NW Nevada Seismic Exp.

Simon Klemperer
Stanford Univ.

Assembled Data Sets:

05-010 NW Nevada Seismic Experiment: HiResVibroseis
05-011 NW Nevada Seismic Experiment: CrustalShots
05-012 NW Nevada Seismic Experiment: CrustalVibroseis

IRIS DATA MANAGEMENT SYSTEM

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2004 Nevada - California Stanford Seismic Experiment

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Project Dates
September 2004 – March 2005

Principal Investigators
Simon Klemperer
Elizabeth Miller

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Project Overview

Northwestern Nevada is characterized by some of the lowest mean elevations, highest heat flow (>100 mW/m2 with a geothermal gradient exceeding 60ºC/km, e.g. Blackwell, 2004), and thinnest crust (28-30 km, e.g. Catchings et al., 1991) in the northern Basin and Range Province. Recent geologic and geo/thermochronologic studies have demonstrated that extensional faulting in this area is both more recent and of considerably lower magnitude than faulting in adjacent parts of the Basin and Range to the south and east (beginning ca. 11-12 Ma and not exceeding 15% in northwestern Nevada, compared to 50-100% or greater extension since Eocene time in central Nevada). Major volcanism across much of Nevada peaked with the great "ignimbrite flareup" in late Oligocene/early Miocene time, but northwestern Nevada was the locus of intense 17-15 Ma bimodal volcanism commonly thought to represent breakout of the Yellowstone hotspot.

If northwestern Nevada is relatively little and recently extended, why is it one of the thinnest parts of the northern Basin and Range? The area was part of the Cretaceous northern Sierra Nevada and probably characterized by 40-45 km thick crust that was only mildly disrupted by late Miocene extensional faulting. How was the crust thinned and when did this occur? We suggest that ductile flow of the lower crust during rapid Miocene extension in nearby regions may play a significant role, and the goal of this experiment was to collect information on the thickness, velocity structure, reflectivity, and anisotropy of the crust in northwestern Nevada that will enable us to address this problem.

Our investigation consisted of three parts:

Phase 1 (September 2004)

Crustal portion of experiment consisting of a 265-km crustal refraction profile, with five in-line shots (1.25 – 2 tons each) and one 1.25 ton fan shot to the south, with ~1000 receivers spaced 100-300 m apart, acquired with ACS/PRF and NSF/EarthScope funding. We also recorded 3 large (up to 75 tons) blasts from nearby gold mines. The goals of the refraction profile are to determine crustal thickness and overall velocity and reflectivity structure.

During the refraction deployment, we collected reflection data in P, SV and SH modes using the tri-axial "T-Rex" vibrator truck operated by the Network for Earthquake Engineering Seismology (NEES) and the University of Texas at Austin. This experiment will asses the capability of this instrument to collect useful crustal-scale reflection data in conjunction with PASSCAL and EarthScope recorders, and if successful will help constrain the types of rocks and structures present beneath the flat-lying Miocene volcanic rocks that cover much of northwestern Nevada and largely obscure older structures.

Forty-eight short-period 3-component receivers (blue triangles) were embedded in the main refraction line, supplemented by two 16-receiver offline deployments perpendicular to the main line. This experiment was designed to measure crustal S-wave splitting (PmS phase) from the active source experiment as an indicator of crustal anisotropy caused by lower crustal flow. We may also detect differences in direct-S travel times using the SV and SH modes of the T-Rex vibrator from the same vibration location.

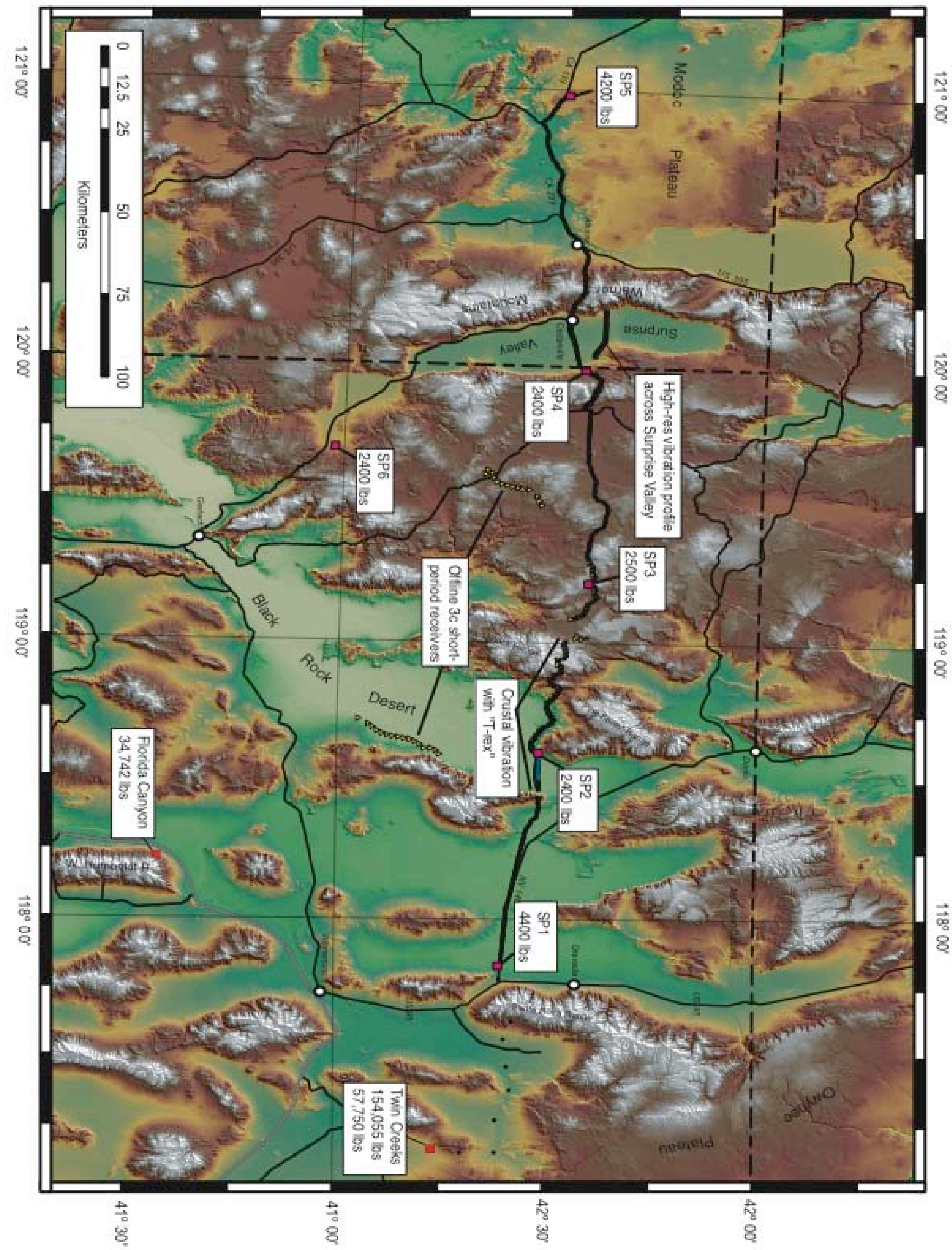

Figure 1. Final experiment layout showing shotpoints, receivers, and vibrator locations

Phase 2 (September 2004)

A 20-km high-resolution (40 m receiver spacing) reflection profile across Surprise Valley, CA. This experiment will test the capabilities of the T-Rex vibrator for shallow, high-resolution P and S-wave imaging in a low-cost experiment, and should yield geologically useful information on the depth and subsurface structure of Surprise Valley adjacent to recently active normal faults along the front of the Warner Range.

Phase 3 (September 2004 – March 2005)

Twenty-eight short-period 3-C receivers covering approximately 60 km were left in place until March of 2005, to collect additional data on crustal anisotropy from teleseismic arrivals.

Funding/Planning/Permitting

Preliminary planning for the layout of the experiment was completed by Joe Colgan, Elizabeth Miller, and Simon Klemperer. The experimental layout was proposed to, and subsequently funded by the American Chemical Society-Petroleum Research Fund in 2002/2003. The scope of the experiment was expanded in 2003 through additional funding from NSF-Earthscope. Supplemental funding from Stanford University and NSF-SGER provided resources for undergraduate involvement and the use of the NEES "T-Rex" vibrator.

Field planning was completed by Joe Colgan, Derek Lerch, and Ewenet Gashawbeza during the summer of 2003. Tom Burdette (USGS, Menlo Park) provided extensive information regarding shotpoint selection and permitting. Permitting and final planning of the experiment was completed over the winter and spring of 2004. This included frequent contact with several governmental agencies, listed below:

BLM – Winnemucca Field Office
BLM – Surprise Valley Field Office
Nevada Dept. of Transportation (NDOT)
California Dept. of Transportation (CalTrans)
Humboldt County Roads
Washoe County Roads
Modoc County Roads
U.S. Forest Service – Modoc Office
U.S. Dept. of Fish and Game – Sheldon National Wildlife Refuge
Summit Lake Indian Reservation

Permits were secured from all agencies mentioned above with the exception of the Summit Lake Indian Reservation. In addition to the required permit application forms, we compiled a brief description of the experiment and the various activities that would be completed on public lands, this report is included as Appendix A. Final scouting of the receiver locations and shotpoints was completed in the spring/summer of 2004.

Logistical aspects of the experiment were completed during the summer of 2004. This included securing all volunteers, vehicles, instruments, lodging, and equipment necessary for the experiment. Due to the distance covered by the experiment, it was necessary to base primary instrument centers out of Winnemucca, NV and Cedarville, CA. A smaller staging area in the central portion of the experiment was located at Soldier Meadows Ranch, NV. Attached below are spreadsheets (Tables 1, 2, 3) related to various logistical parts of the experiment. They are included to provide a picture as to the number of people, vehicles, and time necessary to complete an experiment of this size.

PERSONNEL

	Simon Klemp	Derek Lerch	JoeC Colgan	Charlie Wilson	Ewenet Gashawbeza	JulieF Fosdick	ChrisM Mattinson	KellyG Grijalva	AdamA Abeles	Martins Akintunde	
4-Sep											4-Sep
5-Sep											5-Sep
6-Sep		Arrive Winn		Arrive Winn							6-Sep
7-Sep		WIC Winn	Drill Winn	WIC Winn							7-Sep
8-Sep		WIC Winn	WIC Winn	WIC Winn	Arrive Winn	Arrive Winn					8-Sep
9-Sep		WIC Winn	SM Del Winn	3c2 SM	3c1 SM	3c2 SM					9-Sep
10-Sep	Arrive Winn	WIC Winn	WIC Winn	3c2 SM	3c1 SM	3c2 SM					10-Sep
11-Sep	WIC Winn	Vib Winn	Load Winn	3c2 Winn	3c1 Winn	3c2 Winn					11-Sep
12-Sep	WIC Winn	Vib Winn	Load Ced	Team6Winn	Team5 Winn	Team6 Winn					12-Sep
13-Sep	WIC Winn	Vib Winn	Load Ced	SM Del Winn	Team4 Winn	Ced Del Ced		Arrive Winn	Arrive Winn	Arrive Winn	13-Sep
14-Sep	WIC Winn	Vib Winn	CIC Ced	Team6 SM	Team5 SM	Team8Ced		Team3 Winn	Team4 Winn	Team4 Winn	14-Sep
15-Sep	WIC Winn	Vib Winn	Shoot1 Ced	Team6 SM	Team5 SM	Team8Ced		Team3 Winn	Team4 Winn	Team4 Winn	15-Sep
16-Sep	WIC Winn	Vib Winn	Shoot1 Ced	Team6 SM	Team5 SM	Team8Ced		Team3 Winn	Team4 Winn	Team4 Winn	16-Sep
17-Sep	WIC Winn	Vib Winn	CIC Ced	Team6 SM	Team5 SM	Team8Ced		Team3 Winn	Team4 Winn	Team4 Winn	17-Sep
18-Sep	WIC Winn	Vib Winn	CIC Ced	Team6Ced	Team5 Winn	Team8Ced	Arrive Ced	Team3 Winn	Team4 Winn	Team4 Winn	18-Sep
19-Sep	CIC Ced	Vib Ced	HiRes1 Ced	3c2 SM	3c1 SM	HiRes3Ced	HiRes2 Ced	Team3 Winn	Team4 Winn	Team4 Winn	19-Sep
20-Sep	CIC Ced	Vib Ced	HiRes1 Ced	3c2 SM	3c1 SM	HiRes3Ced	HiRes2 Ced	STAN	STAN	STAN	20-Sep
21-Sep	CIC Ced	Vib Ced	HiRes1 Ced	3c2 SM	3c1 SM	HiRes3Ced	HiRes2 Ced				21-Sep
22-Sep	CIC Ced	Vib Ced	HiRes1 Ced	3c2 Ced	3c1 Ced	HiRes3Ced	HiRes2 Ced				22-Sep
23-Sep	CIC Ced	Vib Ced	COL	CIC Ced	CIC Ced	HiRes3Ced	HiRes2 Ced				23-Sep
24-Sep	CIC Ced	Vib Ced		CIC Ced	CIC Ced	HiRes3Ced	HiRes2 Ced				24-Sep
25-Sep	STAN	STAN		STAN	STAN	STAN	STAN				25-Sep

	Mac McWilliams	ELM Miller	NicM Markman	JuliaJ James	NickL Leindecker	AnneE Egger	Romans Romans	Simone Manganelli	AmyW Weislogel	Marleen Nyst	Trevor Dumitru	Fung Fung	
4-Sep													4-Sep
5-Sep													5-Sep
6-Sep													6-Sep
7-Sep													7-Sep
8-Sep												Arrive Winn	8-Sep
9-Sep												3c1 SM	9-Sep
10-Sep								Arrive Winn				3c1 SM	10-Sep
11-Sep								Backfill Winn				3c1 Winn	11-Sep
12-Sep	Arrive Ced	Arrive Ced	Arrive Ced					Backfill Ced				Team5 Winn	12-Sep
13-Sep	Arrive Winn	Backfill Ced	Backfill Ced	Arrive Ced	Arrive Ced	Arrive Ced		Arrive Winn				WIC Winn	13-Sep
14-Sep	Team6 SM	Team7 Ced	Team7 Ced	Team9 Ced	Team8 Ced	Team9 Ced		Team3 Winn				Team5 SM	14-Sep
15-Sep	Team6 SM	Team7 Ced	Team7 Ced	Team9 Ced	Team8 Ced	Team9 Ced		Team3 Winn				Team5 SM	15-Sep
16-Sep	Team6 SM	Team7 Ced	Team7 Ced	Team9 Ced	Team8 Ced	Team9 Ced		Team3 Winn				Team5 SM	16-Sep
17-Sep	Team6 SM	Team7 Ced	Team7 Ced	Team9 Ced	Team8 Ced	Team9 Ced		Team3 Winn				Team5 SM	17-Sep
18-Sep	Team6Ced	Team7 Ced	Team7 Ced	Team9 Ced	Team8 Ced	Team9 Ced	Arrive Ced	Team3 Winn	Arrive Ced	Arrive Ced	Arrive Ced	Team5 Winn	18-Sep
19-Sep	STAN	STAN	HiRes2 Ced	HiRes4 Ced	HiRes3 Ced	STAN	HiRes1 Ced	STAN	HiRes4 Ced	SMIC SM	3c2 SM	3c1 SM	19-Sep
20-Sep			HiRes2 Ced	HiRes4 Ced	HiRes3 Ced		HiRes1 Ced		HiRes4 Ced	SMIC SM	3c2 SM	3c1 SM	20-Sep
21-Sep			HiRes2 Ced	HiRes4 Ced	HiRes3 Ced		HiRes1 Ced		HiRes4 Ced	SMIC SM	3c2 SM	3c1 SM	21-Sep
22-Sep			HiRes2 Ced	HiRes4 Ced	HiRes3 Ced		HiRes1 Ced		HiRes4 Ced	SMIC Ced	3c2 Ced	3c1 Ced	22-Sep
23-Sep			HiRes2 Ced	HiRes4 Ced	HiRes3 Ced		HiRes1 Ced		HiRes4 Ced	STAN	STAN	CIC Ced	23-Sep
24-Sep			HiRes2 Ced	HiRes4 Ced	HiRes3 Ced		HiRes1 Ced		HiRes4 Ced			CIC Ced	24-Sep
25-Sep			STAN	STAN	STAN		STAN		STAN			STAN	25-Sep

	Ariel Roll	George Thompson	Burdette Burdette	Rufus Catchings	WalterM Mooney	NickH Hoffman	TysonF Fulmer	MattC Coble	Liu Liu	DarleneM McEwan	AaronH Hirsch	SteveA Azevedo	BobG Greschke	LloydC Carothers	Mario Torres	
4-Sep																4-Sep
5-Sep																5-Sep
6-Sep												Arrive Winn	Arrive Winn	Arrive Winn	Arrive Winn	6-Sep
7-Sep												WIC Winn	WIC Winn	WIC Winn	WIC Winn	7-Sep
8-Sep												WIC Winn	WIC Winn	WIC Winn	WIC Winn	8-Sep
9-Sep												WIC Winn	WIC Winn	WIC Winn	WIC Winn	9-Sep
10-Sep			Arrive Winn			Arrive Winn	Arrive Winn	Arrive Winn	Arrive Winn			WIC Winn	WIC Winn	WIC Winn	WIC Winn	10-Sep
11-Sep			Load Winn			Load Winn	Backfill Winn	Backfill Winn	Backfill Winn			WIC Winn	WIC Winn	WIC Winn	WIC Winn	11-Sep
12-Sep	Arrive Winn		Load Ced			Load Ced	Backfill Ced	Backfill Ced	Backfill Ced			WIC Winn	WIC Winn	WIC Winn	WIC Winn	12-Sep
13-Sep	Team4 Winn	Arrive Ced	Load Ced			Load Ced	Backfill Ced	Arrive Winn	Arrive Winn	Arrive Winn	Arrive Winn	CIC Ced	WIC Winn	WIC Winn	WIC Winn	13-Sep
14-Sep	WIC Winn	CIC Ced	CIC Ced			CIC Ced	CIC Ced	Team1 Winn	Team2 Winn	Team1 Winn	Team2 Winn	CIC Ced	WIC Winn	WIC Winn	WIC Winn	14-Sep
15-Sep	WIC Winn	CIC Ced	Shoot1 Ced	Shoot2 Winn	Shoot2 Winn	Shoot1 Ced	CIC Ced	Team1 Winn	Team2 Winn	Team1 Winn	Team2 Winn	CIC Ced	WIC Winn	WIC Winn	WIC Winn	15-Sep
16-Sep	Clean Winn	CIC Ced	Shoot1 Ced	Shoot2 Winn	Shoot2 Winn	Shoot1 Ced	Clean Ced	Team1 Winn	Team2 Winn	Team1 Winn	Team2 Winn	CIC Ced	WIC Winn	WIC Winn	WIC Winn	16-Sep
17-Sep	Team4 Winn	CIC Ced	USGS	USGS	USGS	USGS	USGS	Team1 Winn	Team2 Winn	Team1 Winn	Team2 Winn	CIC Ced	WIC Winn	WIC Winn	WIC Winn	17-Sep
18-Sep	Clean Winn	CIC Ced						Team1 Winn	Team2 Winn	Team1 Winn	Team2 Winn	CIC Ced	WIC Winn	WIC Winn	WIC Winn	18-Sep
19-Sep	STAN	STAN						USGS	USGS	UNLV	UNLV	CIC Ced	WIC Winn	WIC Winn	WIC Winn	19-Sep
20-Sep												CIC Ced	CIC Ced	PIC	PIC	20-Sep
21-Sep												CIC Ced	CIC Ced			21-Sep
22-Sep												CIC Ced	CIC Ced			22-Sep
23-Sep												CIC Ced	CIC Ced			23-Sep
24-Sep												CIC Ced	CIC Ced			24-Sep
25-Sep												CIC Ced	CIC Ced			25-Sep
												PIC	PIC			

Table 1. Personnel activity

DATE	WINNEMUCCA	CEDARVILLE	ALTURAS	SOLDIER MEADOWS
	Name, *needs single* **[room needs] {total people}**	Name, *needs single* **[room needs] {total people}**	Name, *needs single* **[room needs] {total people}**	Name, *needs single* **[room needs] {total people}**
6-Sep	*SteveA* , *BobG* , *LloydC* , *Mario,* Charlie, Derek **[4s, 1d] {6}**			
7-Sep	*SteveA* , *BobG* , *LloydC* , *Mario,* Charlie, Derek **[4s, 1d] {6}**			
8-Sep	*SteveA* , *BobG* , *LloydC* , *Mario,* Charlie, Derek, JoeC, JulieF, Ewenet, Fung **[4s, 2t] {10}**			
9-Sep	*SteveA* , *BobG* , *LloydC* , *Mario* , Derek, JoeC **[4s, 1dt] {6}**			Charlie, Ewenet, JulieF, Fung **[2d] {4}**
10-Sep	*SteveA* , *BobG* , *LloydC* , *Mario* , Derek, *Burdette,* TysonF, NickH, MattC, Liu, Simone, JoeC **[5s, 3dt] {12}**			Charlie, Ewenet, JulieF, Fung **[2d] {4}**
11-Sep	*SteveA* , *BobG* , *LloydC* , *Mario* , Derek, Charlie, Ewenet, JulieF, Fung, *Burdette,* JoeC, TysonF, NickH, MattC, Liu, Simone **[5s, 4dt] {16}**			
12-Sep	*SteveA* , *BobG* , *LloydC* , *Mario* , Derek, Charlie, Ewenet, JulieF, Fung **[4s, 2dt] {9}**	*Burdette,* JoeC, TysonF, NickH, MattC, Liu, Simone, *ELM,* NicM **[2s, 3t] {9}**		
13-Sep	*CathyS* , *BobG* , *LloydC* , *Mario* , Derek, *Simon,* Charlie, Ewenet, Fung, KellyG, AdamA, Martins, *Mac* , Cathy1, Cathy2, MattC, Liu, Simone, Ariel **[6s, 6dt] {19}**	*Burdette, George,* JoeC, TysonF, NickH, *ELM,* NicM, JulieF, *SteveA,* JuliaJ, NickL, AnneE **[3s, 3t] {12}**		
14-Sep	*BobG* , *LloydC* , *Mario* , Derek, *Simon,* KellyG, AdamA, Ariel, Martins, Cathy1, Cathy2, MattC, Liu, Simone **[4s, 5dt] {14}**	*Burdette, George,* JoeC, TysonF, NickH, *ELM,* NicM, JulieF, *SteveA,* JuliaJ, NickL, AnneE **[3s, 3t] {12}**		Charlie, Ewenet, Mac, Fung **[2d] {4}**
15-Sep	*BobG* , *LloydC* , *Mario* , Derek, *Simon,* KellyG, Martins, Cathy1, Cathy2, MattC, Liu, Simone, AdamA, Ariel, *Walter, Rufus* **[6s, 5dt] {16}**	*Burdette, George,* JoeC, TysonF, NickH, *ELM,* NicM, JulieF, *SteveA,* JuliaJ, NickL, AnneE **[3s, 3t] {12}**		Charlie, Ewenet, Mac, Fung **[2d] {4}**
16-Sep	*BobG* , *LloydC* , *Mario* , Derek, *Simon,* KellyG, Martins, Cathy1, Cathy2, MattC, Liu, Simone, AdamA, Ariel, *Walter, Rufus* **[6s, 5dt] {16}**	*Burdette, George,* JoeC, TysonF, NickH, *ELM,* NicM, JulieF, *SteveA,* JuliaJ, NickL, AnneE **[3s, 3t] {12}**		Charlie, Ewenet, Mac, Fung **[2d] {4}**
17-Sep	*BobG* , *LloydC* , *Mario* , Derek, *Simon,* KellyG, AdamA, Ariel, Martins, Cathy1, Cathy2, MattC, Liu, Simone **[4s, 5dt] {14}**	*SteveA* **[1s] {1}**	*George,* JoeC, *ELM,* NicM, JulieF, JuliaJ, NickL, AnneE **[2s, 3d] {8}**	Charlie, Ewenet, Mac, Fung **[2d] {4}**
18-Sep	*BobG* , *LloydC* , *Mario* , Derek, *Simon,* Martins, Cathy1, Cathy2, MattC, Liu, Ewenet, Fung, Trevor, Marleen **[4s, 5dt] {14}**	*SteveA* **[1s] {1}**	*George,* JoeC, *ELM,* NicM, JulieF, JuliaJ, NickL, AnneE, Charlie, *Mac,* AmyW, Romans, Marilyn, CGM, Simone, KellyG **[3s, 6d] {16}**	
19-Sep		*George, Simon, PASSCAL,* JoeC, NicM, JulieF, *SteveA,* JuliaJ, NickL, AmyW, Romans, Derek, CGM **[4s, 4d] {13}**		Charlie, Ewenet, Trevor, Fung, Marleen, Marilyn **[3d] {6}**
20-Sep		*George, Simon, PASSCAL,* JoeC, NicM, JulieF, *SteveA,* JuliaJ, NickL, AmyW, Romans, Derek, CGM **[4s, 4d] {13}**		Charlie, Ewenet, Trevor, Fung, Marleen, Marilyn **[3d] {6}**
21-Sep		*George, Simon, PASSCAL,* JoeC, NicM, JulieF, *SteveA,* JuliaJ, NickL, AmyW, Romans, Derek, CGM **[4s, 4d] {13}**		Charlie, Ewenet, Trevor, Fung, Marleen, Marilyn **[3d] {6}**
22-Sep		*George, Simon, PASSCAL,* NicM, JulieF, *SteveA,* JuliaJ, NickL, AmyW, Romans, Derek, CGM, Charlie, Marilyn, Ewenet, Marleen, JoeC, Trevor **[4s, 7d] {19}**		
23-Sep		*George, Simon, PASSCAL,* NicM, JulieF, *SteveA,* JuliaJ, NickL, AmyW, Romans, Derek, CGM, Charlie, Marilyn, Ewenet, Marleen **[4s, 5d] {16}**		
24-Sep		*George, Simon, PASSCAL,* NicM, JulieF, *SteveA,* JuliaJ, NickL, AmyW, Romans, Derek, CGM, Charlie, Marilyn, Ewenet, Marleen **[4s, 5d] {16}**		
25-Sep				
26-Sep				

Table 2. Lodging needs

VEHICLES

Date	783	925	90	SLK	JC	USGS 1	USGS2	HH1	Date	HH2	HH3	Ariel	Thompson	USGS3	UNLV	ELM	CGM	Date
	4wd white suburban	4wd white suburban	2wd white fullsize van	4wd grey 4runner	4wd red small blazer	4wd red small pickup	4wd white USGS	2wd white fullsize pickup		2wd white fullsize pickup	2wd white fullsize pickup	4wd small pickup	2wd Subaru		4wd SUV	4wd white/brown fullsize pickup	2wd green fullsize pickup	
9/3/04					?				9/3/04									9/3/04
9/4/04					?				9/4/04									9/4/04
9/5/04	STAN				?				9/5/04									9/5/04
9/6/04	Derek Winn				?				9/6/04									9/6/04
9/7/04	Derek Winn	STAN	STAN		Colgan Winn				9/7/04									9/7/04
9/8/04	Derek Winn	Ewenet Winn	JulieF Winn		Colgan Winn				9/8/04									9/8/04
9/9/04	Charlie SM	Ewenet SM	Derek Winn	STAN	Colgan Winn	USGS	USGS	STAN	9/9/04	STAN								9/9/04
9/10/04	Charlie SM	Ewenet SM	Winn	Winn	Colgan Winn	Burdette Winn	TysonF Winn	MattC Winn	9/10/04	Simone Winn								9/10/04
9/11 Sat	Charlie Winn	Ewenet Winn	Winn	Winn	Colgan Winn	Burdette Winn	TysonF Winn	MattC Winn	9/11 Sat	Simone Winn		COLORADO				STAN		9/11 Sat
9/12 Sun	Charlie Winn	Ewenet Winn	Winn	Winn	Colgan Ced	Burdette Ced	TysonF Ced	MattC Ced	9/12 Sun	Simone Ced	STAN	Ariel Winn	STAN		UNLV	ELM Ced		9/12 Sun
9/13 Mon	Charlie Winn	Ewenet Winn	JulieF Ced	Winn	Colgan Ced	Burdette Ced	TysonF Ced	MattC Winn	9/13 Mon	Simone Winn	AdamA Winn	Ariel Winn	George Ced		Cathy2 Winn	ELM Ced		9/13 Mon
9/14 Tue	Charlie SM	Ewenet SM	JulieF Ced	Winn	Colgan Ced	Burdette Ced	TysonF Ced	MattC Winn	9/14 Tue	Simone Winn	AdamA Winn	Ariel Winn	Ced	USGS	Cathy2 Winn	ELM Ced		9/14 Tue
9/15 Wed	Charlie SM	Ewenet SM	JulieF Ced	Winn	Colgan Ced	Burdette Ced	TysonF Ced	MattC Winn	9/15 Wed	Simone Winn	AdamA Winn	Ariel Winn	Ced	Mooney Winn	Cathy2 Winn	ELM Ced		9/15 Wed
9/16 Thu	Charlie SM	Ewenet SM	JulieF Ced	Winn	Colgan Ced	Burdette Ced	TysonF Ced	MattC Winn	9/16 Thu	Simone Winn	AdamA Winn	Ariel Winn	Ced	Mooney Winn	Cathy2 Winn	ELM Ced		9/16 Thu
9/17 Fri	Charlie SM	Ewenet SM	JulieF Ced	Winn	Colgan Ced	Burdette USGS	TysonF USGS	MattC Winn	9/17 Fri	Simone Winn	AdamA Winn	Ariel Winn	Ced	Mooney USGS	Cathy2 Winn	ELM Ced	BISHOP, CA	9/17 Fri
9/18 Sat	Charlie Ced	Ewenet Winn	JulieF Ced	Winn	Colgan Ced			MattC Winn	9/18 Sat	Simone Ced	AdamA Winn	Ariel Winn	Ced		Cathy2 Winn	ELM Ced	CGM Ced	9/18 Sat
9/19 Sun	Charlie SM	Ewenet SM	JulieF Ced	Ced	AmyW Ced			Derek Ced	9/19 Sun	Simone STAN	AdamA STAN	Ariel STAN	Ced		Cathy2 UNLV	Colgan Ced	CGM Ced	9/19 Sun
9/20 Mon	Charlie SM	Ewenet SM	JulieF Ced	Ced	Ced			AmyW Ced	9/20 Mon				Ced			Ced	CGM Ced	9/20 Mon
9/21 Tue	Charlie SM	Ewenet SM	JulieF Ced	Ced	Ced			AmyW Ced	9/21 Tue				Ced			Ced	CGM Ced	9/21 Tue
9/22 Wed	Charlie Ced	Ced	JulieF Ced	Ced	Ced			AmyW Ced	9/22 Wed				Ced			Ced	CGM Ced	9/22 Wed
9/23 Thu	Charlie Ced	Ced	JulieF Ced	Ced	Ced			AmyW Ced	9/23 Thu				Ced			Ced	CGM Ced	9/23 Thu
9/24 Fri	Charlie Ced	Ced	JulieF Ced	Ced	Ced			AmyW Ced	9/24 Fri				Ced			Derek Ced	CGM Ced	9/24 Fri
9/25 Saturday	Charlie STAN	Ewenet STAN	JulieF STAN	SLK STAN	Colgan COLORADO			AmyW STAN	9/25 Saturday				George STAN			Derek STAN	CGM STAN	9/25 Saturday

Table 3. Vehicle activity

Location Description

The location of the seismic-recording line in Modoc County, CA, and Washoe and Humboldt Counties, NV, is shown on the attached regional map (Figure 1). For its entire length, the line follows established paved or graded dirt roads located almost entirely within federally-owned lands. Starting at the eastern end, it begins just west of the State Highway 140/US Highway 95 junction approximately 12 miles south of Orovada, NV. It continues west along State Highway 140 through BLM land until the Leonard Creek Road turnoff, 2 miles south of Quinn River Crossing. At Leonard Creek Road (County Road 214), the line turns southwest around the northern end of the Jackson Mountains and then west across the northernmost part of the Black Rock Desert. At Pearl Canyon, the line turns north-northwest up Pearl Camp Road (County Road 215) for 4 miles before turning south (BLM Road 2052) along the eastern side of Bartlett Peak toward Bartlett Creek. Two miles down this road, the seismic-recording line bends north-northwest around the southern edge of Bartlett Peak and remains north of Bartlett Creek. The seismic-recording line continues across the Lahontan Cutthroat Trout Natural Area (BLM) and into the Summit Lake Indian Reservation. At the western edge of the Summit Lake Indian Reservation, the line turns northwest on County Road 213 and leaves the Summit Lake Indian Reservation land. The seismic-recording line enters Sheldon National Wildlife Refuge land (Fish and Wildlife Service) 5-6 miles after leaving the Summit Lake Indian Reservation. Approximately 12 miles after joining County Road 213, the seismic-recording line turns west toward Baleman Spring Camp. Three miles after this turn, the line leaves the Sheldon National Wildlife Refuge and re-enters BLM land. From here, the seismic-recording line continues west and follows BLM Road 37031 toward Wall Canyon Ranch. Just past Wall Canyon Ranch, the line bends northwest across approximately 3 miles of Sheldon National Wildlife Refuge land before re-entering BLM land as it approaches County Road 8A. The seismic line turns southwest onto County Road 8A and continues along County Road 8A until the California-Nevada border, where the road becomes California State Highway 299. From the California-Nevada border, the line will follow California State Highway 299 west until the junction with California State Highway 139, where it turns northwest. The line continues along California State Highway 139 for ~5 miles, before turning north on Forest Service Road 46. The experiment will end approximately 0.7 miles (1.1 km) north of California State Highway 139 on Forest Service Road 46.

Recording

Instrumentation for the experiment was supplied by various sources. The majority of single-channel RefTek 125s (Texans) and all three-channel RefTek 130s (RT130s) were supplied through IRIS-PASSCAL. Secondary sources of Texans included:

University of Copenhagen
University of Vienna
University of South Carolina
University of Warsaw

In total, approximately 1100 receivers (~1000 Texans, ~100 RT130s) were used during the experiment.

Directory Structure

Data assembly and organization was completed by Mary Templeton from PASSCAL. The file structure is described here:

```
CrustalShots/          Files for Crustal shot and quarry blast line.
  SEGY/                        Standard SEG-Y Reel files containing multiple gathers.
                       File naming convention is:
PSID.Experiment.Line.instrument[[[[[.source_dir].program_window].das_times].part#].SGY

                         where
                               PSID - PASSCAL Experiment ID
                               source_dir - source polarization direction
                               program_window - texan programming window
                               das_times - txn2segy dasfile times (the
                                       gathering program, txn2segy, uses an an
                                       input "dasfile" that describes which
                                       recorders were at which receiver stations)
                               part# - gather files cannot exceed 2 GB so gathers
                                       for a single source polarization must usually
                                       split into separate files.
                       For example,
0313.NNevada.HiResVibroseis.all.Psrc.prog4.2004_265_266.pt4.SGY
               indicates gathers from the HiResVibroseis line of the NNevada experiment
               that include all deployed instruments recording program window 6 that spanned
               julian days 2004,266-267. The Vibroseis trucks were generating P waves.
  notes/
    qc/
```

CrustalShots.texan.filecount
File describing number of files found for RT125 digitizers by serial number. Letter codes indicate reason for missing data when known.

CrustalShots.texan.timing.problems.JJJ
File describing untimed traces for RT125 digitizers by serial number. JJJ indicates the julian day on which data from these instruments were downloaded.

txn2segy_LOGS/ Log files generated by the txn2segy gathering program. Notes instances where dummy traces were substituted for missing data. File naming is the same as for SEGY/ gathers.

txn2segy_stdout/ Standard output and error from the texan2segy gathering program. File naming is the same as for SEGY/ gathers.

responses/ Response files and descriptions (see README.responses) for digitizers and geophones used in the line.

soh_logs/ State of health logs generated from digitizers. File naming convention is as follows: PSID.recstn.YYYYJJJ_YYYYJJJ.Serial.ext

where

PSID - PASSCAL Experiment ID
recstn - receiver station(s) for this file
YYYYJJJ_YYYYJJJ - time span for this file
Serial - digitizer serial number for this file
ext - file type extension: .tsh indicates an RT125; .log indicates an RT130.

supplemental_files/ Files used to generate gathers with the program txn2segy.

Run.Line.instrument
Command lines used to run txn2segy.

SurveyFile.Line
Shot and receiver station geometry file.

dasfiles/ Files mapping a digitizer serial number and channel to a receiver station on the ground.

DasFile.Line.instrument[.das_times]
The file describes the line layout during das_times.

eventfiles/ Files mapping a time to a shot station on the ground and an appropriate dasfile. File naming is the same as for SEGY/ gathers

CrustalVibroseis/ Files for Crustal Vibroseis line.

HiResVibroseis/ Files for High Resolution Vibroseis line.

Digitizers

1) REF TEK 130 Digitizers

For the Crustal Shot and Vibroseis phases of the experiment, the following list of receiver stations had RT130 digitizers.

1414
1426
1438
1450

1462
1474
1486
1498
1510
1522
1534
1546
1558
1570
1582
1594
1642
1654
1666
1678
1690
1702
1714
1726
1738
1750
1762
1774
1786
1798
1810
1822
1834
1846
1858
1870
1882
1894
1906
1918
1930
1942
1954
1966
1978
2014-2082
4011
4018
4024
4045
4060
4074
4089
4102
4117

4130
4138
4142
4153
4159
5285
5293
5308
5325
5336
5349
5362
5378
5393
5408
5422
5436
5449
5461
5472
5499
6000-6002

The A/D scale factor for RT130s is 1.589 uV at unity gain and a preamp gain 32 was applied in addition. These digitizers have an input sample rate of 256,000 samples per second and the response at 250 samples per second is described by the following cascade:

Filename	Description	Output Samples Per Second
crystal.1	decimate by 8	32,000
crystal.2	decimate by 2	16,000
crystal.2	decimate by 2	8,000
crystal.2	decimate by 2	4,000
crystal.2	decimate by 2	2,000
crystal.2	decimate by 2	1,000
crystal.2	decimate by 2	500
crytsal.3	decimate by 2	250

2) REF TEK 125 "Texan" Digitizers

The rest of the receiver stations had RT125 Texan digitizers with A/D scale factors of 5.96046e-08 volts/count and a pre-amp gain of 32.

Geophones

1) Mark Products L28 3-component geophones
Corner frequency 4.5 Hz

Coil	395 ohms
Sensitivity	20.4 V/m/sec
Damping	0.7

See file l28_vel for poles and zeros.

For the Crustal Shot and Vibroseis phases of the experiment, the following list of receiver stations had Mark Products L28 3-component geophones. In each case, the digitizer was a REF TEK 130.

1414
1426
1438
1450
1462
1474
1486
1498
1510
1522
1534
1546
1558
1570
1582
1594
1642
1654
1666
1678
1690
1702
1714
1726
1738
1750
1762
1774
1786
1798
1810
1822
1834
1846
1858
1870
1882
1894
1906
1918

1930
1942
1954
1966
1978
4011
4018
4024
4045
4060
4074
4089
4102
4117
4130
4138
4142
4153
4159
5285
5293
5308
5325
5336
5349
5362
5378
5393
5408
5422
5436
5449
5461
5472
5499

2) Mark Products L28 vertical geophone strings

Geophones/string	6
Corner frequency	4.5 Hz
Coil	120 ohms
Sensitivity	20.4 V/m/sec
Damping	0.7

See file l28_vel for poles and zeros.

For the Crustal Shot and Vibroseis phases of the experiment, the following list of receiver stations had Mark Procuts L28 vertical geophone strings. In each case, the digitizer was a REF TEK 130.

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3) Oyo Geospace GS11D single vertical geophones

Corner frequency	4.5 Hz
Coil	380 ohms
Sensitivity	32 V/m/sec
Damping	0.7

For the Crustal Shot and Vibroseis phases of the experiment, the rest of the receiver stations had Oyo Geospace GS11D single vertical geophones and REF TEK 125 digitizers.

Note: stations 6000-6002 represent a REF TEK 130 recording reference sweep, baseplate accelerometer and force balance respectively.

Sources

Shotpoints

Summary

Six shotpoints and three nearby mine blasts were used as sources for the crustal refraction data (Figure. 1). Of the six shotpoints, five were along the line, and one was positioned off-line to the south. Two active goldmines (Twin Creeks and Florida Canyon) provided a total of three mine blasts. Two of the mine blasts were provided by Twin Creeks (a Newmont Mine), and extended the length of the line to the east by ~70 km. Florida Canyon provided one mine blast to the south of the line, serving as a fan-shot.

Drilling was carried out by Bob Buckner of Western Water Development Inc. (Redmond Oregon), and supervised by Joe Colgan of Stanford University. Explosives were delivered by truck from Alpha Explosives of Lincoln, CA, and loaded and fired by Tom Burdette and Walter Mooney of the U.S. Geological Survey in Menlo Park, CA.

In general, drilling, loading, and shooting proceeded smoothly, with the exception of the lost hole (original SP6 near Gerlach) that required the last-minute location of an alternate drill site. Several potentially serious problems were encountered, however, that should be considered when planning future projects.

Based on Tom Burdette's experience with previous projects, we expected Alpha Explosives to deliver the product (explosive gel) in a small (8,000 lb capacity) truck with a 200 ft hose reeled off the back of the vehicle. Instead, on the day the product was delivered, we discovered that they had sent a much larger truck (12,000 lbs) with a trailer carrying an additional 8000 lbs of product and a 100ft hose reeled off the side of cab.

We had planned on backing the truck into the borehole sites to load them, now had to drive a much larger vehicle up next to each hole – fortunately we were able to do this everywhere (although SP2 was difficult), but if we would have been in serious trouble had actually drilled a hole that required backing the truck in.

The 100 ft hose proved to be a more serious problem, since our boreholes were up to 190 ft deep and the product cannot free-fall more than ~15 ft without potentially crushing the oxidizer. Alpha provided an extra 100 ft length of hose and a clamp to splice the two together, but this fix proved unstable and the hoses came apart during loading on several occasions, spilling product and (at SP3) nearly allowing the 100 ft extension to go down the hole – it was pulled out with some difficulty after we tied it to the back of a truck. At this point the hose was damaged and the last hole (SP6) was loaded by allowing the product to free-fall to the bottom, although it did not appear to affect the subsequent detonation.

In the future, care should be taken to determine the size and setup of the explosives delivery vehicle prior to final site selection and drilling.

Shot Point 1 (SP1) – Bloody Run

Location: Lat: 41.39275N, Long: 117.83045W (center of 4-hole cluster)
T41N, R37E, Sec. 33; NW 1/4 of NW 1/4

Description: Located in flat, grassy field about 100m south of NDOT gravel excavation on Sand Pass Rd., south of State Route 140. Drill site flagged with J.P. Marden (NDOT) on 8/30/2004.

Drilling: Drilling began at 9 AM on Wednesday, 9/1/2004. The first hole was drilled quickly through alluvium (silty sand and gravel) until water was encountered at about 110 ft and it was necessary to case the hole with 8" steel pipe to hold it open. By the end of the day the crew had drilled a cased hole 116 ft. deep. Rather than continue to drill slow and expensive cased holes to 160 feet as originally specified, the next day (9/2), three additional holes were around the original hole (forming a square 50 ft on a side) to depths of about 105 ft each, with short lengths of casing (8-10 ft) in each. Heavy steel lids were padlocked on all holes before the drill rig left the site.

Loading: The holes were loaded with explosive product on 9/11/2004. Product is the name given to the oxidizing (explosive) agent in its raw state, since it is not explosive until confined in a hole with the proper boosters. The product is pumped from a truck down the holes as a thick gel or slurry (see Fig. 2). Each hole was loaded with about 1100 lbs of product, with 4 explosive boosters strung on detonation cord down the hole (see Table 1). After loading, the holes were backfilled to the surface with the local drill cuttings.

Shooting: SP1 was fired at 08:05:00 GMT (01:05:00 AM PDT) on 9/15/2004 (see Table 2). All 4 holes detonated simultaneously, and the explosion was strong and sharp, indicating complete combustion of the product and good energy transferred to the ground. The shot caused no damage at the surface (e.g., cracking, slumping, cratering, etc).

Cleanup: Because the detonations caused no surface damage, remediation consisted of cutting off the steel casing with a torch and filling in, raking, and smoothing the ground around the borehole. The stemming in hole SP1-A settled a few feet down the hole, and this hole was filled back to the surface with local materials prior to raking and smoothing. Cleanup was finished on 9/15/2004.

Figure 1. Drill rig on-site at SP1

Figure 2. Tom Burdette lowering boosters strung on detonation cord down the hole at SP1, explosives delivery truck in the background.

Shot point 2 (SP2) – Windy Point

Location: Lat: 41.4816N, Long: 118.60158W (location of borehole SP2-A)
T42N, R30E, Sec. 27; NE 1/4 of SE 1/4

Description: Located in small borrow pit on BLM land, north of Windy Point on the east flank of the southern Pine Forest Range, near the intersection of Leonard Creek Rd. and Woodward Back Rd.

Drilling: Drilling at SP2 began in the gravel pit on the afternoon of 9/2/2004, and the hole was 70 ft. deep by the end of the day, drilled through about 40 ft of alluvium into thinly bedded basaltic lava flows. When drilling restarted on the morning of 9/3, water was encountered at about 80 feet. Drilling continued until the hole was 110 ft deep and could not be held open any deeper (it would have been difficult to run casing through the hard rock below 40 ft). Because the first hole could not reach the target depth of 180 ft, an additional 70 ft hole was drilled about 40 ft east of the first one; this hole was damp at the bottom but drilling stopped short of the water table. The tops of both holes were cased (15-20 ft; Table 1) to hold them open and allow lids to be locked on.

Loading: SP2 was loaded on the afternoon of 9/11/2004, with a total of 2400 lbs of product (Table 1). No problems were encountered during loading, although one of the pickups got a flat tire at the shot site. Both holes were backfilled to the surface with local drill cuttings.

Shooting: SP2 was fired at 10:35:00 GMT (03:35:00 PDT) on 9/16/2004. Both holes detonated simultaneously, and the resulting explosion was sharp but did not produce a strong impulse to the ground, indicating complete combustion of the product but poor coupling with the surface. We are unsure exactly why the ground coupling was poor with this shot, but the unconsolidated alluvium near the surface may have absorbed much of the upward energy from the blast.

Cleanup: SP2 was cleaned up the day after detonation, 9/17/2004. Cleanup consisted of cutting the surface casing with a torch and filling in and smoothing out the borehole sites with local cuttings, then raking/smoothing out the ground around the holes.

Shot Point 3 (SP3) – Sheldon Wildlife Refuge

Location: Lat: 41.59196N, Long: 119.21556W
T42N, R24E, Sec. 1; NE 1/4 of NW 1/4

Description: Located just south of the Sheldon NWR boundary, access via a small dirt track that turns south off County Rd. 213, through a cattle guard and bends uphill a few hundred meters to the east.

Drilling: Drilling SP3 began about noon on 9/4/2004, and proceeded quickly and smoothly, reaching a depth of 189 ft by 2:30. The hole was dry at the bottom and penetrated rhyolite lava flows all the way down. About 5 ft of casing was run into the top of the hole to hold the padlocked steel lid.

Loading: SP3 was loaded on the morning of 9/13/2004 (0ff-site by 1:15), with 2500 lbs of product (Table 1). During loading, the two-piece hose broke apart at the splice (held together by a hose clamp) and was nearly lost down the hole. With some difficulty, the downhole section of hose was pulled out the hole with a pickup truck and the remaining product loaded with the short (100 ft) hose on the explosives truck. The hole was backfilled to the surface with a combination of local cuttings and gravel from a borrow pit a few miles to the west.

Shooting: SP3 was fired at 08:00:00 GMT (01:00:00 PDT) on 9/16/2004, producing a strong, sharp detonation. No flying rock or surface deformation accompanied the explosion.

Cleanup: SP3 was cleaned up the day after detonation, 9/16/2004. Cleanup consisted of cutting the surface casing with a torch and filling remaining ~2 ft of hole to the surface with local materials, then raking/smoothing out the ground around the hole.

Shot Point 4 (SP4) – Fortynine

Location: Lat: 41.56933N, Long: 119.98969W
T43N, R17E, Sec. 27; NW 1/4 of SW 1/4

Description: Drilled in gravel pit on N. side of Nevada 8A, about 1/4 mile past the end of paved CA 299 at the CA-NV border.

Drilling: SP4 was drilled on the morning of 9/9/2004. After drilling through ~40ft of alluvium the remaining 150 ft was drilled through hard basaltic lava flows to total depth of 190 ft. The hole was dry at the bottom and 8 ft of casing was run into the top so a lid could be locked on.

Loading: SP4 was loaded late on the evening of 9/12/2004, with 2400 lbs of product (Table 1). The hole had belled significantly at the bottom and three boosters (of 8) were stranded above the top of the product, but they did not cut the cord during detonation.

Shooting: SP4 was fired at 10:00:00 GMT (03:00:00 PDT) on 9/15/2004, producing a strong, sharp detonation. No flying rock or surface deformation accompanied the explosion.

Cleanup: SP4 was cleaned up on 9/19/2004; cleanup consisted of cutting surface casing with a torch and backfilling the remaining ~3 ft to the surface with local material.

Shot Point 5 (SP5) – Canby

Location: Lat: 41.50300N, Long: 120.97928W (center of 2 holes 50 ft apart)
42N, R9E, Sec. 6; SE 1/4 of SW 1/4

Description: Turn off Hwy 139 onto Forest Rd. 46, cross the train tracks and turn left (NW) onto small dirt track, boreholes are near small clump of trees about 150 yards from the road.

Drilling: SP5 was drilled on the morning and afternoon of 9/7/2004. The first hole (SP5-A) was drilled by 3 PM and the second was finished by 6:30 PM. Both holes encountered basaltic lava flows with interbeds of ash or lacustrine sediments to depths of 165 ft. Water was encountered at about 60 ft. 10 ft lengths of casing were run into the top of each hole to hold a locking lid.

Loading: SP5 was loaded on the afternoon of 9/12/2004, with 2100 lbs of product in each hole (Table 1). The hose broke during the loading of SP5-B, but was reconnected and loading finished successfully. Because the product was loaded into wet holes, it was allowed to settle overnight prior to backfilling. The holes were backfilled the next day with local cuttings and gravel purchased from a contractor in Alturas.

Shooting: SP5 was fired at 08:00:00 GMT (01:00:00 PDT) on 9/15/2004, producing a strong, sharp detonation. No flying rock or surface deformation accompanied the explosion. A significant amount of tractor-trailer truck traffic on Hwy 139 was ongoing before and during the shot and probably contributed noise to the data.

Shot Point 6 (SP6) – Duck Flat

Location: Lat: 40.97813N, Long: 119.69475W (center of 2 holes 50 ft apart)
42N, R9E, Sec. 6; SE 1/4 of SW 1/4

Description: Located in a gravel pit on the W side of the road at the top of the rise on the gravel track leading N off Hwy 447.

Drilling: SP6 was drilled in the afternoon of 9/9/2004, through well-lithified (volcanic?) sediments to a depth of 190 ft. The hole was dry and 10 ft of casing were run into the top so the hole could be locked shut.

Loading: SP6 was loaded on the evening of 9/13/2004, with 2400 lbs of product (Table 1). Because the hose extension had been broken at SP3 and was no longer useable, the product was allowed to free-fall from the end of the truck-mounted hose (100 ft long) to the bottom of the hole (about 100 ft). Although not recommended, this did not seem to affect the detonation of the explosive.

Shooting: SP6 was fired at 08:05:00 GMT (01:05:00 PDT) on 9/17/2004, producing a strong, sharp detonation. No flying rock or surface deformation accompanied the explosion.

Cleanup: SP6 was cleaned up on 9/19/2004; cleanup consisted of cutting surface casing with a torch and backfilling the remaining ~3 ft to the surface with local material.

<u>Unused borehole near Gerlach (original SP6)</u>

Location: Lat: 41.97813N, Long: 118.69475W
T41N, R37E, Sec. 33; NW 1/4 of NW 1/4

Description: Located south and west of Gerlach, NV and west of Empire, NV. Access is via graded-dirt power line access road that turns south off the highway just west of Gerlach.

Drilling: Drilling at Gerlach began at noon on 9/8/2004. Drilling proceeded quickly through mud with intervals of fine silt until water was encountered at ~45 ft. After an attempt to drill deeper (drilling reached 115 ft), the hole was abandoned since it could not be held open below the water table without expensive steel casing. Four feet of casing was put in the top of the hole to lock the lid on, and it was closed and left while we drilled an alternate hole in the Surprise BLM district.

Cleanup: The unused hole and drill site was cleaned up on 9/18/2004. The hole had collapsed in on itself up to a depth of 40 ft after drilling stopped, probably because it was uncased. A small amount of water remained at the bottom of the hole. The remained 40 ft was backfilled to the surface with the local drill cuttings (primarily clay, with some fine sand). The site was revisited on 9/22 and the rest of the drill site was raked and smoothed out to remove and remaining tire tracks (see Fig. 3, below).

Figure 3. Gerlach hole as it appeared after the hole was plugged and the site cleaned up.

Site Name	Shot Hole Number	Date Drilled 1	Date Loaded	Depth drilled (ft)	Depth loaded2 (ft)	8" Casing (ft)	Water Level (ft)	Product (lbs)	Tamp (ft)	Boosters
Bloody Run	SP1-a	9/2/2004	9/11/2004	116	110	115	110	1100	51	4
Bloody Run	SP1-b	9/2/2004	9/11/2004	101	99	8	dry	1100	67	4
Bloody Run	SP1-c	9/2/2004	9/11/2004	106	106	10	dry	1100	73	4
Bloody Run	SP1-d	9/2/2004	9/11/2004	105	102	10	dry	1100	72	4
Windy Point	SP2-a	9/3/2004	9/11/2004	110	110	15	90	1400	60	4
Windy Point	SP2-b	9/3/2004	9/11/2004	70	70	20	70	1000	60	3
Sheldon	SP3	9/4/2004	9/13/2004	189	189	5	dry	2500	108	6
Fortynine	SP4	9/9/2004	9/12/2004	188	188	8	dry	2400	142	8
Canby	SP5-a	9/7/2004	9/12/2004	164	162	10	71	2100	68	8
Canby	SP5-b	9/7/2004	9/12/2004	162	156	10		2100	78	8
Duck Flat	SP6	9/9/2004	9/13/2004	190	188	10	dry	2400	96	6

Table 4. Drilling and loading information for the shotpoints described above.

Shooter	Site Name	Shot Number	Shot Date	Julian Day	Shot Time (GMT)	Timer (Clock/Blaster)	Est. Acc. (ms)	Shot Size (lbs)	Quality

Burdette	Bloody Run	SP1	9/15/2004	260	8:05:00	USGS 11/5	5	4400	excellent
Burdette	Windy Point	SP2	9/15/2004	260	10:35:00	USGS 11/5	5	2400	weak
Mooney	Sheldon	SP3	9/16/2004	261	8:00:00	USGS 3/4	5	2500	excellent
Mooney	Fortynine	SP4	9/15/2004	260	10:00:00	USGS 3/4	5	2400	excellent
Mooney	Canby	SP5	9/15/2004	260	8:00:00	USGS 3/4	5	4200	excellent
Burdette	Duck Flat	SP6	9/16/2004	261	8:05:00	USGS 11/5	5	2400	excellent

Table 5. Shooting information for shotpoints described above.

Mine Blasts

Twin Creeks Mine

Twin Creeks is an active gold mine northeast of Winnemucca, NV, and is currently operated by Newmont Mining Corporation. Two mine blasts were performed while our instruments were in the field. These blasts were recorded on September 15th and September 16th, 2004 (local date), and correspond to gathers 9010 and 9011, respectively.

Name	Date (local)	Time (local, approximate)	Shot Size (lbs)	# Boreholes	Borehole Depth (ft)
Twin Creeks 1 (9010)	9/15/2004	3:20 p.m.	154,000	169	40
Twin Creeks 2 (9011)	9/16/2004	3:20 p.m.	57,750	88	40

Florida Canyon Mine

Florida Canyon is an active gold mine southwest of Winnemucca, NV, and is currently operated by Apollo Gold Corporation. One mine blast was recorded on September 16th, 2004 (local date), and corresponds to gather 9012.

Name	Date (local)	Time (local, approximate)	Shot Size (lbs)	# Boreholes	Borehole Depth (ft)
Florida Canyon (9012)	9/16/2004	12:30 p.m.	34,742	30	23

Vibrator

In addition to chemical detonations, we used the T-Rex vibrator, owned and operated by the Network for Earthquake Engineering Simulation (NEES) at the University of Texas, Austin. The vibrator, in its first year of use, has the ability to generate ground motion along three perpendicular axes. The T-Rex is a buggy-mounted vibrator with a total weight of ~60,000 lbs and a peak force output of 60,000 lbs in P-mode and 30,000 lbs in S-mode. All vibroseis sweeps were 60 sec long. For sweep type at particular locations, see attached Excel Workbook (VibLogCrustalTag.xls).

In general, work went smoothly with the vibrator, although some down-time occurred due to mechanical problems. The vibrator operators, Cecil Hoffpauir and Farn-Yuh Menq, did an excellent job overcoming technical problems in the field and kept the production rate on schedule. The most serious problem encountered during our use of the T-Rex vibrator resulted from the inability of one of the mass bearings to maintain sufficient air pressure. This stopped all S-mode vibration for the remainder of the experiment, but did not affect the P-mode work. Other technical/logistical problems included the lack of absolute location/timing of the vibrator, and lack of a fuel truck. The first problem was addressed through a convoluted system of GPS timing and location receivers that were recorded by Stanford-supplied laptops in the cab of the vibrator. The second problem was solved by the delivery of approximately 16, 5-gallon, cans of diesel fuel every day by Stanford-supplied personnel. Despite these inconveniences, work went well and we had a productive experience with the vibrator.

Vehicle specifications of the T-Rex vibrator are summarized below:

CATEGORY	ENGLISH	METRIC
Total Weight	64,000 Pounds	29.030 kgf.
Front Axle Weight	31,500 Pounds	14.288 kgf.
Rear Axle Weight	32,500 Pounds	14.742 kgf.
System Pressure	4,000 PSI	276 bar
Transmission	Hydrostatic 8 Speeds	Hydrostatic 8 Speeds
Cab	2 or 3 Man Vista Cab	2 or 3 Man Vista Cab
Turning Radius	28.4 Feet	8,66 meters
Engine-Detroit Diesel Series 60	430 HP @ 2100 RPM	321 kW @ 2100 RPM
Standard Tire	67x34-25 14 ply	67x34-25 14 ply

TRI-AX SPECIFICATIONS

CATEGORY	ENGLISH	METRIC
Holddown Weight	62,000 Pounds	28.123 kgf.
Baseplate Area	6,362 Inches2	41.045 cm2
Lift System Stroke	36 Inches	91,4 cm.
Lift Synchronization	Split Crossbeam	Split Crossbeam
Vibrator Pump Flow	140 GPM @ 2100 RPM	530 l/m @ 2100 RPM
Servovalve	200 GPM	756 l/m
Servovalve Pilot Filter	3 Micron	3 Micron
P-WAVE MODE		
Max. Theoretical Peak Force	60,000 Pounds	266.893 N.
Mass Piston Area	20 Inches2	129 cm2
Reaction Mass Weight	8,000 Pounds	3.630 kgf.
Reaction Mass Stroke	Plus or Minus 1.75 Inches	Plus or Minus 4,45 cm.
S-WAVE MODE		
Max. Theoretical Peak Force	29,900 Pounds	133.002 N.
Mass Piston Area	9.97 Inches2	64,3 cm2
Reaction Mass Weight	4,850 Pounds	2.200 kgf.
Reaction Mass Stroke	Plus or Minus 3.5 Inches	Plus or Minus 9,9 cm.

Passive

In addition to the active-source portion of the experiment, we recorded earthquakes with short-period, 3-component sensors and RT130 digitizers (see above). Passive recording began in late September, 2004, and continued to late March, 2005. At the time of composition of this report, instruments are still deployed in the field, so the total number of useful events is uncertain.

Acknowledgements

Volunteer Personnel

The success of a multi-component geophysical field experiment is dependent on the competency of the many volunteers necessary to complete all of the logistical hurdles in a timely fashion. We were fortunate to have a large, high-quality, group of volunteers who worked tirelessly while in the field. Listed below are the volunteer personnel and their affiliations, and we sincerely thank those involved for all of their help.

LAST	FIRST	AFFILIATION
Klemperer	Simon	Stanford
Colgan	Joe	Stanford
Lerch	Derek	Stanford
Wilson	Charlie	Stanford
Gashawbeza	Ewenet	Stanford
Fosdick	Julie	Stanford
Mattinson	Chris	Stanford
Grijalva	Kelly	Stanford
Abeles	Adam	Stanford
Akintunde	Martins	Stanford
Haines	Seth	Stanford
McWilliams	Mike	Stanford
Miller	Elizabeth	Stanford
Markman	Nic	Stanford
James	Julia	Stanford
Leindecker	Nick	Stanford
Egger	Anne	Stanford
Romans	Brian	Stanford
Manganelli	Simone	Stanford
Weislogel	Amy	Stanford
Nyst	Marleen	Stanford
Dumitru	Trevor	Stanford
Fung	Nathan	Stanford
Thompson	George	Stanford
Hesse	Marc	Stanford
Scholl	Dave	Stanford
Krylov	Kirill	Stanford
Burdette	Tom	USGS
Mooney	Walter	USGS
Hoffman	Nick	USGS
Fulmer	Tyson	USGS
Coble	Matthew	USGS
Liu	Mingjun	USGS
Hirsch	Aaron	UNLV
Darlene	McEwan	UNLV
Rittase	Willy	UNLV

PASSCAL Personnel

PASSCAL provided four, exceptionally competent personnel to manage all of the recording aspects of the experiment. Steve Azevedo, Bob Greschke, Mario Torres, and Lloyd Carothers performed their jobs perfectly: solving problems quickly, and helping to make logistical decisions in the field. They were often the last to leave the instrument center at night, and the first to arrive in the morning.

Permitting Contacts

Permitting was a very time-intensive aspect of the experiment, and we were largely successful in securing permits due to the helpful personnel at various agencies. Listed below are the primary contacts we worked with, many of whom were understanding of needed changes as the experiment evolved.

Agency	**Contact**
BLM – Surprise Valley Field Office	Ken Collum
U.S. Forest Service – Modoc National Forest	Jayne Biggerstaff
CalTrans (District 2)	Stacy Barnes/Becky Houston
BLM – Winnemucca Field Office	Delores Cates/Lynn Trost
Nevada Dept. of Transportation	Dave Lindeman
Humboldt County Roads	John Russom
Washoe County Roads	Rod Savini
Sheldon National Wildlife Refuge	Mike Nunn
Modoc County Roads	John Wistos/Tom Minto

Appendices

Appendix A – BLM Permit Application

STANFORD UNIVERSITY SEISMIC LINE

Northwestern Nevada, Summer 2004

Principal Investigators:

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PROJECT DESCRIPTION

PURPOSE

Stanford University has been funded by the National Science Foundation (NSF; an independent agency of the U.S. government) and the American Chemical Society (ACS; a private foundation) to conduct a seismic refraction/wide-angle reflection experiment in northwestern Nevada. Regional geologic studies have recognized that this part of the Basin and Range province is very little extended compared to regions to the south and east. Despite its low amount of extension, however, the limited geophysical data for this region suggest that the crust is as thin or thinner than that of the more highly stretched region to the south and east.

We suggest the middle and lower crust were attenuated by some 15km (>30%) by ductile flow either prior to or during the 6-8 Ma extension that uplifted the modern mountains. This theory makes northwestern Nevada the ideal region to document the differential behavior of the upper and lower crust during extension and to help quantify the scale and amount of lower crustal flow.

In order to address these problems, our seismic experiment will answer the following questions: 1) How thick is the crust beneath the study area, and 2) Does the middle and lower crust display the subhorizontal reflectivity that is characteristic of extended terranes? Our experiment will help evaluate mechanical models for crustal flow at depth beneath extending regions, and will be key in understanding basic relationships between topography and crustal structure. Our experiment will provide much needed information on the crustal structure and history of the northern boundary of the Basin and Range and insight into the relationship of faulting and extension to magmatism associated with the Snake River Plain-Yellowstone hotspot trend. Because these scientific problems are only exemplified in northernmost Nevada, we can only conduct our seismic experiment in this area. We cannot move our experiment north into Oregon, or south into central Nevada.

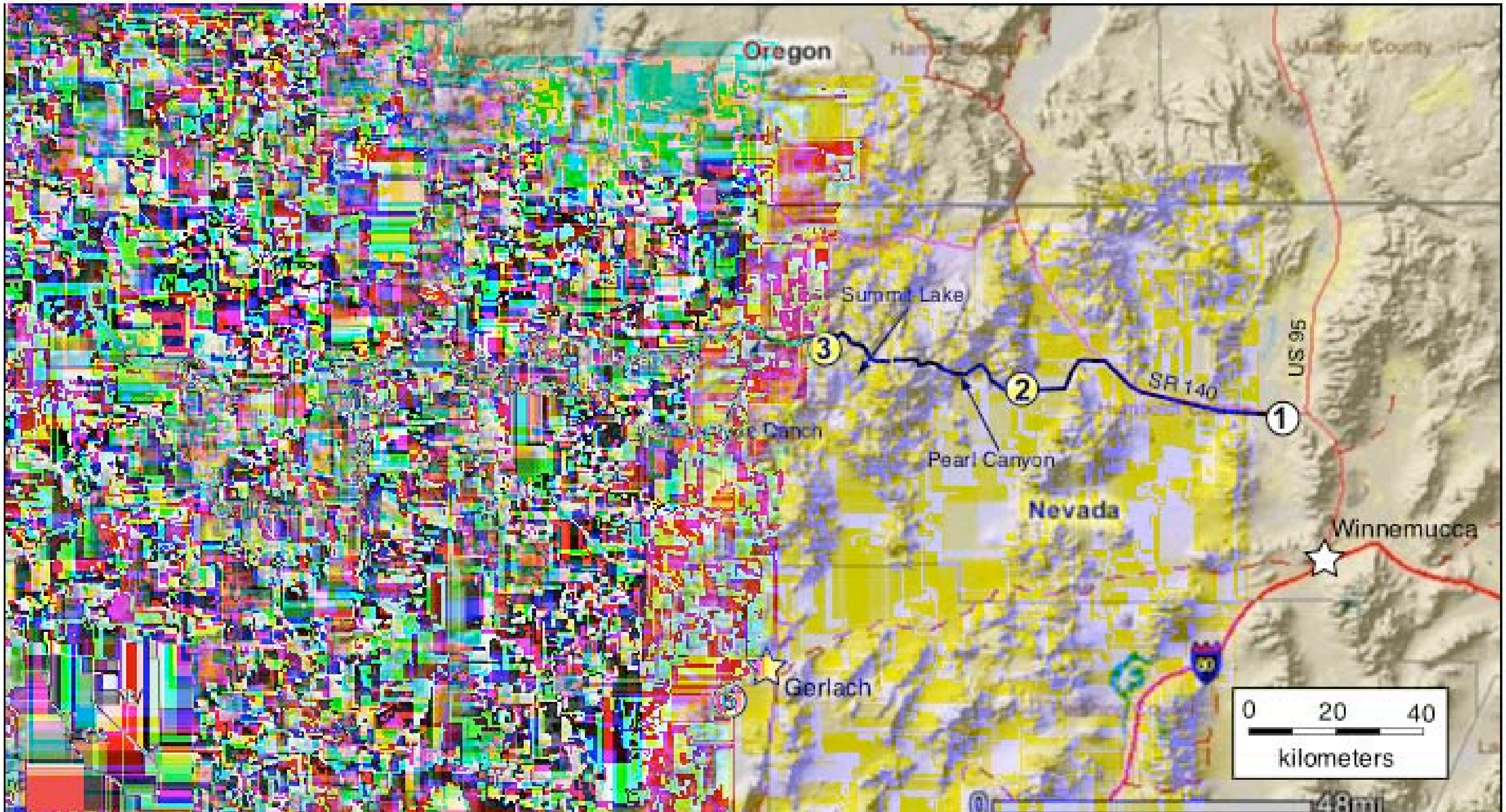
SURVEY DESCRIPTION

Data for this survey will be collected by recording the artificial seismic waves generated by contained chemical detonations loaded in 100-200 ft. deep boreholes using sensitive, portable seismographs. This artificial seismic energy travels through the rock strata below the line of seismographs, penetrating many miles below the surface before being reflected or refracted back to the line of 1400 seismographs deployed on the surface. These recorded data will be analyzed to create cross-sectional maps of the earth's crust across the experimental target area to answer the questions posed above. Results will be published in scientific journals and presented at national conferences, and will be used by us and other scientists studying how the earth's crust deforms during continental extension in Nevada and eastern California. Results will be provided to all landowners and managers, including BLM and USFS, for public dissemination and education. Newspaper reports of our experiment will help educate the general public.

LOCATION DESCRIPTION

The location of the seismic-recording line in Modoc County, CA, and Washoe and Humboldt Counties, NV, is shown on the attached regional map (Figure 1). For its entire length, the line follows established paved or graded dirt roads located almost entirely within federally owned lands. Starting at the eastern end, it begins just west of the State Highway 140/US Highway 95 junction approximately 12 miles south of Orovada, NV. It continues west along State Highway 140 through BLM land until the Leonard Creek Road turnoff, 2 miles south of Quinn River Crossing. At Leonard Creek Road (County Road 214), the line turns southwest around the northern end of the Jackson Mountains and then west across the northernmost part of the Black Rock Desert. At Pearl Canyon, the line turns north-northwest up Pearl Camp Road (County Road 215) for 4 miles before turning south (BLM Road 2052) along the eastern side of Bartlett Peak toward Bartlett Creek. Two miles down this road, the seismic-recording line bends north-northwest around the southern edge of Bartlett Peak and remains north of Bartlett Creek. The seismic-recording line continues across the Lahontan Cutthroat Trout Natural Area (BLM) and into the Summit Lake Indian Reservation. At the western edge of the Summit Lake Indian Reservation, the line turns northwest on County Road 213 and leaves the Summit Lake Indian Reservation land. The seismic-recording line enters Sheldon National Wildlife Refuge land (Fish and Wildlife Service) 5-6 miles after leaving the Summit Lake Indian Reservation. Approximately 12 miles after joining

County Road 213, the seismic-recording line turns west toward Bateman Spring Camp. Three miles after this turn, the line leaves the Sheldon National Wildlife Refuge and re-enters BLM land. From here, the seismic-recording line continues west and follows BLM Road 37031 toward Wall Canyon Ranch. Just past Wall Canyon Ranch, the



... 1-5 lie along the axis of the line, shot 6 is an off-axis fan shot. Boreholes 1, 2, ... ations not to exceed 4000 lbs. Borehole 3 will be 140 feet deep and will ...

line bends northwest across approximately 3 miles of Sheldon National Wildlife Refuge land before re-entering BLM land as it approaches County Road 8A. The seismic line turns southwest onto County Road 8A and continues along County Road 8A until the California-Nevada border, where the road becomes California State Highway 299. From the California-Nevada border, the line will follow California State Highway 299 west until the junction with California State Highway 139, where it turns northwest. The line continues along California State Highway 139 for ~5 miles, before turning north on Forest Service Road 46. The experiment will end approximately 0.7 miles (1.1 km) north of California State Highway 139 on Forest Service Road 46.

DRILLING AND DETONATION INFORMATION

Six 'shot' locations (shotpoints) are required for this survey. Five will be on BLM controlled public lands (see Figure 1 and attached shotpoint descriptions 1,2,3,4, and 6), and one shotpoint (number 5) will be on Forest Service-controlled land. Two of the shot locations (5 and 6) are at points previously permitted by BLM and the Forest Service for similar detonations in 1982 and 1988. Both were permitted under BLM Form 3040-1 for seismograph operations. Shotpoint 2 is sited in an old gravel pit. On the outer ends of the ~255 km line (Shot Point 1, Shot Point 2, Shot Point 4, and Shot Point 5), a maximum of 4000lbs (1814kg) of explosive will be detonated in boreholes approximately 160ft. deep. In the center of the line, one smaller (not to exceed 2500lbs or 937kg) shot (Shot Point 3) will be fired in a borehole approximately 140ft. deep. An off-axis shot (Shot Point 6) will contain a maximum of 4000lbs (1814kg) of explosive. All detonations will be completed in 36 hours (one day and two nights).

Each borehole will be 10 inches in diameter and will be drilled by a standard air-rotary, commercial drill rig mounted on a twin, rear-axle diesel truck, weighing 25 to 30 tons. A second truck carrying water, drill stem, and other accessories will accompany the drilling rig. The drill rig will remain at each site for one to two days. A minimum of 50 ft. of standard steel well casing will be used in each borehole. The casing's sole purpose is to keep the hole open for explosives loading, and to provide a locked safety enclosure at the surface until the explosives are detonated.

Careful consideration is given to minimizing the impact of this work on the landscape. The drill rig will remain on existing graded dirt roads when traveling from site to site, and each drill location has been sited at a previously disturbed location, or directly adjacent to an existing road. The total pad area required for drilling is approximately 1800 sq. ft. (60ft. x 30ft.) The drill rig will only drill with water and ‘drilling foam’, which evaporate after use. No driller's mud or other potentially harmful chemical drilling agents will be used. Following drilling and shooting the location will be reclaimed, and the borehole will be refilled with local materials if necessary. The surface casing pipe will either be removed or cut off and capped two feet below the surface, and the drill pad area around the hole will be recontoured and leveled by hand.

After drilling, each hole is capped using a steel lid, which is interlocked into the casing with a 1 inch diameter steel rod. One or two days before detonation, the explosives emulsion is transported to each borehole and the lower portions of the holes are loaded with the emulsion using a specially designed explosive supplier's delivery pump truck. The boreholes are then backfilled (stemmed) with local materials created by the drilling operation. A minimum of 55 ft. of back stemming is used in each borehole to contain the energy of the shot, and to minimize blowout potential. After loading, the holes will be secured with the above described lid system and will remain locked until the night of actual shooting. In this condition, the boreholes are very safe. The shot holes are not primed (no detonator cap is attached) and only a small piece of primercord (it looks like nylon rope) is exposed under the locked lid should the lock and lid be removed. The blasting cap needed to initiate the explosion is not attached to the primercord until a few minutes before detonation.

On the nights of the detonations, the six shots will be detonated in succession by shooting crews of 3 people (one shooter and two assistants). Before the shots are primed, the shotpoint areas will be checked and cleared for safety and the shooting assistants will visually monitor the borehole using lights until the shot is fired. Visual and audio alarms will be used to signal the impending shot. Noise from the shot is a muffled thud sometimes accompanied by a sharp crack similar to a rifle shot that may be heard up to one mile away. The ground roll from the detonation may be felt up to a few hundred feet away. The shooting team will be positioned about 400 feet from the shotpoint when shooting. To fire the shots, we will use equipment and trained personnel from the U.S. Geological Survey.

At this time we are requesting permits for the six deep boreholes and detonations that are essential to this project. However, we have submitted a further proposal to the Geological Society of America to fund approximately 40 small detonations (not to exceed 2.5 kg) in shallow boreholes (not to exceed 20 feet) to be dug by a truck-mounted auger. These smaller detonations would be divided into two groups of 20, with each detonation in the respective groups spaced approximately 500 meters apart. One group of detonations would be placed along County Road 214, near Windy Point. The second group of detonations would be placed along County Road 215, near the junction with BLM Road 2052. We will provide further details of these tiny detonations and shallow boreholes when we have raised the funding for them. At that time we will request you include them with this permit.

SEISMOMETER INFORMATION

The seismographs are small, digital instruments that are self-contained and need no outside power source. These instruments will record the ground motion from the detonations. They will be deployed during the two days preceding the detonations, and retrieved during the two days following the detonations. The seismometer is buried in an 8-inch wide by 10-inch deep hole dug in the ground. The recorder is only the size of a lunch box and is powered by internal D-cell batteries. The actual ground motion produced by the detonations is negligible (millionths of an inch), and as such, the recording instrument must be very sensitive and background noise at its lowest. Because of this, detonations and recording are done at night, when ground motion from moving cars, pumps, wind, etc., are at a minimum.

Along the survey line from Borehole 1 to Borehole 5, the receivers will be spaced every 100 to 300 meters. In addition to the single-channel receivers, we will also deploy ~2km of high resolution (33m spacing) recording equipment around Borehole 2 and Borehole 3 (4km total). All instruments will be deployed adjacent to existing paved or graded dirt roads, or will be walked into a recording site from an existing road. No motorized cross-country travel will be necessary.

SAFETY PRECAUTIONS

Seismic experiments are routinely performed by scientists from Stanford University and the USGS. The field crew will consist of approximately 20 people, most of whom are familiar with all aspects of the operation. All drilling activity will be overseen by at least one project supervisor. During the shooting phase of the experiment, proper safety measurements will be followed at each of the shot points to ensure that no people or animals are endangered. The party-chief who will supervise crewmembers in loading and detonation has over 20 years of experience in handling explosives. All staff who will handle explosives hold required Federal licenses documenting their training.

PRELIMINARY SCHEDULE

The precise timing of the experiment will be determined by the availability of instruments, but will take place between August 15th and September 15th of 2004. The staging location for the experiment will be Winnemucca, NV and Alturas, CA. Project coordinators will be on-call 24 hours/day at these locations. In the month leading up to the detonations, the receiver locations will be surveyed with GPS and flagged, and the boreholes will be drilled and capped. In the week prior to deployment, the boreholes will be loaded. Ten teams of two people each will have two days to deploy the receivers using standard SUV's or equivalent. The detonations will be at night to reduce anthropogenic noise. The receivers will be retrieved following the detonations and returned to Winnemucca where data will be transferred to a central computer.

Affected Environment

TOPOGRAPHY

Not affected by proposed action.

CLIMATE

Not affected by proposed action.

AIR QUALITY

During the drilling phase, small amounts of fugitive dust will be intermittently released into the air. Dust plumes created by mechanical activity will cease upon termination of drilling. The sites will not be disturbed in terms of causing an increase in suspended particles derived from wind erosion. No long-term detrimental effects on the air quality are foreseen. No suspended particulate will be produced by the shooting phase of the operation.

GEOLOGY

Not affected by the proposed action. Also, no earthquakes will be triggered by the blasts. Our blasts are similar in size to construction or mine blasts and pose no greater hazard to triggering of earthquakes than those blasts. Our blast is equal to a magnitude 1.5 earthquake, too small to be widely felt or reported in the news media, and of a size that occurs on an almost daily basis in Nevada.

SOIL QUALITY

The sites are accessible by established roads, and thus only the topsoil off the edge of the road at the site will be susceptible to disruption during drilling activity. Although unlikely, the shot detonation may cause the ground to slump a maximum of 10 feet in diameter and 5 feet deep. Reclamation will be performed at all sites to restore the original soil character.

WATER

There are no springs at or near our sites. The water quality will not be affected by the detonation of chemical explosives. Specialists from Dupont and Ireco, manufacturers of blasting agents used in our experiments, state that the byproducts of detonation are carbon dioxide, nitrogen, and water. These products have been widely used throughout the world for over fifteen years and no instances of ground-water contamination have been reported.

VEGETATION

Drilling hole sites are placed so as to have no impact from vehicles on vegetation. Access to the sites is via already existing dirt roads. Seismometers will be carried off road manually, and digging of sensor holes will be by hand shovel. Detonation has no effect on vegetation.

BOREHOLE DESCRIPTIONS

BOREHOLE 1
Under Jurisdiction of BLM, Winnemucca Field Office

Township/Range	Lat/Long	UTM **(Zone 11T)**
T40N, R37E, Sec. 5	N 41° 22.843'	Northing: 4581375.0
NE 1/4 of NW 1/4	W 117° 50.404'	Easting: 429762.25

Borehole 1 is located on BLM land, approximately 100 meters off of Sand Pass Road, south of State Highway 140. It is 1.5-2 km from the paved State Highway 140, and at least 3 km from the nearest building. Borehole 1 is located in sagebrush-covered alluvium (Figures 1 and 2). To reach this location:

-take Sand Pass Road southwest from State Highway 140

-continue for ~3km, Shot Point 1 is approximately 100 meters to the north


Figure 2. View looking north from Borehole 1

Figure 3. View looking south from Borehole 1. Cars are parked on Sand Pass Road.

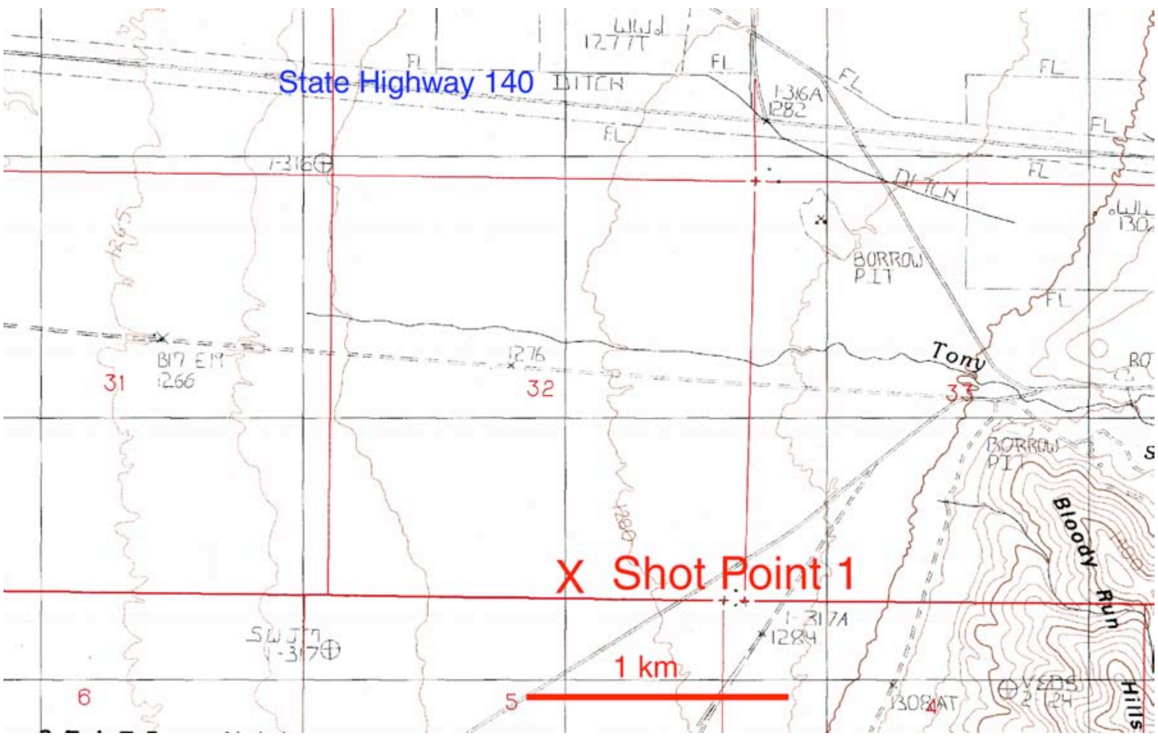


Figure 4. Detail map of detonation location, taken from Andorno Ranch Quadrangle, NV

BOREHOLE 2
Under Jurisdiction of BLM, Winnemucca Field Office

Township/Range	Lat/Long	UTM **(Zone 11T)**
T42N, R30E, Sec. 34	N 41º 28.344’	Northing: 4592465.5
SE 1/4 of NW 1/4	W 118º 36.730’	Easting: 365380.47

Borehole 2 is located on BLM land, just off of Leonard Creek Road near Windy Point. This shot is situated in a small gravel quarry (probably used for local roads). Borehole 2 is at least 4 km from the nearest building. To reach this location:

-drive west on Leonard Creek Rd from State Highway 140

-after approximately 15 miles (24km), the road bends south and then west around Windy Point

-as Leonard Creek Road turns west, take the small road to the north and continue uphill for approximately 300 meters

Figure 5. Borehole 2 location in local quarry

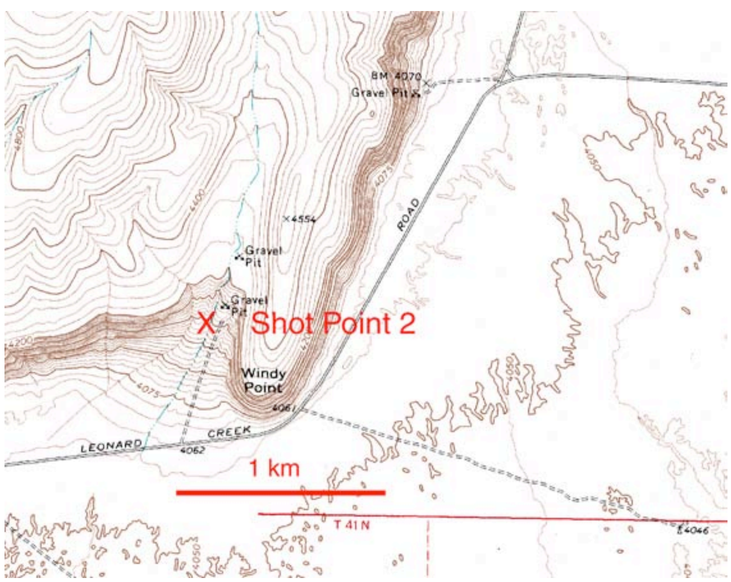


Figure 6. Detail map of Borehole 2 (Deer Creek Slough Quadrangle, NV)

BOREHOLE 3
Under Jurisdiction of BLM, Winnemucca Field Office

Township/Range	Lat/Long	UTM **(Zone 11T)**
T42N, R24E, Sec. 1	N 41º 35.663'	Northing: 4607099.5
NE 1/4 of NW 1/4	W 119º 13.222'	Easting: 314952.72

Borehole 3 is located on BLM land just south of the Sheldon National Wildlife Refuge, approximately 0.5km south of Humboldt County Road 213. The location is in sagebrush-covered alluvium and is at least 4 km to the nearest building. To get to this location:

-take Humboldt County Road 213 northwest from the Summit Lake Indian Reservation for approximately 14.5km

-then turn south on small (unmarked) road for another 0.5km

Figure 7. Borehole 3 location

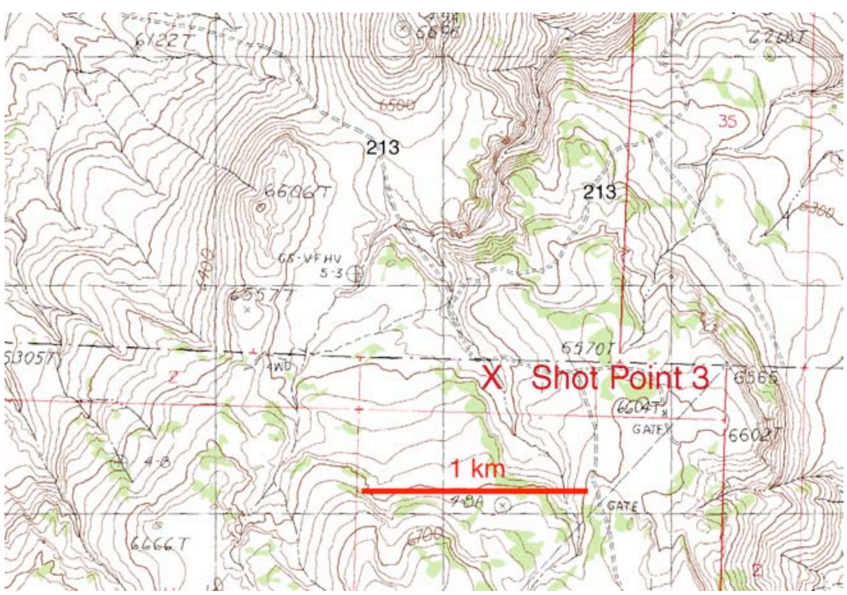


Figure 8. Detail map of Borehole 3 (Bear Buttes Quadrangle, NV)

BOREHOLE 4
Under Jurisdiction of BLM, Cedarville Field Office

Township/Range	Lat/Long	UTM **(Zone 10T)**
T43N, R17N, Sec. 27	N 41º 33.709'	Northing: 4605421.0
NW 1/4 of SW 1/4	W 120º 01.399'	Easting: 748217.1

Borehole 4 is located on BLM land, approximately 0.7 miles north of California State Highway 299, along Modoc County Road 18. Location is in sagebrush-covered alluvium and is at least 2 km to the nearest building. To reach this location:

-take California State Highway 299 east from Cedarville

-turn north on Modoc County Road 18, and continue for ~0.7 miles (1.1km)

Figure 9. View to the west from Borehole 4

Figure 10. View south along County Road 18

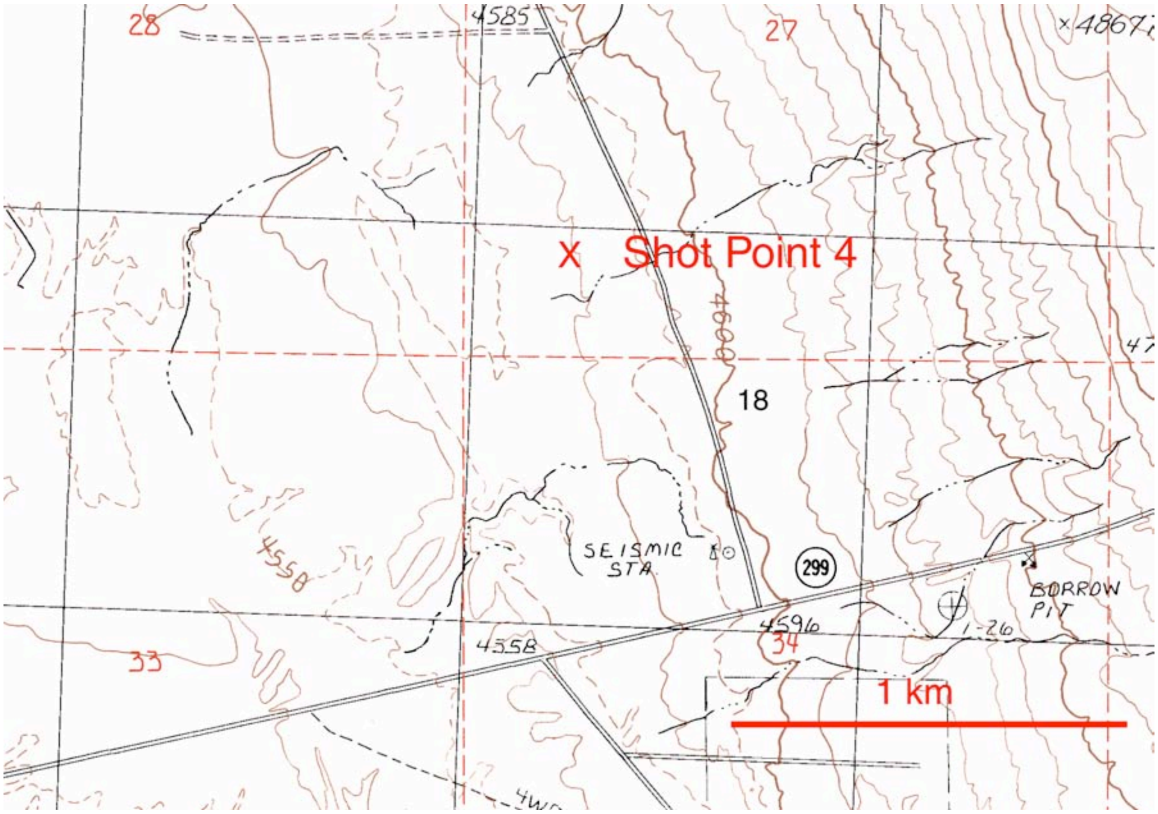


Figure 11. Detail map of Borehole 4 (Leonards Hot Springs Quadrangle, CA)

BOREHOLE 5
Under Jurisdiction of Modoc National Forest

Township/Range	Lat/Long	UTM **(Zone 10T)**
T42N, R9E, Sec. 6	N 41º 30.22’	Northing: 4596639.0
SE 1/4 of SW 1/4	W 120º 58.69’	Easting: 668751.9

Borehole 5 is located on Modoc National Forest land and has been previously used drill boreholes for large seismic detonations (Zucca et al., 1986; Fuis et al., 1987). This location is in sagebrush-covered alluvium. To get to this location:

-take California State Highway 299 west from Alturas
-turn northwest onto California State Highway 139
-turn north onto Forest Service Road 46 and continue for ~0.7 miles (1.1 km)

Figure 12. View from Borehole 5 looking south

Figure 13. View from Borehole 5 looking north

BOREHOLE 6
Under Jurisdiction of BLM, Winnemucca Field Office

Township/Range	Lat/Long	UTM **(Zone 11T)**
T31N, R22E, Sec. 11	N 40° 34.962'	Northing: 4495348.0
NE 1/4 of NE 1/4	W 119° 27.517'	Easting: 291918.8

BOREHOLE 6 is located on BLM land and has been previously used to drill boreholes for large seismic detonations (Catchings and Mooney, 1991; Holbrook et al., 1991; and Jarchow et al., 1993). The location is in sagebrush-covered alluvium. To reach this location:

- take Nevada State Highway 447 north through Gerlach
- turn southwest on BLM road 2075, and continue for ~7.2 miles (12 km)

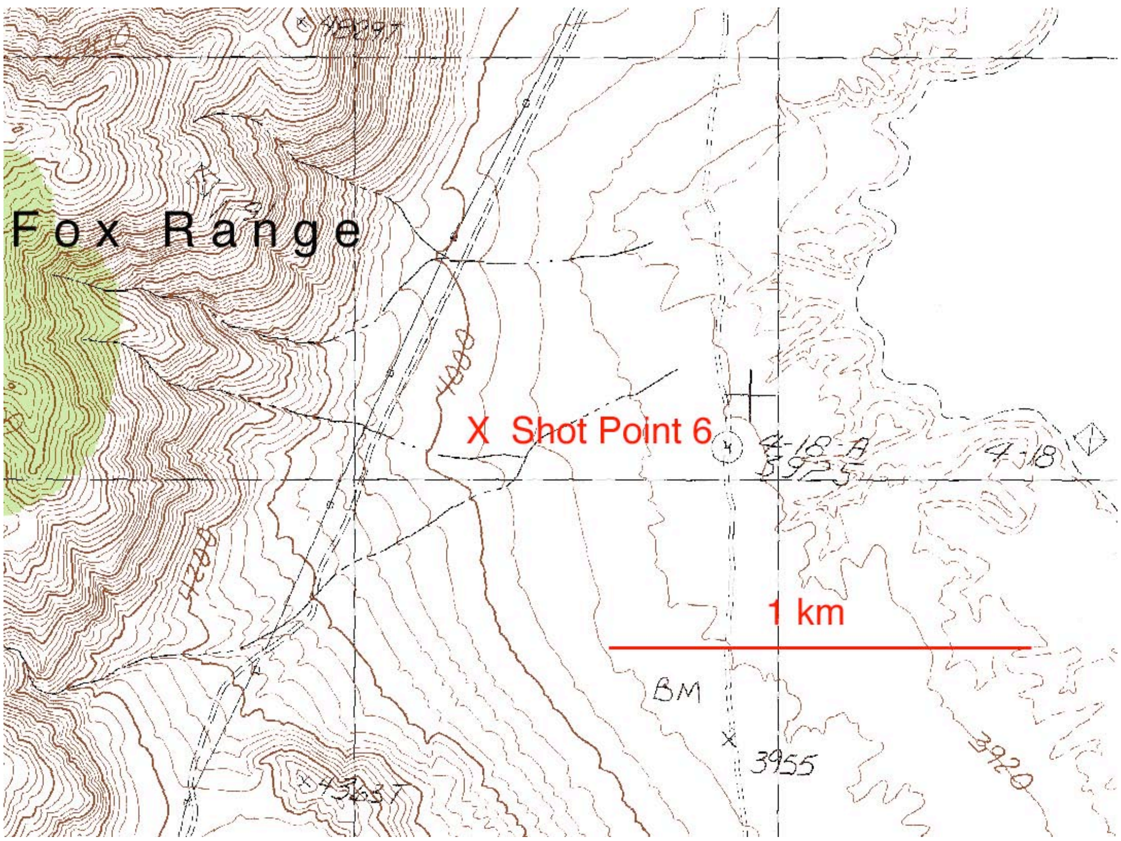


Figure 14. Detail Map of Borehole 6 (West of Empire Quadrangle, NV)