Boulder Creek Critical Zone Observatory Seismic Refraction data

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Purpose

We explore subsurface structure and the development of weathered profiles in three drainages within the Boulder Creek watershed in the Front Range of northern Colorado. The field areas span three erosional regimes experiencing recent and continuing geomorphic forcings: fluvial rejuvenation, long-term quiescent erosion, and glaciation. We employ the seismic refraction method towards quantifying the erosional signature of these forcings within the shallow subsurface of the three catchments: Betasso, Gordon Gulch, and the upper Green Lakes Valley.

Data are stored as an assembled dataset at the IRIS DMC. The table appended to this document gives information on seismic line orientation and start and end points. Full inclination files, needed to replicate the analysis, are provided as electronic files with the assembled dataset and are in the folder /InclinationFiles. Scans of all field notes are in the folder /FieldNotes.

Field methods

In the Boulder Creek Critical Zone Observatory shallow seismic refraction surveys, we used a 24-channel Geometrics Stratavisor seismograph with twenty-four 40 Hz vertical component geophones. A ~5 kg steel sledgehammer produced the seismic source of energy when striking a 10 x 10 x 7 cm 15 kg steel plate on the ground surface. Using a standard geophone spacing of 2 m (individual line information available in Appendix 1), the spread length covered 46 m, allowing generally a minimum 15 m depth of investigation (although this is dependent upon the subsurface geometry and velocity structure). Increased geophone spacing allows a greater depth of investigation at the cost of a lower resolution survey. Multiple gathers with different geometries (change geophone spacing) can overcome this shortcoming. Five shots

within the spread gave detailed shallow data while off-end shots 2 m and 5 m from the end geophones provide deeper information.

GPS points marked the end geophones of each 24-geophone spread. A carefully straightened tape measure ensured that the geophones were in-line. Topographic relief along the line was measured using an inclinometer and the bearing with a compass. Rock outcropping along the line and significant vegetation changes were noted. When additional spreads were used, the final geophone of the previous spread became the first geophone of the next spread, allowing continuity of results across spreads. Occasionally, multiple end geophones were retained as the beginning channels of the next survey.

At each shot and geophone location, up to 5 cm of organic surficial debris was removed to better couple the shot plate and geophones with the ground surface. Also, three hammer blows secured the plate and compacted additional organic matter or loose soil to improve the plate's coupling with the ground. When recording the seismic signal, ten shots were stacked, or summed, at each location to reduce uncorrelated noise and increase the amplitude of the seismic signal. Three to five blows at each shot location are standard (Schrott and Sass, 2008), but noise from wind and energy loss due to steep, irregular topography along the lines made ten blows necessary to ensure quality data.

Guide to Abbreviations and Data Organization

Data are stored as raw Geometrics files. The folder name includes the location, year, month, day, line number. For example, bet090603_1, refers to data collected at Betasso on June 3, 2009, and is line 1 of that day. Within the bet090603_1 folder, files 1.dat, 2.dat, etc. are the raw Geometrics data files, assumed to be in SEG-2 format, one .dat file for each shot. The .dat format files can be read in to the Geometrics PickWin module of SeisImager. Elevation .elev files for the lines are in the folder 2009Data\ElevFiles or \Fieldwork\Inclication Files*catchment*\.

Folders *_remi contain data collected for Refraction Microtremov (ReMi) surface wave analysis, and files with *_vs refer to S wave data collection, files with *lf refer to low frequency geophones (4.5 hz instead of 40 hz). *_remi data were collected on vertical component geophones. *_vs data were collected on horizontal component geophones.

'bet' refers to the Betasso watershed catchment, 'gg' refers to the Gordon Gulch watershed, 'glv' refers to the Green Lakes Valley watershed catchment. Please see the cited reference for location maps and analysis results from this data set.

Inclination files are organized by catchment. Within the catchment (Betasso, GG, and GLV) folders, the files include *.csv files, where the .elev files are made from the .csv files with Fieldwork\InclicationFiles\readinc2EDDITED.m (renamed to readinc.m in subfolders)

Description of files in Inclination Folders.

BetElev.txt – starting elevations for all Betasso lines, read in by BetassoInclinationMaker.m

Betassoseis.m – Matlab code for plotting original time series data…buggy

BetassoInclinationMaker.m –code to make .elev file for inversion for all Betasso lines, calls Readinc.m

Readinc.m - updated but renamed Matlab file to convert slope angles and distances to distance, elevation for inversion

Readinc2.m – second attempt Matlab file to convert slope angles and distances to distance, elevation for inversion, Readinc.m is updated version

BetLine1.csv – standard input for creating .elev file from slope angle and distances

BetLine1ELEV.elev – standard name for .elev file for reading into PlotRefa with distance, elevation

BetLine1PlotRefa1.elev – first attempt at making an .elev file

BetLine1Vs.csv – another standard input for creating .elev file from slope angle and distances

High quality photos of all field notes are available in the folder FieldNotes. Users are strongly urged to carefully consult the field notes for field and data acquisition details.

These data are provided as is with no guarantees.

References

Andrus, A., K. Befus, T. Kelsay, and A. F. Sheehan (2009), Shallow geophysical exploration of the Boulder Creek Critical Zone Observatory, Fall 2009 American Geophysical Union (AGU) National Meeting, abstract EP53D-0645.

Befus, K.M. (2010), Applied geophysical characterization of the shallow subsurface: Towards quantifying recent landscape evolution and current processes in the Boulder Creek watershed, Colorado, M.S. thesis, 93 pages, University of Colorado, Boulder.

Befus, K. M., A. F. Sheehan, M. Leopold, S. P. Anderson, and R. S. Anderson (2011), Seismic Constraints on Critical Zone Architecture, Boulder Creek Watershed, Front Range, Colorado, *Vadose Zone J.*, 10(3), 915-927, doi: 10.2136/vzj2010.0108.

Schrott, L., and O. Sass (2008), Application of field geophysics in geomorphology: Advances and limitations exemplified by case studies, *Geomorphology, 93*(1-2), 55-73.

Appendix 1 – Line information

SSR – Shallow seismic refraction

SSWR – Shallow surface wave refraction

REMI – Refraction microtremor

Line name convention:

"catchment abbreviation" YYMMDD _"line #"

Type	Line Name	Start GPS		End GPS		Orientation	# of Spreads	# Shots	Geophone Spacing (m)
		UTM E	UTM N	UTM E	UTM N				
		Zn 13 N				° from N			
Betasso (Lines 1-38)									
SSR	bet090603_1	470706	4429284	470705	4429239	358	1	26	2
SSR	bet090603_2	470905	4429250	470775	4429317	297	2	19	3
SSR	bet090604_3	470956	4429521	470988	4429394	349	3	35	2
SSR	bet090604_4	470949	4429425	470998	4429425	273	1	9	2
SSR	bet090604_5	470942	4429464	470997	4429473	267	1	9	2.5
SSR	bet090604_6	470972	4429361	470963	4429234	6	3	27	2
SSR	bet090605_7	470958	4429523	471153	4429449	290	5	45	2
SSR	bet090606_8	471059	4429432	471084	4429515	20	2	18	2
SSR	bet090606_9	471084	4429515	471106	4429695	8	4	36	2
SSR	bet090610_10	471007	4429652	471010	4429478	0	4	36	2
SSR	bet090611_11	470922	4429228	470880	4429199	50	1	9	2
SSR	bet090611_12	470884	4429144	470811	4429002	25	4	36	2
SSR	bet090611_13	470829	4429075	470850	4429042	326	1	9	2
SSR	bet090612_14	470888	4429245	470899	4429264	25	1	9	1
SSR	bet090612_15	470875	4429257	470880	4429285	19	1	9	1.5
SSR	bet090612_16	470867	4429255	470873	4429288	5	1	9	1.5
SSR	bet090612_17	470830	4429266	470860	4429386	16	3	28	1.5
SSR	bet090616_18	471014	4428929	471155	4429044	60	4	36	2
SSR	bet090616_19	471287	4429162	471187	4429021	38	4	36	2
SSR	bet090616_20	471305	4428840	471380	4428938	32	3	27	2
SSR	bet090617_21	471376	4428922	471312	4428941	300	1	9	2
SSR	bet090617_22	471351	4428840	471318	4428871	312	1	9	2
SSR	bet090618_23	471289	4428785	471176	4428708	237	3	27	2

SSR	bet090618_24	471204	4428689	471191	4428731	347	1	9	2
SSR	bet090618_25	471087	4428849	471182	4428891	243	2.5	27	2
SSR	bet090618_26	471232	4428781	471257	4428741	148	1	9	2
SSR	bet090619_27	471277	4428794	471295	4428764	328	1	9	2
SSR	bet090619_28	471043	4429003	471072	4428958	153	1	9	2
SSR	bet090619_29	471091	4429029	471127	4429006	140	1	9	2
SSR	bet090619_30	471196	4429077	471241	4429048	323	1	9	2
SSR	bet090619_31	471244	4429149	471275	4429111	313	1	9	2
SSR	bet090622_32	470704	4429239	470693	4429152	7	2	18	2
SSR	bet090625_33	471022	4429299	471085	4429257	320	2	18	2
SSR	bet090625_34	470946	4429298	471043	4429263	295	2	19	2
SSR	bet090625_35	470967	4429298	470961	4429228	6	2	18	2
SSR	bet090803_37	470933	4429278	471091	4429101	323	6	54	2
SSR	bet090807_38	471054	4429356	471060	4429176	nr	4	36	2
SSWR	bet090603_1sw	470705	4429239	470705	4429239	358	1	27	2
SSWR	bet090622_vs1	470708	4429283	470678	4429100	7	4	36	2
SSWR	bet090623_vs2	471085	4429257	471022	4429299	320	2	18	2
SSWR	bet090623_vs3	470978	4429365	470961	4429228	6	3	27	2
SSWR	bet090623_vs4	470946	4429298	471059	4429261	295	3	27	2
REMI	bet090622_remi1	470704	4429239	470693	4429152	7	2		2
REMI	bet090625_33remi2	471085	4429257	471022	4429299	320	2		2
REMI	bet090625_34remi3	470947	4429298	471043	4429263	295	2		2
REMI	bet090625_35remi4	470978	4429365	470967	4429298	6	2		2
							102.5	901	
Gordon Gulch (Lines 1-35)									
SSR	gg090626_1	460575	4429191	460592	4429415	0	5	45	2
SSR	gg090629_2	460565	4429372	460601	4429368	271	1	9	2
SSR	gg090629_3	460559	4429328	460619	4429340	95	1	9	2
SSR	gg090629_4	460557	4429257	460591	4429236	90	1	9	2
SSR	gg090630_5	460575	4429175	460571	4428998	180	4	36	2
SSR	gg090630_6	460555	4429057	460610	4429061	90	1	9	2
SSR	gg090630_7	460545	4429167	460593	4429168	272	1	9	2
SSR	gg090630_8	460556	4429194	460593	4429208	272	1	9	2
SSR	gg090701_9	458751	4430281	458756	4430192	2	2	18	2
SSR	gg090701_10	458734	4430233	458914	4430198	276	4	36	2

SSR	gg090706_11	459087	4430050	459098	4430419	3	8	72	2
SSR	gg090707_12	459132	4430230	458928	4430205	270	5	45	2
SSR	gg090707_13	458952	4430181	458950	4430220	0	1	9	2
SSR	gg090708_14	459060	4430194	459057	4430225	nr	1	9	2
SSR	gg090708_15	459077	4430386	459118	4430384	277	1	9	2
SSR	gg090709_16	459082	4430294	459115	4430281	nr	1	9	2
SSR	gg090709_17	459124	4430117	458931	4430165	287	4	36	2
SSR	gg090710_18	458945	4430170	458800	4430126	273	3	27	2
SSR	gg090710_19	458815	4430124	458840	4430212	3	2	18	2
SSR	gg090716_20	458749	4430274	458772	4430320	3	1	9	2
SSR	gg090716_21	458772	4430331	458772	4430389	3	1	9	2
SSR	gg090716_22	458791	4430344	458745	4430353	330	1	9	2
SSR	gg090716_23	458748	4430350	458731	4430432	340	1.5	18	2
SSR	gg090716_24	458760	4430201	458713	4430061	10	3	27	2
SSR	gg090716_25	458752	4430069	458714	4430074	nr	1	9	2
SSR	gg090722_26	458298	4430361	458499	4430255	116	5	45	2
SSR	gg090722_27	458396	4430288	458443	4430369	31	2	18	2
SSR	gg090723_28	458462	4430260	458501	4430381	20	3	27	2
SSR	gg090724_29	458330	4430321	458400	4430468	23	4	36	2
SSR	gg090727_30	459487	4430442	459304	4430113	30	9	81	2
SSR	gg090729_31	459331	4430110	459277	4430175	325	2	18	2
SSR	gg090804_32	459428	4430261	459255	4430258	78	4	36	2
SSR	gg090804_33	459435	4430299	459396	4430307	285	2	18	2
SSR	gg090810_34	459299	4430099	459167	4429962	50	5	44	2
SSR	gg090810_35	459251	4430049	459285	4430030	nr	1	9	2
						Total	92.5	836	
Green Lakes Valley (Lines 1-13)									
SSR	glv090721_1	446977	4433827	447148	4433897	251	4	36	2
SSR	glv090721_2	447148	4433897	447193	4433909	80	1	9	2
SSR	glv090728_3	447188	4434262	447166	4434418	355	4	36	2
SSR	glv090730_4	nr	nr	nr	nr	354	0.8	7	2
SSR	glv090805_5	447167	4434472	447142	4434561	343	2	18	2
SSR	glv090805_6	447109	4434498	447232	4434541	63	3	27	2
SSR	glv090805_7	447221	4434515	447205	4434555	337	1	9	2
SSR	glv090805_8	447158	4434376	447198	4434379	273	1	9	2
SSR	glv090806_9	447497	4434094	447650	4434279	45	6	54	2
SSR	glv090806_10	447028	4433800	446994	4433867	3	1	9	2
SSR	glv090806_11	447025	4433817	447028	4433864	355	1	9	2

SSR	glv090806_12	447057	4433845	447062	4433891		5	1	9	2
SSR	glv090806_13	447142	4433857	447157	4433903		11	1	9	2
						Total	26.8	241		