Geophysical Imaging of Possible Faulted Strata near Matagorda, Texas

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Introduction

We used ground-penetrating radar (GPR) and shallow seismic reflection methods to image the shallow subsurface across the surface trace of the suspected fault crossing tidal flats, marshes, and open water on Matagorda Peninsula near Matagorda, Texas. The fault is considered to be the possible surface expression of a deeper gulfward-dipping growth fault cutting Cenozoic strata.

Methods

Shallow seismic reflection and ground-penetrating radar data were acquired by researchers from the Bureau of Economic Geology and Texas A&M University in December 2008. Seismic and GPR data were processed at the Bureau of Economic Geology using the software package Seismic Processing Workshop (SPW) following procedures presented in Yilmaz (1987) and Young (2004).

GPR data were acquired using a GSSI SIR 3000 unit with a 200 MHz bistatic antenna, 100 kHz transmitter rate and 20 traces per meter. Record length was 100 nanoseconds (ns) and encompassed 512 samples per trace. Steel pipe fittings were buried to depths of 0.3, 0.6, and 0.9 m to provide depth control. Data were acquired along a single 10-m-long test line over the pipe fittings, a series of 30-m-long lines separated by 0.5 m within a 12- by 30-m rectangular grid straddling the interpreted surface trace of the fault, and along a single 100-m long line crossing the fault and coinciding with the shallow seismic reflection line. Minimal GPR data processing included downloading from the GSSI instrument to a personal computer, reformatting to SPW data format, and adjusting display gain for optimal subsurface depiction.

Seismic reflection data were acquired using a 24-channel Geometrics Geode seismograph, a modified soil probe hammer seismic source with electronic instrument triggering, 40 Hz Mark Products geophones, and a roll box to permit roll-along surveying with recording on 24 channels simultaneously. Data acquisition employed an end-on geometry, 1-m geophone spacing, 1-m minimum source-receiver offset, and 24-m maximum source-receiver offset. Source and offset testing on-site governed acquisition parameters that included four source stacks per shot point to minimize random noise, 62.5 microsecond (us) sample interval, and 0.5 s record interval. Seismic data were acquired at 159 source points along a total seismic line length of 130 m. Seismic data processing included downloading from the seismograph to a personal computer, reformatting to SPW data format, assigning surveyed locations to seismic data records, deleting bad or excessively noisy traces, sorting traces into common-midpoint gathers, conducting velocity analysis using constant-velocity stacks and semblance analysis, and stacking common-midpoint traces to produce a common-midpoint stacked section.

Results

GPR data provided no useful subsurface images across the interpreted fault. GPR data were dominated by pulse reverberations likely caused by highly conductive subsurface conditions related to elevated water content and pore-water salinity. In the test line, no signal was recognized from steel pipe fittings buried at depths of 0.3 to 0.9 m. In the 100-m long line that crosses the surface trace of the suspected fault (Figure 1), only data from about 20 to 50 nanoseconds two-way time appeared to contain strata information, but no prominent reflectors were evident. Penetration depth was likely limited to about 1.5 m (assuming typical wet sand velocities).

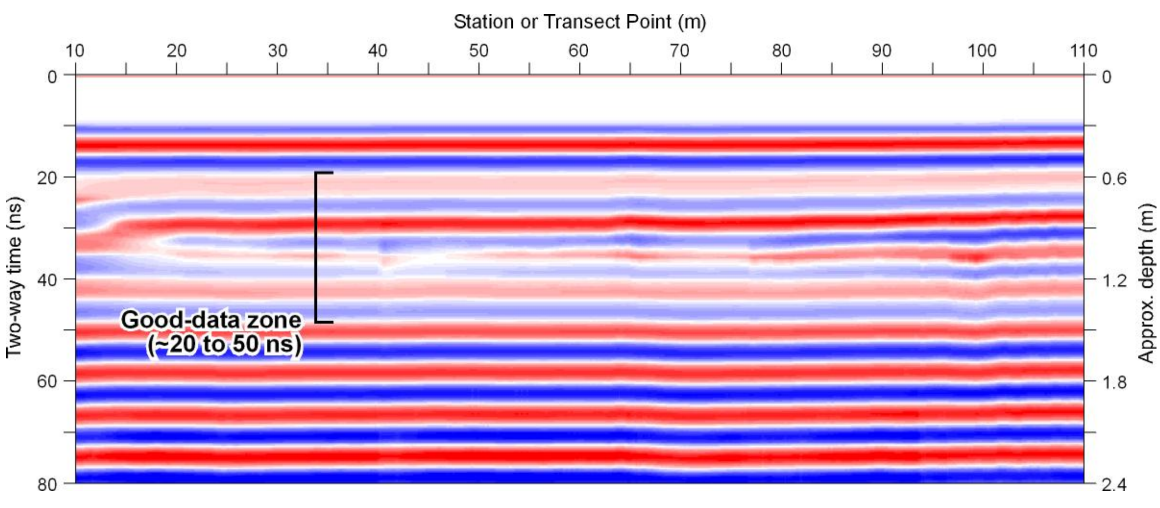

Figure 1. 100-m-long ground-penetrating radar section across inferred fault trace at about 80 m along the section. Gulfward direction is to the right. Reverberations from wet, conductive, and saline ground dominate the record and reveal little useful geologic information. Data collected with a 200 MHz antenna.

Better results were obtained from the shallow seismic data. The low-noise environment and water-saturated conditions produced high-quality seismic records that contained prominent reflections from several stratigraphic horizons at two-way times ranging from less than 20 milliseconds (ms) to more than 300 ms (Figure 2a). These times translate to depths of less than 8 m to more than 100 m.

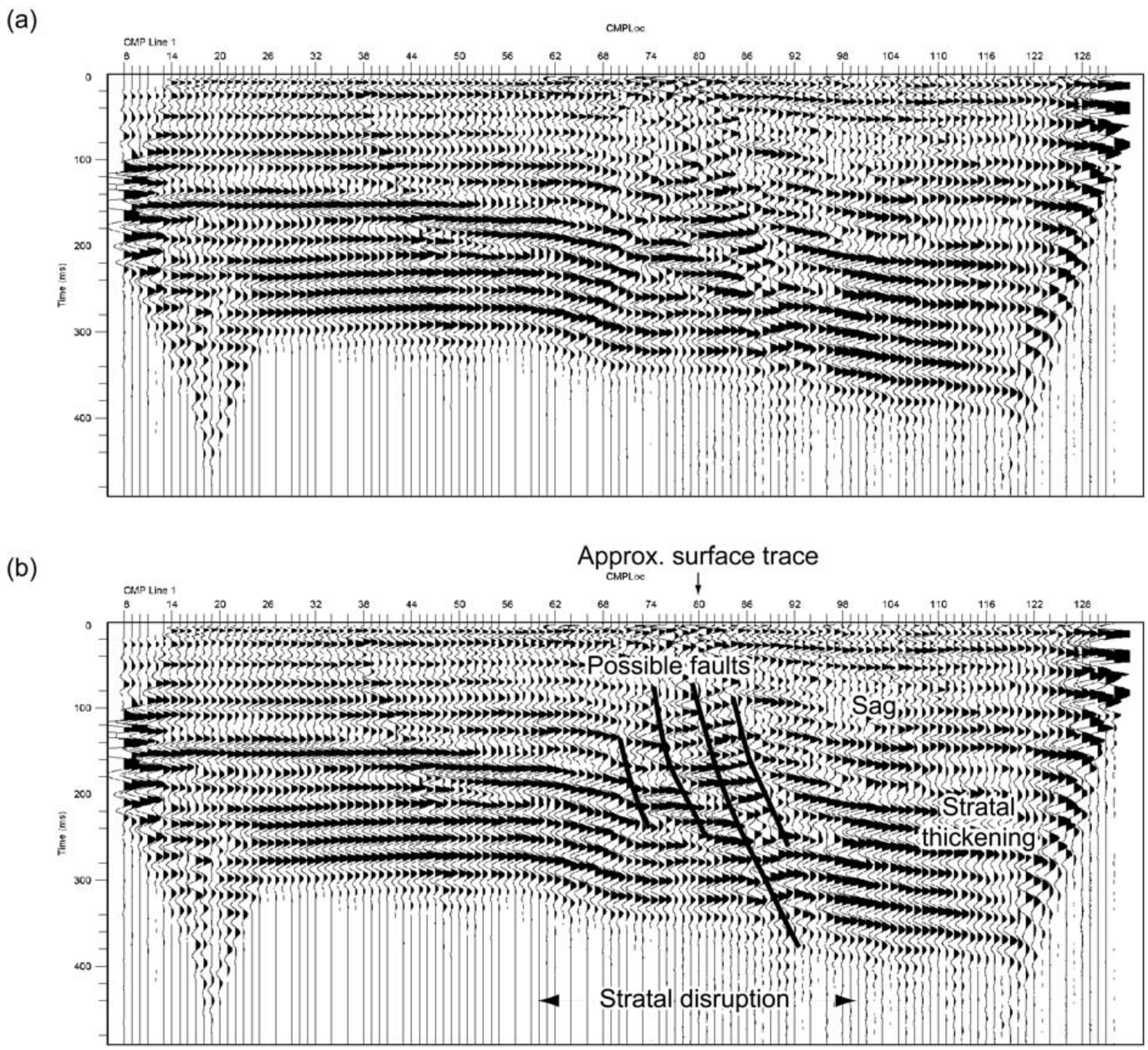

Figure 2. Stacked common-midpoint shallow seismic reflection section acquired along a transect perpendicular to the inferred surface trace of a suspected growth fault near Matagorda, Texas. Gulfward direction is to the right. (a) is the raw section; (b) has been annotated with the approximate surface position of the fault, the zone of strata disruption, possible faults, and sag on strata on the downthrown (gulfward) side of the inferred fault. To convert seismic two-way time (left axis) to approximate depth, multiply the time (in seconds) by 1500 and divide by two.

Individual reflectors show strong continuity across the section. Correlative reflections arrive at later times on the right end of the section than they do on the left end, revealing general gulfward apparent dip of the strata. Between CMP locations 60 and 100, undulations and discontinuities in reflections are evident that are consistent with the presence of a principal fault dipping from left to right (west to east) and possible secondary faults with similar as well as right-to-left dip (Figure 2b). Stratal disruptions are most severe later than about 100 ms in two-way time, corresponding to depths of 50 m or more. Surface elevations across the interpreted fault and evidence from recent aerial photographs suggest that the surface expression of the interpreted fault crosses the seismic line near CMP location 80, which matches well with subsurface seismic features such as prominent drag on the upthrown (left) side of the fault, the main stratal discontinuity between CMPs 80 and 90, leftward dip adjacent to the fault between CMPs 80 and 90, minor stratal sagging on the downthrown side of the fault between CMPs 90 and 110, and general thickening of strata on the downdip side of the interpreted fault zone.

References

Yilmaz, O., 1987, Seismic data processing: Investigations in Geophysics No. 2, Society of Exploration Geophysicists, Tulsa, Oklahoma, ISBN 09-31830-40-0, 526 p.

Young, R. A.,2004, A lab manual of seismic reflection processing: European Association of Geoscientists and Engineers, Houten, Netherlands, ISBN 90-73781-34-5, 126 p. + CD.