Mapping the San Gabriel Mountains Bright Spot using local seismic events.

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Abstract

Data returned from the Los Angeles Regional Seismic Experiment (LARSE I) in 1994, which consisted of information gathered from a series of man-made seismic events, showed a zone of high velocity beneath the San Gabriel Mountains. This zone was named the San Gabriel Mountains Bright Spot (SGMBS). In order to further characterize this zone, I spent the summer at the University of California, Los Angeles, working under Dr. Paul Davis. The aim of this project was to try and find reflection phases in local seismic events, such as earthquakes. We looked primarily for P-P and P-S phases, which showed up in seismograms from the LARSE I experiment, as well as spending time looking for S-S and S-P reflection phases. While nothing immediately jumped out at us, lining up P-P phases at their expected arrival times showed some promising results.

Introduction

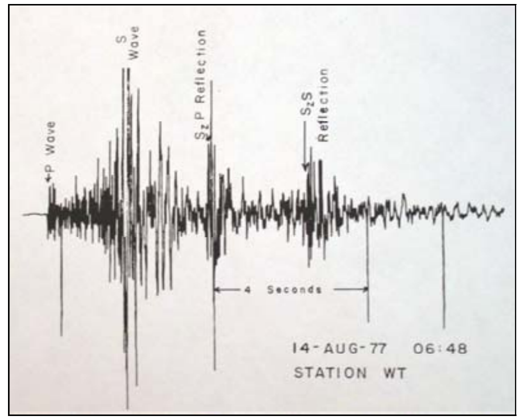

Fig. 1: An example of a seismogram showing S-P and S-S reflection phases.
Source: Rinehart *et. al.(1981)*

Underground explosions carried out in the LARSE I experiment in 1994 showed a strongly reflective area beneath the San Gabriel Mountains. It was named the San Gabriel Mountains Bright Spot (SGMBS).

The goal of my project this summer was to use past and current data on earthquakes in the San Gabriel Mountains from the Southern California Seismic Network to try and further map the extent of the SGMBS.

Similar research, carried out by Eric Rinehart and Allan Sanford towards the end of the 1970's in New Mexico, showed very well defined reflection phases present in microearthquake seismograms (Rinehart, 1981).

What is LARSE?

The purpose of the Los Angeles Region Seismic Experiment was to create an accurate map of the crust beneath the Los Angeles Basin, in order to help reassess the hazards posed by earthquakes on unknown faults.

In order to map the crust, a network of over 600 seismograms placed along the LARSE I line and around Southern California recorded the arrival of sound waves generated by small explosions. These sound waves consist of both direct waves that travel from the explosion to the station as well as waves that reflect off structures in the crust that are of different densities. About 60 detonations were carried out in a line stretching northeast from Seal Beach, across the Los Angeles Basin, through the San Gabriel Mountains and into the desert. The segment that ran through the San Gabriel Mountains had explosives placed at a spacing of 1 kilometer apart (Murphy, 1996).

Fig. 2: Map view of Southern California, showing where detonations for the LARSE I experiment took place.
Source: SCEC LARSE I News Release
http://www.scec.org/news/00news/spot001018.html

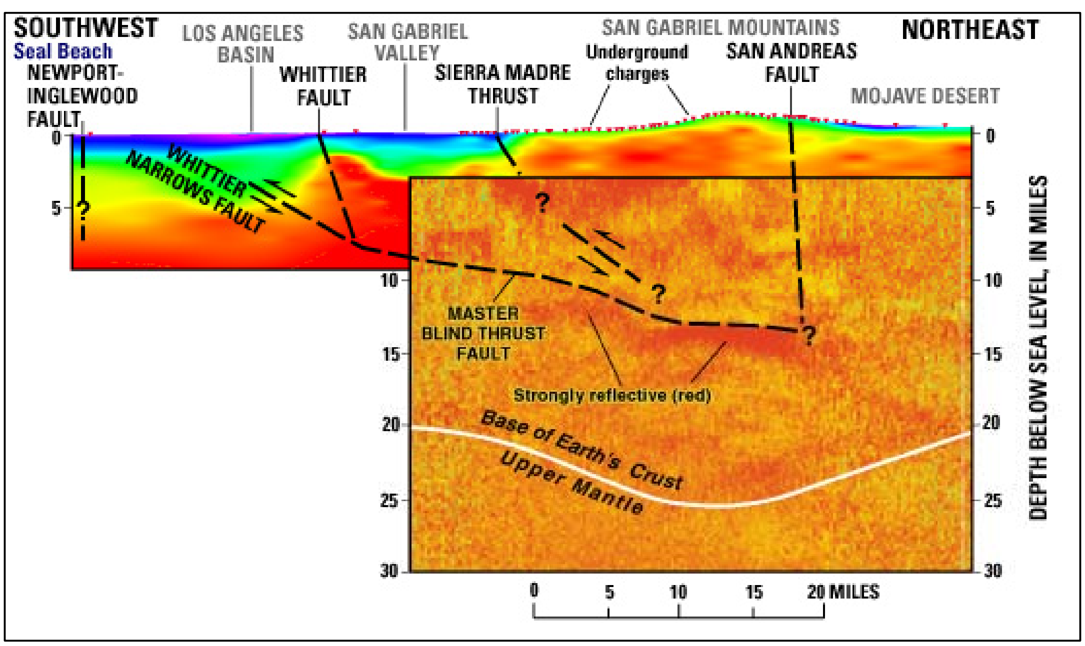

Fig. 3: Cross section through Southern California from the LARSE I survey, showing a reflective spot beneath the San Gabriel Mountains.
Source: SCEC LARSE I News Release - http://www.scec.org/news/00news/spot001018.html

Event ID	Type	Date	Lat.	Long.	Depth (km)	Magnitude
3199531	le	1995/01/09,02:08:24.990	34.21	-117.659	9.34	2.19
3200780	le	1995/01/20,23:42:41.820	34.165	-117.606	13.43	1.39
3204975	le	1995/02/26,11:33:32.147	34.258	-117.947	11.71	0.95
3206308	le	1995/03/12,07:06:35.061	34.192	-117.83	11.01	0.98
3206526	le	1995/03/14,08:21:27.453	34.221	-117.597	10.27	0.62
3206665	le	1995/03/15,10:51:41.393	34.183	-117.823	13.36	0.79
2198254	le	1995/03/21,01:58:13.108	34.186	-117.618	5.35	1.45
3207708	le	1995/03/24,07:12:12.506	34.31	-117.705	6.16	1.33
3208143	le	1995/03/27,23:56:43.836	34.196	-117.782	15.37	1.36
3209037	le	1995/04/05,12:40:00.882	34.193	-117.597	13.98	1.61
3209242	le	1995/04/07,09:27:14.176	34.185	-117.659	12.1	1.14
3210238	le	1995/04/17,17:22:32.949	34.236	-117.985	7.28	2.02
3212873	le	1995/05/13,15:45:50.898	34.306	-117.825	7.18	2.22
3214368	le	1995/05/26,03:37:25.243	34.307	-117.692	5.54	1.82
3215423	qb	1995/06/05,20:11:05.276	34.156	-117.946	0	1.2
3216775	le	1995/06/18,01:58:17.180	34.157	-117.71	12.56	1.03
3217110	le	1995/06/21,14:08:12.643	34.213	-117.746	14.85	1.12
3218251	le	1995/07/01,08:13:31.479	34.39	-117.627	6.78	1.66
3218360	le	1995/07/02,12:02:28.662	34.265	-117.642	10.51	1.9
3219575	le	1995/07/15,03:05:41.243	34.183	-117.637	11.18	1.39
3219586	le	1995/07/15,07:59:51.226	34.165	-117.622	13.29	1.25
3219649	le	1995/07/15,21:45:59.574	34.385	-117.713	9.49	1.1
3220135	le	1995/07/19,23:16:35.675	34.185	-117.621	5.44	1.83

Fig. 4: A small sample of data for the San Gabriel Mountains collected using the Seismic Transfer Program.

Methods

In order to characterize what was happening in terms of the arrival of reflection phases, I did the following:

- Created a simplified model to represent what was happening in terms of reflection phases from the SGMBS.
- Select stations and earthquakes that are near the LARSE I line, as these should be the best candidates for showing reflection phases.
- Calculate arrival times for reflection phases (*PP, PS, SS, SP)*

- Examine individual event seismograms for both vertical (Z) and horizontal (N, E) components.
- Filter seismograms using a low pass filter at 10hz, as well as various band pass filters.
- Create source-array diagrams to examine any signs of consistent move-out from reflection phases.
- Signal Stacking - line up multiple seismograms along expected arrival times of reflection phases and stack the signals to look for a larger burst of energy.

To calculate the arrival times, an average velocity for both the P-wave and the S-wave was determined by using the Southern California Earthquake Center Velocity Model, yielding a speed of 6.8 km/s for P-waves and 3.7 km/s for S-waves (Magistrale, 2000). We also needed to know the horizontal distance from the epicenter of an earthquake to our station, as well as an assumed depth of the SGMBS, which we put at a depth of 22 km based on data returned from the LARSE I survey.

I wrote a program to automatically carry out trigonometric operations and iteration to find the approximate values of reflection phase arrival times. To test these calculations, we compared the expected arrival times of P and S-waves with the real world values. Depending on the distance from the epicenter of an earthquake to our station, our times were off by 1/5 of a second in either direction.

We began by looking at individual earthquakes that ranged in size from about M1.0 to M3.0 in an area around the LARSE I line in the San Gabriel Mountains. The hope was to find readily apparent reflection phases, similar to what Rinehart and Sanford found in New Mexico. While nothing immediately jumped out, there were some interesting phases that arrived about where we would expect them too. However, when comparing multiple seismograms, the phases were not very consistent.

Discussion

The apparent reflection phases that we point out in the source array diagram do not line up perfectly with our predicted arrival time. A possible explanation for this is the method we used in calculating arrival times. I used a simplified model that showed seismic waves traveling through the lithosphere in a linear fashion, when in reality, waves actually propagate through the Earth’s surface in a curved fashion. This would add to the amount of time it would take for the wave to arrive, and we notice most of the apparent reflection phases arriving after our expected time.

Results

Individual seismograms from station MWC, located at Mt. Wilson, California, show possible reflection phases in the waveforms. The following seismograms show pulses of energy coming in approximately at the times we would expect in our calculations. However, despite apparent pulses of energy visible in each of the seismograms, the actual reflection phases that these pulses line up with are not consistent between each seismogram.

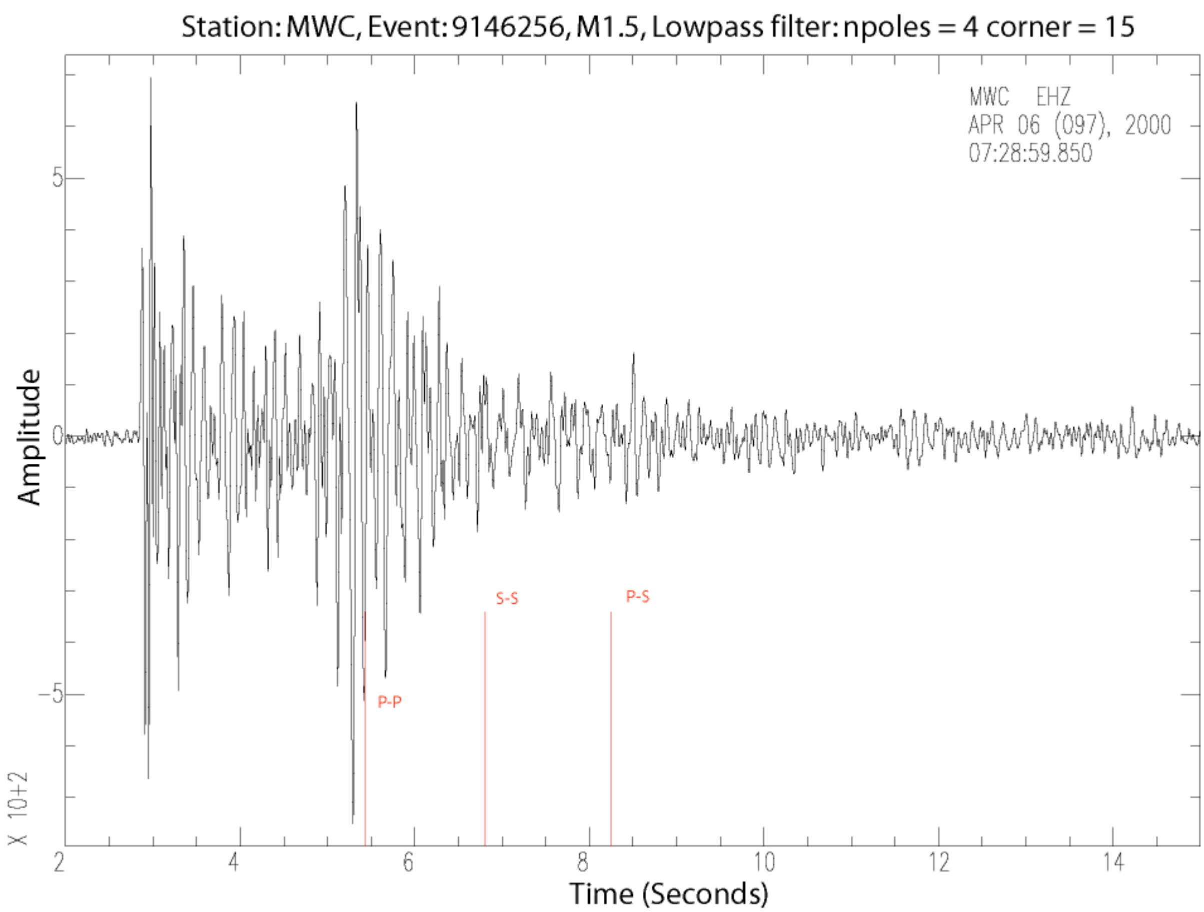

Fig. 5: Event – 9146256, a M1.5 earthquake at a depth of 10.84km as recorded by MWC on April 6, 2000. Note the pulse of energy visible at about 8.25 seconds. This coincides with the arrival of a P-S phase.

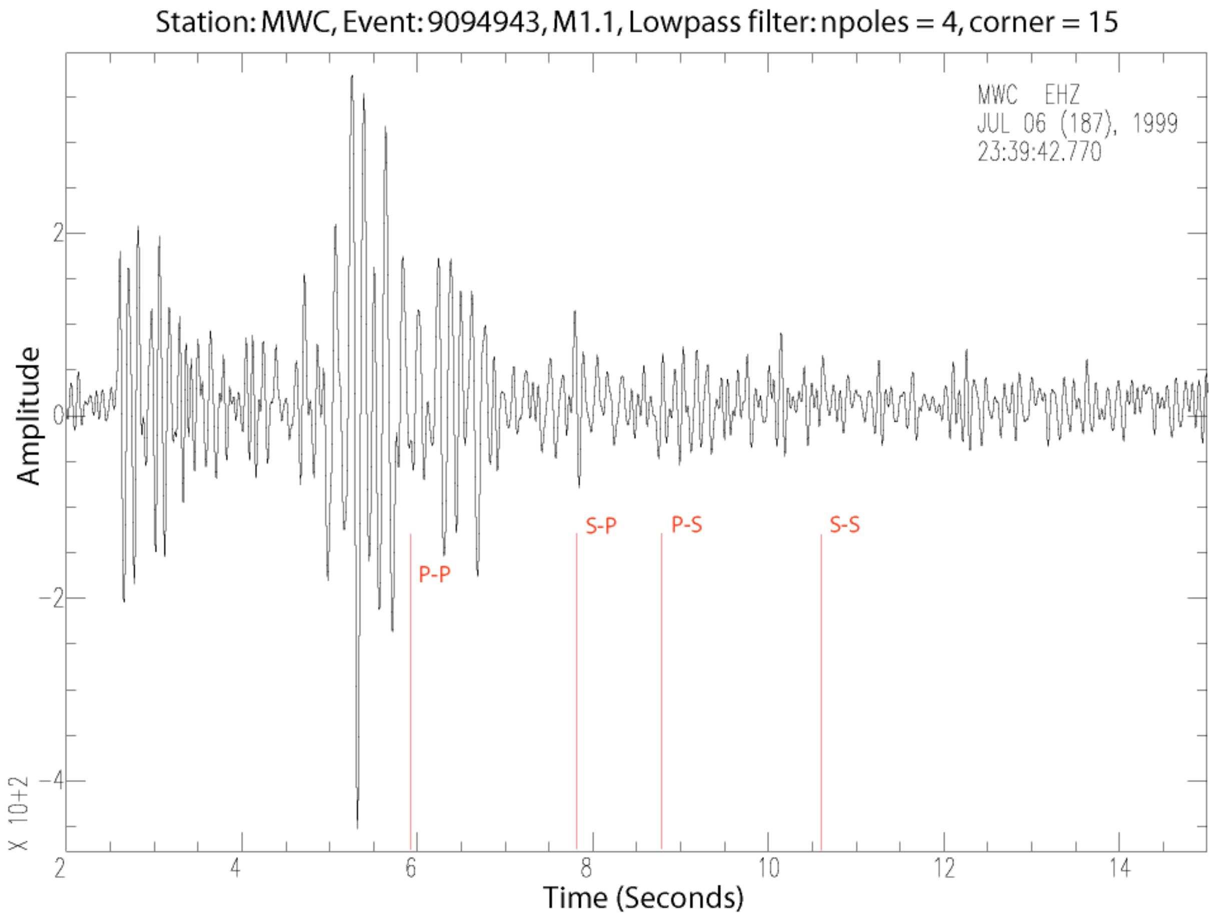

Fig. 6: Event – 9094943, a M1.1 earthquake at a depth of 7.06km as recorded by MWC on July 6, 1999. Note the pulse of energy at about 7.8 seconds. This coincides with the arrival of the S-P phase.

Another method we used was to create a source array diagram. We lined up multiple seismic events that were recorded by one station and then line each individual seismogram up by the expected arrival time of the particular reflection phases we are looking for. This way, we could examine the diagram for consistent arrivals. However, the seismograms are fairly noisy, so it was difficult to determine what was just background noise or S-wave coda and what was actually a reflection phase.

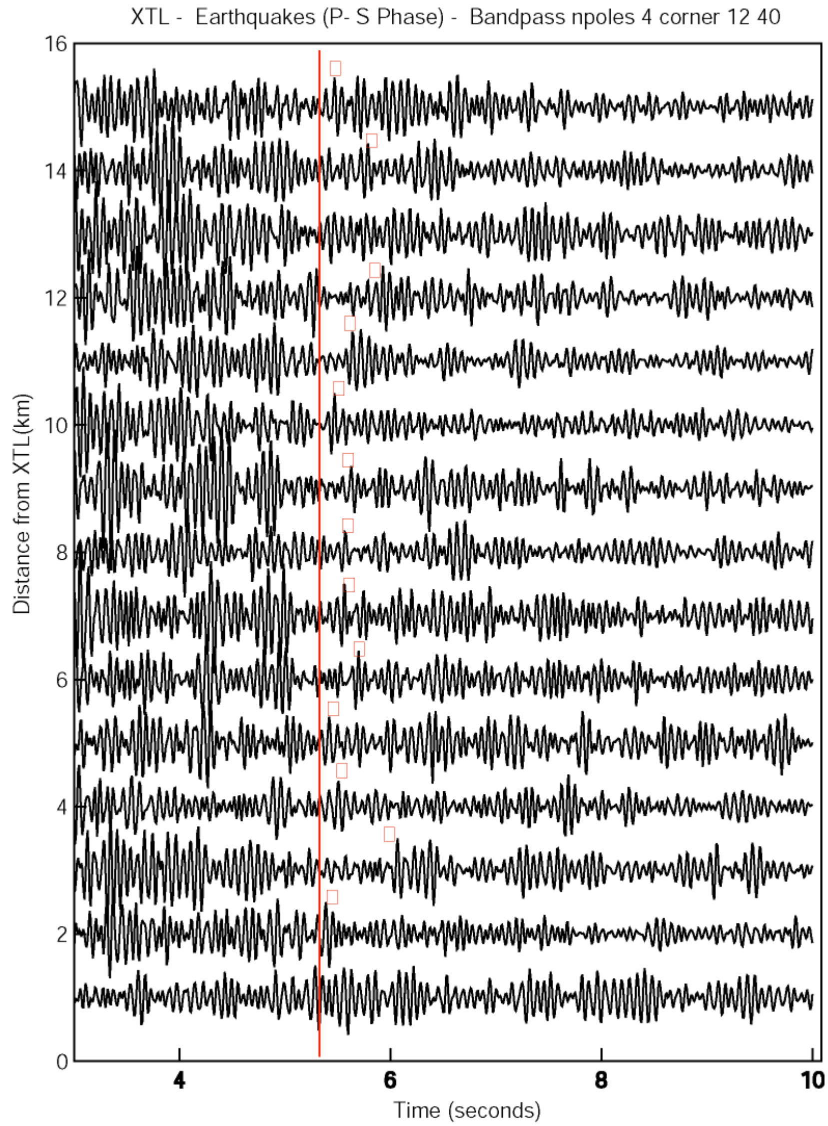

Fig. 7: Source array diagram for station XTL using 15 microearthquakes that were located around the LARSE I line. All the seismograms are lined up with respect to the predicted arrival of the P-S phase, which is noted by the vertical red line. The square symbols indicate what we believe is the actual P-S phase.

Conclusion

Based on the phases that we saw in the individual seismograms, and the interesting results we saw when we lined up the source array diagram, we think this method has potential to map the San Gabriel Mountains Bright Spot.

Unfortunately, I ran out of time during the internship to pursue this method further, so we were not able to actually map the SGMBS. However, with further time and effort, it should be possible to map this high velocity zone using local seismic events.

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