BOREHOLE INVESTIGATION OF EARTHQUAKE-INDUCED SOFT-SEDIMENT DEFORMATION AT LEFAIVRE; A CONTRIBUTION TO THE OTTAWA VALLEY LANDSLIDE PROJECT

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A 46 km^2 area near Lefaivre, Ontario, east of Ottawa, shows evidence of severe near-surface deformation of marine sediments, lateral spreading towards the Ottawa River, and irregular surface subsidence on an otherwise flat erosional plain. Geological evidence suggests this disturbance was induced by a high-magnitude (≥6.5) earthquake about 7060 yr BP. Seismic surveys have mapped the existence of a small deep bedrock basin (max. depth 180 m) underlying the disturbed area. As part of the Ottawa Valley Landslide Project, three boreholes were drilled through thick Quaternary sediments to bedrock. One borehole, 150 m deep, is within the deepest part of the bedrock basin where surface disturbance is greatest. A second borehole is near the edge of the disturbed area where topographic expression is muted and the underlying bedrock is closer to the surface (64 m). The third borehole lies 1 km outside the disturbed area and encountered bedrock at 37 m depth.

Continuous core was collected, logged for detailed stratigraphy, and tested for texture, moisture content, porewater salinity, Atterberg limits and fall cone sensitivity at 1 m intervals. Compressional and shear wave velocity measurements were made at acoustic frequencies on samples collected at about 1 m intervals along the core, and electrical resistivity and magnetic susceptibility measurements were taken at 15 cm intervals along the intact core. The boreholes were cased for downhole geophysical measurements, including compressional and shear wave velocities, natural gamma, induction electrical conductivity, magnetic susceptibility, gamma-gamma density, temperature, and temperature gradient. Results are presented in this poster.

The sequence from the deep borehole comprises 110 m of Champlain Sea sediments overlying 34 m of glaciofluvial and glacial deposits. Two thick layers of saturated, fine to medium sand, at 17-35 m and 45-53 m depth, occur within the marine sequence. Thick sand layers are uncommon in the Ottawa Valley marine sequence. The two sand layers at Lefaivre are interpreted to be deltaic sediments deposited in the deep bedrock basin by two large, rapid, fluvial or glaciofluvial drainage events from the north.

Sediment deformation within the clay ranges from brittle shear to extreme plastic deformation and liquefaction. Sand dykes also intrude the clay. Within the two thick sand layers, liquefaction, intrusion and other fluidized structures were found, although lengths of core with intact fluvial bedding also exist. Deformation decreases in intensity with depth below 35 m, but extends to 50 m depth in the deep borehole. The maximum depth of deformation in this borehole coincides with a strong regional reflector in a surface seismic profile across the disturbed area. Deformation is less, both in depth and intensity, in the second, shallower borehole, in which the two sand layers are minor (<0.5 m thick). Outside the disturbed area, bedrock is shallower (37 m) and both sand layers and sediment deformation are absent.

The clay samples are not geotechnically sensitive, probably because of the high pore water salinity in the area. The downhole electrical conductivity log shows a typical curve for Champlain Sea sediments, with lower electrical conductivity in the upper, ‘leached’ clay, increasing conductivity (increasing pore-water salinity) with depth, and a “roll-over” towards the base of the Holocene sequence indicating deposition in a less saline environment. The sand units, which are associated with bursts of freshwater, also have lower electrical conductivity.

Both the P and S wave velocity logs indicate strong velocity contrasts between the Champlain Sea sediments and the underlying older gravel, till and bedrock. These direct measurements of velocity contrasts agree with measurements made during surface seismic surveys, which indicate the possibility of substantial earthquake ground motion amplification and resonance effects. We conclude that, within the thick unconsolidated deposits filling this deep bedrock basin, ground motion amplification and resonance effects caused liquefaction of the buried saturated sand bodies, leading to loss of shear strength, deformation, and possible liquefaction of the clay.

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