

The record at the Van Matre Ranch site should be very helpful in correlating ruptures between Pallet Creek and the Carrizo Plain, and therefore estimating the magnitude of already documented earthquakes, plus variation of displacement. For example: Recent work by Liu and Sieh (Liu, 2003) demonstrates that slip per event at Wallace Creek was approximately 8 m, 7.5 m, 5.5 m, 1.5 m, 8 m and 5.5 m in each of the last 6 ruptures. Grant and Sieh (1994) had previously suggested that at least one of the last 5 events had significantly less slip than the others, and proposed that their event "D" might correlate with a rupture (event "T") at Pallett Creek. From Liu and Sieh's work (Liu, 2003), it appears that Event D had the least amount of slip (1.5 m) in the Carrizo Plain, although if it does correlate with Event T, it is one of the longest rupture earthquakes in the Carrizo record. This type of testing of rupture correlation and magnitude hypotheses is only possible when there are multiple, good paleoseismic sites. Results from the Van Matre Ranch site will provide new observations AND make the existing data more valuable.

And these important objectives can be achieved for relatively low cost because several excavations have already been completed.

Project plan

Proposed work Due to our previous work at the site, the proposed project is well well defined. We plan to complete the work initiated in 1993 and documented in Figures 2 and 4. Specifically, at the Van Matre Ranch site, we propose to:

- date previous ruptures for comparison with dates of events and average recurrence intervals at other sites.

- measure slip per event from the last few earthquakes, including the 1857 earthquake
- estimate the magnitude and extent of past ruptures along the San Andreas fault between the Carrizo Plain, Cholame, and Pallett Creek
- test working group Carrizo segmentation models (WGCEP, 1988; SCECWG, 1994).

For the 2004 project year, we request modest funding to compile our existing field data, re-excavate the 1993 trenches, check and update logging, reconstruct offset channels with establishment of complete 3 dimensional geometric control, sample for ^{14}C, and support the initiation of Gould's dissertation research in the Carrizo Plain.

The trenches will be excavated with a backhoe and propped open with hydraulic shoring. Standard safety procedures including hard hats and a trench escape/rescue plan will be applied. We will first locate the fault and then evaluate the stratigraphy before excavating further. We expect that the excavations will be staged and we will incorporate field reviews (see below in project management plan) so that we minimize the potential for destruction of important relationships by inadvertent digging. Some relationships (in particular, offset and any evidence we encounter for historic ground cracking such as that found at LY4 and also important channels as they cross the fault zone) will be hand excavated and serially documented. All surfaces will be scraped, cleaned, and gridded. Important control features will be surveyed with the total station into the site coordinate system. We will log at 1:10 for detailed portions of the exposures and 1:25 for broader stratigraphic coverage. We will use USGS-"Trenchomatic" low distortion mosaic photography of the exposures in the logging and for archival purposes.

Fig. 2c shows the 1993 trench layout. We emphasized gully #44 (in Sieh's terminology) and cut across the upstream and downstream legs of the channel (T2 and T6), as well as a number of fault-crossing locations. We were able to follow a series of channels as they crossed the fault zone. The pattern of stratigraphy implied the following model of offset and subsequent channel response: 1) Either a new channel is cut or inherited. 2) After initial offset, the channel may continue to incise. 3) Continued offset and channel lengthening decreases local along-fault channel slope and deposition occurs as shingled, nested cut-in-fill channel deposits. 4) Further offset of the along fault segment promotes increased deposition and filling of the channel. The filled channel may now be capped by fan deposits and allow incision of a new channel across the fault or be captured by a topographic low juxtaposed by recurrent offset (Sims, et al., 1993). We will exploit this behavior for both our evaluation of the offset history of the channel system as well as in the documentation of the earthquake surface ruptures.

Our field plan will begin with Arrowsmith and Gould spending five days to prepare the site, coordinate logistics with the National Monument staff, and survey for the excavation and reoccupy the 1993 surveys. The major effort will be centered on a one month intensive field investigation at the Van Matre site in summer 2004.

Age control

Radiocarbon dating is essential to the success of this project, and indeed all paleoseismic research in the Carrizo Plain. Although the Carrizo Plain is in many respects an ideal place for studying the San Andreas fault, the semi-arid environment does not encourage the growth of the type of vegetation (peat) that has made Pallett Creek and Wrightwood such paleoseismic gold mines. In contrast, age control is the achilles heal of the Carrizo paleoseismic record. Grant and Sieh (1993) described some of the problems of applying radiocarbon dating in this area including: inherited age

from detrital wood, the high cost of AMS dating (which is required for the typically tiny samples of organic material), the presence of shrubs that can live more than 800 years and therefore yield dramatically different dates from different portions of the same (small!) shrub, and common flora with both C-3 and C-4 pathways resulting in substantially different fractionation of carbon isotopes. Liu and Sieh (Liu, 2003) also discovered evidence of climatic variation leading to episodes of non-deposition.

To successfully apply radiocarbon dating in such a challenging environment, it is essential to know what you are doing! We already have the benefit of experience with the field conditions, and knowledge of the problems they may present. Starting with this project, we will have the opportunity to improve by learning how to do the actual dating under the supervision of Dr. John Southon, who has recently moved to UCI to establish an AMS facility dedicated to carbon isotopes. (See attached letter, and technical description in the facilities section.) This facility is only available to UCI researchers, and at greatly reduced cost. We will have the opportunity to learn from some of the world's most recognized experts in radiocarbon dating and its applications in field research. John Southon previously supervised Gordon Seitz at the LLNL CAMS lab, and this resulted in a significant improvement in dates at the Wrightwood paleoseismic site (Fumal et al., 2002). We anticipate similar improvements in dates of events in the Carrizo Plain, beginning with the Van Matre Ranch site, and extending to other sites in the future as we become more experienced.

Final report and dissemination

Our team has been very productive in our initial research along the Cholame and Carrizo segments of the SAF. From the beginning of our research efforts there in 1996 to the present, we have made numerous presentations at national meetings, published one review paper in Seismological Research Letters (Arrowsmith, et al., 1997), completed one M.S. thesis (Stone, 1999), a Ph.D. is in progress (Young), published 3 manuscripts for publication in the Bulletin of the Seismological Society of America, and participated in and contributed to numerous informal and formal (Grant and Lettis, 2002) discussions of San Andreas Fault earthquake rupture geometry and history.

We expect to continue a comparable level of productivity and plan to prepare at least one major journal article on the results of this research, in a timely manner. Of course, we will also prepare the annual and final technical reports for USGS NEHRP, and this work will be included as a chapter in Gould's dissertation (see project management plan). We will participate as requested and as availability permits in informal discussions about San Andreas Fault earthquake rupture geometry and history in the field and at meetings. To keep costs down, we have not requested support for presentations at national meetings such as AGU or SSA, but we do expect to make such presentations, support for which will come from other sources or personal funds.

Related efforts

In this proposal we have already described several other research projects in the Carrizo Plain. These investigations have either been conducted by us (individually or jointly), or by our close associates (e.g. Sieh was Grant's Ph.D. supervisor). As we train our students in the Carrizo Plain, we envision the development of a Carrizo Plain Working Group of close associates and friendly competitors to unravel the mysteries of the San Andreas fault.

Curriculum Vitae for J Ramón Arrowsmith

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Tempe, AZ 85287-1404
WWW: http://www.asu.public.edu/~arrows
EMAIL: ramon.arrowsmith@asu.edu

Arizona State University
PHONE: (480) 965-3541
http://activetectonics.la.asu.edu

Academic Training

- Whittier College–B.A. (Summa Cum Laude) in Geology and Spanish, 1989, supervised by Dr. Dallas D. Rhodes. Presidential Scholarship at Whittier College (full tuition 1985–1989).
- Stanford University–Ph.D. Geological and Environmental Sciences, 1995, supervised by Dr. David D. Pollard. Dissertation title: "Coupled Tectonic Deformation and Geomorphic Degradation along the San Andreas Fault System."
- Stanford University, Department of Geological and Environmental Sciences, Post-Doctoral Scholar, April 1, 1995–July 31, 1995

Appointment

Arizona State University, Department of Geological Sciences
Assistant Prof., August 1, 1995–July 1, 2001; Associate Professor of Geology, July 1, 2001–

Related Publications

Young, J. J., Arrowsmith, J R., Colini, L., and Grant, L. B., 3-D excavation and measurement of recent rupture history along the Cholame segment of the San Andreas Fault, *Bulletin of the Seismological Society of America: Special Issue on Paleoseismology of the San Andreas fault, 92,*2,670-2,688,2002.

Runnerstrom, E. E., Grant, L. B., Arrowsmith, J R., Rhodes, D. D., and Stone, E. M., Displacement across the Cholame segment of the San Andreas Fault between 1855 and 1896 from cadastral surveys, *Bulletin of the Seismological Society of America: Special Issue on Paleoseismology of the San Andreas fault, 92,*2,659-2,669, 2002.

Stone, E.M., Grant, L., and Arrowsmith, J R., Recent rupture history of the San Andreas Fault southeast of Cholame in the northern Carrizo Plain, California, *Bulletin of the Seismological Society of America, 92,*983-997, 2002.

Hilley, G. E., Arrowsmith, J R., and Stone, E. M., Using microseismicity and surface offset data to define fault segment boundaries along low friction faults, with an example from the Cholame-Carrizo segment boundary along the San Andreas Fault, Southern California, *Bulletin of the Seismological Society of America*, *91,* 427-440, 2001.

Arrowsmith, J R., Rhodes, D. D., and Pollard, D. D., Morphologic dating of scarps formed by repeated slip events along the San Andreas Fault, Carrizo Plain, California, *Journal of Geophysical Research, 103,* B5, 10,141–10,160, 1998.

Arrowsmith, J R., McNally, K., and Davis, J., Potential for earthquake rupture and M 7 earthquakes along the Parkfield, Cholame, and Carrizo segments of the San Andreas Fault, *Seismological Research Letters, 68,* 6, 902–916, 1997.

Related activities and experience

- USGS NEHRP proposal review panel (1996–1998, 2001-2002)
- NSF-AGU Geoinformatics interim steering committee (2000–Present)
- Arizona state government service: ASU representative of Arizona Earthquake Information Network and member of Arizona Council for Earthquake Safety
- California state government service: external reviewer for the California Earthquake Prediction Evaluation Council (1997–Present)
- Courses taught at Arizona State University: Introduction to Geology, Structural Geology, Geomorphology, Computers in Geology, Desert surface processes and Quaternary geology seminar, Field Geophysics (with James A. Tyburczy), Advanced Field Geology (with Philip A. Pearthree, Arizona Geological Survey), Advanced Structural Geology (with Stephen J. Reynolds).

Curriculum Vitae for Lisa B. Grant, Ph.D.

Education: Ph.D. Geology and Geophysics, 1993, Caltech
Thesis advisor: Kerry Sieh
M.S. Geology, 1990, Caltech
M.S. Environmental Engineering Science, 1989, Caltech
B.S. Environmental Earth Science, 1985, Stanford University

Relevant Experience and Appointments:

- Assistant Professor, Dept Environmental Analysis & Design, UC Irvine (7- 98 to present)
- Guest Editor, Special Issue on Paleoseismology of the San Andreas Fault, *BSSA* (1999-2002); and Associate Editor, *BSSA* (1997 to present)
- Member, Board of Directors, Southern California Earthquake Center (2002 to present)
- Assistant Professor, Dept of Environmental & Chemical Sciences, Chapman University (8-95 to 6-98, Coordinator of Environmental Science Program, 97-98)
- Assistant Project Scientist, Woodward-Clyde Consultants, (6-93 to 7-95)
- Graduate Research and Teaching Assistant, Caltech, Dept. Environmental Engineering Science; Div. of Geological & Planetary Sciences (1987 - 1993)

Related Publications (not including abstracts).

1. **Grant, L. B.** and M. M. Gould (in press). Assimilation of paleoseismic data for earthquake simulation. Pure and Applied Geophysics.
2. **Grant, L. B.** and W. R. Lettis (2002). Introduction to the Special Issue on Paleoseismology of the San Andreas Fault System, In (**Grant, L. B.** and Lettis, W. R., Eds.) *Paleoseismology of the San Andreas Fault System* Bulletin Seismological Society of America, v.92, no. 7.
3. Runnerstrom, E. E., **L. B. Grant**, J R. Arrowsmith, D. D. Rhodes, and E. M. Stone (2002). Displacement across the Cholame segment of the San Andreas fault between 1855 and 1893 from cadastral surveys, BSSA, 92, 7, 2659-2669.
4. Young, J. J., J R. Arrowsmith, L. Colini, **L. B. Grant,** and B. Gootee (2002). 3-D excavation and measurement of recent rupture history along the Cholame segment of the San Andreas fault, BSSA, 92, 7, 2670-2688.
5. Stone, E. M., **Grant, L. B.** and Arrowsmith, J R. (2002). Recent rupture history of the San Andreas fault, southeast of Cholame in the northern Carrizo Plain, California, BSSA, 93, 3, 983-997.
6. **Grant, L. B.** (2002). Paleoseismology. Chapter 30 In "IASPEI International Handbook of Earthquake and Engineering Seismology" (W. H. Lee, H. Kanamori, and P.C. Jennings, Eds.), International Association of Seismology and Physics of the Earth's Interior, v. 81A, p. 475-489.
7. **Grant, L. B.** (1996).Uncharacteristic Earthquakes on the San Andreas Fault, Science, 272,826 - 827.
8. **Grant, L. B.** and K. Sieh (1994), Paleoseismic Evidence of Clustered Earthquakes on the San Andreas Fault in the Carrizo Plain, California, JGR, 99, no. B4,6819-6841, 1994.
9. **Grant, L. B.** and A. Donnellan (1994). 1855 and 1991 Surveys of the San Andreas Fault:Implications for Fault Mechanics, BSSA, 84, 2, 241-246.
10. **Grant, L. B.** and K. Sieh (1993), Stratigraphic Evidence for 7 Meters of Dextral Slip on the San Andreas Fault During the Great 1857 Earthquake in the Carrizo Plain.BSSA, 83, 3, 619-635.

Curriculum Vitae for Miryha M. Gould

EDUCATION:

Ph.D. student in Environmental Analysis & Design, UC Irvine, 2001 to present
Thesis and research advisor: Lisa Grant

B. S., Department of Geological Sciences, Central Washington University, (Summa Cum Laude), 2001

EXPERIENCE:

Research Assistant

- UCI, Environmental Analysis & Design, 2001 to present

Investigated XML-database-web browser compatibility challenges for an on-line fault database. Co-developed mandatory fields for California fault database. Implemented California fault database.

- Central Washington University, Dept. Geological Sciences, 2000 to 2001.

Collected and processed paleomagnetic rock core samples from Kyrgyzstan, Central Asia. Analyzed and interpreted paleomagnetic data sets. Created geologic maps of the At Bashi, Kochkorka and Naryn Basins, Kyrgyzstan.

Field Experience

1. Orange County, 2002. Summer investigation of structural geology, geomorphology and tectonic deformation in the Santa Ana Mountains, Orange County, California.
2. Field Methods, 2001 Six-week structural geology field class in Eastern Oregon.
3. Kyrgyzstan, Central Asia 2000: Three-week investigation of structural geology and neotectonics of the Tien Shan Mountain Range.
4. Introduction to Geologic Field Methods1999: Two-week investigation of structural geology in the Eastern Sierra Nevada Range, California.

PUBLICATIONS:

Gould, M. M., Weberling, K., Weldon, R., II, Miller, M. M., Abdrakhmatov, K., & August, M. S. (2000). Neogene magnetostratigraphy in the At Bashi basin: Constraints on late Cenozoic deformation in the central Tien Shan, Kyrgyzstan. *Geological Society of America Annual Meeting Abstracts with Programs*, A-441. [abstract]

Grant, L. B., & Gould, M. M. (2002). Paleoseismic and geologic data for earthquake simulation. *3rd APEC Cooperation for Earthquake Simulation (ACES) International Workshop, May 5-10, 2002, Maui, HI*, 30. [abstract]

Gould, M. M., Grant, L. B., Donnellan, A., & McLeod, D. (2002). The GEM fault database: A preliminary report on design and approach. *2002 Southern California Earthquake Center (SCEC) Annual Meeting Proceedings and Abstracts, September 8-11, 2002, Oxnard, CA*. [abstract]

Gould, M. M. (2003). Content analysis of historic newspaper reports: A link between seismic risk communication and social representations. *12th Annual Greening Conference, January 25, 2003, Santa Barbara, CA*. [abstract]

Gould, M. M., Grant, L. B., Donnellan, A., & McLeod, D. (2003). The GEM fault database: An update on design and approach. *2003 European Geophysical Society-American Geophysical Union-European Union of Geosciences Joint Assembly Meeting, April 6-11, 2003, Nice, France*. [abstract]

Grant, L. B., & Gould, M. M. (in press). Assimilation of paleoseismic data for earthquake simulation. Pure and Applied Geophysics.

Institutional qualifications

As a team, we have excellent equipment and access to superb facilities that are more than adequate for the field and office portions of the proposed research. As described below (and in a letter from John Southon), we also have access to UCI's new AMS facility dedicated to carbon isotope research. This will allow us to develop expertise in applying radiocarbon dating to paleoseismology, and provide a significant reduction in costs. Facilities at ASU and UCI are described separately although we will utilize them as a team.

ASU - The Active Tectonics, Quantitative Structural Geology and Geomorphology research group at Arizona State University is housed in a several hundred square foot laboratory space with 3 adjacent student offices. In this laboratory and related facilities, available computer hardware tools include 8 Macintosh and PC desktop computers, 2 PC laptop computers, 3 unix workstations (Silicon Graphics and Sun), a FreeBSD data server, a CD-writer, and 3 color printers. Available software (beyond standard Mac/PC drafting and image editing, word-processing, and spreadsheet tools) includes ERDAS Imagine (including photogrammetric module Orthomax) for analysis of remotely sensed data and digital topographic data, ArcGIS and ArcView for GIS compilation, MatLab for analysis and visualization, POLY3D, DIS3D, and COULOMB for boundary element mechanical modeling. We maintain an active web site where research results and data are presented and frequently updated: http://activetectonics.la.asu.edu.

Field tools essential for our project include 2 Leica-Wild TCM 1100 total stations (consisting of an electronic theodolite and electronic distance meter (EDM)) providing high precision 3 dimensional locations of sighted targets within a few seconds over about 1 km providing a linear accuracy of 2 mm – 2 ppm and angular accuracy of 3" and recording the data digitally. For data reduction, we use both custom UNIX and Macintosh software and LISCAD--the Leica-Wild surveying and engineering software that is designed to work with these instruments. Two portable printers and two laptops permit us to work with survey data in the field. 5 Motorola radios provide field communications. We also have a full suite of field tools necessary for supporting large earthquake geology excavations. Two digital cameras and two film cameras are available for field work. We also have helium balloon and kite-based aerial photography systems available for detailed documentation of important landforms (http://activetectonics.la.asu.edu/kites/index.html).

UCI

Computer, laboratory and library facilities - The collections of the more than 100 UC libraries are surpassed in size on the American continent only by the Library of Congress collection. As UC faculty and students, we have access to nearly the entire library collection. Materials that are not in the UC Irvine library are available through interlibrary loan. Much of the data analysis for this project will be done in Grant's Environmental Geology & GIS Laboratory (http://geolab.seweb.uci.edu). The lab currently has 6 dedicated computers (with 3 of them upgraded or purchased this year), 2 color printers, a large format professional quality poster printer for maps, laser printer, scanner and related equipment. We currently have RiverTools, ArcView, Spatial Analyst, ArcGIS, DEM data, MATLab, and standard illustration and word processing software. UCI has licenses for common software programs and additional computer labs are readily accessible to graduate students and faculty. The lab also has equipment for field work including a Leica-Wild total station with portable printer,

laptop computer and radios, handheld GPS receiver, cameras for digital and film photography; and camping equipment.

The Keck Carbon Cycle AMS Facility at UC Irvine, is based around a compact 0.5MV AMS spectrometer purchased from National Electrostatics Corp. The spectrometer was installed over a 2-3 week period in June 2002, funded by the W.M. Keck Foundation and UC Irvine School of Physical Sciences to promote application of AMS techniques to carbon cycle research. This system is just the third production version of a new generation of small AMS spectrometers which can be located in a laboratory, as opposed to requiring construction of an entire building, and development and improvement of the instrument is ongoing. However, it has run routinely since October 2002 and has already produced AMS ^{14}C data with precision/accuracy as good as 2 to 3 per mil (equivalent to a dating precision of ±25 years). Stable carbon isotope ratios measured on the AMS instrument are accurate to 1 per mil; plus a new Finnegan Delta Plus mass spectrometer purchased as part of the AMS facility and equipped with Gas Bench and Elemental Analyzer inputs provides precise $^{13}C/^{12}C$ ratios when these are required. AMS backgrounds are currently equivalent to radiocarbon ages of 50,000 - 55,000 years. Sample throughput is currently a few hundred per month, and is expected to increase as planned upgrades to the spectrometer ion source boost its output. The facility is staffed by three PI's and two research specialists, and a search for an additional sample-preparation technician is underway. Three sample preparation laboratories within the Department, including a 450 ft^2 lab immediately adjacent to the spectrometer, provide capabilities for handling carbonate, organic, seawater, and gas (air) samples in addition to CO_2, and for both sealed-tube batch processing (Zn reduction) and hydrogen reactor based graphitizations (32 reactor heads). The AMS system will be moved in June/July 2003, on completion of Croul Hall. The new Croul Hall facility includes a larger spectrometer laboratory with sufficient space for a second ion source should this become desirable, office space for technicians and specialists, and 1200 ft^2 of chemistry space for sample preparation.

Project management plan

As we have done in the past, we will work collaboratively on all aspects of the project and jointly supervise UCI doctoral student Miryha Gould, as we did for ASU students Elizabeth Stone and Jeri Young. We have found joint supervision to be effective because it allows us to bring our complementary expertise (paleoseismology for Grant; active tectonics and geomorphology for Arrowsmith) to the research project, and to continuously supervise student research by trading off responsibilities when we are traveling or involved in other projects. This approach has allowed us to publish results fairly quickly. We anticipate that the project will develop into Gould's Ph.D. dissertation. Gould is well qualified for this project through her research and field experience, course work in paleoseismology, and training by Grant. Our schedule for research progress is outlined below, followed by discussion of field review and radiocarbon dating.

Research progress

The following table lays out our planned research tasks and the time frame for their completion (assuming a 2/01/2004 start date):

Task	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Field work												
Site preparation												
Trench investigations												
Office work												
Planning and logistical arangements												
Drafting, C14 dating & initial interpretation												
Manuscript preparation												
Final report preparation												
Fall American Geophysical Union presentation												

Field consultation and review

We recognize the importance of field review in paleoseismologic investigations. We have had field reviews at the LY4 site by T. Fumal, H. Stenner, T. Dawson, D. Schwartz, T. Rockwell, G. Seitz, and J. Lienkaemper among others. These reviews were important for us to have conversations about our observations and interpretations during the research. They provided us motivation and inspiration to modify our investigations and further test the interpretations. We expect to schedule field review with scientists in both Southern and Northern California several times during the project. In particular, we will seek feedback from other Carrizo researchers such as Kerry Sieh and Jing Liu. We will host a "trench party" near the end of our efforts in the trench and make a broad invitation to colleagues and interested parties.

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April 24 2003

Dear Lisa,

This letter is to follow up our conversation concerning radiocarbon dating of organic samples from your paleoseismology trenching sites. The UCI Keck AMS facility was funded for carbon cycle studies, but we are happy to help out UCI colleagues in other fields of research.

As we discussed, the best strategy is clearly to have one of your students spend some time working in our laboratory, learning sample preparation techniques and carrying out the preparation of your samples (plus an appropriate number of standards and blanks) under our supervision. This has the advantage that the student learns some of the basics of radiocarbon and AMS at the same time and goes back into the field with an improved appreciation of what is and is not a good sample for ^{14}C dating . In addition, since the student is carrying out the preparation work, the relevant facility recharge cost is the measurement-only cost of $80 per sample.

Good luck with the proposal.

Sincerely

John Southon
co-director, Keck AMS facility

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Grant, L. B. and A. Donnellan (1994). 1855 and 1991 Surveys of the San Andreas Fault:Implications for Fault Mechanics, BSSA, 84, 2, 241-246.

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Young, J. J., Arrowsmith, J R., Colini, L., and Grant, L. B., 3-D excavation and measurement of recent rupture history along the Cholame segment of the San Andreas Fault, *Bulletin of the Seismological Society of America: Special Issue on Paleoseismology of the San Andreas fault, 92,*2,670-2,688,2002.
Young, J. J., Earthquake Geology along the Cholame Segment of the San Andreas Fault, Ph.D. dissertation in progress, Arizona State University.

Current support and pending applications

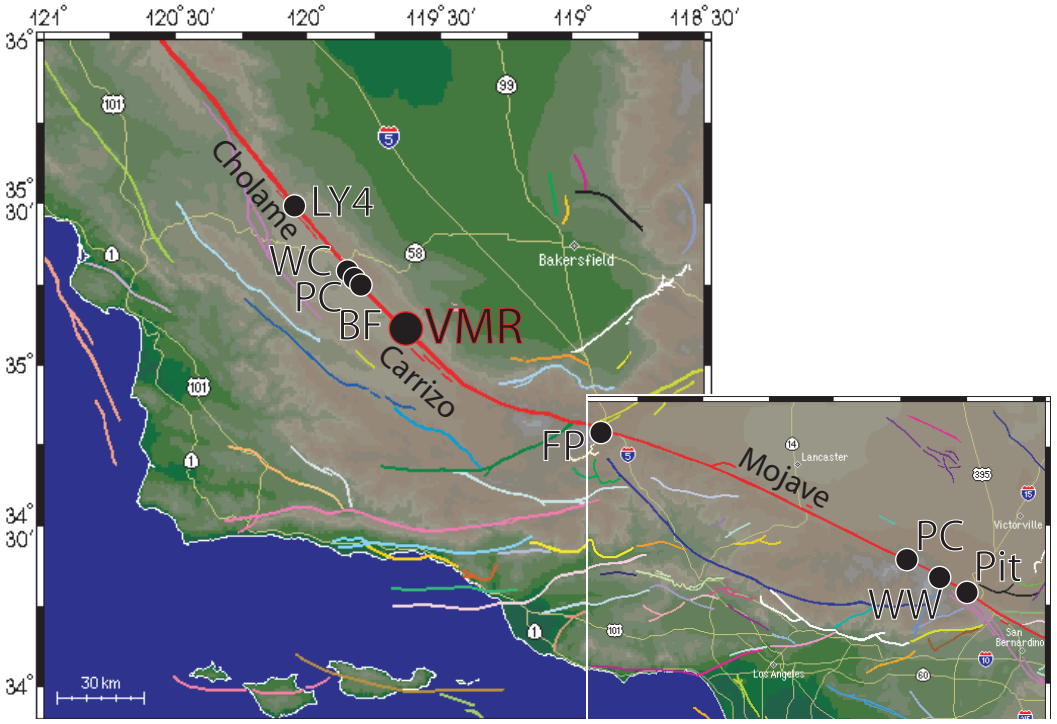
J Ramón Arrowsmith

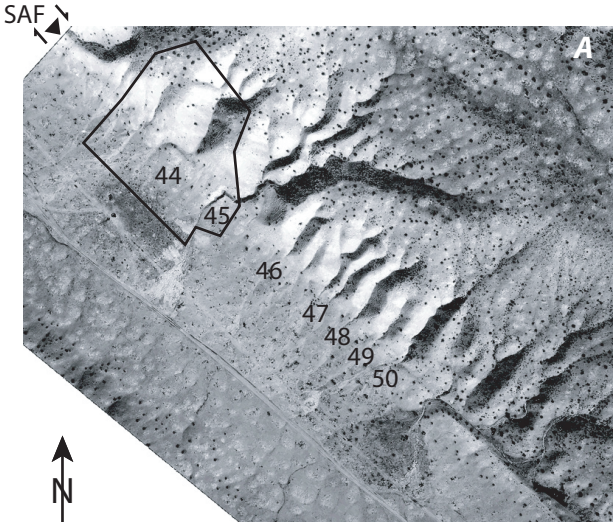
1) NSF-ITR - Arizona State University and University of Texas El Paso: Creation of a Geospatial data system for the transition between the Colorado Plateau and Basin and Range, 10/01/01 – 9/30/04, $200,000, P.I. Summer Month: 0.33
2) NSF-ITR - GEON: A Research Project to Create Cyberinfrastructure for the Geosciences, 9/01/02 – 8/31/07, $400,000, P.I. Summer Month: 0.50
3) NSF Physical Anthropology - Paleoanthropology and Geology of the Ledi-Geraru Region, Afar Regional State, Ethiopia, pending, 12/01/03 – 11/30/04, $97,784, P.I. Summer Month: 0.75
4) USGS EDMAP - Geological Mapping of the San Andreas Fault near Parkfield California, pending, 5/01/03 – 2/28/04, $13,881, P.I. Summer Month: 0.00
5) NSF Bioinformatics - Landuse and Landscape Socioecology in the Mediterranean Basin: A Natural Laboratory for the Study of Longterm Interaction of Human and Natural Systems (CoI), pending, 1/15/04 – 1/14/08, $1,999,400, P.I. Summer Month: 0.70
6) NSF - Kilometer-scale fault zone structure and kinematics along the San Andreas Fault near Parkfield, California, pending, 7/01/03 – 6/30/05, $187,956, P.I. Summer Month: 1.00
7) USGS NEHRP - Rupture History of the San Andreas Fault at Van Matre Ranch, Carrizo Plain, California: Collaborative Research with University of California, Irvine and Arizona State University, pending, this proposal, 2/01/04-1/31/05, P.I. Summer Month: 1.00.
8) USGS NEHRP - Collaborative Research with Northern Arizona University and Arizona State University: Determination of seismic hazard to Flagstaff, Arizona from the Lake Mary Fault, pending, this proposal, 11/1/03-10/31/04, P.I. Summer Month: 0.5.

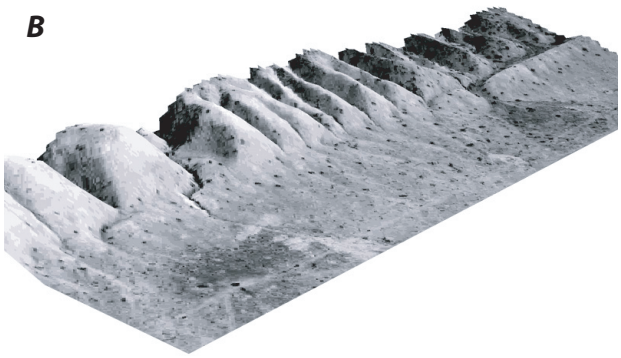
Lisa B. Grant

1) USGS NEHRP – Active deformation and earthquake potential of the southern Los Angeles Basin, Orange County, California, 2/03 – 1/04 $30,000 (P.I.) – 8.5 days summer
2) NASA/JPL, Numerical simulations for active tectonic processes: Increasing interoperability and performance, 5/9/02-12/31/03 $137,000 UCI portion (Co-PI) 1.0 summer
3) Southern California Earthquake Center (SCEC), Dating support for measuring late Quaternary uplift of the Santa Ana Mountains, , 2/1/03-1/31/04, $10,000 (P.I.) 0.1 summer
4) SCEC - Effective Risk Mitigation for SCEC Target Audiences, 2/1/03-1/31/04, $12,000 (P.I.) 0.1 summer
4) SCEC -Collaborative research: Paleoseismic constraints on earthquake simulation models of southern California,, 2/1/03-1/31/04, $5,000 (co-P.I.) 0.48 summer
5) USGS NEHRP - Collaborative research: Rupture history of the San Andreas fault at Van Matre Ranch, Carrizo Plain, CA, pending, this application, 2/1/04-2/1/05 - $48,000– 0.75 summer
5) USGS NEHRP - Active deformation and earthquake potential of the southern Los Angeles Basin, Orange Co, CA, pending, 2/1/04-2/1/05 - $39,000– 1.0 summer

Figure 1. Location map of major paleoseismic sites along the south-central SAF (red line). Van Matre Ranch (VMR) is located in the central portion of the Carrizo section of the SAF; south of LY4-Cholame, Wallace Creek study site of Liu, 2003 (WC), Phelan Creeks (PC; Sims, et al.), and Bidart Fan (BF; Grant and Sieh, 1994). The Frazier Park site of Lindvall, et al. (2002) is along the northern portion of the Mojave section which is well characterzed to the southeast at Pallet Creek (PC; most recently by Biasi, et al., in press), Wrightwood (WW; Fumal, et al., (2002)), and Pitman Canyon (Pit; Seitz, et al.). Other Southern California SAF sites (Plunge Creek, Burro Flat, and Thousand Palms) are located southwest of this map. Base comes from the SCEC fault map (http://www.scecdc.scec.org/faultmap.html).







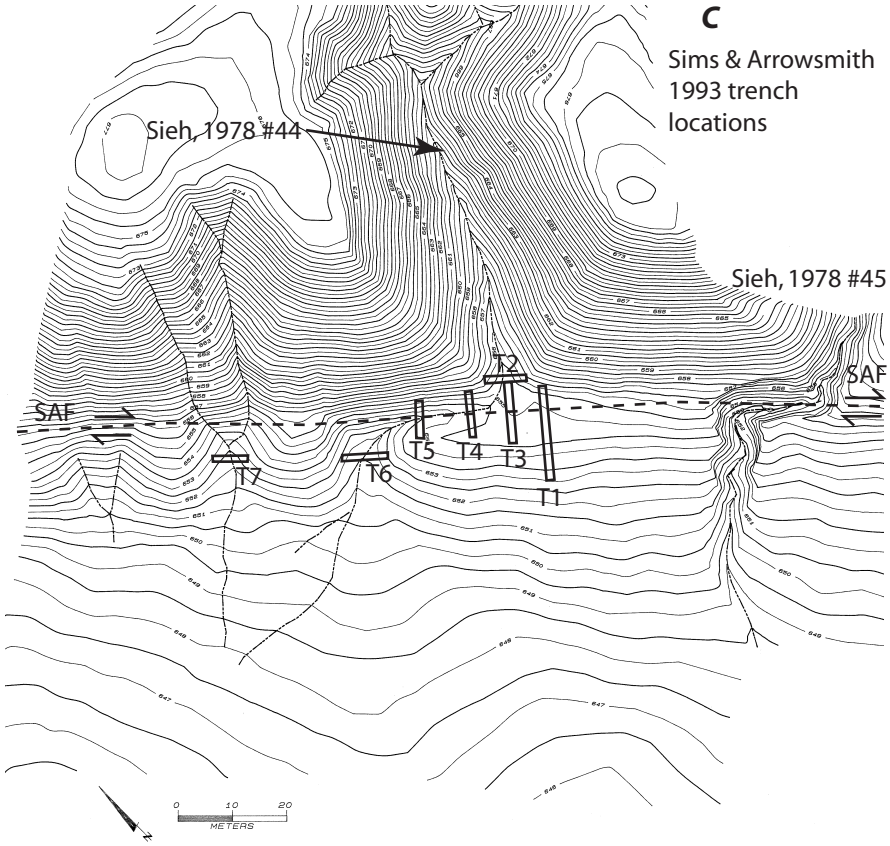
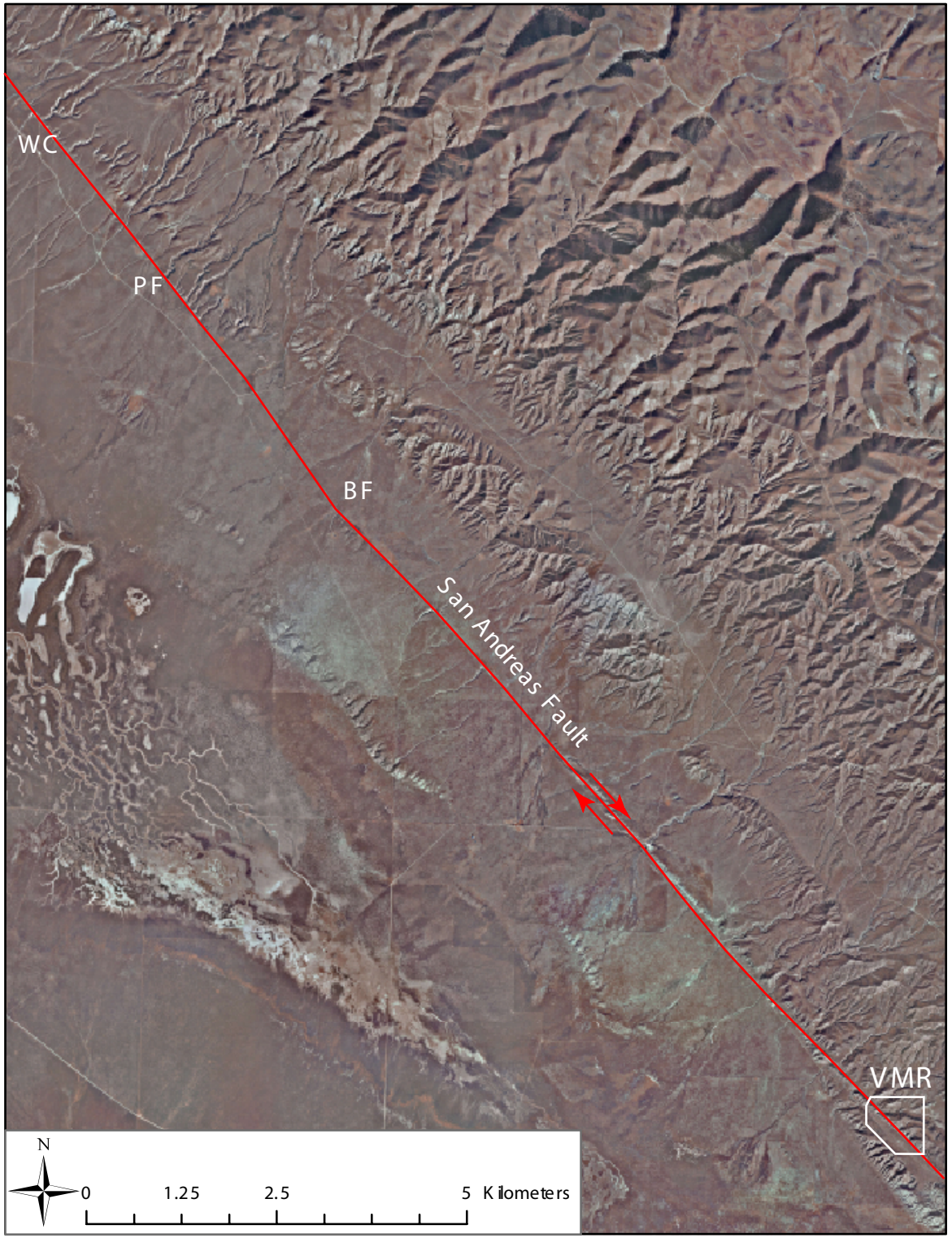
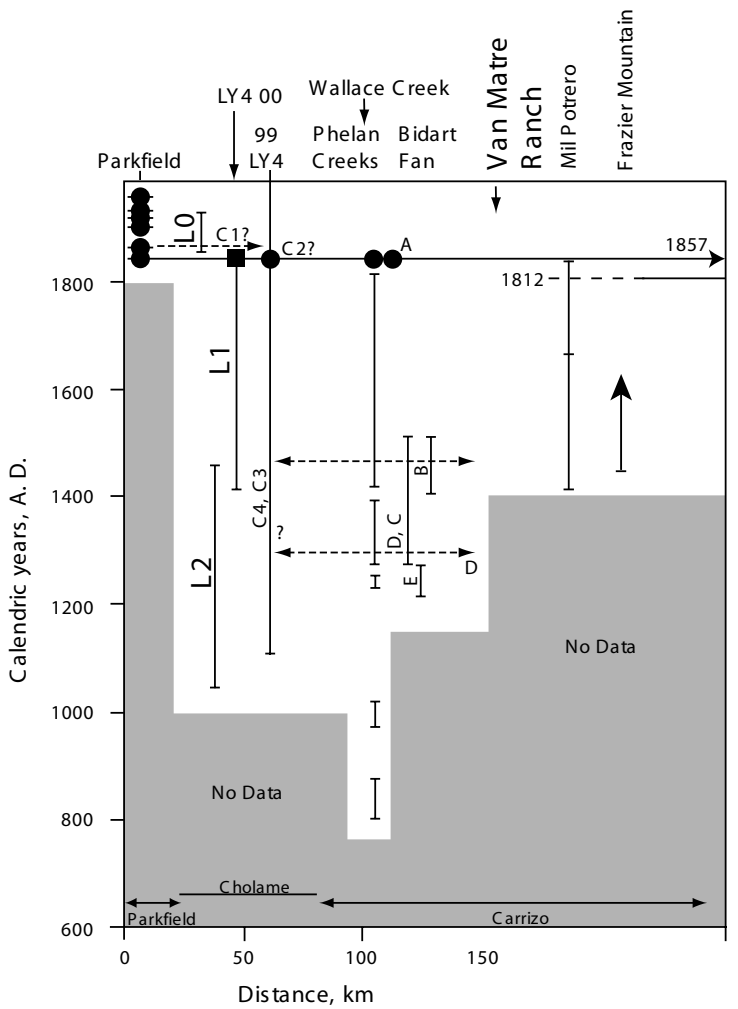


Figure 2. Aerial photographs and topography for the Van Matre Ranch site. A) Rectified aerial photograph (3-9-1991; original scale 1 : 3,000) showing the clear trace of the SAF with numerous 1-10s of meter offsets (those studied by Sieh, 1978 are shown with corresponding numbers). B) Oblique view of aerial photo draped on photogrammetrically produced elevation data (view to ESE; photos and topography from Kerry Sieh; images produced by Miryha Gould at UCI). C) 1 meter contour interval map of Sims and Arrowsmith 1993 study site (shown as polygon in A) with trench locations spanning the offset channel complex. We plan to re-excavate these trenches, check and update logging, reconstruct offset channels with establishment of complete 3 dimensional geometric control, and sample stratigraphy for ^{14}C dating (topographic surveying by J. C. Hamilton, J R. Arrowsmith, and C. Garvin and plotting by Hamilton).

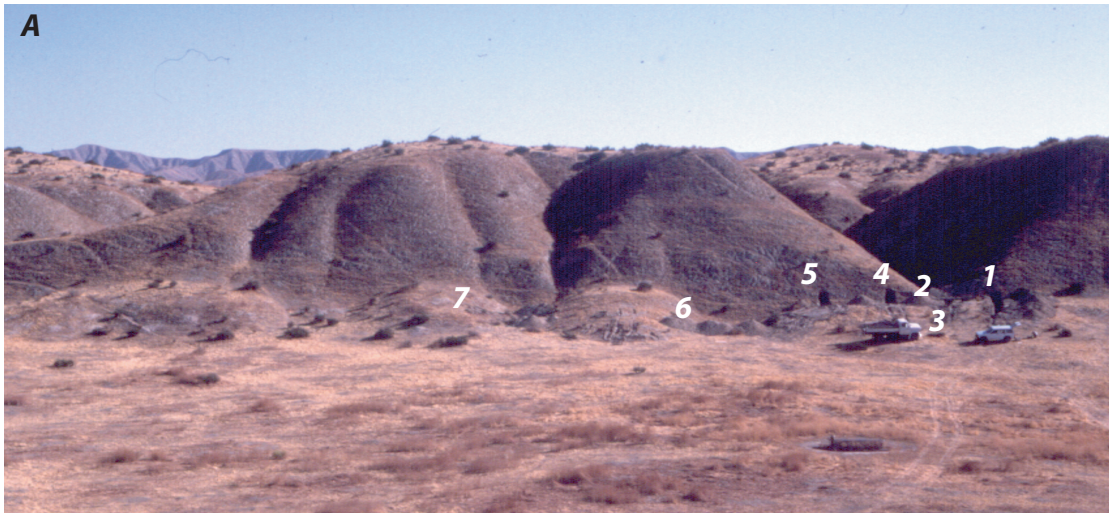




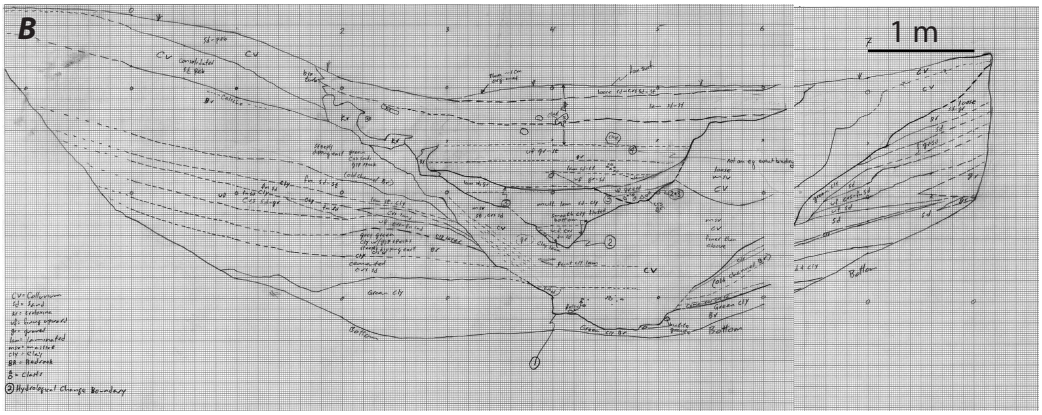
Arrowsmith and Grant 2003 Van Matre Ranch NEHRP proposal

Figure 3. A) Aerial photography (from AirPhoto USA) of the central Carrizo Plain showing the locations of major paleoseismic study sites (WC, Wallace Creek; PF, Phelan Fan; BF, Bidart Fan; and VMR, Van Matre Ranch). B) Event correlation diagram for the Parkfield, Cholame, and Carrizo segments of the SAF (modified from Young, et al., 2002 and Liu, 2003). The Van Matre Ranch site is located in an important position in the south-central Carrizo Plain between the cluster between WC and BF and Mill Potrero and Frazier Mountain to the southeast. Data are from: The historic Parkfield record (e.g., Bakun and Lindh, 1985), LY4-99 (Stone, et al., 2002), LY4-00 (Young, et al., 2002), Phelan Creeks (J. D. Sims, personal comm.), Bidart Fan (Grant and Sieh, 1994), Mil Potrero (Davis, 1983), and Frazier Mountain (Lindvall, et al., 2002).

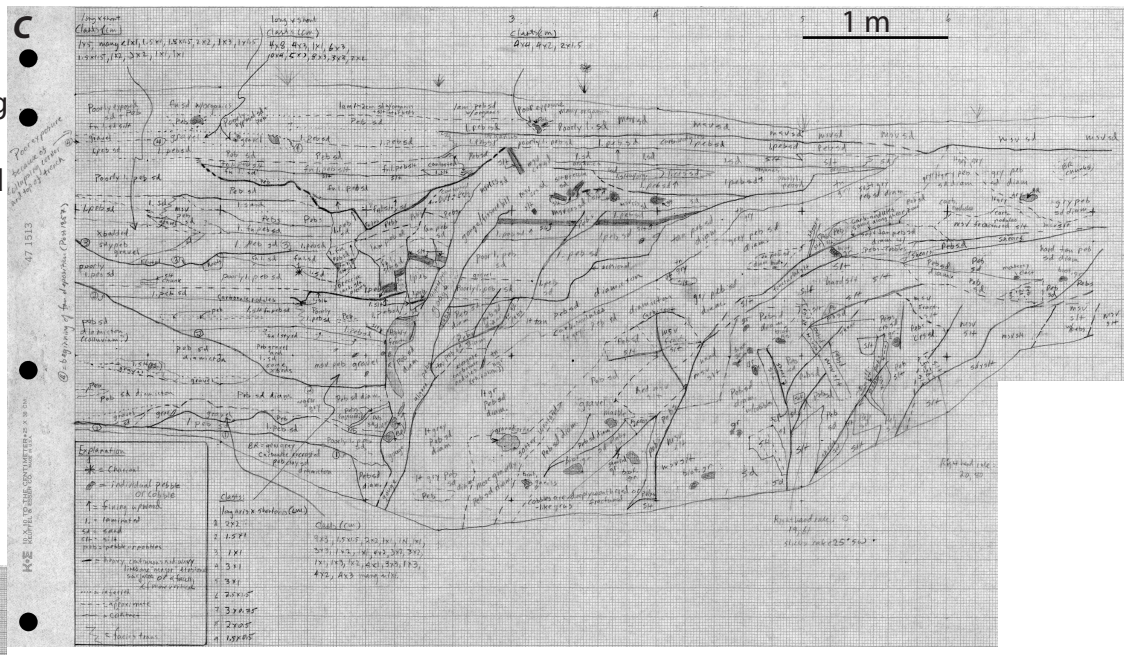
Figure 4. Van Matre Ranch trenches of Sims and Arrowsmith, 1993. ***A)*** Photograph looking northeast at site with open excavations (numbered as in Figure 2 and for locations below). Raw trench logs presented below indicate quality of stratigraphy and the potential to document earthquake offset and timing information.



B) Trench log of Fault parallel trench 2 northeast side showing nested channel cuts and fills that may be traced through the site.



C) Trench log of Fault normal trench 3 souththeast side showing good event stratigraphy, channels, and juxtaposed units. Logged by Arrowsmith.



D) Trench log of Fault parallel trench 6 northeast side again showing the nested channel cuts and fills.