Harsh imaging techniques for shallow high resolution seismic data

David C. Henley (Consortium for Research in Elastic Wave Exploration Seismology)

Summary

There is increasing interest in the use of high resolution seismic methods to image the shallowest layers of the earth. The various objectives include bedrock features, buried cultural structures such as pipelines, and paleontological or archaeological anomalies. Shallow surveys are often carried out with some difficulty under non-ideal conditions, however, and the resulting data may be poor in quality and sparse in fold or coverage. Presented here are the results of using some unconventional, rather "harsh" techniques to image data from two components of a 3-C seismic survey conducted in the vicinity of archaeological ruins in Belize during the summer of 2000 in order to locate interesting subsurface features. Positive identification of the 3-C components remains uncertain, but images for both 'vertical' and 'inline' components of the survey show similar subsurface features.

Introduction

Shallow high resolution seismic data frequently present imaging difficulties because they are often acquired with portable seismic acquisition systems having a limited number of channels, using inexpensive surface sources like sledge hammer or projectile impacts. The consequence of the channel limitation is often insufficient fold for combating noise, uneven binning, and either a limited source-receiver offset range or inadequate spatial sampling. The consequence of using a surface source, on the other hand, is often a high level of source-generated noise on the records. Under these circumstances, conventional processing, with its goal of imaging both structure and character of seismic data, often fails to satisfactorily image even the structure. Since the imaging objective for shallow data is often just the structure, the opportunity arises to use techniques that emphasise structural coherence, sometimes at the expense of character.

A 3-C survey acquired in Belize in the summer of 2000 with a portable seismograph and sledge hammer (Stewart, 2000) exhibited all the characteristics described above and hence became a prime candidate for unconventional imaging techniques. To illustrate the difficulties with the data, Figure 1 shows receiver gathers from the tentatively identified 'vertical' component of the Belize survey, while Figure 2 shows comparable receiver gathers from the 'inline' component. Almost all the visible energy on either set of gathers is linear source-generated noise; it is difficult to distinguish between the two components by inspection. Only during processing was the current tentative identification of these components as vertical or inline adopted, a designation which disagrees with that made in the field.

Harsh Imaging Techniques

Because of the sparsity of the Belize data and their very poor signal to noise ratio, imaging efforts focussed on techniques which sometimes consciously trade lateral resolution and vertical bandwidth for increased coherence. Radial trace dip filtering, supergather processing, and "wavefront healing" all constitute elements of the "harsh" methods used on these data. Radial trace dip filtering, described by Henley (2000), was used in preference to F-K velocity filtering because it is relatively free from lateral smearing; and several filter passes, designed for specific noise modes, can be applied sequentially. Supergather processing increases the coherence length of linear events dominating input gathers, and improves their attenuation in the radial trace domain. Wavefront healing is a process in which simulated Huygens wavelet propagation through an isotropic medium blurs and smoothes irregular reflection wavefronts, explicitly trading resolution and bandwidth for coherence.

Normal moveout (NMO) velocities, determined from filtered common-offset supergathers, led to tentative identification of the vertical and inline components, based on their dramatically different NMO velocities. The two components were subsequently processed as P-wave and converted-wave (P-S) data, respectively. The only differences in the processing flow for the two components were the velocity used for NMO correction, wavefront healing, and migration; and the binning, which was common midpoint (CMP) for the vertical component and common conversion point (CCP) for the inline component. The general processing flow was: 1) several sequential passes of radial trace dip filtering on shot supergather; 2) NMO velocity determination and application on common-offset supergather; 3) stack of CMP gathers (or CCP gathers for inline component); 4) wavefront healing; 5) migration; 6) minimum phase predictive deconvolution.

Imaging Results

Figures 3 and 4 show the results of using harsh techniques on the vertical and inline components of the Belize data set, respectively. Figure 3 contains mostly compressional reflection energy, while Figure 4 is mostly converted (P-S) energy. The strong reflection at about 12 ms in Figure 3 corresponds to the reflection at 36 ms in Figure 4. The obvious anomaly between CMP 20095 and 20125 on the P section appears between CCP 20090 and 20145 on the P-S section; and a smaller anomaly between points 20005 and 20020 on the P section occurs on the P-S section between 19990 and 20015. Interestingly, the apparent S velocity is so low with respect to the P velocity, that the vertical resolution of the P-S section exceeds that of the P section; but the lateral resolution of the latter is superior.

After these results were obtained, each component was imaged again using the processing flow for the other component. Surprisingly, it is possible to form an acceptable vertical image from the inline component, and vice versa. This observation implies that both P and P-S energy are strongly represented in both wavefield components, and that an image of these data depends more on the processing flow used to create it than on which component was used. This further suggests that for very shallow, unconsolidated sediments with very large Vp/Vs ratios, the usual particle motion components at the earth's surface may not be predominantly pure P or S modes. The previously noted difficulty in distinguishing between the vertical and inline components by inspection is consistent with this finding.

Conclusions

Shallow high resolution seismic data sometimes present unique imaging challenges because of their typically low fold, high coherent noise, and irregular bin population. Nevertheless, useful images can sometimes be formed from such data, if the processing sequence is altered, and if some less conventional 'harsh' operations are included in the flow. Another interesting observation is that the image obtained depends more upon which processing flow is applied than on which seismic component is processed, for these very shallow, unconsolidated sediments.

Acknowledgements

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References

Henley, David C., 2000, Wavefield separation in the radial trace domain, Geo-Canada 2000 Expanded abstract No. 131
Stewart, Robert R., 2000, Personal communication.

Figures

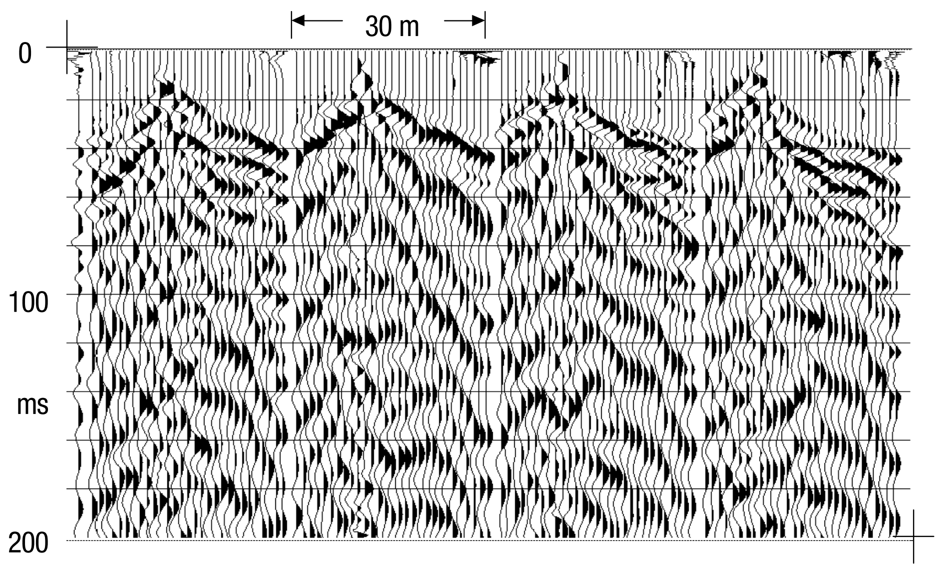

Figure 1. Presumed 'vertical' component receiver gathers from the 2000 Belize high resolution 3-C seismic survey.

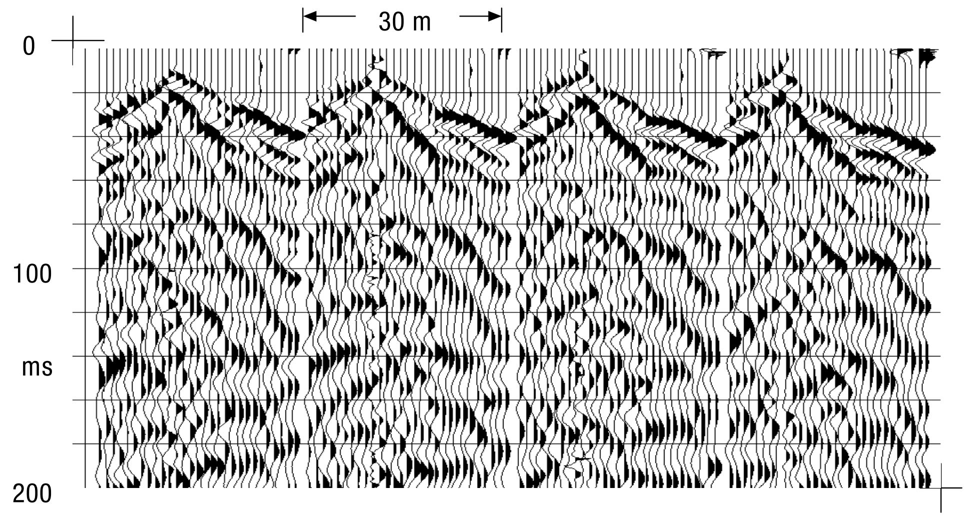

Figure 2. Presumed ‘inline’ horizontal component receiver gathers from the 2000 Belize high resolution 3-C seismic survey.

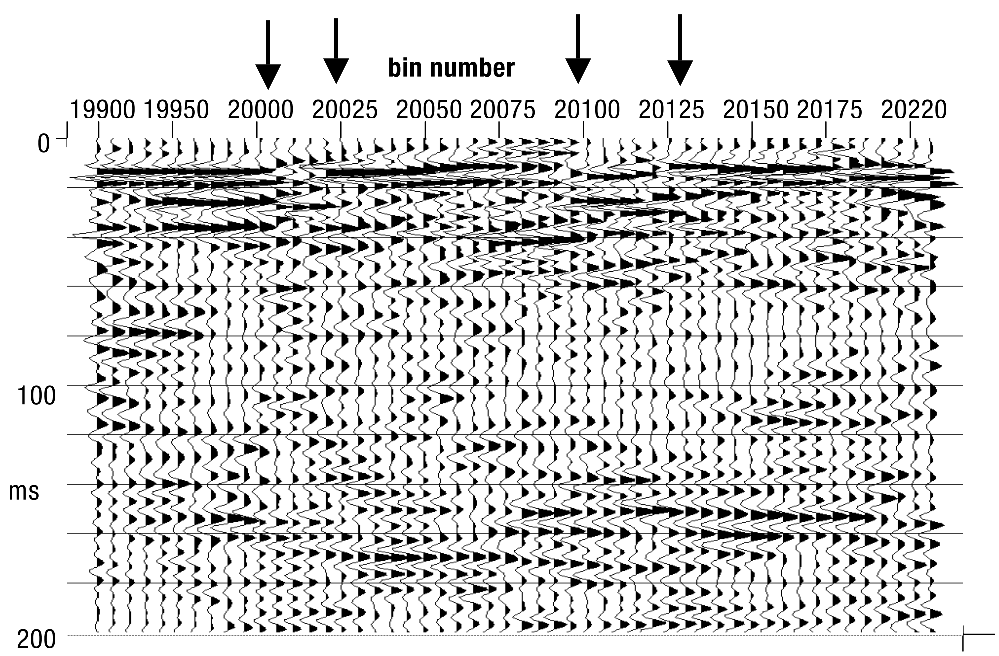

Figure 3. CDP stack of ‘vertical’ component data after wavefront healing, Kirchhoff migration, and predictive deconvolution.

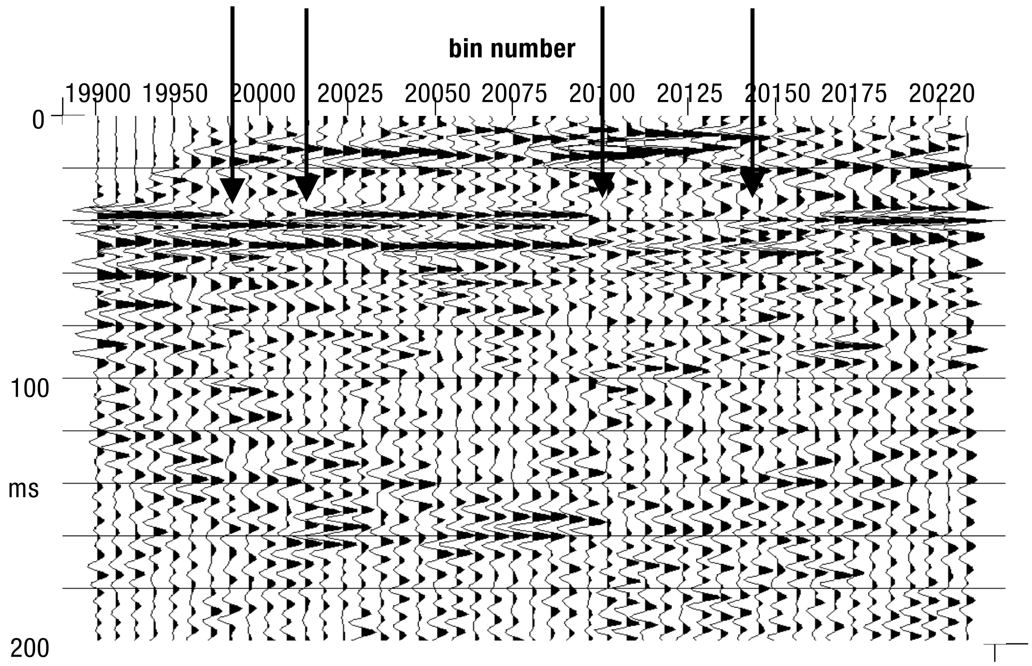

Figure 4. CCP stack of 'inline' component after wavefront healing, Kirchhoff migration and predictive deconvolution. Remarkably high frequencies are recovered for the events between 40 and 60 ms.