East Bank Fault geophysical characterization investigation, Portland, Oregon: Collaborative Research with Boise State University and Oregon Department of Geology and Mineral Industries

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Abstract

Historically, the Portland metropolitan area is the most seismically active region in Oregon. Probabilistic hazard maps, constructed at 500 and 2,500 year return periods show that the local faults dominate the hazard, even more than the Cascadia subduction zone. Ground shaking hazard maps for the Portland area show that calculated ground motions exceed 1 g for a scenario involving a moderate magnitude (MW 6.8) earthquake on shallow crustal faults. The Portland Hills, East Bank, and Oatfield faults form the Portland Hills-Clackamas fault zone that extends through downtown Portland. Little is known about the temporal and behavioral characteristics of these faults and whether the faults are active or related. This report summarizes a geologic and geophysical investigation of the East Bank fault, a mapped fault that extends through downtown Portland. Here, I present the results from two seismic reflection surveys and magnetic gradiometer surveys. My results suggest we have identified structures consistent with the presence of the East Bank fault at two locations. The data are inconclusive as to the history of motion associated with the fault.

Introduction

The Portland metropolitan area and surrounding vicinity (population near 2 million) has been the most seismically active region in Oregon in historical times. Based on the relatively brief 150-year historic record, six earthquakes of Richter magnitude (ML) 5 or greater have occurred within the greater Portland area including the damaging 1962 ML 51/2 Portland and 1993 ML 5.6 Scotts Mills earthquakes (Bott and Wong, 1993). In contrast, recent seismic reflection and aeromagnetic studies (Blakely et al., 1995); (Liberty et al., 2001); (Pratt et al., 2001) indicate the presence of at least three crustal faults beneath the Portland metropolitan area which could generate much more damaging crustal earthquakes of ML 61/2 or larger: the Portland Hills, East Bank (EBF), and Oatfield faults (Figure 1). An evaluation of earthquake recurrence based on the historical record suggests that crustal earthquakes of ML 6 or larger occur somewhere in the Portland region on average about every 1000-2000 years (Bott and Wong, 1993). Strong ground shaking generated by either a nearby crustal event, or a Cascadia subduction zone earthquake will certainly have a major future impact on the Portland area.

The principal objective of this investigation is to better locate and characterize the EBF for earthquake hazards assessment, a mapped fault that extends through downtown Portland (Figure 1). The East Bank fault (Madin, 1990), located east of and parallel to the Portland Hills fault, was originally proposed based on apparent offsets of Miocene volcanic rocks from well data (Beeson et al., 1991). The EBF location and character was further supported on the basis of a significant regional magnetic anomaly (Blakely et al., 1995). Pratt and others (2001) collected shallow marine and terrestrial seimic data across the EBF that suggest faulting of Pleistocene sediments, but the seismic results are not clear. Although no surficial expression is associated with the EBF, Wong et al. (2000) characterized the East Bank fault at the same degree of seismic hazard as the Portland Hills fault, a structure that is now considered active.

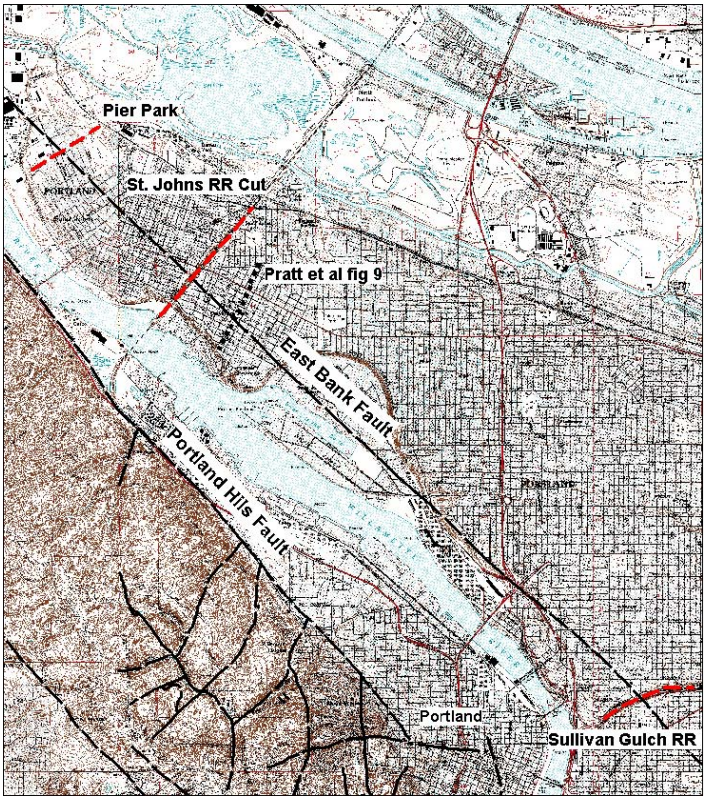

Figure 1. Topographic map of the Portland region showing the location of the East Bank and Portland Hills faults. Also, this figure shows the location of our seismic reflection profiles (Sullivan Gulch and St. Johns) and also the location of the Pratt et al (2000) seismic survey.

Methods

The principal objective of this investigation is to better locate and characterize the EBF for earthquake hazards assessment. Our approach was to acquire regional well log information, acquire ground-based magnetic profiles, combine newly acquired magnetic data with regional aeromagnetic data, and acquire seismic reflection profiles across the presumed fault location. We acquired 4 magnetic transects and two seismic profiles tied to nearby water well and geotechnical boring logs.

We integrated ground-based magnetic gradiometer surveys with regional aeromagnetic data (Blakely et al., 1995) to more clearly identify near-surface magnetic anomalies that may suggest tectonic offset of basalt units. Based on the regional aeromagnetic data, Blakely et al. (1995) suggest that the magnetic basement is offset by more than 200 m across the inferred location of the EBF (Figure 2). However, the regional aeromagnetic data poorly constrain offsets in the upper few hundred meters. Therefore based solely on aeromagnetic data, fault activity across the EBF is ambiguous. The problems with ground-based magnetic surveys in an urban environment are the collected data often are influenced by cultural noise. Our approach was to locate profiles that did not contain a significant cultural noise component, then utilize the gradiometer component of the signal to remove noisy measurements. We collected magnetic data with a 1 m vertical gradient.

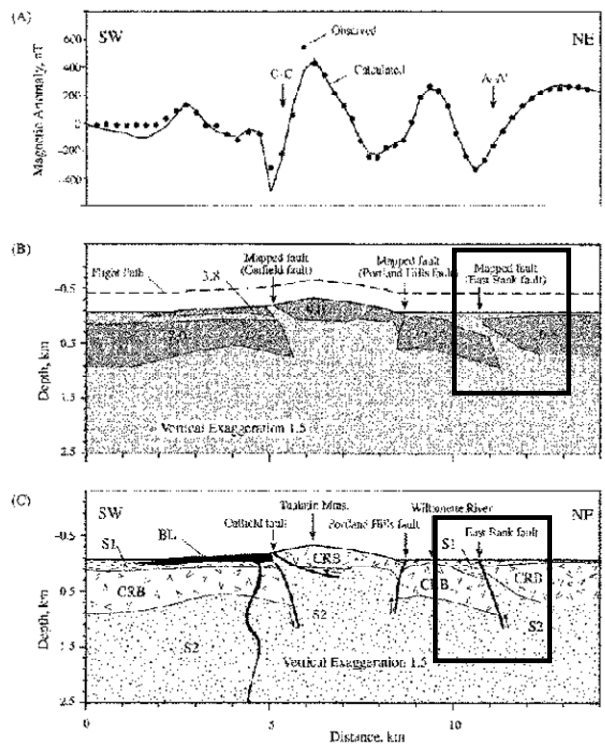

Figure 2. Magnetic profile and geologic interpretation from the Portland area (from Blakely et al., 1995). Note the 600 nT anomaly across the EBF (box) and interpreted offsets of Columbia River Basalt and older rocks.

We removed signal that contained a vertical gradient that exceeded 1-2 nT (depending on survey), assuming these stations contained very near-surface or surface cultural noise. We then interpolated and smoothed the resulting field.

We acquired two high-resolution seismic reflection profiles that crossed the projected location of the EBF. We used a 120-channel, 24-bit Geometrics seismograph with 5 m geophone spacing. We used an accelerated weight drop source to image the upper few hundred m of the subsurface. We processed the data with Landmark's ProMAX seismic processing software. The first profile was located at Sullivan Gulch north of Interstate 84 in Portland (Figure 1). We collected an 800 m long profile along a railroad gravel access road. Highway traffic along the adjacent interstate was steady and trains occasionally stopped seismic acquisition. With signal processing, we successfully imaged the upper 200 m. The second 1700 m long profile was located at Peninsula Park 10 km northwest of the Sullivan Gulch profile. This profile was acquired along a bike path above the St. John railroad cut. Here, we imaged the upper 300 m below land surface.

Results

Sullivan Gulch

We combine all geophysical and geological data and discuss the results at two sites: Sullivan Gulch and Peninsula Park. At Sullivan Gulch (Figures 1 and 3), land elevations ranged from 20-25 m above sea level. The geologic section consists of artificial fill over Missoula Flood deposits, over Pliocene Troutdale Formation conglomerate over Troutdale Formation mudstone. From the few available wells, an east-side up offset of as much as 100 m of the top of the mudstone is plausible. It is very difficult to discern the contact between Troutdale conglomerate and Missoula Flood gravels in drillers logs. The base of the Missoula Flood silt and sand shows an apparent warp across the proposed fault location, but this surface is notoriously irregular, and the wells are projected from some distance.

Ground-based magnetic data from this region were difficult to analyze and we will not present those results. Here, we show the aeromagnetic data from this region (Figure 3). The magnetic data show a northwest-trending lineament associated with the EBF (Blakely et al., 1995). This lineament may represent offsets of Columbia River basalts (CRB) or may be influenced by near-surface Boring lava or deeper Eocene basement.

The seismic reflection data (Figure 3) show a continuous package of reflections along the eastern portions of the profile to an estimated depth of 150 m. At surface position 250 m, these flat-lying reflections are truncated. To the west, reflections appear discontinuous and dip slightly eastward. The discontinuity at position 250 m matches the projected location of the EBF from drillers logs (Madin, 2005) and aeromagnetic data (Blakely et al., 1995). A fault at this location is further supported by results from a gravity survey (Figure 3) conducted by the U.S. Geological Survey (R. Morin, personal comm.). This profile shows a clear anomaly at the same location as the seismic reflection anomaly.

The evidence for the EBF at this location is supported by the seismic, gravity data, and engineering borings. The aeromagnetic data suggest that a lineament extends to the northwest and southeast from this location. Thus, the upper 150 m across the inferred location of the EBF shows a discontinuity that supports an east-side up thrust fault that cuts the youngest imaged strata. The amount of offset across the EBF is not clear from either borehole logs or seismic results.

Peninsula Park

At Peninsula Park, the top of the Troutdale/Missoula Flood gravel appears to be slightly warped across the proposed fault location near Lombard Street (Figures 1 and 4). There is a plausible offset from driller's logs of about 50 m on the top of the Troutdale conglomerate. Magnetic data from the area (Figure 5) show a northwest-trending lineament identified as the EBF (Blakely et al., 1995). The readings from two nearby ground-based magnetic surveys (Figure 5; St Johns Railroad and Pratt seismic survey) are noisy, but show a trend similar to the airborne data where more than a 50 nT increase in the total magnetic field appears across the projected EBF location. Blakely et al. (1995) interpret the increase in total field across the EBF as an indication of a northeast-side up fault

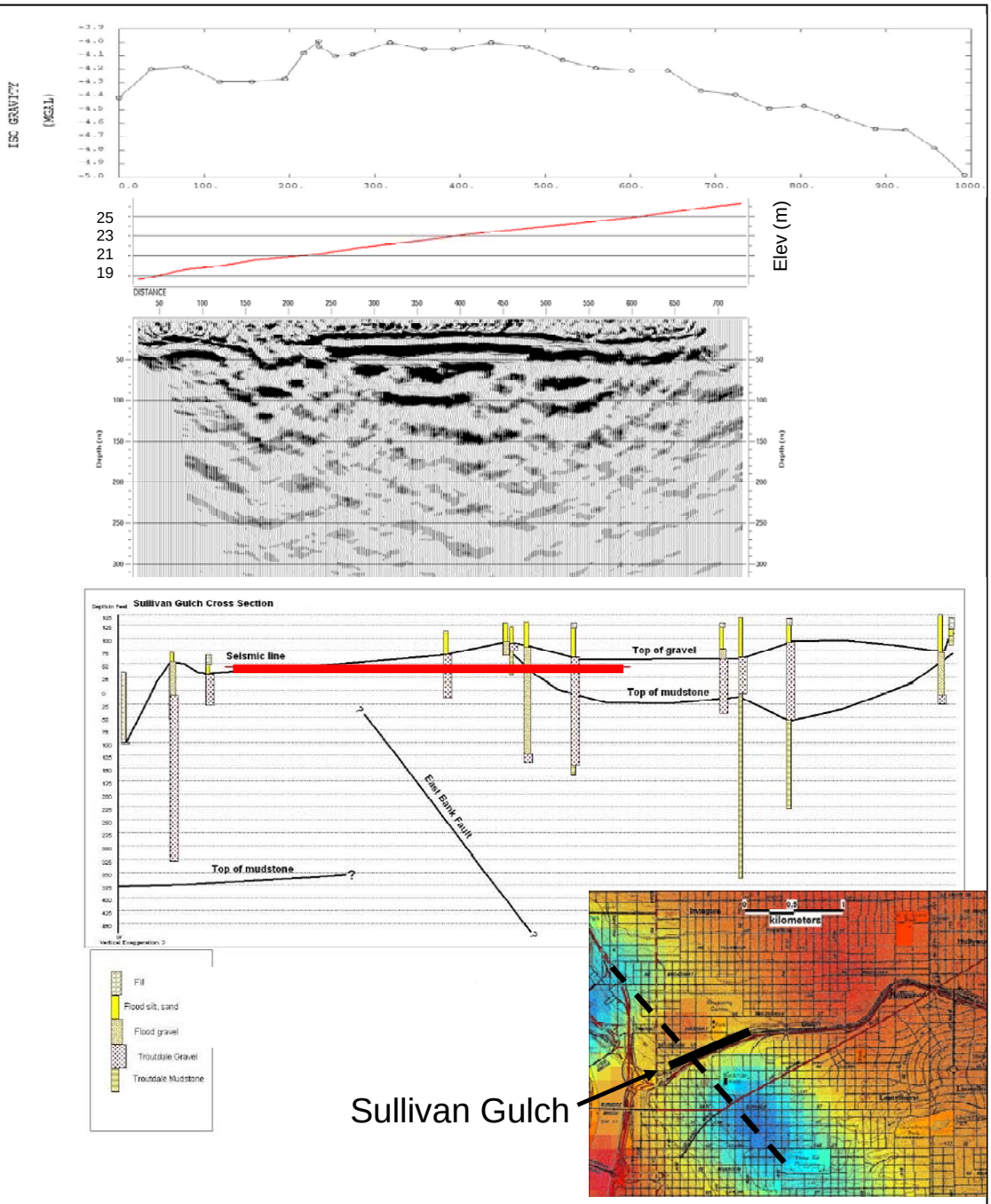

Figure 3. (A) Gravity profile (from B. Morin, personal comm.), (B) elevation profile, (C) seismic reflection profile, (D) borehole logs (from Madin, 2005), and (E) aeromagnetic image (Blakely et al., 1995) for the Sullivan Gulch survey. The gravity, magnetic, seismic, and borehole information all suggest the EBF crosses Sullivan gulch near position 200-300 m.

The seismic reflection results from Peninsula Park are shown on two separate images. The upper image of Figure 5 shows a stack emphasizing near-surface geology above the elevation of the water table (30-40 m). The second image emphasizes structures and stratigraphy below the water table. I separated the two reflection sections due to the extreme vertical velocity gradient at the water table boundary. We did not design the

acquisition parameters to image below 300 m. The near-surface section shows reflections that are relatively flat-lying. Discontinuities appear at positions 450 m and 1250 m, but vertical offsets of the strata greater than 20 m do not appear. The most significant reflection on Figure 5b may be a northeast dipping arrival that I interpret as the top of the CRB. CRB exposures appear immediately west of the Willamette River and also in engineering borings below the Willamette River at 25 m depth (URS Corp). Approximately 5.5 km to the northeast of Lombard Street crossing, the top of the CRB surface is mapped at 500 m depth on a Columbia River seismic profile (Liberty, in review) and nearby at the airport in an engineering boring (Mabey and Madin, 1992). The dipping CRB reflection is truncated near Lombard Street, the approximate location of the magnetic anomalies shown in Figure 5. Although it is difficult to trace the CRB reflection to the northeast, significant vertical uplift across the EBF is not supported.

The discontinuities in the upper reflections shown on Figure 5a and the step in CRB reflection from Figure 5b may suggest the EBF crosses this profile. Offsets and locations are consistent with aeromagnetic data from Blakely et al (1995) and marine and land high resolution profiles presented by Pratt et al. (2001). However, the limited imaging depth of the seismic to track the CRB trace and the potentially rugged surface of flood deposits and CRB surface makes it difficult to characterize the EBF at this location

Conclusions

Results from two seismic surveys and associated magnetic gradiometer surveys suggest we identified structures associated with the mapped location of the EBF. At both the Sullivan Gulch and Peninsula Park sites, deformation appears within the upper 30 m of the surface. Vertical offsets at the Sullivan Gulch site are not clear due to the large contrast in reflection character across the EBF. At Peninsula Park, offset of a few meters across the upper reflection section are evident, but longer term deformation as defined by offsets along the CRB surface are unknown. Although the history of deformation from the geophysics and borehole logs is not clear, additional paleoseismic studies across the EBF are warranted.

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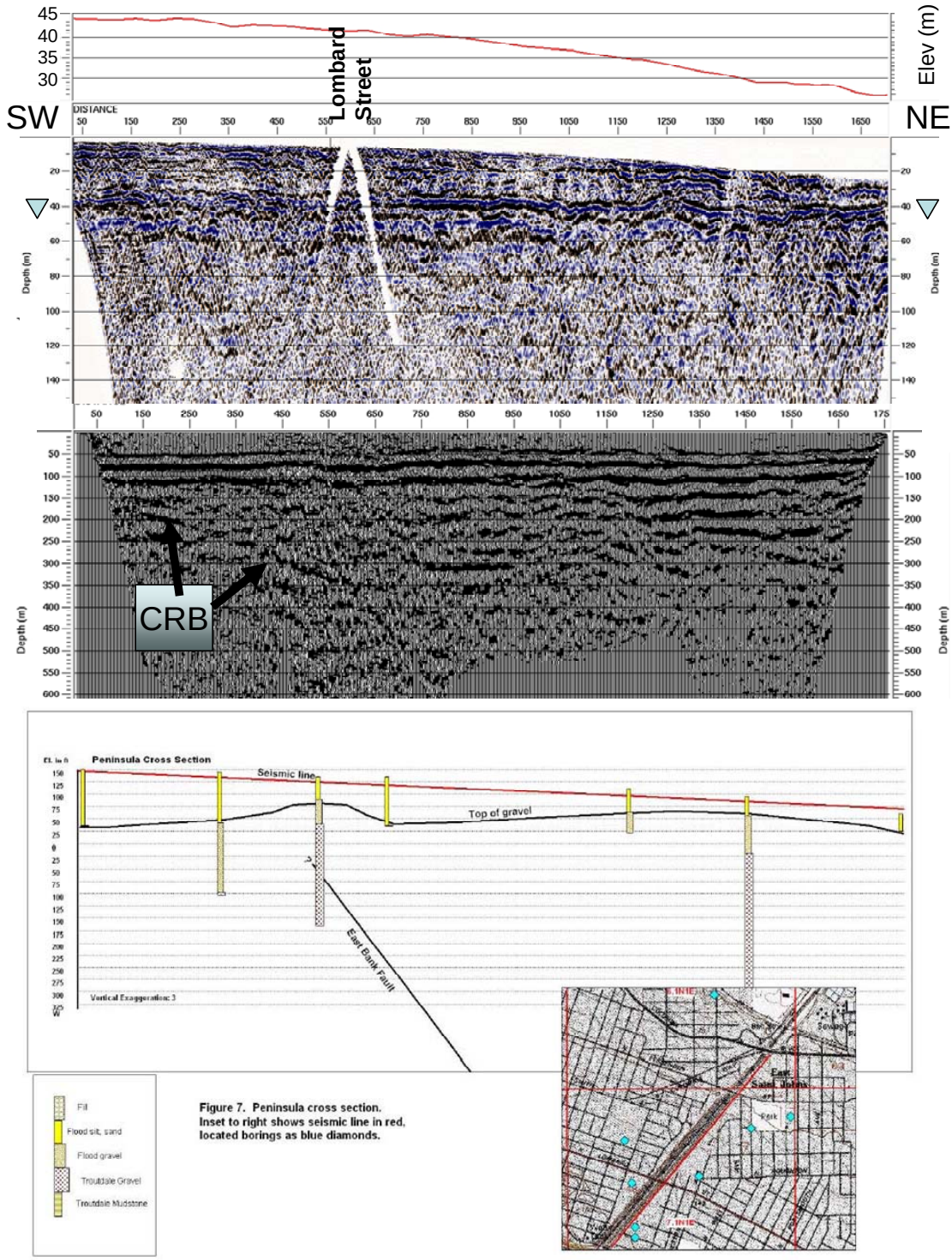

Figure 7. Peninsula cross section.
Inset to right shows seismic line in red,
located borings as blue diamonds.

Figure 4. Topography, seismic reflection images (upper image emphasizes reflections above the water table), borehole logs (from Madin, 2005) from the Peninsula Park survey. Water table depth is labeled as inverted triangle

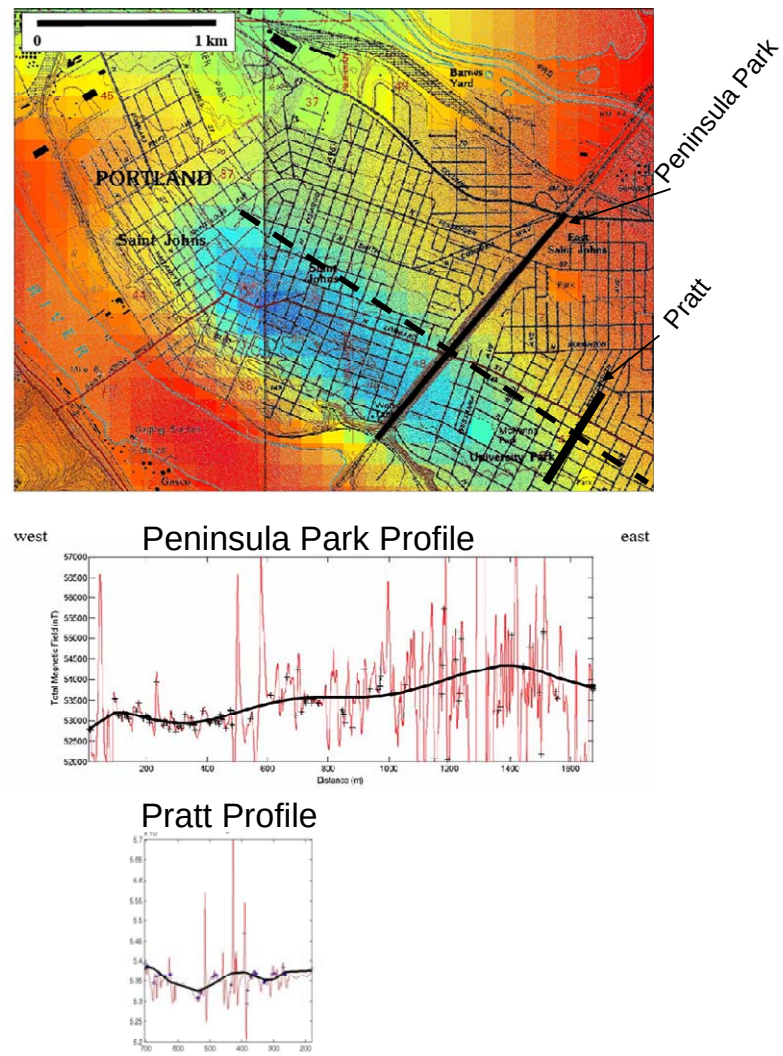

Figure 5. Aeromagnetic image (from Blakely et al., 1995) and ground-based magnetic profiles from St. John's railroad (black line) below Peninsula Park and along the Pratt et al. (2001) seismic profile. The profiles show raw data (red), data points that show a vertical gradient of less than 1 nT over a 1 m vertical distance (black crosses), and a least-squares fit using the select points. An approximate 500 nT step in the total magnetic field appears near the the projected location of the East Bank Fault on both profiles.

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