New imaging results at the Chan Chich archaeological site

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SUMMARY

The Chan Chich archaeological site in Belize has been the location for two experimental high-resolution 3-C seismic surveys, one each in 2000 and 2001. In spite of poor data quality on the 2000 survey, interesting images were produced for both the vertical and inline horizontal components of the survey. In spite of an unexpected ambiguity between the two components, two of the images showed a shallow anomaly of interest to archaeologists as a possible indication of an unexcavated burial site. The 3-C survey conducted in the summer of 2001 was characterised by better spatial coverage and higher quality data. Two images have been obtained so far from the newer data; a P-P reflection image and a turning ray tomographic image from first break times. These images jointly confirm the existence of an anomalous near surface zone.

INTRODUCTION

One of the more interesting uses of near-surface seismic techniques is surveying archaeological sites to help locate potential targets for excavation. In this connection, a near-surface 3-C survey was conducted at the Chan Chich archaeological site in Belize in the summer of 2000, to test the method and to attempt to image any anomaly associated with a suspected but unconfirmed burial site. Field conditions and equipment difficulties contributed to the poor quality of the resulting seismic data. Nevertheless, efforts to form images from two of the three components were successful (Henley, 2001). Several interesting results emerged during the course of these imaging efforts: Both the P and S velocities of the surface earth materials were extraordinarily low and the ratio of P velocity to S velocity was quite large; P-P and P-S energy are both strongly present on both the vertical and inline horizontal components of the data; and a shallow anomaly was observed near the centre of two of the resulting P-P and P-S images.

The near-surface earth at Chan Chich is known to consist of a high-velocity carbonate bedrock overlain by low-velocity unconsolidated material, with a large velocity gradient above the carbonate interface. In such an environment, only a fraction of the total seismic energy will travel nearly vertically downward from the source to penetrate the bedrock and be reflected from deeper layers; the bulk of the energy will propagate laterally in the near-surface, some of it emerging at the surface as first arrivals. This situation makes it likely that first break time picks can be used in turning ray tomography to successfully image the near surface velocity structure at Chan Chich. Thus, with data of the appropriate quality, tomography might be useful for obtaining another image supplementary to a reflection image. Fortuitously, a new 3-C survey was conducted in the summer of 2001 over the same profile as the 2000 survey. The newer survey has both more complete spatial coverage and better quality data. Consequently, two images have thus far been obtained using the vertical component data only; a P-P reflection image and a turning ray tomographic image from the first break picks. Both images show a low velocity anomaly near the centre of the survey profile.

DETAILS

Both the 2000 and 2001 seismic surveys were acquired using 3-C surface phones, a 60 channel portable seismograph unit, and a sledge hammer as a surface impact source. The technique for both surveys was similar: The 20 station spread was laid out with 1 metre station spacing; and the source position was moved through the spread from one end to the other, taking a “shot” at each new position. In 2000, records of each of several impacts of the hammer at each source position were stacked to build up source energy, while in 2001, a single impact was used at each source point. Because of the surface source, the records of both surveys are dominated by near surface source-generated coherent noise; but the noise level on the 2001 data is lower. This may be due to either the single impact technique, or to the distinctly different surface conditions between the 2000 and 2001 surveys (very wet in 2000, very dry in 2001).

The image in Figure 1 is the P-P reflection image from the CMP stack of the 2000 vertical component data. A key part of the processing required by this image was coherent noise attenuation (Henley, 2000) applied to a supergather of all the traces. The strong reflection at about 12 ms marking the carbonate bedrock interface shows weaker amplitudes, a slight time sag, and an underlying fragmentary reflection just to the right of the centre of the line. The same anomaly can be seen in Figure 2 on the P-S converted wave section, on the carbonate interface event at about 36 ms. This image was formed from the inline horizontal component of the data via coherent noise attenuation and a CCP stack. A remarkable feature of these two images is the extremely low moveout velocities encountered for both the P-P reflection and the P-S converted wave; 300 m/s for the former and 75 m/s for the latter. Since part of the travel path for the P-S energy is associated with the P velocity of 300 m/s, the shear velocity must be quite low to give a combined P-S moveout velocity of 75 m/s.; perhaps as low as 50-60 m/s..

In contrast, Figure 3 shows the P-P reflection image obtained from the 2001 vertical component data. Once again the most prominent feature of the image is the carbonate interface reflection; but it is much shallower in time in this image than in the 2000 P-P image. Furthermore, the moveout velocity determined during the processing was over 600 m/s, twice that of the 2000 data. This event is so shallow, however, that its offset range is rather limited, and its velocity less accurately estimated. The dramatic difference between the P-P reflection images for the two surveys is thought to be due to the difference in the surface conditions. The very wet surface materials in 2000 may have been near saturation with water, causing the materials to act almost like a fluid-supported sediment, while the same materials in the drier year 2001 would have been more nearly grain-supported. Of more interest, however, is the presence of a clear anomaly in the centre of the profile—a weakening and slight time sag of the reflection accompanied by an underlying reflection fragment.

Because the data set is small (21 gathers of 20 traces each) the first breaks were manually picked and edited for input to the turning ray raytracing and tomography modules in ProMAX. A layercake starting model was chosen for the raytracing, with velocities similar to those determined during the P-P reflection processing. This model is shown in Figure 4, with an approximate aspect ratio of 1:1. Note that the surface velocity of this model is 500 m/s, slightly lower than the P-P moveout velocity; there is a large velocity gradient at about 3 m depth, corresponding to the carbonate interface; and a gentler gradient beneath that results in a velocity of 1200 m/s at 6 m depth. With this model, most of the attempted rays generated by the raytracing module will remain inside the 6 m depth range—in fact the depth of the model is constrained so that rays corresponding to reflection energy travelling through the carbonate interface to deeper layers are excluded, since they are clearly not a part of the turning ray solution. After considerable model adjustment, raytracing, and time pick evaluation, a tomographic solution was found which minimised the errors between the input picks and raytraced travel times after four iterations of the tomographic algorithm. That solution is shown in Figure 5. In addition to reducing the steep velocity gradient above 3 m, it can be seen that the solution shows a significant trench in the carbonate interface, filled with lower velocity material (750 m/s compared with 1100 m/s on either side). For comparison, Figure 6 is a close-up of the top portion of the P-P section in Figure 3, in which the time scale has been stretched to approximately match the anomaly reflection with the trench bottom shown in Figure 5. As an additional point of comparison, note that the lower loop of the P-P reflection in Figure 6 shows a slight time sag to the right of the anomaly, and that the tomographic image in Figure 5 shows a region of near surface low velocity in about the same area.

DISCUSSION

The near surface anomalies in the P-P and P-S images of the 2000 Chan Chich data, while interesting, were not compelling because of the poor quality of the raw data and the strenuous processing required to obtain the images. The observation of a relatively unambiguous anomaly on images from the better quality 2001 survey is more persuasive, particularly because the two images were obtained from nearly independent attributes of the data set (P-P reflection waveforms, and first break arrival times). The agreement between the two images is striking, and their information was considered interesting enough to forward to the archaeologist supervising the site work at Chan Chich. Hopefully, future excavation will confirm the near surface velocity model, even if the anomaly proves not to be of archaeological interest.

ACKNOWLEDGEMENTS

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References

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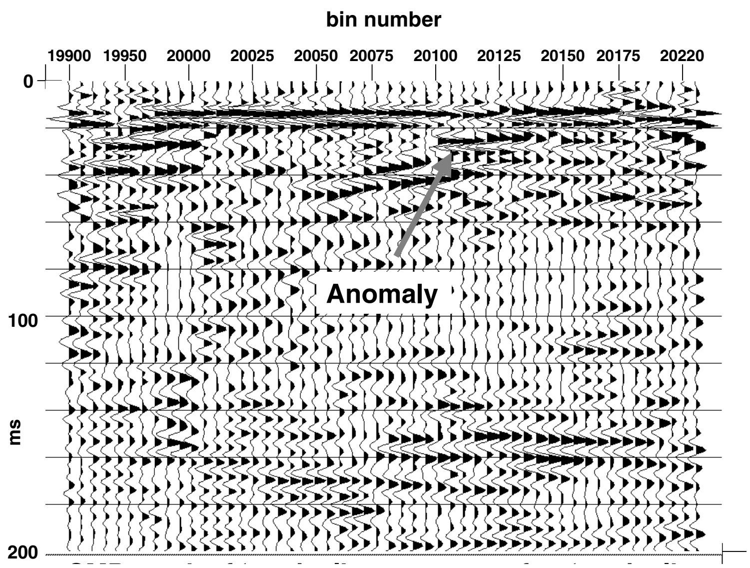


Figure 1. P-P reflection image formed from vertical component of 2000 Chan Chich 3-C seismic survey. Length of the survey is 20m

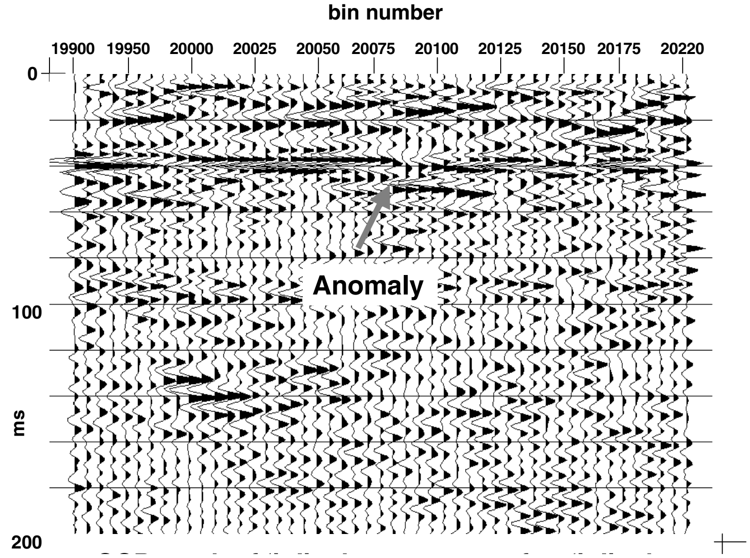


Figure 2. P-S image formed from inline horizontal component of 2000 Chan Chich 3-C seismic survey.

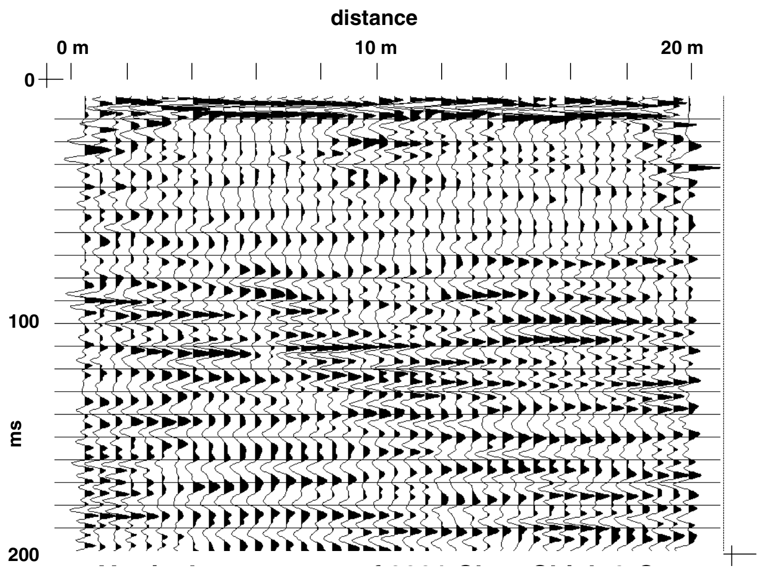
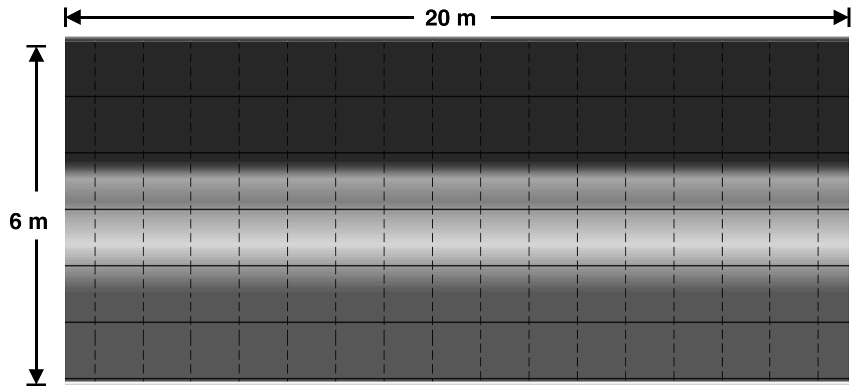
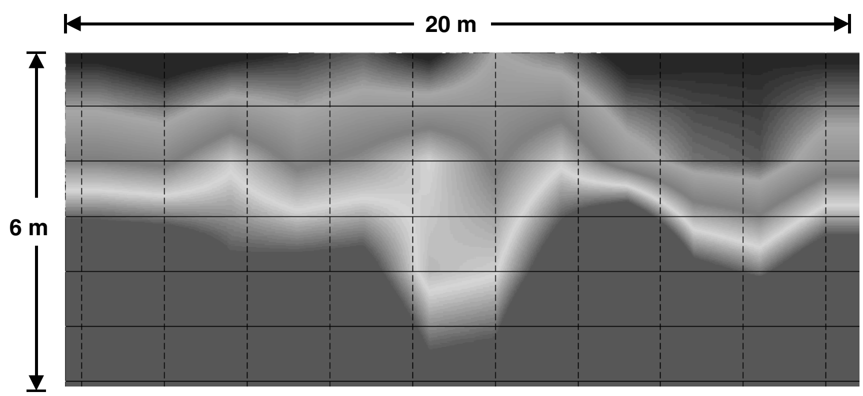


Figure 3. P-P reflection image formed from vertical component of 2001 Chan Chich 3-C seismic survey.



Starting velocity model for Chan Chich first break turning-ray tomography

Figure 4. Starting velocity model for turning ray tomography of first break times from vertical component of 2001 Chan Chich 3-C seismic survey. Velocity ranges from 500 m/s at the surface of the model to 1200 m/s at 6 m depth. There is a steep gradient just above 3 m to simulate the carbonate bedrock interface.



Turning-ray tomographic image of near surface at Chan Chich, from first breaks

Figure 5. Tomographic image of the near surface at chan chich formed from the first break times of the vertical component of the 2001 Chan Chich 3-C seismic survey.

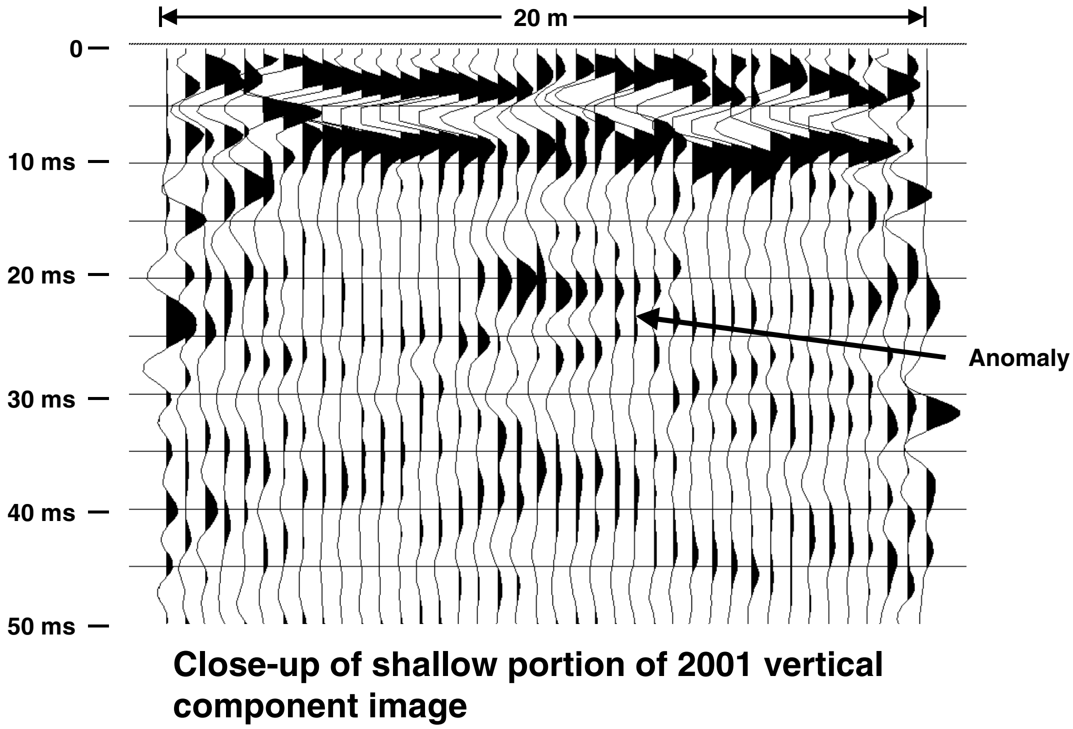


Figure 6. Close-up of P-P reflection section formed from vertical component of the 2001 Chan Chich 3-C seismic survey.