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CAJON PASS BOREHOLE SEISMIC RECORDING

Submitted By

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Cajon Pass Borehole Seismic Recording - Instrumentation

Data Submitted to IRIS April 1997

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This document describes the Cajon Pass borehole seismic recording, including the instrument responses, timing and other relevant information concerning the earthquake data recorded during this project. The results have been published in a number of papers which also include further information about the experiment and instruments used.

Description of Experiment

Deep seismic recording began at Cajon Pass in August 1991 when Peter Leary and Derek Manov (University of Southern California) installed a triaxial set of geophones at 2.5 km depth. These instruments continued to record until August 1993, and a surface instrument was also deployed during 1992. Phase II recording with instruments at the surface, 300 m, 1.5 and 2.9 km began in November 1993 and the instruments were withdrawn in August 1995. Only Phase II was performed using IRIS instruments and so only Phase II is archived here (Julian days 326 1993 to 286 1994). If you would like data from Phase I then please contact Rachel Abercrombie directly.

The Cajon Pass Scientific Drillhole (also known as the DOSECC hole) was drilled in the late 1980's to investigate the state of stress and heat flow along the San Andreas Fault. Volume 15 of Geophysical Research Letters (August 1988) and volume 97 of Journal of Geophysical Research (April 1992) contain selections of papers related to the borehole. The top of the hole is at 34.3144°N, 117.4772°W, 960 m above sea level.

Description of Data

The data are in the form of RefTek SEGY triggered event files, all 60 s long. The files have all been compressed using the UNIX compress command. No timing corrections have been implied to any of the data (see the Summary below for details of when a clock was running - all recording took place in UT). Triggering always took place on a borehole sensor and so false triggers only arise from electronic problems (e. g. water in the connectors) and not from external noise sources. All triggers have been kept. The data were sent to IRIS on a DAT tape (928 megabytes). The tape also includes (a) a tape list (tape.list), (b) an event catalogue (cajon.cat) in the format described below, and (c) README (which contains this text in ascii), README.RTF (which contains this text in RTF format) and README.DOC (which contains this text in Microsoft Word 6 for Windows) files.

Significant Earthquakes During Recording Period

17 January 1994, Northridge earthquake: The array was not recording during the mainshock but many aftershocks were recorded.

Bibliography of Work to Date from this Experiment

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Abercrombie, R. E. (1995a) Earthquake locations using single station deep borehole recordings: implications for microseismicity on the San Andreas fault in southern California, *J. Geophys. Res.*, **100**, 24003-24014.

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Abercrombie, R. E. (1996) The magnitude-frequency distribution of earthquakes recorded with deep seismometers at Cajon Pass, southern California, *Tectonophysics*, **261**, 1-7.

Manov, D. V., Abercrombie, R. E. and Leary, P. C. (1995) Reliable and economical high temperature deep borehole seismic recording, *Bull. Seism. Soc. Am.*, **86**, 204-211.

Abercrombie, R. E. (1997) Near surface attenuation and site effects from comparison of surface and deep borehole recordings, *Bull. Seism. Soc. Am.*, June, in press.

Adams, D. A. and R. E. Abercrombie (1997). Seismic attenuation at high frequencies in southern California from coda waves recorded at a range of depths, *J. Geophys. Res., in prep.*

CAJON PASS PHASE II - SUMMARY

Dates and times in California Local Time

1993 325 Nov 21	seismometers installed - 60 Hz from junction box (3 km = RefTek 028, 1.5 km = RefTek 027, Surface and 300 m = RefTek 029. On RefTek 029, Surface = channels 1,2,3 and 300 m = channels 4,5,6)
1993 328 Nov 28	Put to event trigger on 1.5 km and 300/0 m - No relative timing
1993 334 Nov 30	Reinstalled junction box. Timing good on all levels. Some waveform problems (e.g. 60 Hz and calibration type pulse) on some channels
1994 007 Jan 7	RefTeks removed for testing
1994 019 Jan 19	RefTeks installed again, 1.5 km now 028 (surface and 300 m on 029), no 3 km 2 RefTeks triggering together - good timing
1994 028 Jan 28	separate triggering on 2 RefTeks, clock only on 1.5 km
1994 031 Jan 31	RefTek 027 connected to 3 km, separate triggering, clock only on 1.5 km wrong trigger parameters on 3 and 1.5 km -> weird recording
1994 044 Feb 13	GPS stolen -> no clock ...
1994 054 Feb 23	Corrected triggering channel parameters on 3 and 1.5 km Still no clock
1994 059 Feb 28	Corrected triggering channel parameters on surface and 300 m, not a real problem Still no clock
1994 123 May 2	Found 3 km wet. Could not dry properly. Still no clock
1994 131 May 11	Dried out 3 km, connected new GPS to 1.5 km Good timing on 1.5 km, not on others.
1994 147 May 27	New RefTek junction box. All RefTeks connected, all RefTeks have GPS time
1994 182 Jul 1	RefTek 027 removed from 3 km, DC offset Channel 1 deteriorating to this date on 3 km
1994 211 Jul 30	3 km RefTek 027 reinstalled, channel 1 fixed BUT RefTek not working so no data recorded at 3 km Good timing on all levels still.
1994 216 Aug 4	L22-D 2 Hz installed on granite site near Cajon Pass hole
1994 222 Aug 10	Cables cut at 04.40 hrs GMT
1994 224 Aug 12	Discovered cables cut to 3 and 1.5 km All borehole RefTeks brought to lab. Granite site fine
1994 234 Aug 22	Got borehole array working again!! All 5 stations working well with timing from this date!
1994 264 Sep 20	RefTek 029 (surface + 300 m) ran out of power
1994 256 Sep 12	Granite site RefTek blew a fuse.
1994 267 Sep 23	Granite site pulled out.
1994 270 Sep 26	Visited borehole and gave new batteries. All 4 levels working.
1994 286 Oct 13	Visited borehole. All levels working. Brought all RefTeks back to USC as no replacement batteries and also some water on RefTeks
1994 297 Oct 24	Reinstalled all levels for LARSE onshore shots
1994 313 Nov 9	Retrieved all RefTeks and clock and left for the winter

Event Catalogue

All earthquakes recorded at 1.5 km, up to and including day 286, 1994, have been picked and catalogued and are included on the tape in the file cajon.cat A description of the cataloguing process is given in Abercrombie (1996)

Format:

```
format i4,1x,i3,1x,i3,1x, i2,i2,f6.3,1x,2(i6,1x),3(i5,1x),
read   iyr,  jday, itrig, th,tm,ts,     Pt,St,   Az,Ah1,Ah2,

-- a6,1x,      i6,1x,  a1,   f3.1, a30
-- polarity,  coda,   comm1, mli, comment
```

Explanation:

iyr	Year of event
jday	Julian day of event
itrig	Number of trigger at 1.5 km on jday
th	Hour of event trigger (note that timing is not always correct - see above)
tm	Minute of event trigger
ts	Second of event trigger
Pt	P time pick measured from trigger time (milliseconds)
St	S time pick measured from trigger time (milliseconds)
Az	Max amplitude on vertical component (counts)
Ah1	Max amplitude on 1st horizontal (h1) component (counts)
Ah2	Max amplitude on 2nd horizontal (h2) component (counts)
polarity	3 component P and S polarities (P on Z,H1,H2, S on Z,H1,H2) up:down = +:- for P; *:/ for S.
coda	Time at which coda on H1 reaches approximately 3 times background (milliseconds after trigger time)
comm1	M - prefix to magnitude from SCSN
mli	SCSN magnitude where available (some events may be missed)
comment	Various comments - includes SCSN CUSPID if available. Also used to identify "ringers" - strange high frequency events which may be nearfield radiation or something else (e. g. cable slip). No S is seen for these events.

Table 1: Cajon Pass Instrument Characteristics.

Depth	Operation Dates	Gain	Sample Rate (/s)	Instrument	Vertical			Horizontal 1			Horizontal 2			Polarity	Comments
					G (V/in/s)	*fc* (Hz)	*D*	*G* (V/in/s)	*fc* (Hz)	*D*	*G* (V/in/s)	*fc* (Hz)	*D*		
Surface	April 1992 - July 1992[3]	8	250	L22-D 2 Hz	0.86	2	0.46	0.86	2	0.46	0.86	2	0.46	Z = up, H1 = W (±3°), H2 = N (±3°)	General instrument specifications. Accurate timing relative to 2.5 km, not absolute time.
2.5 km	April 1992 - August 1993[3]	512[6]	500[6]	L-15LA-TW-HT 10 Hz	0.65	10	0.7	0.65	10	0.7	0.65	10	0.7	Z = up, H1 = 18° (±3°), H2 = 72° (±3°)[7]	General instrument specifications. No absolute time (accuracy ± 5 s)
Surface	November 1993 - August 1995[4]	8	250	L22-D 2 Hz	0.968	2.533	0.433	0.960	2.064	0.458	0.988	2.060	0.495	Z = up, H1 = N, H2 = E	Measured in situ[2]
300 m	November 1993 - August 1995	32	500	L1-B 4.5 Hz	4.765	4.114	0.945	5.105	4.297	0.725	4.346	4.423	1.284	Z = up, H1 ~ -10° (±10°), H2 ~ -100° (±10°)[8]	Measured in situ
1.5 km	November 1993 - August 1995	512	1000	L-15LA-TW-HT 10 Hz	0.615	10.977	0.583	0.602	10.593	0.597	0.617	11.211	0.606	Z = up, H1 ~ 142° (±5°), H2 ~ 50° (±5°)	Measured in situ
2.9 km	November 1993 - August 1995	512	1000	L-15LA-TW-HT 10 Hz	0.526	10.471	0.565	0.551	10.309	0.534	0.513	10.111	0.535	Z = up, H1~ 115° (±10°), H2 ~ 25° (±10°)	Measured in situ
Granite[9]	August 1994 - September 1994	8	250	L22-D 2 Hz	0.876	2	0.72	0.870	2	0.72	0.873	2	0.72	Z = up, H1 = N, H2 = E	*G* from measured geophone coil resistances

Notes:

1. All Instruments (Mark Products Geophones) are run on 16 bit RefTeks, with full scale ±3.75 V. *G* is the generator constant, *fc* is the geophone corner frequency and *D* is the damping factor.
2. In situ calibration in May 1994 and June 1995 using the technique developed by Rodgers et al. (1995). The calibrations showed negligible changes in the response of the geophones, after 11 months at elevated temperatures, within the errors of the calibration system (in this case < 5%, A. Martin, pers. comm.)
3. Phase I operation. The 2.5 km instrument was installed in August 1991 but recording prior to April 1992 was in short periods using a USC made recording system. Down time in April due to water problems in the recording system. No RefTek 26 July to 2 September 1992, so no recording. Downtime during winter on account of water getting into RefTeks as site flooded following rain.
4. Phase II operation. A summary of the second phase of recording follows.
5. All data was recorded on field exabyte tapes. Then it was loaded onto the SUN using ref2segy, and the RefTek SEGY files were backed up in duplicate using TAR onto exabyte tapes. These data were compressed and loaded onto one DAT tape to send to IRIS.
6. Gain increased to 2048 and sample rate to 1000 between 27 January and 7 March 1993.
7. Determination of 2.5 km horizontal orientation in Abercrombie (1995a). Note North = 0°, East = 90° etc.
8. Borehole horizontal orientations in Phase II are estimated by the same method described in Abercrombie (1995a). The angles are preliminary using only a small number of earthquakes.
9. The "granite" instrument was installed on hard granite with plaster of Paris. Location: 34.3113°N, 117.4625°W.