Sign-count stacking velocity analysis, slant stacks, and beam stacks

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ABSTRACT

Sign-count stacking counts the number of same polarity samples to a stack rather than summing the samples together. Given a wide enough summation aperture, sign-count stacking has similar signal discrimination as conventional stacking, but superior aliasing and edge control. It made slight improvements in stacking velocity analysis and beam stacks. Slant stacks were worse because relatively few traces contribute to each stack.

INTRODUCTION

Sign-count stacking, introduced by Cochran (1973) and Hansen, et. al., (1988), replaces straight summation by count of signals with the same polarity within the summation aperture. Then a count threshhold is applied as a signal discriminant. Cochran and Hansen also discusses some of the statistical aspects of this discriminant. Cochran applied this to stacking velocity analysis and Hansen to linear events on stacked sections with good results.

I was intrigued by the high quality of results by Hansen from such a simple discriminant. I had tried sign bit slant stacking on thousand-channel, common-receiver gathers (Alaska marine sonobouy data) a few years ago without satisfactory results. This paper conducts a more systematic empirical study of several sign-count stacking geometries: hyperbolic stacks, slant stacks, and beam stacks.

THE MODEL

A depth-variable velocity phase shift algorithm was used to model a three flat-reflector common midpoint gather. The spatially well-sampled model has all offsets from zero offset to the velocity asymptote (Figure 1). A spatially poor-sampled model subsampled a factor of four and truncated inner and wide offsets (Figure 1).

Table 1: Model parameters
Well-sampled offsets
`nt=200 dt=1 t0=1`
`nh=128 dh=1 h0=1`
`z1=50 v1=.5`
`z2=100 v1=1.`
`z3=100 v1=1.5`
Poorly-sampled offsets
`nh=20 dh=4 h0=11`
(everything else the same)

RESULTS

The following suite of figures each include three stack statistics:

left: Semblance (square of the sum over the sum of the squares smoothed by five samples);

middle: Mean (straight sum); and

right: Sign-count (count of positive polarities, less than 50% is black, more than 50% is white, *not threshholded*).

Each statistic was weighted by number of offsets contributing to the statistic. Apertures less than a quarter offsets where muted.

The stacking geometries include:

Hyperbolic stack analysis: well-sampled offsets (Figure 2), poorly-sampled offsets (Figure 3) and field data (Figure 4).

Slant stacks: well-sampled offsets (Figure 5) and poorly-sampled offsets (Figure 6).

Beam stacks: well-sampled offsets (Figure 7) and poorly-sampled offsets (Figure 8).

Recall that beam stacks are method of ray-parameter analysis. They weight each point of the seismic gather by the semblance of the moveout hyperbola intersecting that point tangent to the ray-parameter slope. Beam stacks are used for velocity analysis (Biondi, 1987), to attenuate slant stack noise (Kostov and Biondi, 1987) and to generate radial traces (Ottolini, 1987).

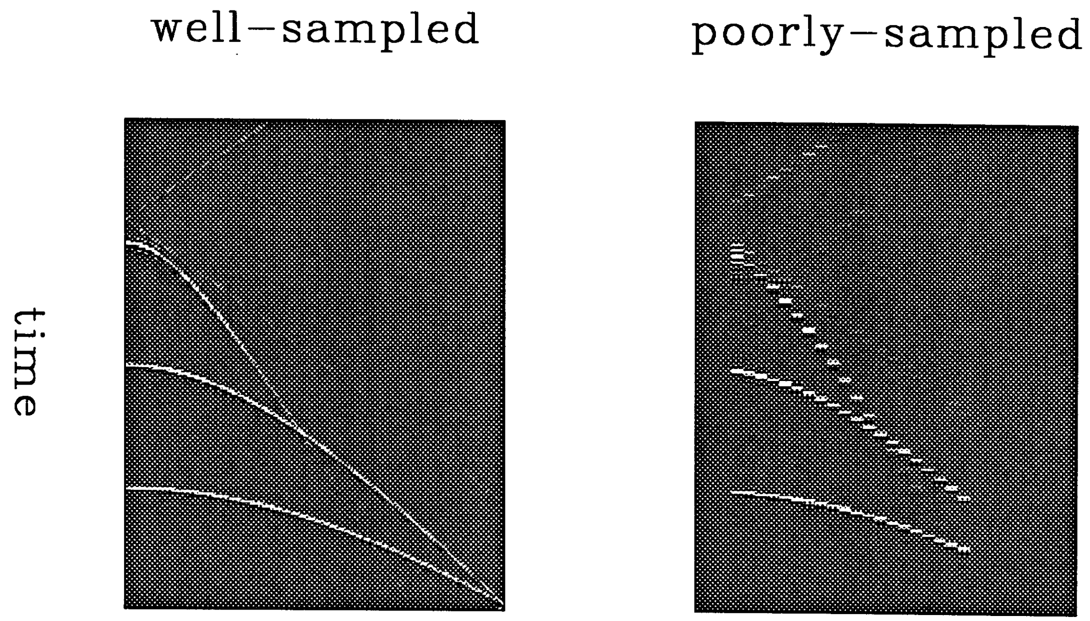

FIG. 1. Synthetic datasets: well-sampled offsets and poorly-sampled offsets. Generated with a phase shift algorithm according to parameters in Table 1.

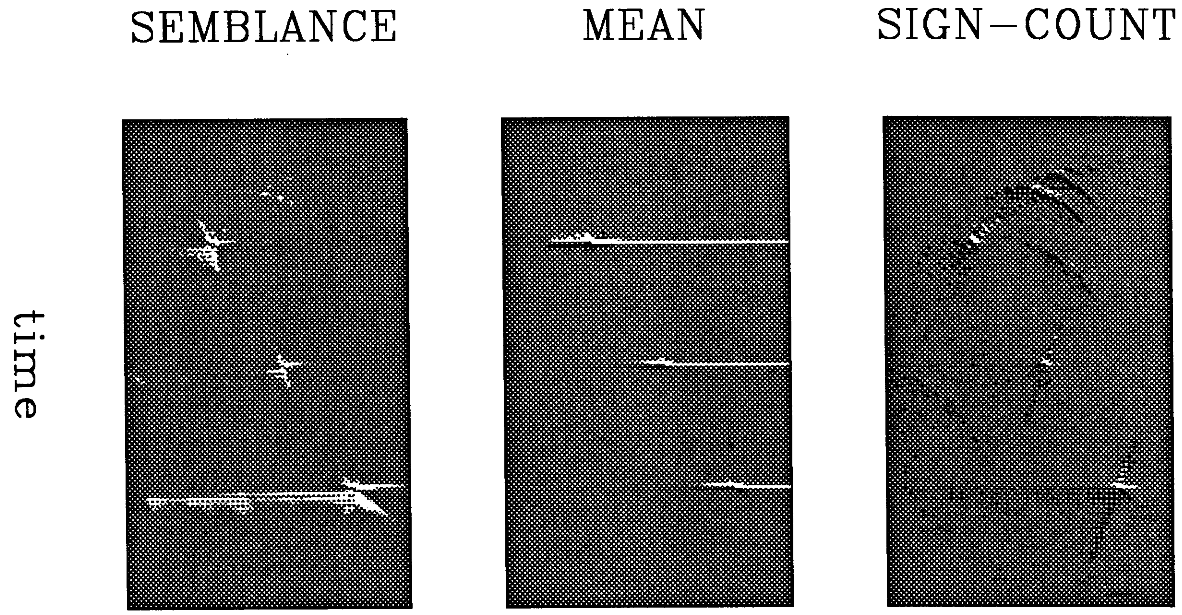

FIG. 2. Hyperbolic stack results for well-sampled offsets. The sign-count result has tighter foci and attenuates the linear artifact caused by inner-offset edge truncation.

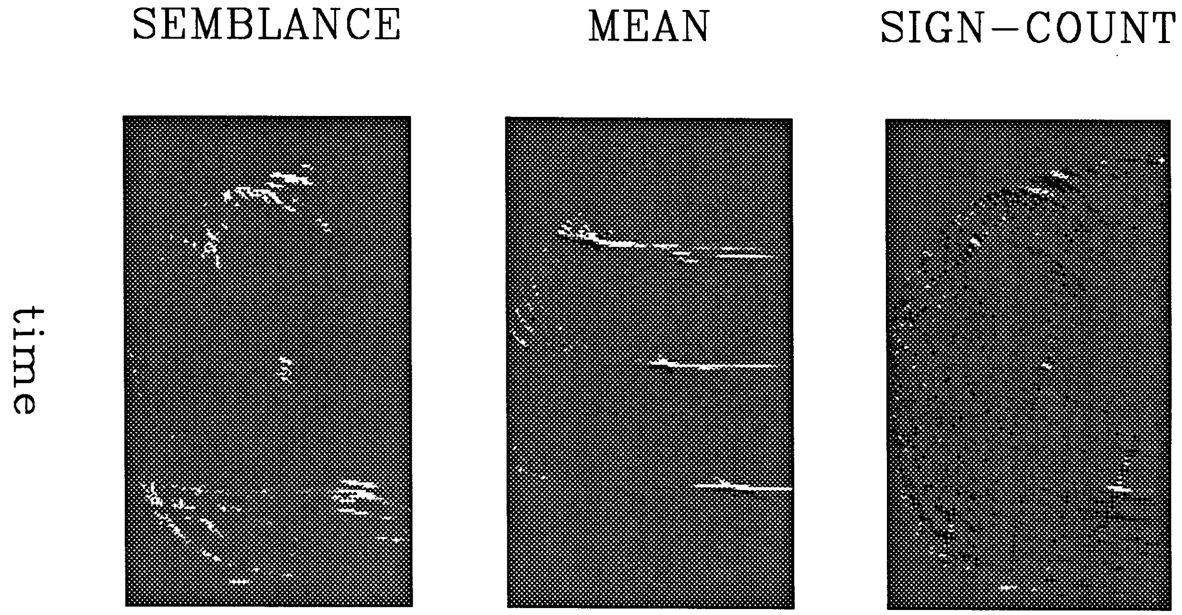

FIG. 3. Hyperbolic stack results for poorly-sampled offsets. The sign-count foci don't stand out as well as for Figure 1. Again, the inner-offset and outer-offset truncation linear artifacts are attenuated better than the semblance and mean.

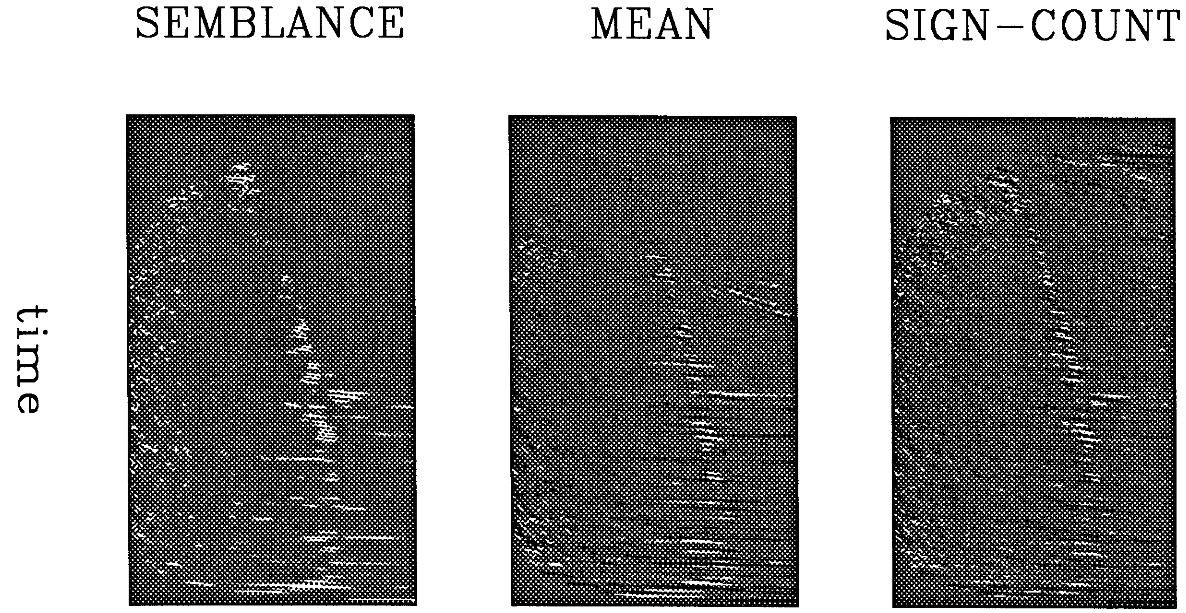

FIG. 4. Hyperbolic stack results on a 24 offset Gulf coast gather. The offset distribution is similar to the poorly-sampled offset model. In addition, field data has noise. The sign-count result has more foci and fewer high velocity artifacts.

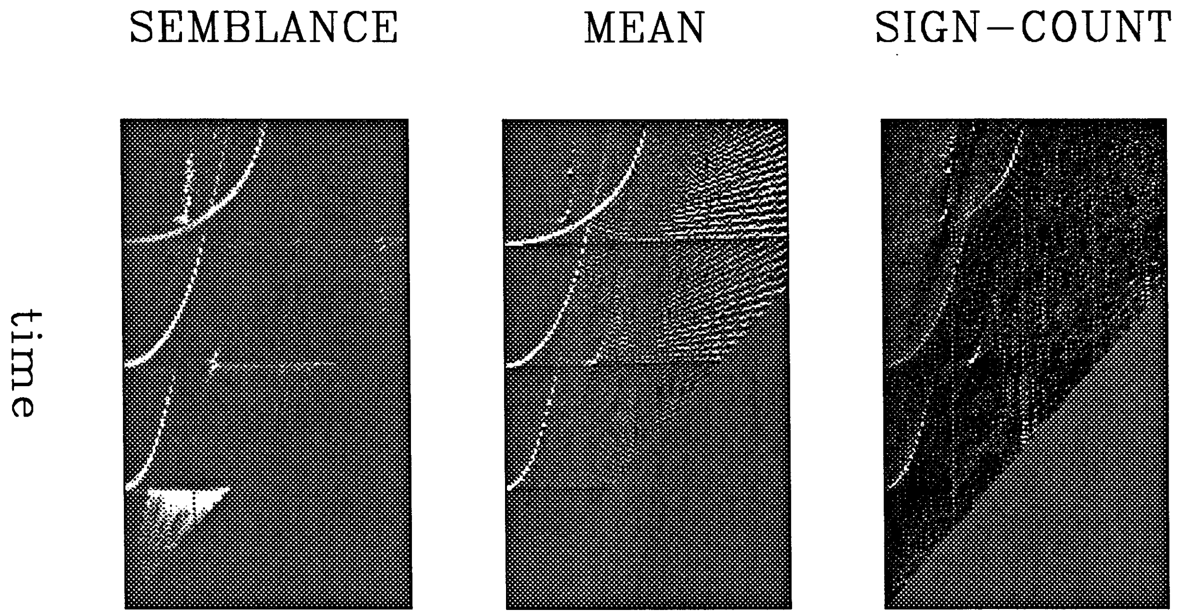

FIG. 5. Slant stack results for well-sampled offsets. The signal discrimination is poor. However, the slant stack artifact reduction is good. The effective slant stack summation aperture, the Fresnel zone width, is too few traces for sign-count discrimination to be effective.

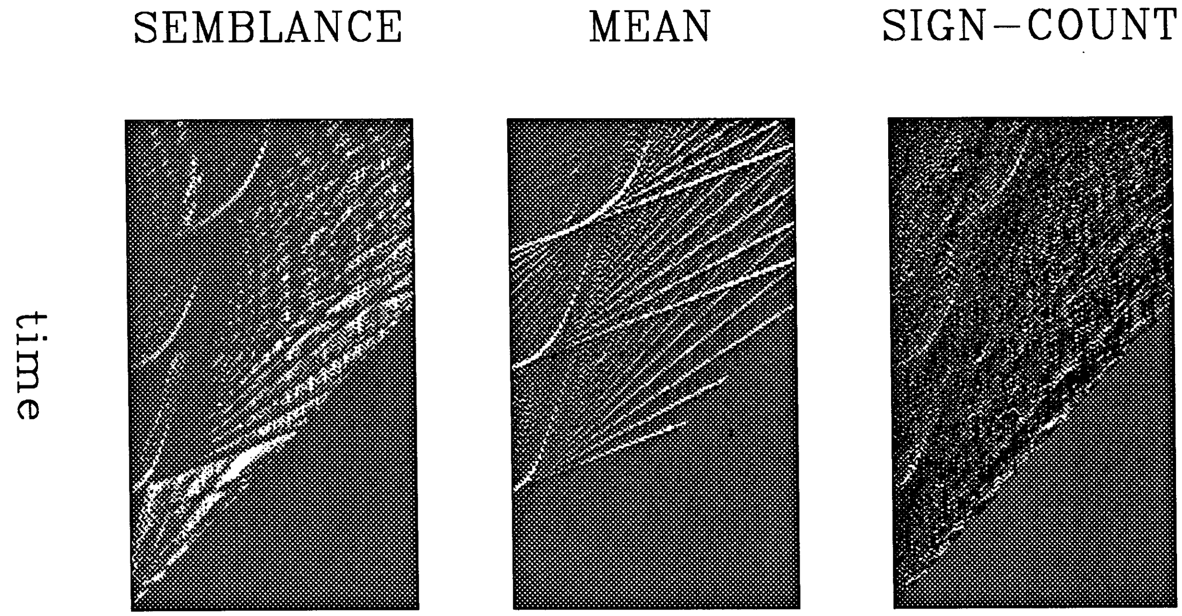

FIG. 6. Slack results stack for poorly-sampled offsets. The signal discrimination is even worse than Figure 4 for the same reasons. There are relatively few artifacts though.

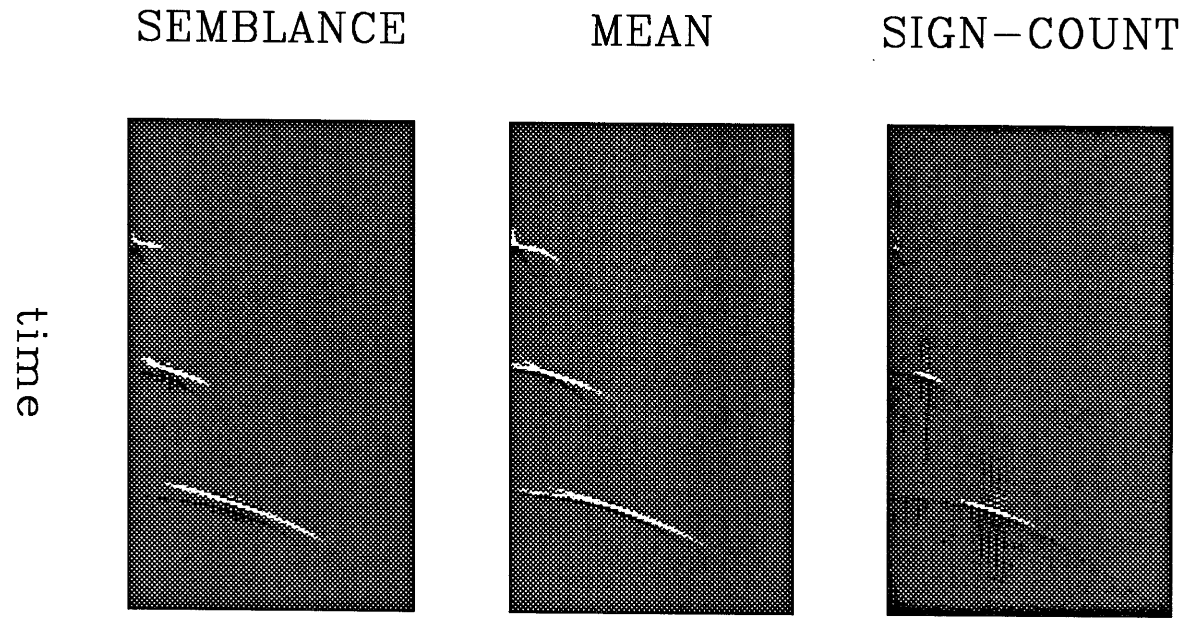

FIG. 7. Beam stack results for well-sampled offsets. The beam aperture was 25 traces, or a quarter of the offsets. The sign-count signal discrimination is superior to semblance. Event tail artifacts are non-existent.

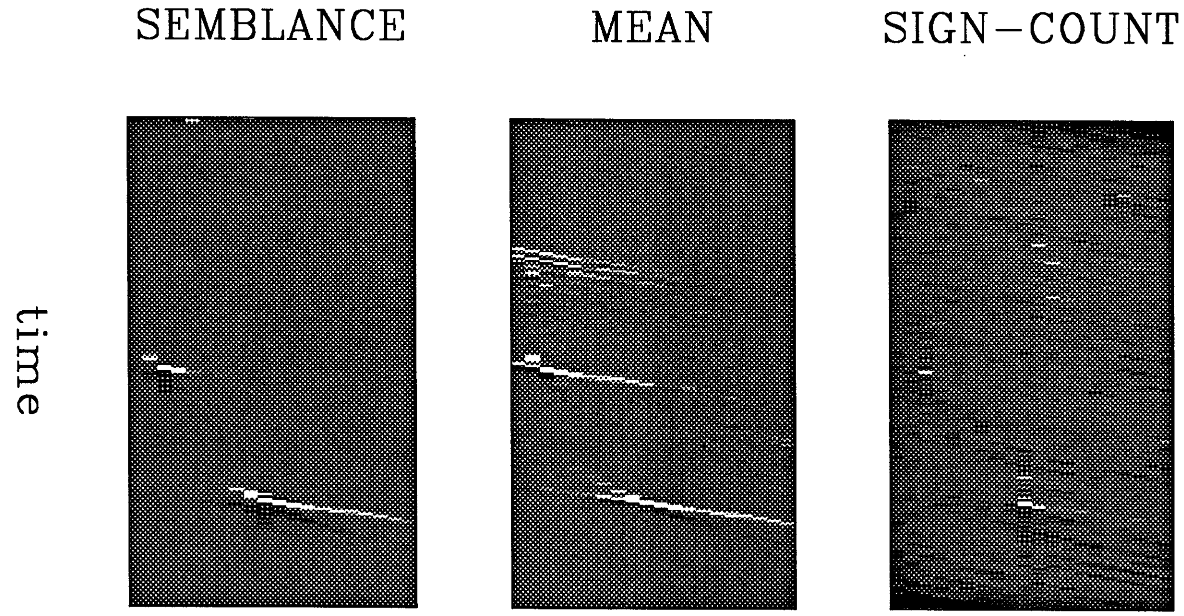

FIG. 8. Beam stack results for poorly-sampled offsets. The beam aperture was 25 traces, exceeding the offset number. Again, the signal discrimination and artifact attenuation is superior to semblance.

CONCLUSIONS

Sign-count signal discrimination and artifact reduction was a good as conventional semblance for hyperbolic stacks and beam stacks. It not work so well for slant stacking because the effective number of traces contributing to the result was too small. Slant stacking can be improved, however, by starting with beam stacks as suggested by Kostov and Biondi (1987).

In 1973 (Cochran) sign-count analysis was computationally interesting because it consumed less computer memory. This advantage is less significant today except when applied to 3-D surveys and kiloseis arrays (Cole, 1988). The major computer cost now is computing the stacking trajectories.

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Geophysical equipment donated for seismic study

Amoco Production Co. has given Stanford geophysical equipment worth more than $1 million to be used in the Geophysics Department's worldwide studies of the earth's crust.

The equipment — primarily 200 Seismic Group Recorders (SGRs) — will be used by the U.S. Geological Survey, Stanford and research personnel from other universities to record seismic waves at various locations around the world. Seismic waves from small explosions provide an image of rock structures in the earth's crust and upper mantle.

Research goals include a better understanding of earthquakes and volcanoes and of the processes that build mountains, create sedimentary basins and concentrate mineral resources.

In addition to the SGRs, the gift includes multiple seismometer arrays and complete supporting equipment including a playback computer to analyze data and a trailer to house the equipment.

Eighty-five of the instruments already have been deployed by Rice University geophysicists in the Brooks Range of Alaska, according to Dean George A. Thompson of the Stanford School of Earth Sciences. He added that the full set of 200 SGRs will be used by Stanford Prof. Jon Claerbout this month in an attempt to record seismic signals created by ocean waves. In November the instruments will be used in Washington by Thompson and his graduate students in an experiment on the Columbia Plateau.

"The gift of SGRs gives the academic research community a capability it did not have and could not otherwise afford," Thompson said. "Geophysical research in academic institutions has benefited enormously from state-of-the-art instrumentation developed by the oil and gas exploration industry."

According to Thompson, the SGRs allow the academic community to explore the entire earth's crust in key areas, thereby serving both teaching and research objectives.

"This set of SGRs is not only a gift to Stanford but indirectly a gift to universities throughout the country associated with international crustal studies," said Gordon Greve, manager of geophysics for Amoco Production Co., the worldwide oil and gas exploration and production subsidiary of Amoco Corp. "It gives students the opportunity to learn how to use the equipment and plan field experiments."

Stanford will act as the prime repository for the system and will coordinate its use by other research institutions. The Menlo Park branch of the U.S. Geological Survey, a partner in research with the Stanford Geophysics Department, will help to provide maintenance, repair and improvements for the system.