Paleoseismology of the East Great Salt Lake Fault

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Investigations undertaken

The goal of this study is to directly assess the seismic hazard posed by the East Great Salt Lake normal fault (EGSLF) to the Ogden-Salt Lake City urban corridor (pop. >1 million). Our integrated reflection seismic-coring approach to the problem is conceptually analogous to a trenching exercise. We used high-resolution seismic reflection profiling to map the EGSLF and subsidiary structures and to characterize stratigraphic and structural geometries directly attributable to Quaternary surface offsets on the EGSLF, including bedding rotations, angular conformities, and offsets on auxiliary faults. In the second component of the study, funded by NEHRP for 2000-2001, key horizons in cores adjacent to the fault will be radiometrically dated to determine recurrence intervals of major earthquakes.

Data collection

We acquired ~325 kilometers of high-resolution seismic reflection data from the southwestern Great Salt Lake basin during the period September 9-18, 1998, including 31 crossings of the EGSLF and related subsidiary faults west of Antelope and Fremont Islands, between Promontory Point and the south lakeshore (Fig. 1). Sources and hydrophones were towed from a 27-foot Boston Whaler in water depths of 2-10 m at speeds ranging from 6-8 km/hr. Two seismic systems were operated simultaneously: a Datasonics Chirp II subbottom profiler and a Geopulse boomer profiler, towed from opposite sides of the survey vessel and triggered at identical 0.5-sec intervals. Data were printed on thermal paper in real time on an EPC graphics recorder, and also recorded in modified SEG-Y format on 2-Gb Jaz disks. Chirp transducers and hydrophones housed in a single towfish were towed ~1 meter beneath the lake surface. The transducers swept a 2-7-kHz frequency range in 0.005 s, typically producing good images of unconsolidated lake sediments as deep as 15-20 m below the lakebed. The Geopulse boomer plate assembly was towed close to the hull ~0.25 m below the lake surface and produced energy primarily in the 800-3000 Hz range. The hydrophone streamer was towed ~2 m forward of the source at the same depth. Operating at 200 Joules, this system commonly imaged strata to 75 m below the lakebed, exceptionally as deep as 150 m. A 12-channel Trimble ProXR GPS mapping system was employed both for real-time navigation accurate to ±60 m, and to acquire trackline position data that have been differentially corrected to submeter accuracy.

Results

High resolution seismic reflection profiles from the southwest basin of the Great Salt Lake provide evidence of multiple Holocene earthquakes on the EGSLF, as well as detailed images of the near-surface geometry of this fault and related subsidiary faults. A new active fault map of the south central Great Salt Lake made from these data shows that (1) a 2-km left step in the active trace of the EGSLF west of northern Antelope Island appears to separate the fault south of Promontory Point into two NNW-striking segments: a 35-km-long Antelope Island segment and a 30-km-long Fremont Island segment, (2) the Antelope Island segment bends sharply southwestward near its southern end, possibly transferring displacement into the Oquirrh fault zone south of the lake, and (3) the hanging wall of the EGSLF is itself extending on numerous active normal faults (Fig. 1). Stratigraphic and structural geometries in hanging-wall strata adjacent to the EGSLF preserve evidence of at least three surface-faulting earthquakes each on the Fremont and Antelope Island segments since the end of the Bonneville highstand ~13,000-14,000 calendar years B.P., and of an early or mid-Holocene period of desiccation and subaerial erosion during which debris flow fans accumulated at the base of the EGSLF scarp (Figs. 2 and 3). Evidence of repeated large surface offsets in Holocene time, a preserved scarp with up to 3.6 meters of relief at the lakebed west of Antelope Island, and an association with auxiliary faults that cut the lakebed in areas of active sedimentation indicate that the EGSLF is active and capable of producing large earthquakes in the heavily populated Ogden-Salt Lake City urban corridor. For the observed segment lengths, empirical relationships for normal faults imply events in the range M6.8-6.9. Our current best estimate of the recurrence interval of such events on each of the two EGSLF segments south of Promontory Point is 4500 (+1100/-786) years (Tables 1 and 2).

Table 1: Surface-Faulting Characteristics, East Great Salt Lake Fault

	Antelope Island Segment	Fremont Island Segment
Post-Bonneville events (N)	3	3
Average Recurrence Interval (ARI) (13,500±500 yrs)/(N±1 intervals)	3250 to 7000 yrs	3250 to 7000 yrs
Best-Estimate ARI* 2x(13,500±500 yrs)/(6±1 intervals)	4500 (3714 to 5600) yrs	4500 (3714 to 5600) yrs
Segment Length (straight line end to end)	35 km	30 km

* Assumes both segments have the same ARI and that all six ruptures were single-segment.

Table 2: Maximum Magnitude Estimates, East Great Salt Lake Fault
(from empirical relationships in Wells and Coppersmith, 1994, BSSA v. 84, 974-1002)
Note: Uncertainty limits are one standard deviation.

Faulting Parameter	Antelope Island Segment	Fremont Island Segment
Surface rupture length	6.9 ± 0.3	6.8 ± 0.3
Rupture area (23-km width)	6.9 ± 0.3	6.8 ± 0.3

Nontechnical summary

We used geophysical methods analogous to sonar to study the East Great Salt Lake fault (EGSLF), a major active extensional fault submerged beneath the Great Salt Lake. Images formed from sonic echoes provided cross sections of layers disrupted by faulting and enabled us to map the EGSLF south of Promontory Point, to identify evidence for six large prehistoric earthquakes on the fault (M 6.8-6.9), and to estimate that such earthquakes occur at intervals of ~2,250 years. Our work indicates that this fault poses a major earthquake risk to the Ogden-Salt Lake City urban corridor.

Publications to date

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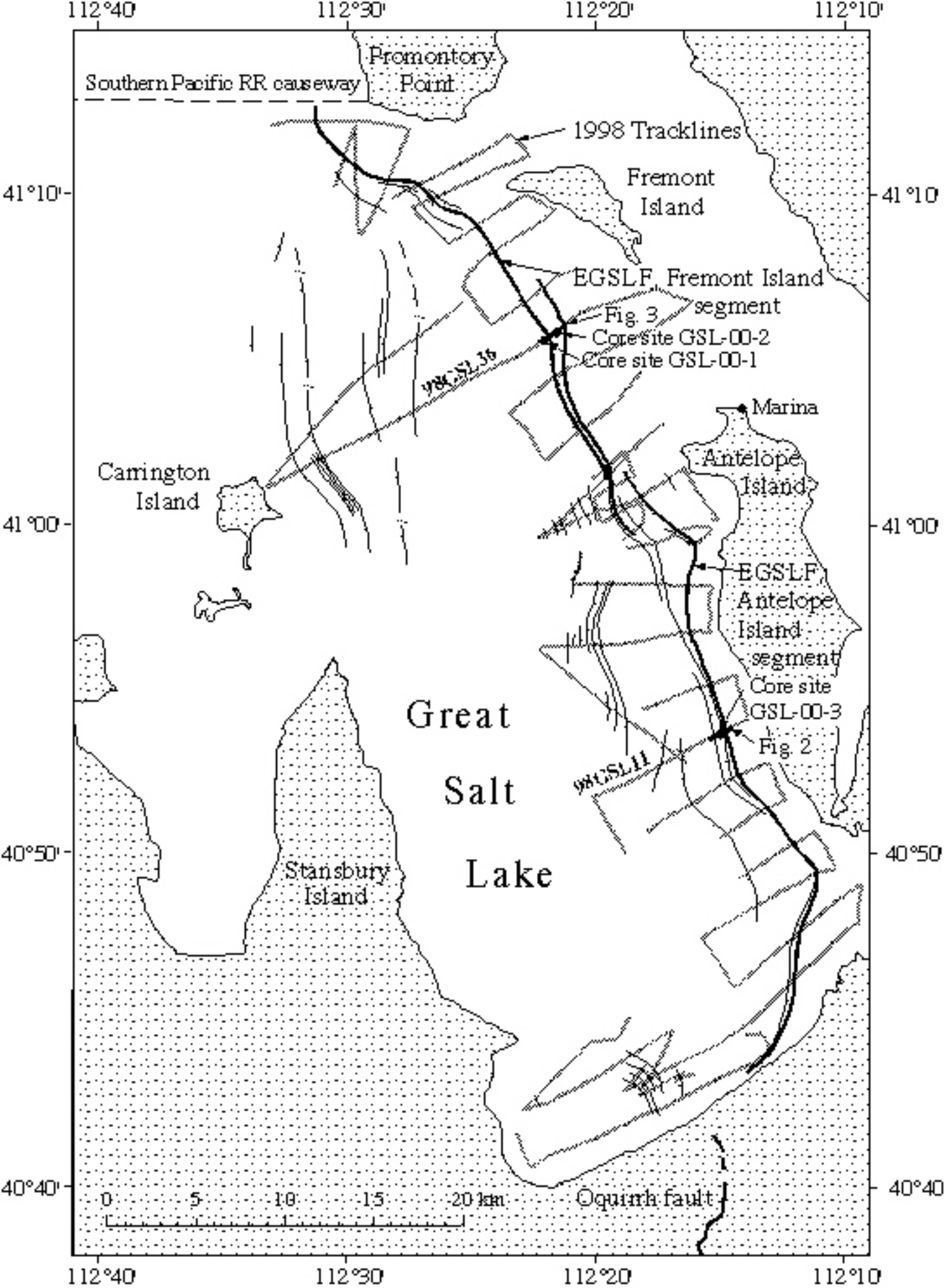

Fig. 1. Active faults in southern Great Salt Lake basin mapped from 1998 University of Utah and 1997 USGS high-resolution seismic reflection profiles (Dinter and Pechmann, 1999a, b; Colman and Kelts, 1997, GSA Abs. with Prgms., A-253); August, 2000 core sites - solid circles; East Great Salt Lake fault - heavy lines; auxiliary normal faults - light lines with hachures, dashed where inferred.

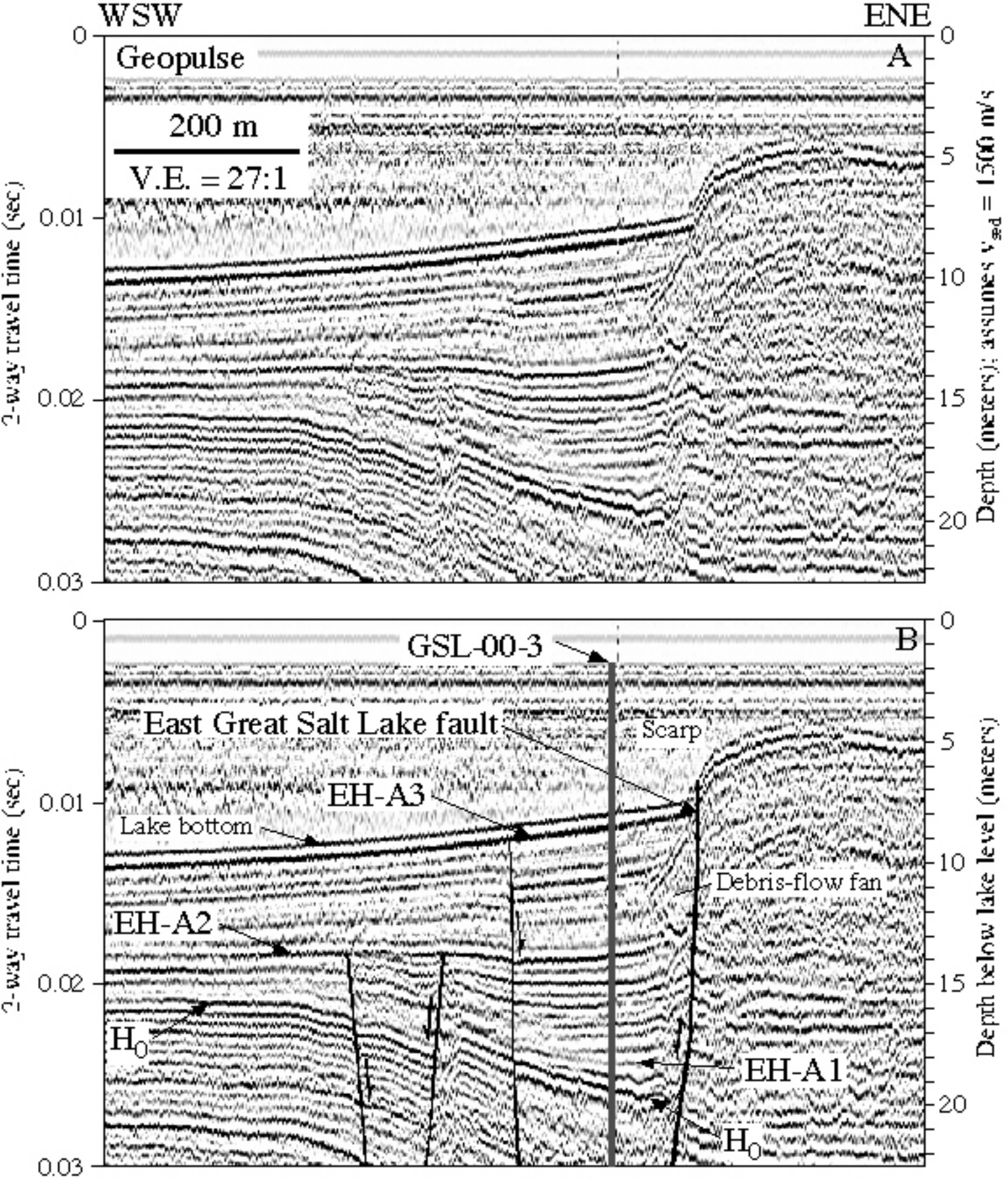

Fig. 2. Tectonostratigraphy at core site GSL-00-3 in hanging wall of EGSLF, Antelope Island segment, Geopulse Line 98GSL11 (Dinter and Pechmann, 1999a, b). V.E. = 27:1. A - Uninterpreted profile. B - Interpreted profile showing EGSLF and subsidiary normal faults, disconformity H_0 (base of modern lake deposits), Antelope-segment earthquake event horizons EH-A1 (onlap surface), EH-A2 (angular unconformity), and EH-A3 (fault termination surface). Note also middle Holocene debris-flow fan. See Fig. 1 for location.

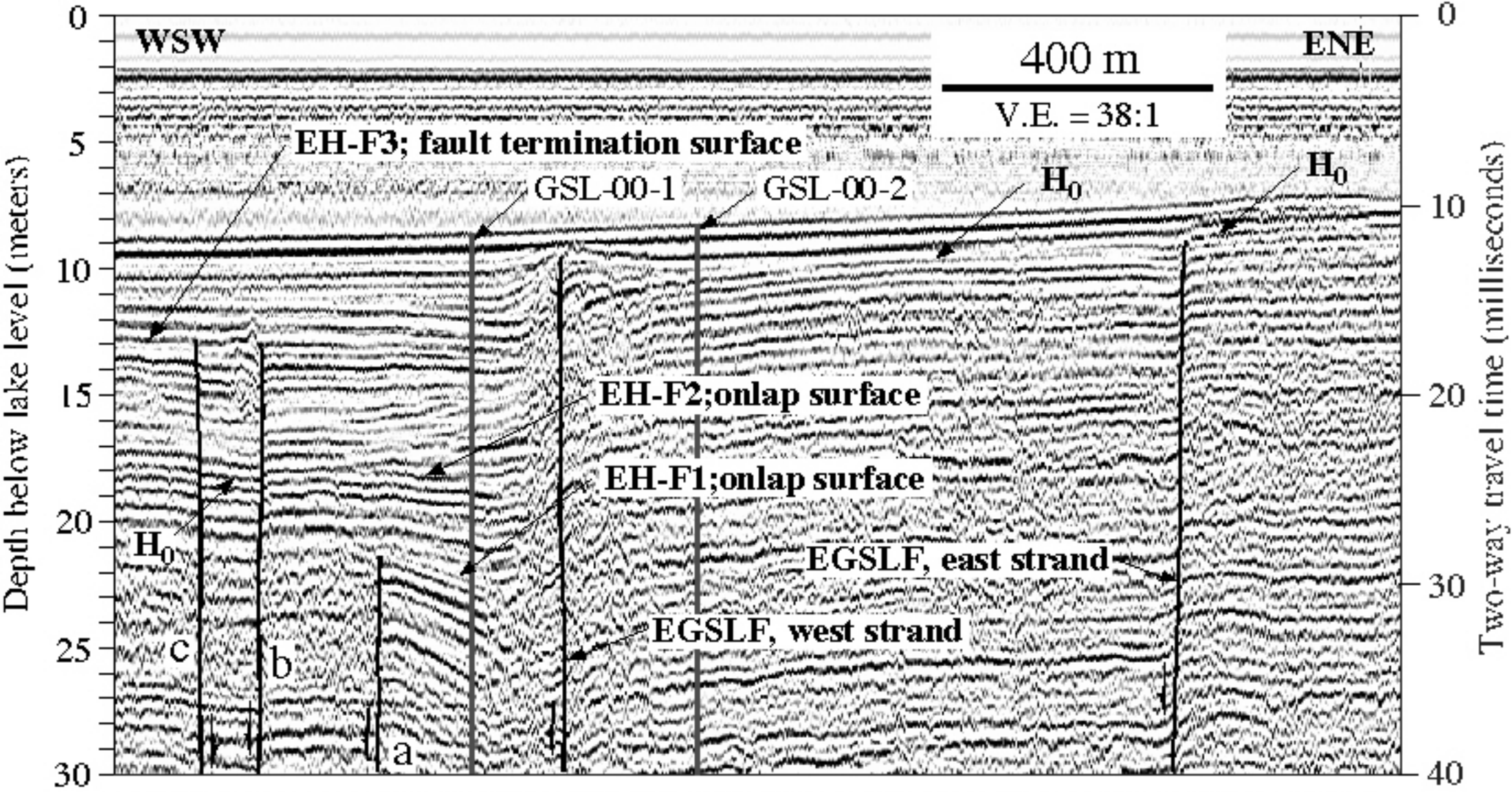

Fig. 3. Tectonostratigraphy at core sites GSL-00-1 and GSL-00-2 in hanging wall and footwall, respectively, of EGSLF west strand, Fremont Island segment, Geopulse Line 98GSL36 (Dinter and Pechmann, 1999a, b). V.E.=38:1. Note earthquake event horizons EH-F1 and EH-F2 (onlap surfaces) and EH-F3 (auxiliary fault termination surface). Auxiliary normal fault a is coseismic with Event F1; b and c are coseismic with Event F3. Disconformity H_0 is base of modern lake deposits, underlain by 12.5-m-thick halite-sapropel sequence in hanging wall. See Fig. 1 for location.