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Testing the viability of 3-component active-source recording with “Texans”

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Introduction and Motivation

EarthScope aims to understand lithospheric structure and continental evolution through integrated, multi-scale studies of North America. The High Lava Plains (HLP) experiment in September, 2008, offered an opportunity for an innovative piggy-back experiment to collect three-component (3C) active-source seismic data using RT-125 “Texans”. Prior to this experiment Texans were limited to collecting single-component (vertical) data. This piggy-back experiment used a specialized harness developed at PASSCAL to connect 900 EarthScope Texans to 300 3C 4.5-Hz geophones at 100-m spacing. Here we test if the 3C Texan recording was successful; if so, this methodology can be used routinely in future studies. 3C data at the crustal scale has the potential to markedly expand the utility of active-source datasets in number and types of analyses that can be applied in crustal studies.

Initial Steps

- Use a higher frequency source (a sledgehammer) with minimal source-to-geophone spacing to better analyze the temporal precision.
- Cross-correlate corresponding traces from the three components to quantitatively determine the temporal precision of the individual components.
- Con irm that the horizontal components successfully recorded shear-wave energy.

Background

The High Lava Plains (HLP) experiment in September, 2008, collected seismic data to examine the lithospheric structure of southeastern Oregon. At the surface, the area is mostly obscured by Cenozoic basalt lows. The HLP is considered the best example of active intraplate continental volcanism in the world. Geophysical data will help elucidate upper mantle structure, Moho structure, the extent of magmatic underplating, and detect possible mantle plume conduits. A series of 15 shots ran approximately north-south and east-west (Figure 1) and approximately 2612 RT-125 Texans deployed for single component seismic data. A piggy-back experiment collected 3-C data using the Texans and 3C RT-130 dataloggers. The Texans and the RT-130’s were deployed at 100 m station spacing.

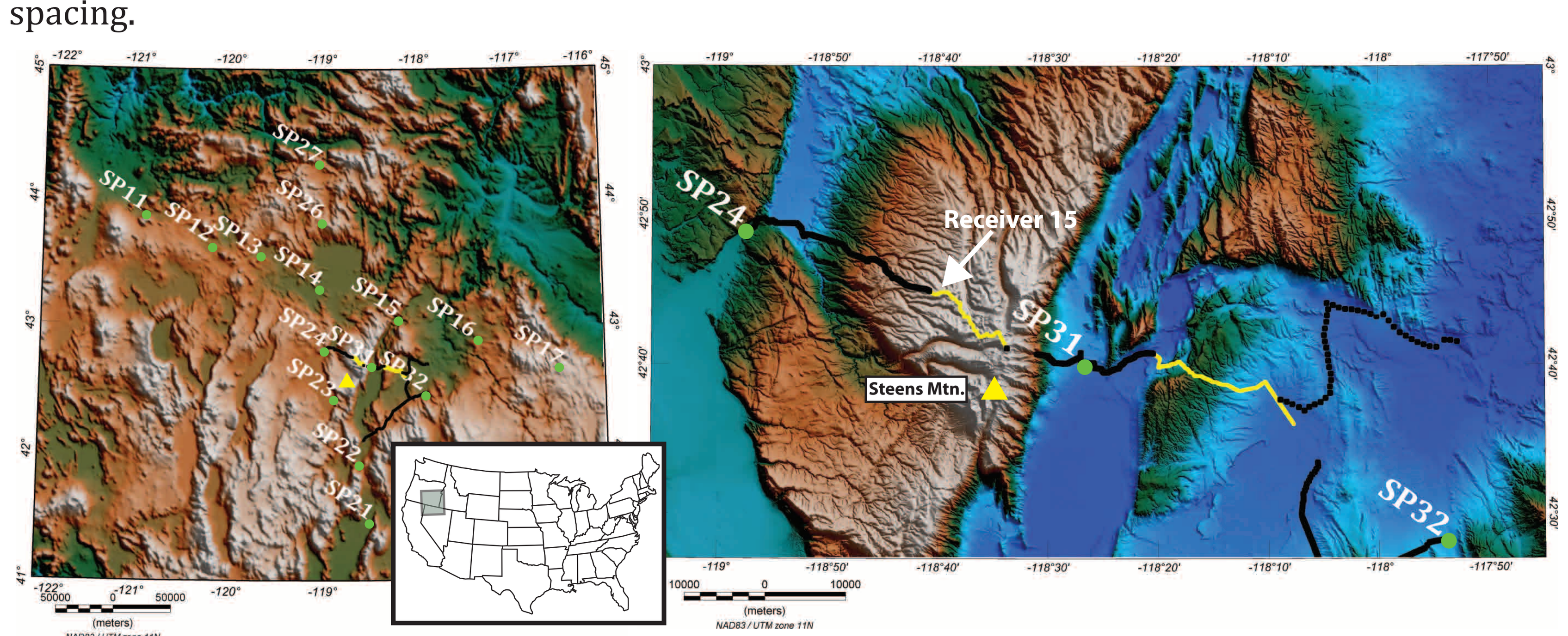


Figure 1: Digital elevation models (DEM) showing the ield area with shot locations and 3C RT-125 Texan locations. a) DEM of the entire HLP ield area. Yellow dots denote 3C Texan locations. Black dots denote a subset of 1C Texan locations focused on the southern portion of Devine Canyon. Green dots denote shot locations. b) High resolution DEM of the 3C Texan deployment locations. White arrow denotes receiver data used in poster. Steens Mountain, denoted by yellow triangle, is the site of the best exposure of feeder dikes in the HLP.

Acknowledgements

We thank the HLP deployment teams, particularly Steve Harder and Galen Kaip for planning and logistics. We owe a very special debt of gratitude to Mike Fort and Lloyd Carothers for shipping Texans and help programming and of loading the data for the high frequency data collection. Thanks to Jefferson Chang for Matlab and general coding assistance.

Three-Component Data Collection using “Pigtails”

3C data collection using Texan dataloggers uses three Texans connected to one 3C 4.5 Hz geophone via a split cable system referred to as “pigtails”. Each Texan records a single component (N,E, or Z), and the pigtails are color-coded to identify the three components. The pigtail connectors to the Texans are identical to the vertical geophone cables and are spliced together so all three “Texans” can be joined to the 3C geophone.

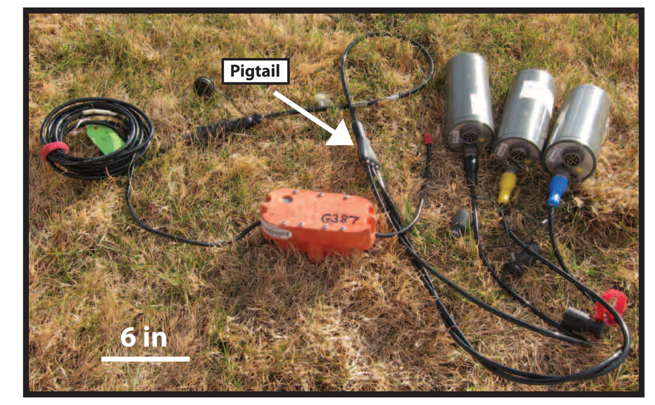
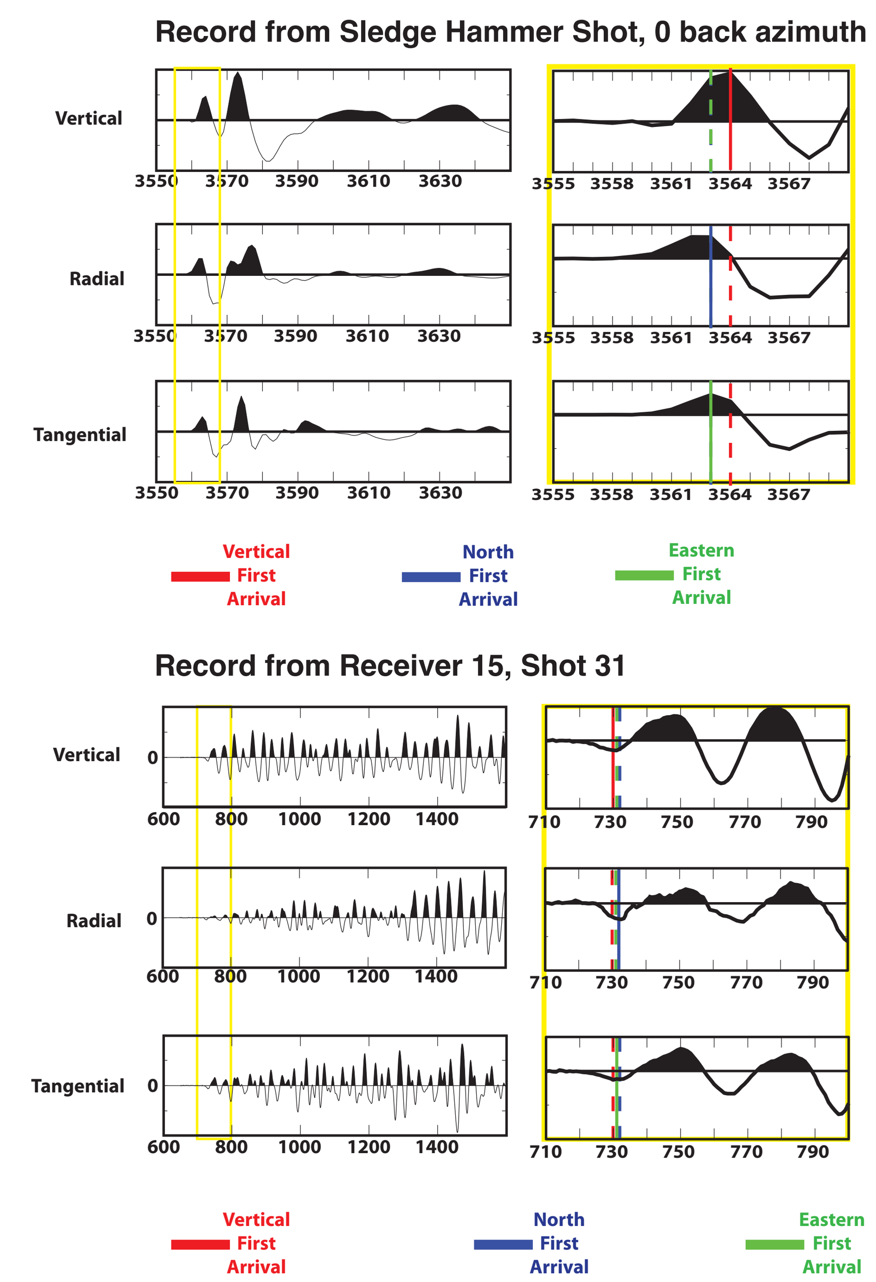


Figure 2: 3C Texan assembly

Time Stability Analysis

Precise time correlation between the three channels is required. Prior to this work, the time stability of the Texan with the pigtail setup had not been tested. High frequency data were collected using a sledgehammer with a source offset of 1.5 m with back azimuths of 0°, 30° and 300°. A side-by-side comparison of the vertical, north and east components show a maximum time difference of ± 1 ms. This is the same as the sampling interval. The HLP data are lower frequency and the time stability could only be veri ied to be within ± 5 ms.



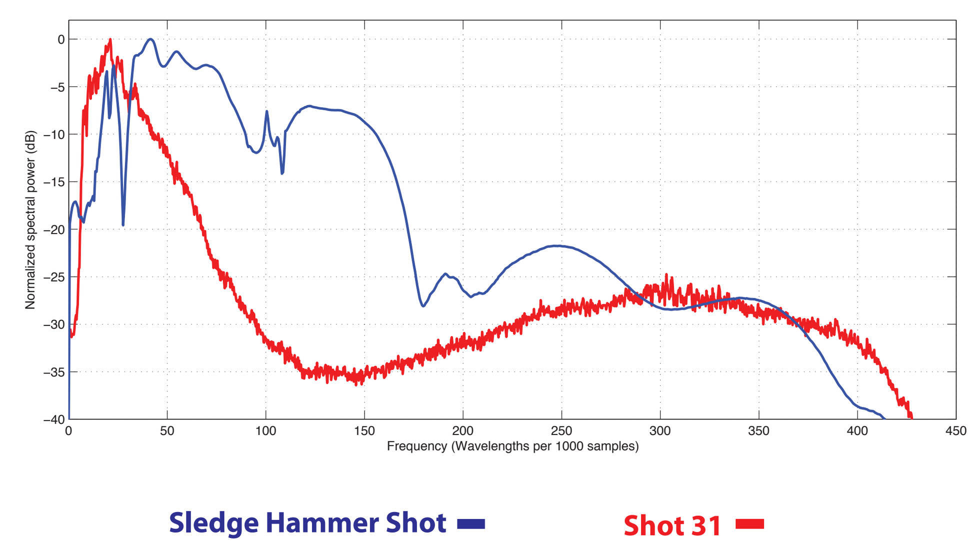


Figure 3: Top: 3C record from high frequency data showing precise time correlation. Right: 3C record from Shot 31. Above: Frequency spectrum of shots.

Statistical Analysis of Geophone Orientation

Field problems resulted in a number of geophones that were not oriented properly (i.e. horizontal components were not north and east). From particle motion, we can determine the approximte back azimuth, and properly rotate the components.

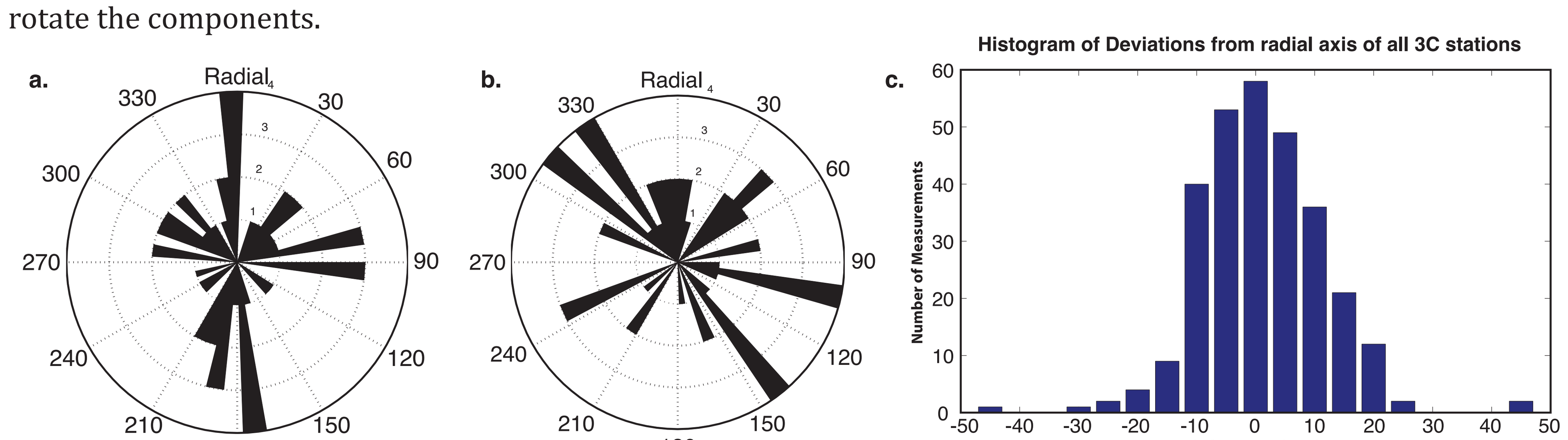


Figure 4: a. Rose diagram showing angle from radial axis for one properly aligned station. Note most of the angles lie approximately on the radial axis. b. Rose diagram showing angle from radial axis for one improperly aligned station. The predominant angles are approximately 30° from the radial axis. c. Histogram showing distribution of stations with deviation angle from the radial axis. Approximately 20% of the stations were not properly aligned, which matches the number of stations found improperly oriented in the ield.

Particle Motion Diagrams

We rotated the traces from the north and east components to radial and tangential components. After rotation, virtually all energy is seen on the radial trace and very low amplitudes are seen on the tangential, as expected.

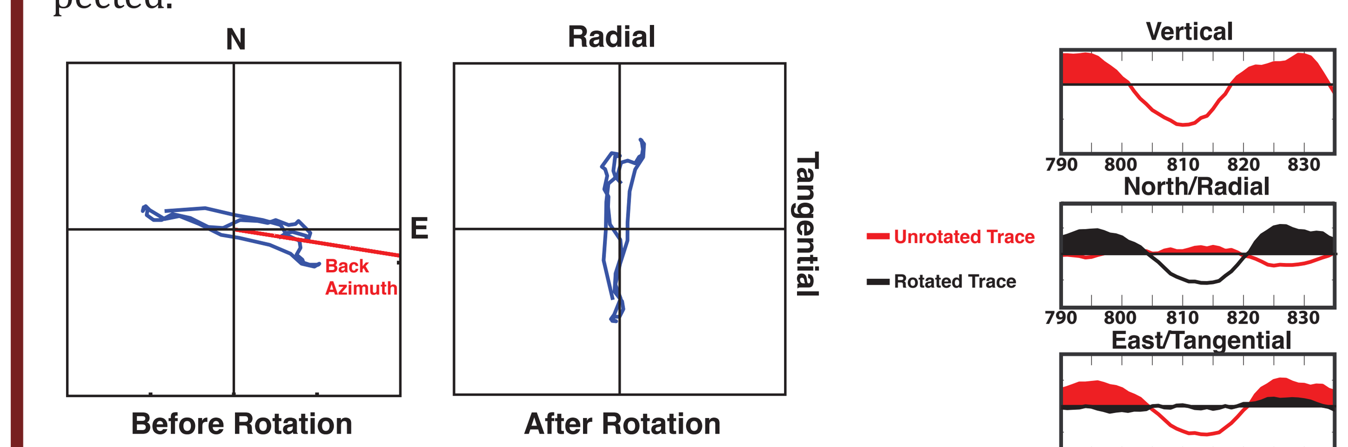


Figure 5: Particle motion of a representative trace from the 3C dataset. Green line on diagram represents back azimuth of station from shot 31. Seismograms showing original traces (red) and rotated traces (black).

Shear Waves Observed on Horizontal Components

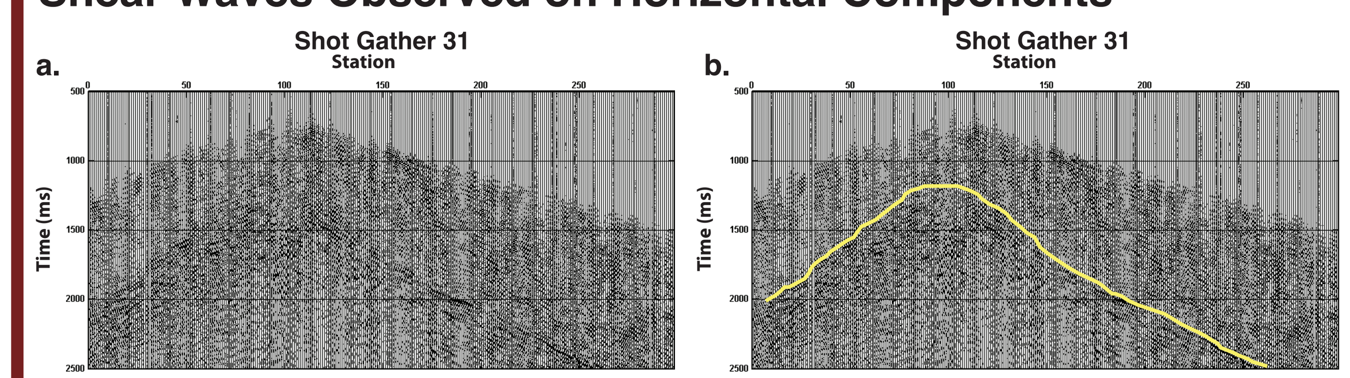
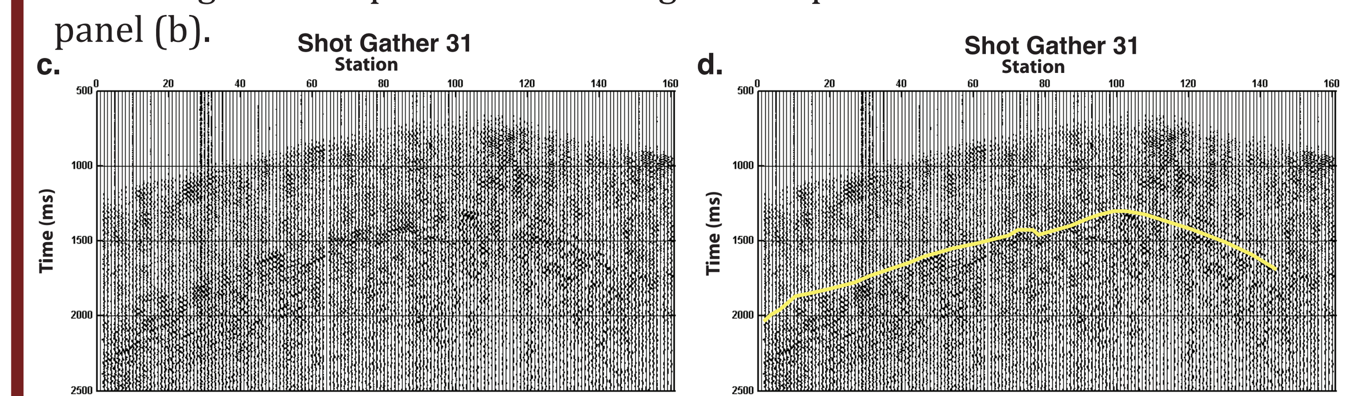


Figure 6: a. Shear wave arrivals seen on section using north components. b. Interpreted shear wave arrivals from panel (a). c. Shear wave arrivals seen on section using east components. Lower right: Interpreted shear wave arrivals from panel (b).



Initial Results

- The seismic energy is recorded by each component within ± 1 ms (equal to the sampling rate).
- The horizontal components show strong shear wave energy (Figure 6a and c).
- Improperly aligned stations can be identi ied using particle motion diagrams (Figure 4c).

Planned Analyses

- We will use single and three-component data from near Steens Mountain to develop a small-scale, high resolution tomographic velocity model.
  - Steens Mountain lies within the southern section of Devine Canyon, where the majority of the magmatic activity occurred.
- Shear-wave splitting analyses will be done to analyze anisotropy of the upper crust.