Investigation of Parkfield borehole earthquake catalog for fault zone trapped waves

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Proposal Activity Examine the complete microearthquake catalog of the borehole seismic network on the San Andreas fault at Parkfield, California, for evidence of fault zone trapped waves.

Background A systematic borehole seismic investigation of the small normal fault near Oroville, CA, that ruptured in a 1975 M=5.7 earthquake, showed that fault zone trapped waves could be excited by sources within the fault trace (Li and Leary, 1990). The observed propagating waveforms agreed with calculations based on a plane parallel four-layered fault with layer thicknesses and velocities controlled by body wave travel time data. On the basis of these observations similar waveforms were identified in a limited collection of vertical component seismograms recorded by the San Andreas fault zone borehole seismometer network (Li, et al. 1990). Interpretation of the waveforms in terms of the plane parallel fault structure seen at Oroville yielded a fault zone model consistent with body wave tomography velocities for the wall rock and having a narrow low velocity fault zone core layer for which there was no body wave tomographic control. The Parkfield fault zone trapped mode waveforms were observed at a single borehole seismometer network station, MM, that is immediately adjacent to the San Andreas fault (Fig.1). Stations located further from the fault, EA, FR, VC, ST, JS, JN, and GP were not observed to record such waveforms. In the context of a very simple uniform vertical, planar, parallel layered San Andreas fault, this result was not unexpected. However, it was important to the identification and interpretation of the trapped mode waveforms to confirm the systematics of the trapped wave observations with the complete Parkfield borehole seismic network catalog.

Data The complete catalog of event recorded by the Parkfield borehole seismic network from start-up in 1987 through 1990 were acquired, first on 9-track tape (12/90), and latterly on Exabyte cassette (3/91), in the form of UNIX tape archive ('tar') files. Seismograms for a month of events -- 50 to 80 events -- are read in for screen and plotter display. Four months of events -- 4/90, 5/90, 6/90 and 7/90 -- have been examined. As a first pass, events recorded at station MM that appear to have conspicuous trapped mode waveforms are selected for comparison with the same events recorded elsewhere in the network. This selection is made with two tests in mind: systematic features of the source location and possible uniqueness of these waveforms to station MM.

Results Of the approximately 200 events examined, some 20 to 30 have possible to probable trapped mode waveforms appearing at station MM. The lower panel of Fig. 1 shows 6 events from the May, 1990, catalog month that show clear trapped mode waveforms at MM. The events are located by number in the upper panel of Fig. 1. The seismograms are vertically spaced to indicate the offset from station MM relative to the offset of the nearest event (15). The events are approximately aligned to a common P-wave first arrival. All candidate trapped waves arrivals lie behind the direct S wave arrival time as computed for a uniform Possion halfspace of P-wave velocity 5.2 km/s (as given by velocity tomography). It is interesting to note that intermediate offset events 10, 13, 25 are

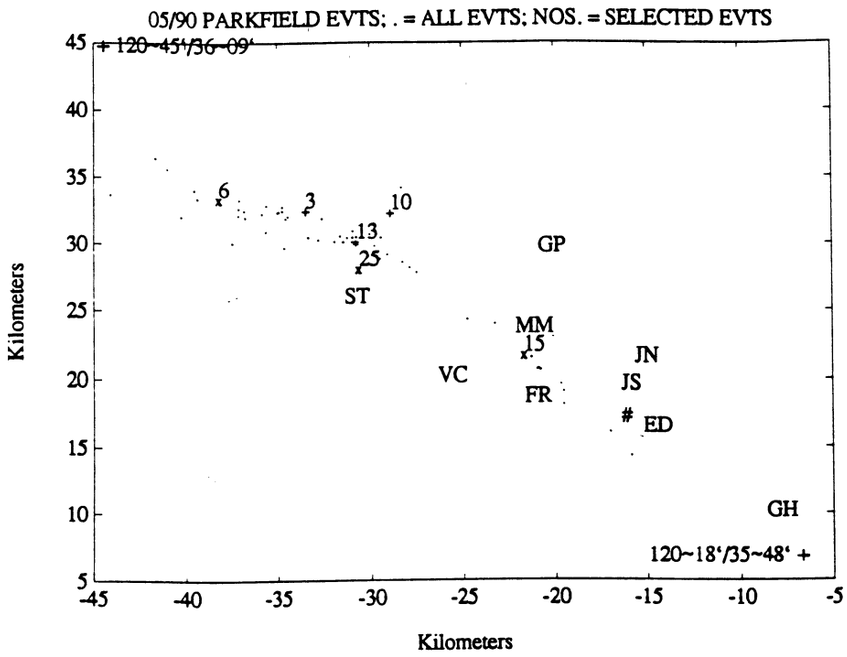
reported as located over a 4 km line normal to fault. The MM waveforms of events 10 (relative offset 6 km) and 25 (relative offset 10 km) suggest that they are mislocated.

Fig. 2 shows another selection of 05/90 events showing trapped mode waveforms at station MM. The events are located in the upper left panel. In the remaining panels the vertical offset of trace is in kilometers relative to the closest event (in this case #52), and the P-wave arrivals are approximately aligned. Shear wave arrival times for a uniform shear wave velocities associated with uniform P-wave velocities of 5.2 and 4.8 km/s are shown. Candidate fault zone trapped waves energy is seen to follow the shear wave arrival times, as expected. Station FR, located on the faster, granite terrain of the western crustal block, and station EA, located 1 km from the San Andreas fault in the slower, metasedimentary terrain of the eastern crustal block, show no evidence for trapped mode waveforms. On the other hand, for events 40, 46, 50 and 52 stations JN and JS show waveforms similar to the MM waveforms identified as trapped waves. For the near-by event 52, JS records a waveform that appears after the expected S-wave arrival.
The absence of trapped mode waveforms at FR and EA is consistent with a San Andreas fault zone trapped wave interpretation, as the stations are too far from the fault to allow evanescent waves to reach these stations at amplitude. The presence of prominent post S arrival waveforms at stations JS and JN is not consistent with a simple fault zone geometry, suggesting instead that trapped wave energy is moving along shallow low velocity structures excited by fault zone trapped wave energy. This interpretation of station JS and JN waveforms is consistent with the location of these stations in a canyon surface structure that may be fault controlled.

At present the prime avenue of investigation of Parkfield trapped wave systematics is to attempt to decide if the waveforms recorded at station MM represent near surface waveguide structures that have little relevance to the deep structure of the San Andreas fault. However, even if the trapped mode waveforms are characteristic of near surface structures, the excitation of these near surface structures may proceed only via deep fault zone trapped mode excitation. In this case, the critical use of trapped mode observations as a means of precisely locating events relative to the fault at depth remains intact.

Fig. 1 Top: Parkfield event location map. Locations of all recorded Parkfield borehole seismic network events for May, 1990 are shown as dots; locations of events shown in below are numbered; locations of borehole seismic stations are given by letters; # denotes the town of Parkfield. Bottom: Parkfield events showing trapped mode waveforms as recorded at station MM; the horizontal axis is time in units of 16 msec; the events are approximately aligned at a common P-wave first arrival time; the vertical axis is relative offset from MM in km; the solid line is the shear wave arrival time for a Poisson solid with V_P = 5.2 km/s.

Fig. 2 Upper left: same as Fig. 1. All other panels: clockwise from upper right, events 40, 42, 46, 50, and 52 as recorded at stations MM, EA, JN, JS, and FR approximately aligned to a common P-wave first arrival and vertically adjusted for relative offset from the recording station. A single line denotes expected arrival times of shear body wave for a Poisson solid with P-wave velocity 5.2 km/s; where two lines are shown the shallower line denotes S arrival times for a P-wave velocity of 4.8 km/s. Events were selected as showing a trapped mode waveform at station MM. No such arrivals appear at stations FR and EA, while stations JN and JS shown some form of arrival at approximately the same times as the waveforms at MM.


05/90 PARKFIELD EVTS: . = ALL EVTS; NOS. = SELECTED EVTS
+ 120~45'/36~09'
6
3
10
13
25
ST
GP
MM
15
VC
JN
JS
FR
#
ED
GH
120~18'/35~48' +
Kilometers
Kilometers

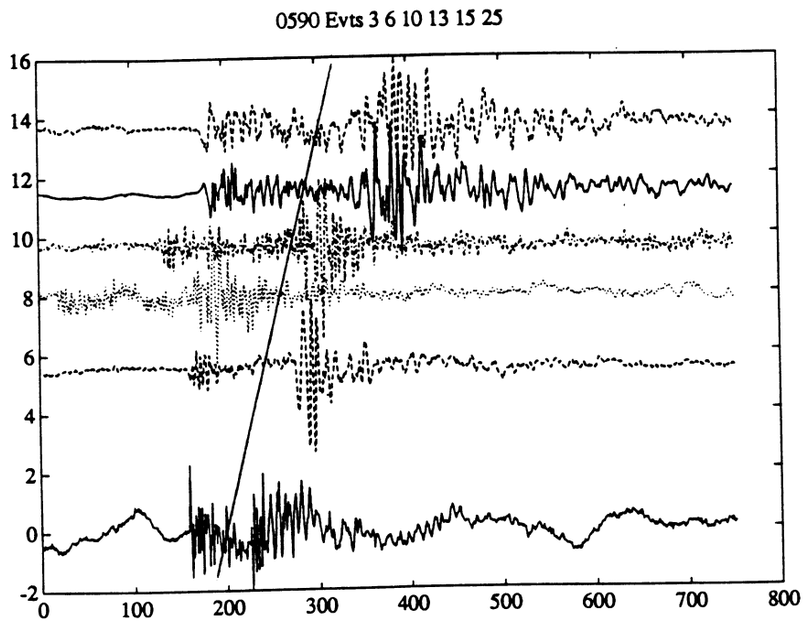
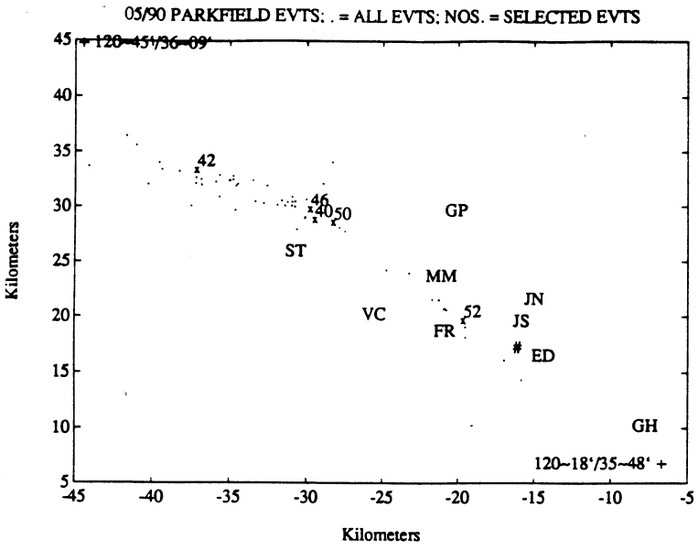
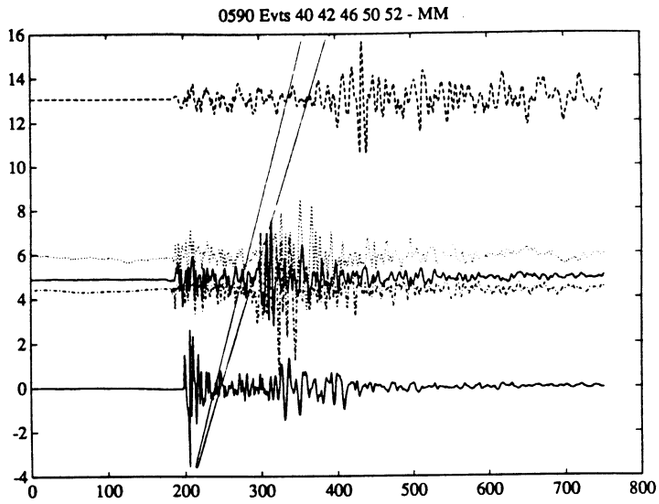
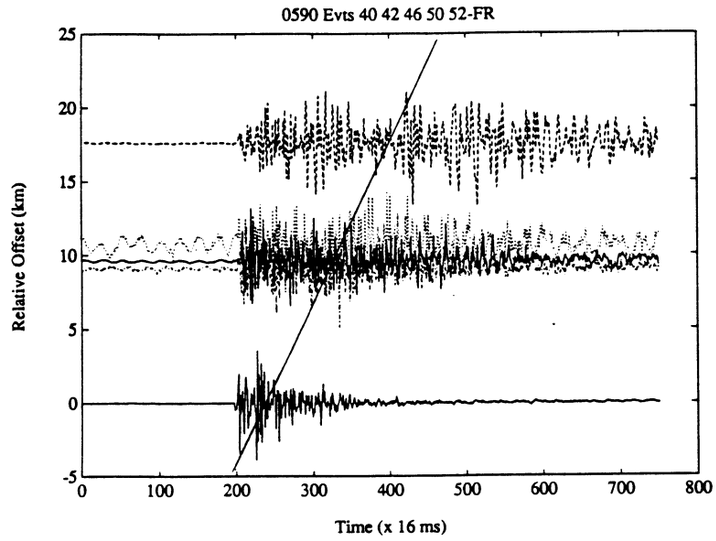
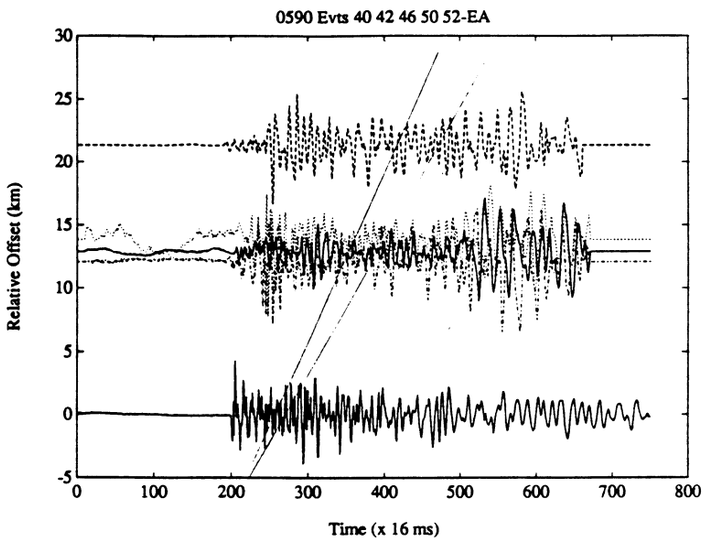

0590 Evts 3 6 10 13 15 25

Figure 1


05/90 PARKFIELD EVTS: . = ALL EVTS; NOS. = SELECTED EVTS
120-45'/36-09'
42
46
40
50
GP
ST
MM
VC
52
JN
JS
FR
ED
GH
120-18'/35-48' +
Kilometers
Kilometers


0590 Evts 40 42 46 50 52 - MM


0590 Evts 40 42 46 50 52-FR
Relative Offset (km)
Time (x 16 ms)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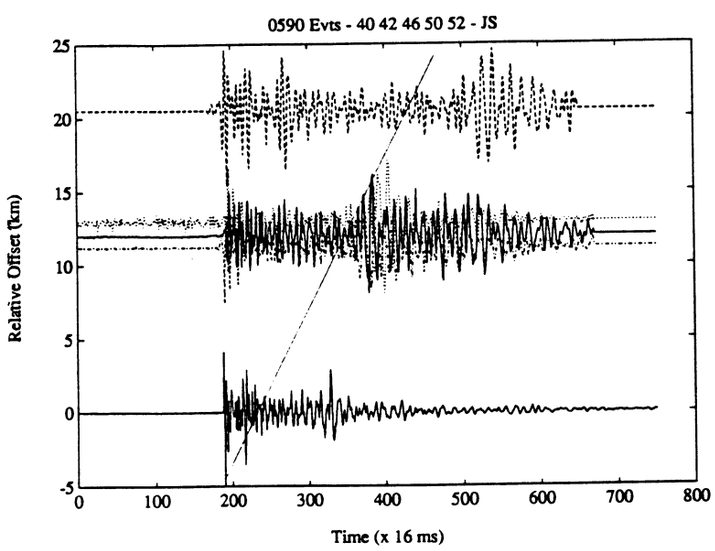
Relative Offset (km)
Time (x 16 ms)


0590 Evts - 40 42 46 50 52 - JS
Relative Offset (km)
Time (x 16 ms)

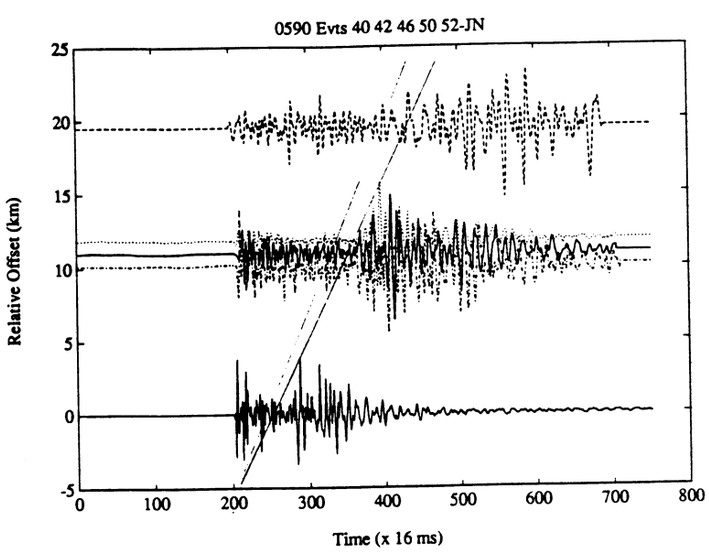

0590 Evts 40 42 46 50 52-JN
Relative Offset (km)
Time (x 16 ms)

Figure 2