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Frontier Exploration Using Passive Seismic

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SUMMARY

We present a case history of 3-D seismic imaging in the Uinta Basin of Utah using passive seismic as an example of how passive techniques can aid exploration efforts in frontier areas. The area is topographically rugged making conventional seismic exploration expensive. Additionally, surface access is controlled by federal authorities and subject to stringent regulations which make permitting of conventional seismic almost impossible. The survey began in June, 2005. Over 12 months of passive data have been acquired. The catalogue of located events exceeds 6000 events. Tomographic inversion to a velocity model has shown structures of exploration interest.

Setting

Figure 1 shows the location of the survey area. The survey covers approximately 800 km^2 in the Uinta Basin, Utah in mountains that form part of the Laramide age Wasatch uplift. The area is sparsely populated with access limited to a very few roads along the floors of steep valleys. Most of the surface is controlled by federal authorities who impose strict rules on surface disturbance and encroachment on areas that may have archaeological significance. As a consequence seismic coverage in the area is very limited and new 3-D coverage is both difficult to justify and probably more difficult to permit. Yet, the area is prospective for hydrocarbon accumulation and in need of seismic coverage to evaluate its prospectivity.

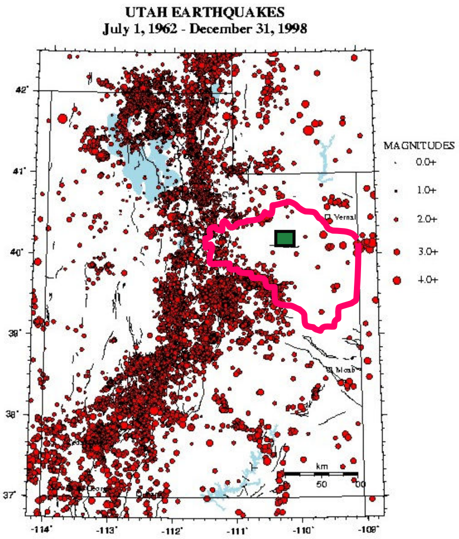

Figure 1: Survey area represented by the green rectangle. Pink outline is the Uinta Basin. Thin dark line is the Utah state line. Red dots are eathquakes reported by the USGS over the period 1962 to 1998.

An initial evaluation of the level of seismicity in the area using public domain sources was not very encouraging (see Figure 1). Government sources reported no seismic events in the survey area over a 25 year period. To test this observation, 3 portable seismometers were deployed in the area in 2003 for a period of two months. During that period several hundred small events were detected by the array. On the strength of this observation, sponsors for a 3-D passive survey were sought. That survey was funded and field work began in June 2005.

Survey Parameters

The survey plan called for 53 stations to be deployed in the survey area in three phases. Each station consisted of a single 3-component geophone set in a shallow borehole anywhere from 3 to 30 m below surface level depending upon local noise and soil conditions. Each geophone was connected to a portable seismometer that recorded 250 samples per second for each component continuously, 24 hours a day. Data were written to flash memory with a time stamp derived from a GPS calibrated time signal. Power to drive each station was supplied by a large capacity battery and a solar panel. Data were retrieved from each station by hand on average about once every two weeks.

During Phase One, 20 stations were distributed over the entire survey area for a period of two months in order to confirm the level of seismicity (see Figure 2). If the level of seismic activity were confirmed, another 13 stations were to be added to the array for two more months of observation as Phase Two. If the tomography results from these data showed promise of being useful to the exploration of this frontier area, then a further 20 stations were to be deployed for another 8 months to complete the survey.

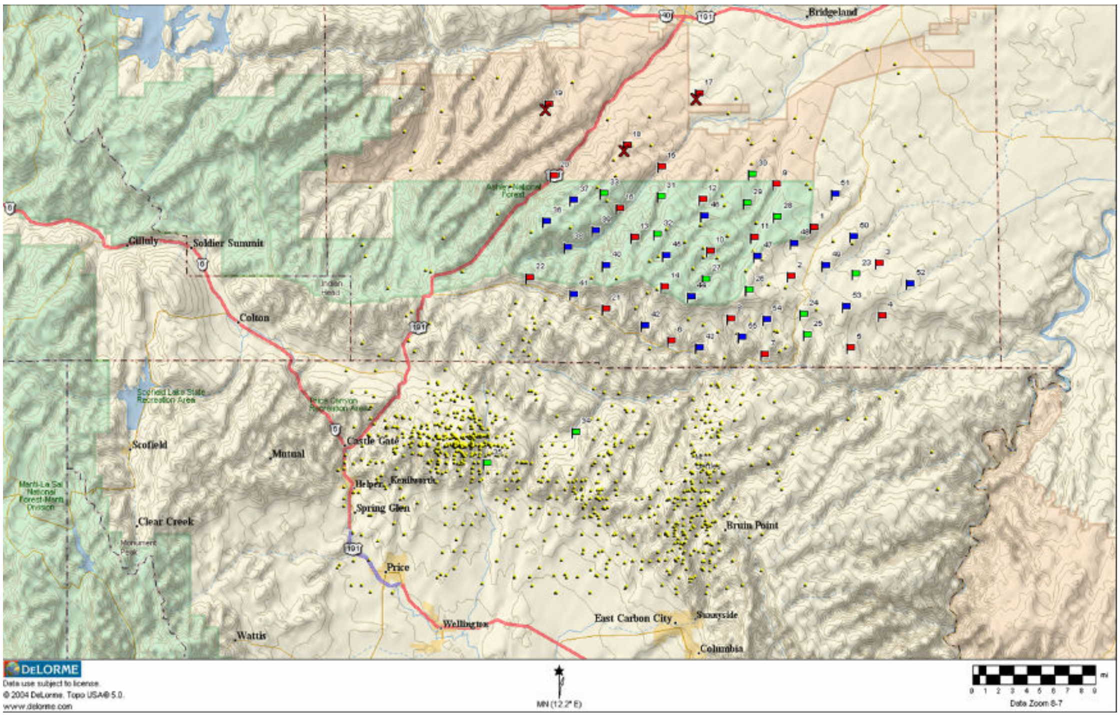

Figure 2: Survey area with yellow dots showing epicenter locations of event catalogue and flags for the survey stations - red for Phase One, green for Phase Two and blue for Phase Three.

The decision criteria for continuation of the survey beyond Phases One and Two were successfully met. However, heavy rains and snows, as well as some permitting issues, delayed the deployment of the Phase 3 stations until late spring 2006. At the writing of this abstract the stations are still in the field.

Data Processing

The data were consolidated on DVD and shipped to Houston. Processing consisted of the following steps: reformatting the data to SEGY, trace editing, filtering, triggering on events using an adaptive STA/LTA algorithm, visual inspection to reject false triggers, picking first arrival times on all possible stations for each valid trigger file, least squares inversion to estimate origin time and hypocenter location for each validated event, tomographic inversion to estimate the velocity structure in the prospect area using the event catalogue. New inversions were run at least once a month as the catalogue of events grew.

Survey Results

Figure 2 shows the epicenter locations of the event catalogue through December 2005. More than 3000 events had been located to that date, although most were to the south of the prospect area along the location of a major thrust fault. As a result of this distribution of raypaths, shallow coverage is not very good in the dataset. This caused us to alter our station distribution later in the survey and to permit a number of new locations for observation after the initial survey period had expired in order to fill in the holes in coverage.

Figure 3 shows a perspective view of the velocity inversion obtained from the arrival time picks of the events shown in Figure 3. The general agreement of this structure with some old 2-D seismic in the area led to the approval of the continuation of the survey to completion.

We anticipate being able to show the results of the completed survey at the conference in Dubai in December.

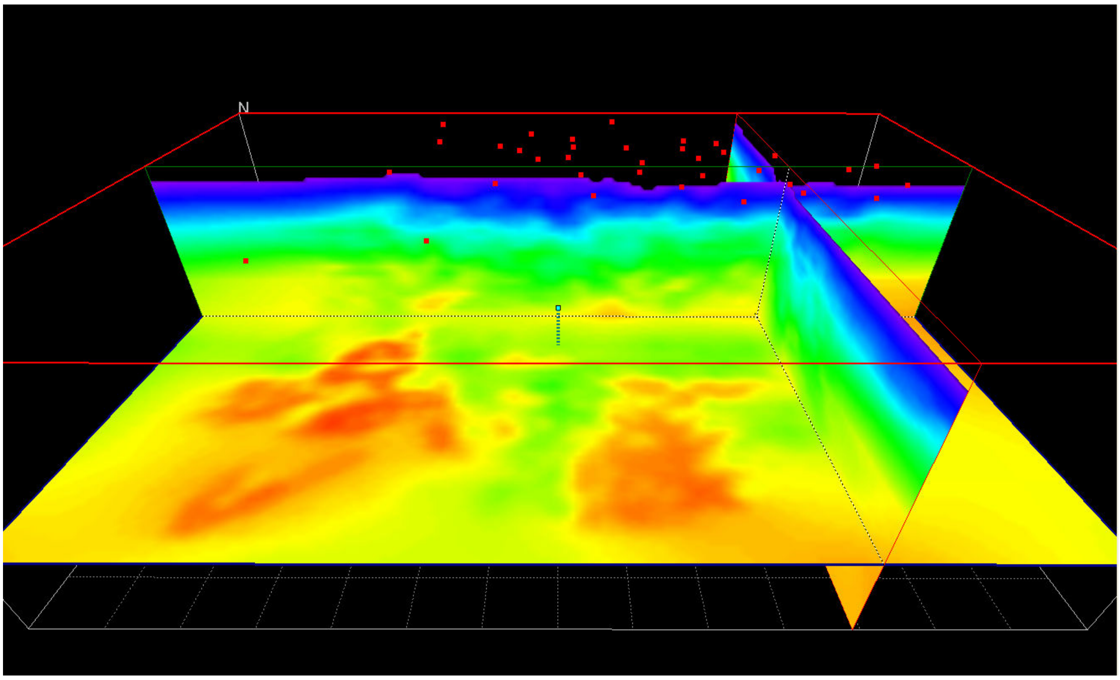

Figure 3: Result of velocity inversion of arrival time data for events in Figure 2. Hotter colors are faster velocities. Horizontal slice is at 2 km depth. Red dots are the station locations. Two basement structures are seen separated by a valley.