Paleoseismology of the Promontory Segment, East Great Salt Lake Fault

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Investigations undertaken (October 1, 2002 – September 30, 2003)

The goal of this study is to directly assess the seismic hazard posed to the Ogden-Salt Lake City urban corridor by the segment(s?) of the East Great Salt Lake normal fault (EGSLF) that lie submerged beneath the Great Salt Lake west of the Promontory Peninsula and north of the Southern Pacific Railway causeway (Fig. 1). The strategy employed is to map the active fault trace and identify seismic event horizons in hanging wall deposits using high-resolution seismic data, then provisionally date the event horizons using depositional rates extrapolated from cored locations to the south. The collection and analysis of some 300 kilometers of new high-resolution seismic reflection data, including some 30 crossings of the EGSLF Promontory segment(s) and auxiliary faults, are funded in the present grant. Assuming that event horizons for the last 2-3 surface-rupturing earthquakes are well profiled, support will be requested in a subsequent proposal to core and date the horizons directly by radiocarbon methods.

This effort to assess the segmentation and Holocene displacement history of the northern half of the East Great Salt Lake fault system is the logical and geographical complement to our earlier (1998-1999, 2000-2001), highly successful NEHRP-funded high-resolution seismic reflection and coring study of the southern half of the EGSLF. Profiling the northern and southern sectors of the EGSLF system in separate campaigns is a logistical necessity imposed by the Southern Pacific causeway, which has since1953 formed a complete navigational barrier and a nearly complete mixing barrier between the north and south arms of the lake. Any scientific target in the south arm is at most a 90-minute commute by boat from one of two marinas with concrete boat ramps. Collecting marine geophysical data in the north arm is more challenging. Boat and seismic gear must be trailered >75 kilometers on dirt roads and launched across a soft sand beach using landing mats and two trucks equipped with winches. Fuel, fresh water, and camping and support equipment must also be transported to the isolated and uninhabited desert launch site. Water in the north arm is a saturated brine; halite crystals float on the surface or are dispersed in the water column, creating numerous maintenance problems with boat motors, seismic sources, and electronic gear.

Data collection

We acquired ~70 kilometers of new high-resolution seismic reflection data from the southwest arm of the Great Salt Lake and ~25 km of data from our primary target, the northwest arm of the lake, during the period June 10 - August 12, 2003. The southern-sector data include two crossings of the EGSLF in the tectonically complex segment stepover zone west of northern Antelope Island, five crossings of the Carrington fault, which has a 2-meter scarp at the lake bottom and bounds a subbasin in the west-central part of the lake, and three crossings of auxiliary faults that may underlie Interstate 80 at the south margin of the lake. Northern sector data, collected during only two successful survey days, include five of some 30 planned profiles of the EGSLF and auxiliary hanging-wall faults north of the S.P. causeway.

Sources and hydrophones were towed from a 27-foot cathedral-hull research boat with twin 170-HP marine motors in water depths of 2-10 m at speeds ranging from 4-8 km/hr. Two seismic sources were operated simultaneously: an Edgetech SB-216S high-frequency (Chirp) subbottom profiler and a Geopulse boomer, towed from opposite sides of the survey vessel and triggered at identical 0.5-sec intervals. Data were digitized and written to a hard disk in SEG-Y format using Triton Elics hardware and Delph SeismicPlus software. Chirp transducers and hydrophones housed in a single towfish were towed ~1 meter beneath the lake surface. The transducers sweep 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 on a catamaran ~0.25 m below the lake surface, and produced energy primarily in the 800-3000 Hz range. The Geopulse hydrophone streamer was towed ~2 m forward of the source at the same depth, but on the opposite side of the hull. Operating at 200 Joules, this system commonly images strata to 75 m below the lakebed, exceptionally as deep as 150 m. A 12-channel Trimble ProXR GPS system was employed for real-time navigation and trackline locations accurate to ±10 m.

Results

South Arm

Seismic and navigation equipment were first rigged on the survey boat for testing and optimization in the Great Salt Lake South Marina. The hardware functioned well; however, numerous bugs were discovered in a new “upgrade” to the Delph Seismic profiling software of Triton Elics, Inc. As a result, we were unable to print the data to a thermal plotter, to synchronize shot points between the two seismic systems, or to display the data with time event markers rather than shot points.

During this unanticipated beta-testing period, which occupied some 10 days, we profiled critical tectonic targets in the south arm of the lake that we had identified in the course of analyzing our 1998 south arm seismic data (see above). The new 2003 data allowed us to: (1) map the active trace of the Carrington fault and determine that it does not merge with the Promontory segment of the EGSLF as previously believed (e.g., Colman et al., 2002), but dies out to the north, ~10 km south of the S.P. causeway, (2) more accurately characterize the complex stepover zone between the Fremont and Antelope segments of the EGSLF, and (3) map and determine surface offsets of the swarm of active auxiliary normal faults near the southwest lakeshore.

North Arm

On June 28, 2003, the survey boat, seismic gear, and camping and support equipment were transported to the north arm launch site, a small artificial harbor dredged for oil exploration and abandoned more than 30 years ago. On June 29, we successfully collected three long seismic lines immediately north of the causeway. The seismic gear functioned well; however, the data near and over the EGSLF active trace are poor in quality, possibly owing to the presence of dredge piles and/or a layer of crystalline salt blanketing the lakebed in that area, reducing the penetration of the source energy. Data from deeper water further west in the basin are of high quality, showing Quaternary basin deposits warped into a series of gentle, north-trending, open folds with wavelengths of several kilometers.

After a full day of surveying at low speed, we discovered while returning to the harbor that one of the marine outboards was overheating, coughing, and functioning at only ~20% of full power. As commute distances to survey sites in the north arm are long, radio and cell phone coverage are marginal to nonexistent, and no rescue or support craft exist, it is critical that both motors on the survey vessel be in good working order. We were unable to diagnose the problem ourselves, and so had to derig and pull out the boat on June 30 and deliver it to a repair shop. The repairs were not straightforward. After weeks of unsuccessful tinkering by local mechanics, the manufacturer (Mercury) sent out their own mechanic, who completely disassembled the motor in early August and discovered a salt-related short in the electronics. He repaired the unit and we redeployed in the north arm on August 9. On August 10, we profiled the area north of the old harbor facility and acquired two high-quality crossings of the EGSLF, learning that (1) the southern part of the Promontory segment has a lakebottom scarp with relief as great as 3 meters, and (2) that hanging-wall stratigraphic geometries are similar to those off Fremont and Antelope Islands. Thus, it is likely that we will be able to identify discrete Holocene seismic event horizons.

During the commute back to the harbor, the same motor developed exactly the same problem as before, and the second motor also showed signs of malfunctioning. We were, therefore, again forced to demobilize the next day and end our profiling for the season. The problem with the motors appears to be a design flaw that allows water to contact electronical control elements of the fuel injection system. Apparently this flaw becomes critical when running the motors at low power for long periods in the north arm water, which is nearly twice as saline as that in the south arm. We are working over the winter to solve this problem, with several options to be tested before we redeploy in Summer, 2004. Our first trial solution will be to use Johnson marine outboards and hope that they function better than the Mercuries. Alternatively, we may use the large motors only for commuting to survey sites, and rig a smaller trolling motor to use during actual profiling.

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. We refined our maps of the EGSLF and related faults in the south arm of the lake, and began to extend our survey to the north. Technical problems with running boat motors in the hypersaline north arm forced us to abort further data collection until next summer. The data we did obtain indicate that we will be able to assess the seismic hazard of the Promontory segment when the motor problems are solved.

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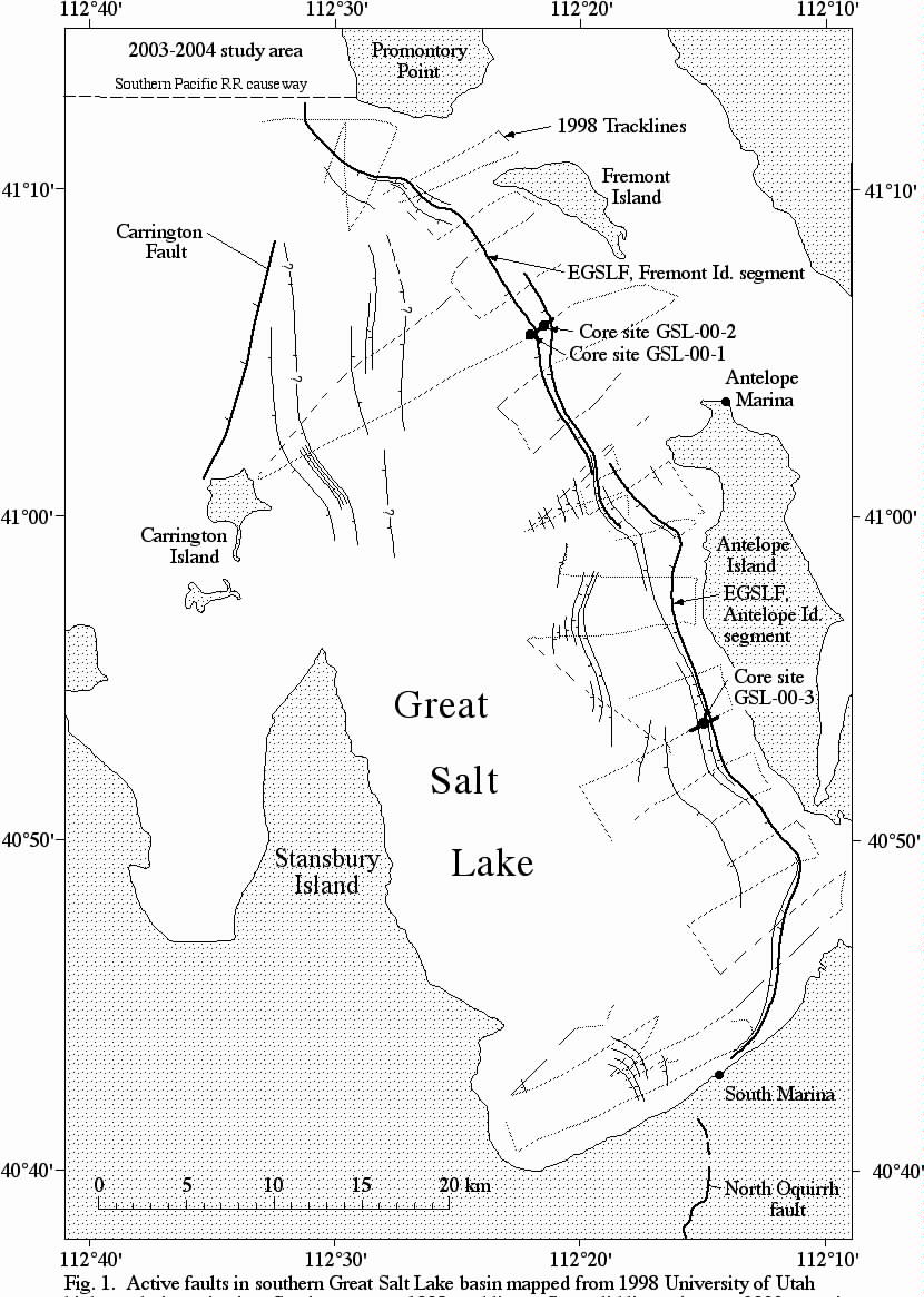

Fig. 1. Active faults in southern Great Salt Lake basin mapped from 1998 University of Utah high-resolution seismic reflection survey. 1998 tracklines - fine solid lines; August, 2000 core sites - solid circles; East Great Salt Lake fault - heavy solid lines; auxiliary normal faults - medium solid lines, dashed where inferred.