Potrillo Volcanic Field Experimental Shots (PVFX)

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Background

In crustal seismology large shots meant to propagate 100 or 200 km are usually constructed by drilling a large diameter (20 cm) borehole 50 to 60 m deep and filling it with 35 to 45 m of explosives followed by stemming to the surface. The theoretical directivity pattern generated by explosives in this vertical cylindrical cavity has been calculated by Heelan (1953) and is shown in Fig. 1. Note that virtually all of the energy is directed in horizontal directions, as one would expect given that virtually all of the surface area of the cylindrical cavity is vertical. However, in crustal seismology the energy that propagates to distant receivers leaves the shotpoint at high angles within 10 to 15 degrees of vertical. Horizontally propagating energy becomes direct waves or surface waves and is lost quickly to attenuation. Heelan's (1953) work leads one to the conclusion that crustal seismic shots designed in this way are quite inefficient.

A better design for a crustal seismic shot would be to direct most of the energy from the shot downward where it would propagate to distant receivers. Miller and Pursey (1954) calculated the directivity of a vertically acting horizontal disk. The directivity of this disk force is shown in Fig. 2. Note that energy is directed downward with the largest amplitude is directed vertically. However, to place a large force on a horizontal surface requires a large mass on the surface either to produce the force directly or as a reaction mass to a force. A convenient way to produce a large reaction mass is to bury the horizontal disk of explosive a few meters below the surface creating a large reaction mass of soil and directing the explosive energy downward. However, it is not practical to excavate such a hole. Something that is practical is to concentrate the explosive into discrete charges distributed over a disk shaped area in the subsurface. A schematic diagram of such an array is shown in Fig. 3.

In seismology source arrays are used to sum the amplitudes of the individual charges and form a downward directed beam of energy. In our array the objective is for individual charges to interact to produce a downward force on the earth below the array that will rebound with a frequency characteristic of a disk acting on an area of a similar size. That is, we expect the dominant frequency of the array to be substantially lower than the dominant frequency of an individual charge.

The Experiment

To test the above hypothesis, we conducted an experiment at the site of a previous 1000 kg shot from the Potrillo Volcanic Field (PVF) experiment that was conducted in 2003. We drilled, loaded and shot three shots a single 0.45 kg shot, a 7-element hexagonal array and 91-element hexagonal array you see in Fig. 3. Each shot hole in the array was drilled to a depth of 3.3 m with great care to insure the drill was oriented vertically and located precisely. After placing the charge in the hole, ~8 liters of viscous water (~2.0 centipoises) was pumped into the hole to saturate the earth surrounding the charge and improve coupling. Holes were then tamped with cuttings to the surface. The charges in the array were connected with carefully measured lengths of detonating cord to insure simultaneous detonation. The array was initiated from a central point with a single detonator. In addition, a seven-element array and a single shot of the same design were detonated for comparison. Texans recorders were deployed in the same locations as in the PVF experiment, although not over the large spread used in PVF.

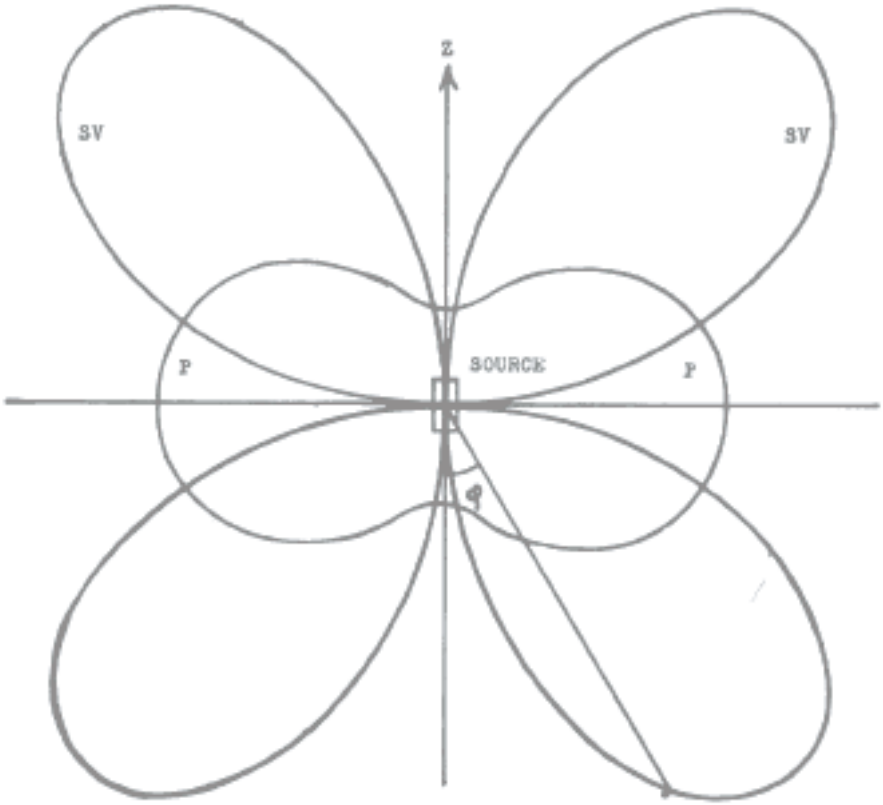

Figure 1. P and SV amplitude directivity from a pressure source in a cylindrical vertical cavity. From Heelan (1953).

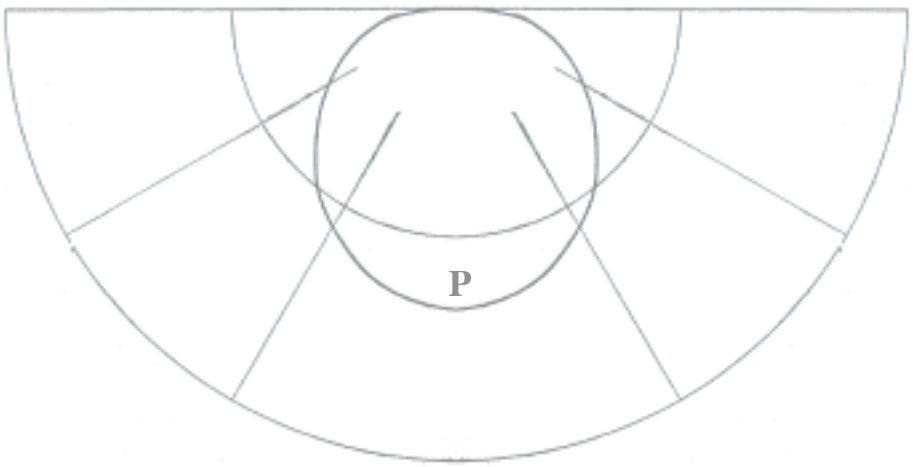

Figure 2. P-wave amplitude directivity from a horizontal disk acting vertical on a horizontal half-space. From Miller and Pursey (1954).

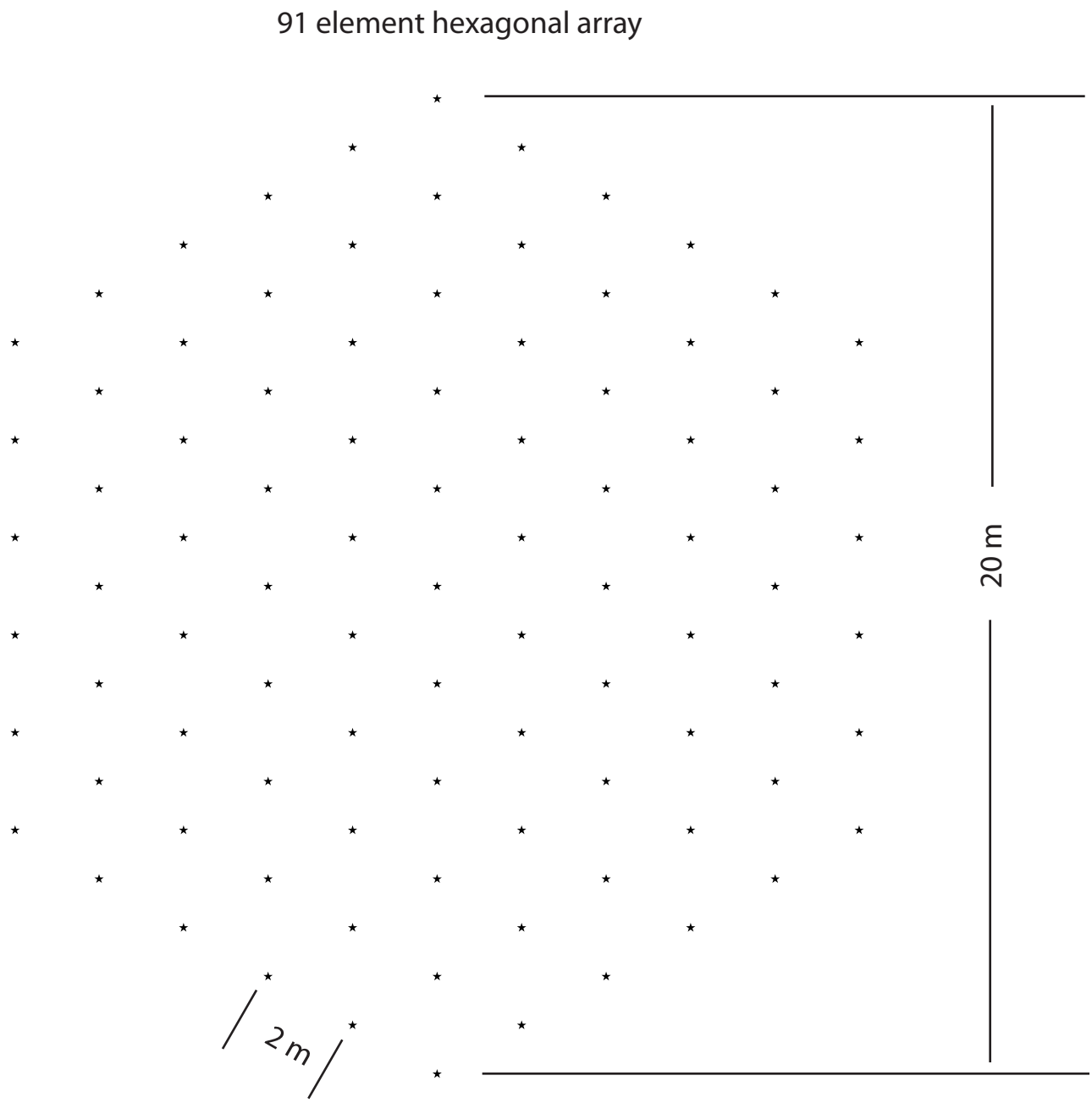

Figure 3. Plan view of the 91-element array used in this experiment.