Near-surface common-midpoint seismic data recorded with automatically planted geophones

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[1] We introduce the Autojuggie II as a device to speed the emplacement of geophones for near-surface seismic common-midpoint (CMP) surveys. Hydraulic cylinders force rigidly interconnected geophones into the ground simultaneously and automatically. We demonstrate that accurate CMP data can be recorded with geophones planted by this device, and that a CMP stacked section can be processed, from which reliable geologic information can be extracted. To make this demonstration, we compare the stacked section to a coincident and parallel section, whose data was acquired using conventionally hand-planted geophones. The two sections are very similar in amplitude, phase, and frequency. A slight difference in coherency exists in a ∼35-ms reflection; the stack corresponding to the automatically planted geophones shows better coherency relative to the comparison stack. However, the similarity of the sections indicates that accurate CMP data can be recorded using geophones planted by the Autojuggie II.
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1. Introduction

[2] The common-midpoint (CMP) seismic reflection method currently is an expensive geophysical application when used for shallow geotechnical or environmental site characterization. Despite its high cost, this technique is useful for extracting geologic information from the subsurface without using destructive digging or drilling techniques. Ground-penetrating radar (GPR) is the method of choice for subsurface imaging to less than 30 m depth because of its affordability. However, GPR is ineffective at locations where electrically conductive materials, such as clays and shales, are present in the subsurface. The near-surface CMP reflection method typically is useful at such locations because the water-saturated clays or shales that attenuate electromagnetic waves often conduct high-frequency *P*-waves quite well [*Davis and Annan*, 1989]. Unfortunately, the cost of a CMP reflection survey is commonly about an order of magnitude greater than that of a comparable GPR survey. For these two methods to be used interchangeably, the cost of near-surface seismic surveying must decrease.

[3] In a conventional seismic survey, spike-mounted geophones are planted individually by hand, and each must be placed at a particular location, a time consuming and costly practice. One way to reduce this cost is to reduce the amount of time required to plant geophones. Efforts have been made to improve the recording rates of terrestrial surveys for petroleum exploration by using a land streamer, in which the receivers were connected to a central cable at predetermined intervals, and the cable was then towed behind a vehicle [*Kruppenbach and Bedenbender*, 1975, 1976]. *Eiken et al.* [1989] introduced the "snowstreamer" as a tool for acquiring seismic data over ice- and snow-covered areas. The geophones used in these two devices were self-orienting gimbaled geophones that rested on the surface.

[4] *van der Veen and Green* [1998] and *van der Veen et al.* [2001] discussed a land streamer that also used gimbaled geophones, in which the geophones were housed in a 1-kg enclosure. This device was designed to reduce the cost of seismic data acquisition for engineering applications over terrains more rugged than snow-covered areas. Similarly, *Inazaki* [2004] used an S-wave land streamer where metal base plates provided proper geophone orientation.

[5] For each of the land-streamer variations, except *Kruppenbach and Bedenbender* [1975, 1976], the authors reported similar results between seismic data collected with the gimbaled or base-plate geophones and coincident data collected with conventional spike-mounted geophones. However, the land-streamer receivers were not coupled to the ground by geophone spikes. *Drijkoningen* [2000] stated that geophones are considered well-coupled to the ground when they are mounted on a spike, and the spike is planted firmly in the ground. This coupling is called spike-shear coupling and is necessary to record high enough frequencies (>200 Hz) to image very shallow (<50 ms) reflections. The land streamers have not yet achieved this degree of coupling.

[6] The purpose of the research presented here is to demonstrate the viability of the next-generation automatic geophone-planting device, the Autojuggie II, for very shallow 2-D seismic profiling (Figure 1). We used 72 spike-mounted geophones bolted to four segments of channel iron at a predefined interval. The geophones on the channel-iron segments were planted automatically and simultaneously using the hydraulically powered Autojuggie II in <90 s.

[7] *Steeples et al.* [1999a] first studied the recording of seismic data with rigidly interconnected geophones using 12

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