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PALEOSEISMIC INVESTIGATIONS OF HOLOCENE EARTHQUAKES ON THE PROVO SEGMENT, WASATCH FAULT ZONE, UTAH

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TABLE OF CONTENTS

FIGURES

ABSTRACT

The Utah Geological Survey (UGS) in cooperation with the U.S. Geological Survey (USGS) conducted two paleoseismic trench investigations on the Provo segment of the Wasatch fault zone, Utah. We excavated trenches near the southern (Flat Canyon site) and northern (Alpine site) ends of the segment to evaluate the role of fault segmentation in limiting earthquake rupture length and magnitude along the Wasatch fault zone, and to improve estimates of Holocene surface-faulting earthquake timing, displacement, and extent. The UGS oversaw the excavation of both trenches and provided project field support. The bulk of the scientific research was completed by the USGS.

INTRODUCTION

Purpose and Scope

The five central segments of the Wasatch fault zone (WFZ) trend through the most densely populated part of Utah, and have the potential to generate large-magnitude (M ~6.5-7.5) surface-rupturing earthquakes. These segments have been the subject of numerous paleoseismic trench investigations, which have revealed evidence of repeated Holocene earthquakes, and have determined earthquake recurrence intervals and fault slip rates. However, at the time of this investigation, questions remained regarding (1) whether segment boundaries always act as barriers to large (>M7) ruptures along the WFZ, (2) whether ruptures tend to break full or partial segments, (3) what the potential maximum magnitude earthquake is for a multi-segment rupture, and (4) how these findings impact seismic hazard analysis along the populated Wasatch Front.

The Utah Geological Survey (UGS) in cooperation with the U.S. Geological Survey (USGS) conducted two paleoseismic trench investigations on the Provo segment (PS) of the WFZ. The first investigation took place near Salem, Utah (figure 1), and the second near Alpine, Utah (figure 2). The purpose of this joint UGS-USGS project was to evaluate the role of fault segmentation in limiting earthquake rupture length and magnitude, and to determine the timing and spatial extent of Holocene surface-rupturing earthquakes at the northern and southern ends of the PS. To improve rupture-length estimates and evaluate the persistence of Holocene rupture termination at central WFZ segment boundaries, the two sites selected for investigation were chosen based on their locations near the northern and southern ends of the PS, and their proximity to other paleoseismic investigations near the north end of the Nephi segment (NS) (DuRoss and others, in review) and south end of the Salt Lake City segment (SLCS) (DuRoss and others, 2015). At both sites, we (1) constructed detailed topographic and geologic maps of the trench site, (2) measured scarp profiles, (3) excavated one trench, (4) photographed and mapped trench-wall exposures in detail, and (5) sampled organic material for radiocarbon (^{14}C) dating and fine-grained sediment for optically stimulated luminescence (OSL) dating. Using these data, we can calculate inter-event and mean earthquake recurrence intervals as well as vertical slip rates. Evaluated in the context of previous paleoseismic data, we can calculate more robust mean recurrence intervals for the PS and improve our understanding of the role that fault segmentation plays in limiting earthquake rupture length and magnitude along the WFZ (Bennett and others, 2014, 2015).

For this investigation, the UGS managed the excavation services and trench excavation, and provided field support to the USGS. The bulk of the scientific research was completed by the USGS. The UGS contracted with Skyline Excavators to perform the trench excavation and backfill for both locations.

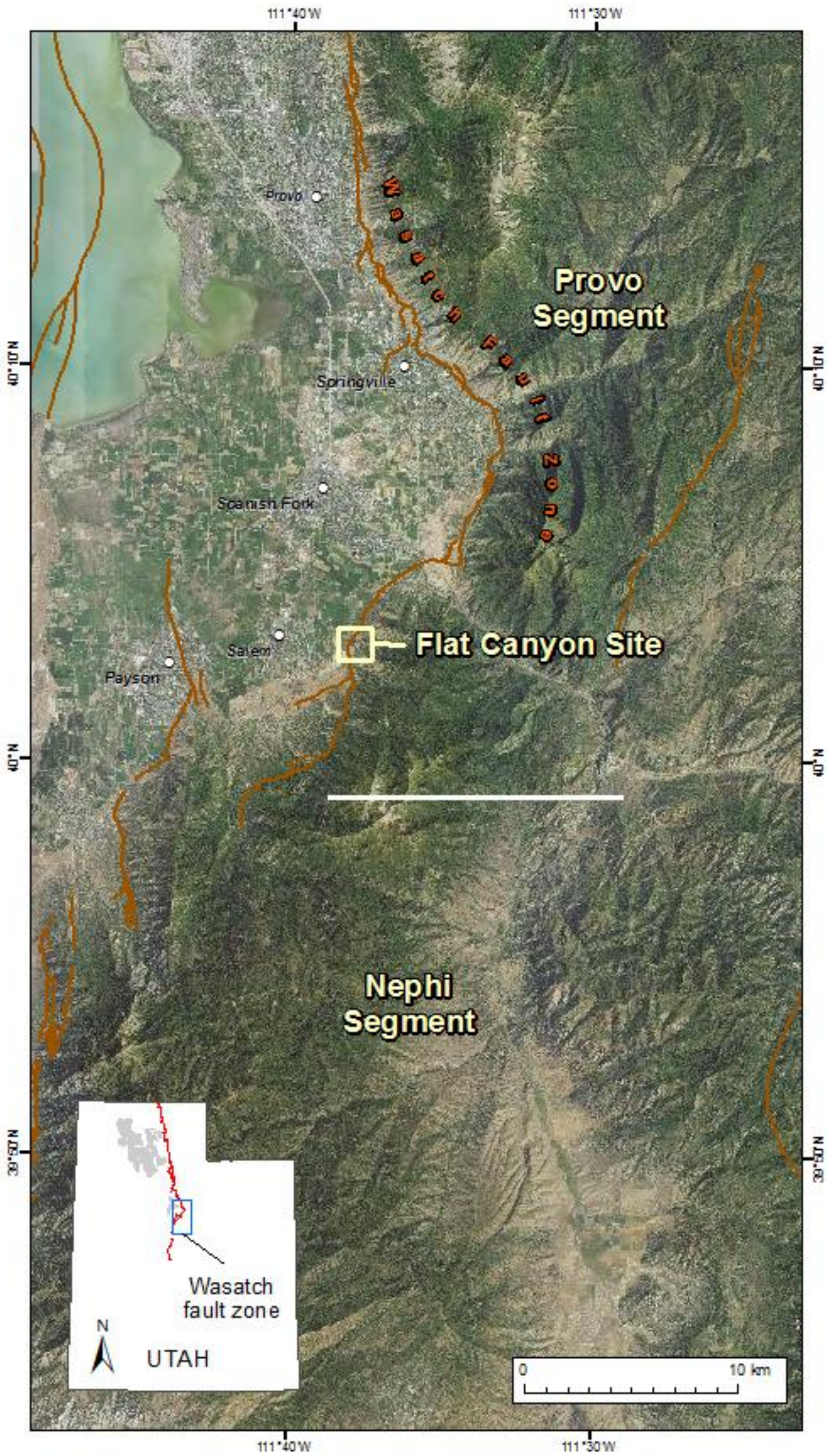

Figure 1. *Flat Canyon trench study area near southern end of the Provo Segment shown by tan box. Fault traces shown in red (from Black and others, 2003). Basemap from U.S. Department of Agriculture (2014).*

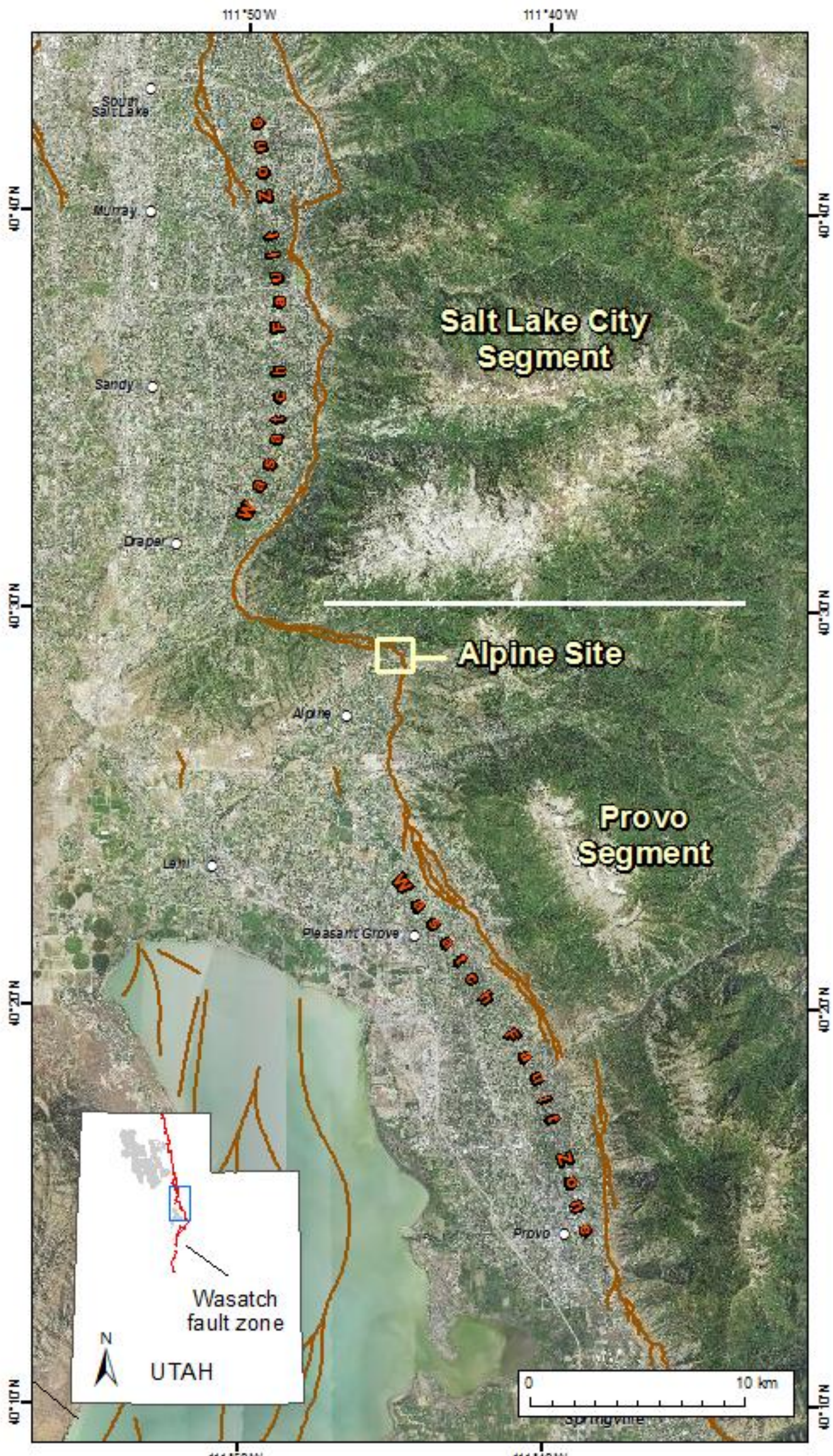

Figure 2. *Alpine trench study area near northern end of the Provo segment shown by tan box. Fault traces shown in red (from Black and others, 2003). Basemap from U.S. Department of Agriculture (2014).*

OVERVIEW AND METHODS

Trench Investigations

Selection of the Alpine trench site was based on analysis of 2-meter LiDAR data (Utah Automated Geographic Reference Center [AGRC], 2006a) and derivative products. Selection of the Flat Canyon trench site was based on analysis of 5-meter auto-correlated elevation models (AGRC, 2006b) and derivative products. Site selection at both sites also relied upon existing geologic maps, 2006-2011 orthophotography from the National Agriculture Imagery Program (NAIP) (United States Department of Agriculture [USDA], 2014), and field reconnaissance. Both sites were located on private property, and required authorization from the property owners to proceed.

Flat Canyon Site

The Flat Canyon trench site is approximately 575 meters west of the mouth of Flat Canyon (figure 3). The site is crossed by a 12–13-meter high northwest-facing fault scarp. We chose the site in part due to its apparent lack of historical modification, and the relatively large scarp height that likely would provide a more complete Holocene earthquake history. Access was from an unimproved road running along an orchard north of the site.

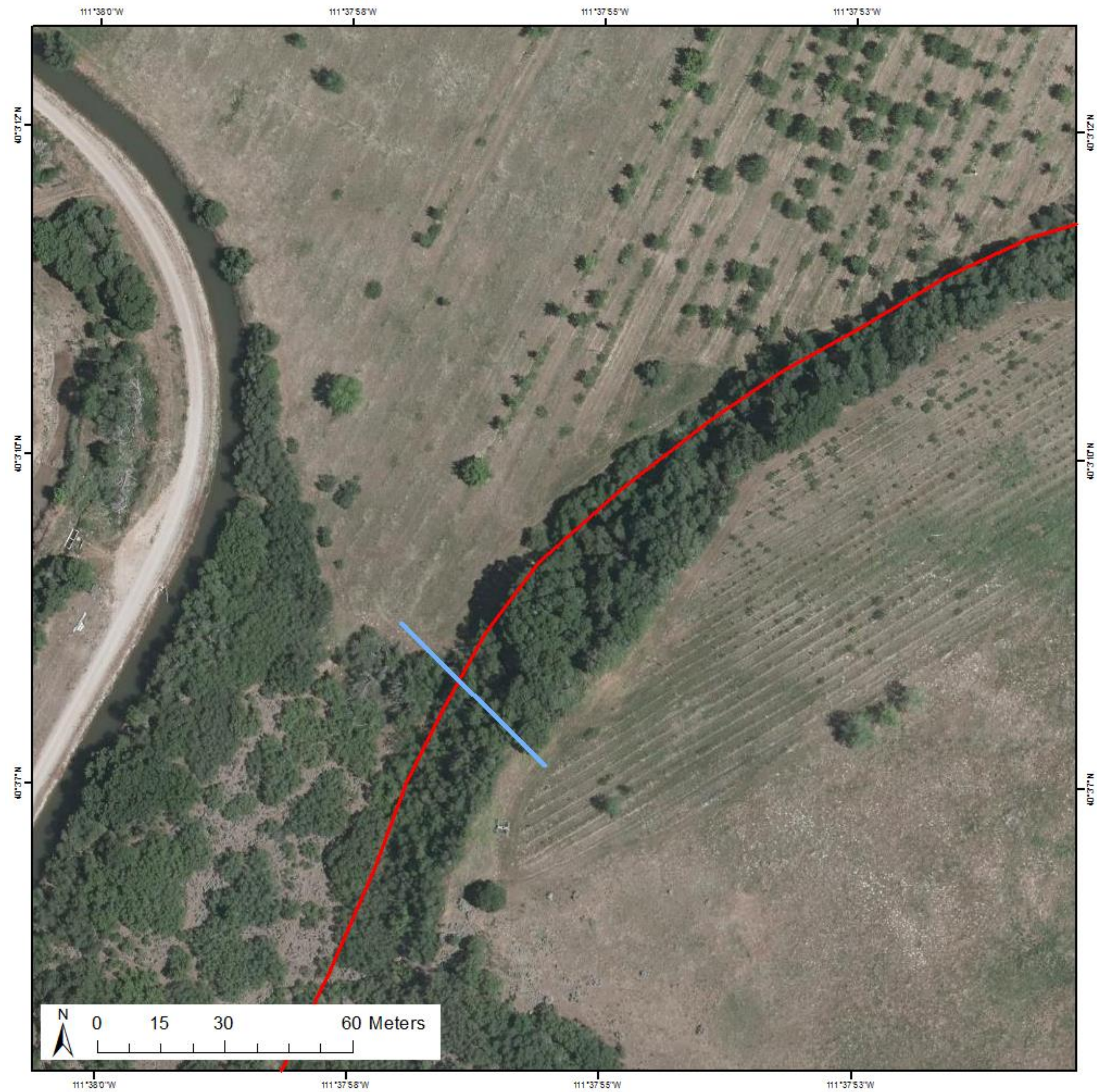

Figure 3. *Flat Canyon trench site near Salem, Utah County, Utah. Trench location shown in blue, fault trace shown in red (modified from Black and others, 2003). Basemap from Utah Automated Geographic Reference Center (2012).*

We excavated a 40-meter long trench, up to 5 meters deep, in October 2013. The excavation was originally planned for the first week of October, but was delayed 2.5 weeks, until late October, due to the 2013 federal government shutdown. The excavation proved difficult due to the size of the scarp and the depth and volume of the excavation to maintain safe working conditions, and took approximately 16 hours to complete. The trench was open for 16 days from October 17, 2013 to November 1, 2013. Backfilling took place on November 1, 2013, and took approximately 9-10 hours to complete.

To map the trench wall exposures, we constructed a 1-meter square grid using a total station instrument (Trimble TTS 500) to project points to an average, vertical plane parallel to the trench walls. We then took approximately 200 photographs of each trench wall. We created photomosaics manually using Adobe Photoshop software, and then printed the mosaics in sections for ease of trench logging. We collected OSL and ^{14}C samples throughout the trench to estimate burial ages of various alluvial-fan and scarp-derived colluvial-wedge units.

Alpine Site

The Alpine trench site is approximately 410 meters southeast of the mouth of Dry Creek Canyon (figure 4). An 8-meter high west-southwest-facing fault scarp crosses the site. We selected the site for its simple scarp geometry, relatively large scarp height, and minimal evidence of historical modification. Access for the excavator was via a private road that crosses the fault scarp approximately 15 meters to the south. We also selected a backup site that was partially located on the same private property as the primary trench site, but was partially on U.S. Forest Service property about 100 meters south of the mouth of Dry Creek Canyon (figure 5). This backup site also had easy access and favorable fault scarp geometry and height, but was not excavated during this investigation.

We excavated a 33-meter long trench, up to 4 meters deep, in May 2014. The excavation took approximately 10 hours to complete. The trench was open for 16 days from May 22, 2014 to June 6, 2014. Backfilling took place on June 6, 2014 and took 6 – 7 hours to complete.

A similar process to that at Flat Canyon was followed to construct a 1-m square grid on both trench walls. We then took approximately 600 photographs of each trench wall, and created photomosaics using the structure-from-motion (SFM) method with Agisoft Photoscan Professional software and printed the finished mosaics in sections for ease of trench logging. We then followed a similar process of logging and sampling as at the Flat Canyon site.

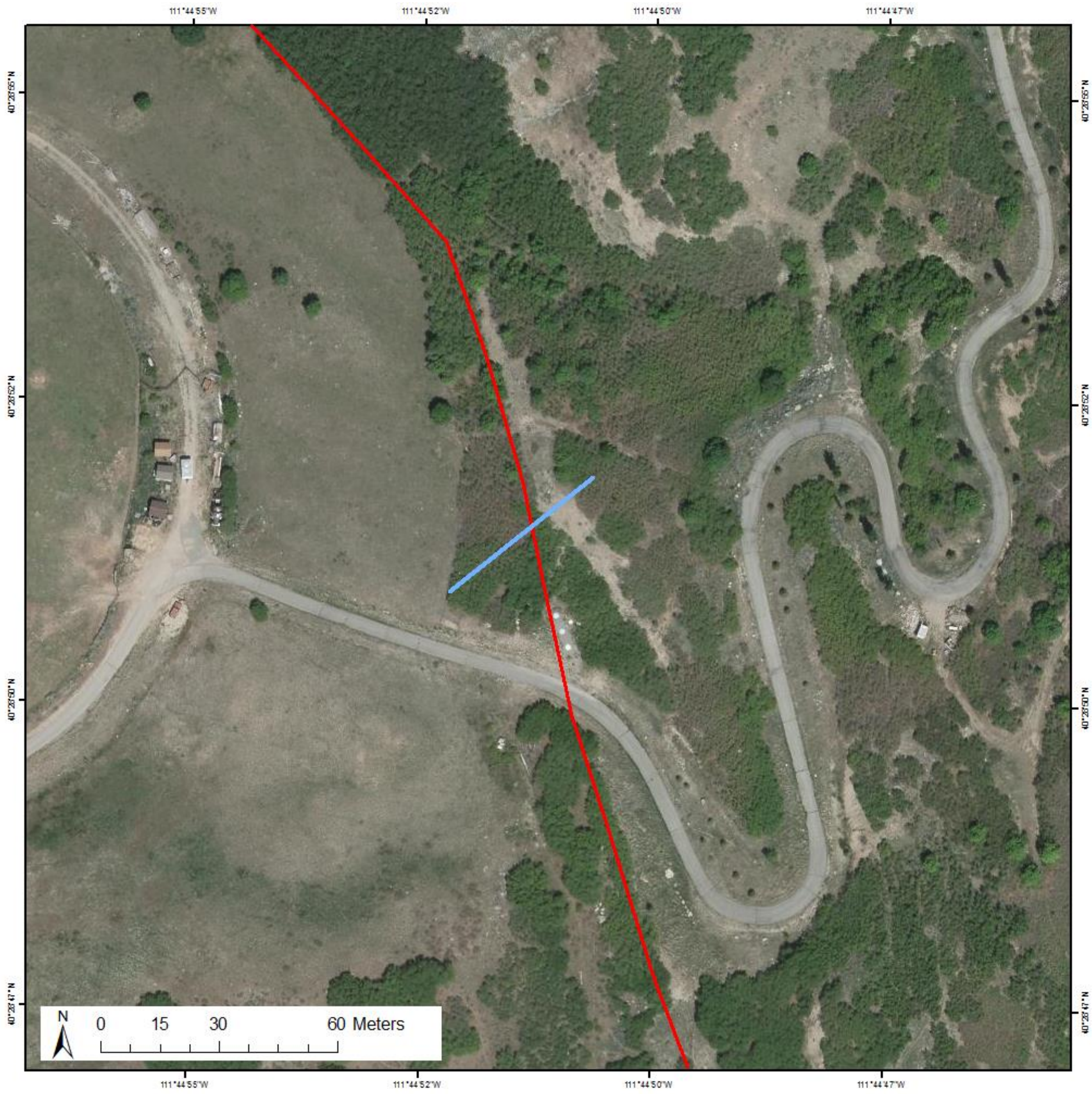

Figure 4. *Alpine trench site, near the mouth of Dry Creek Canyon, Utah County, Utah. Trench location shown in blue, fault trace shown in red (modified from Black and others, 2003). Basemap from Utah Automated Geographic Reference Center (2012).*

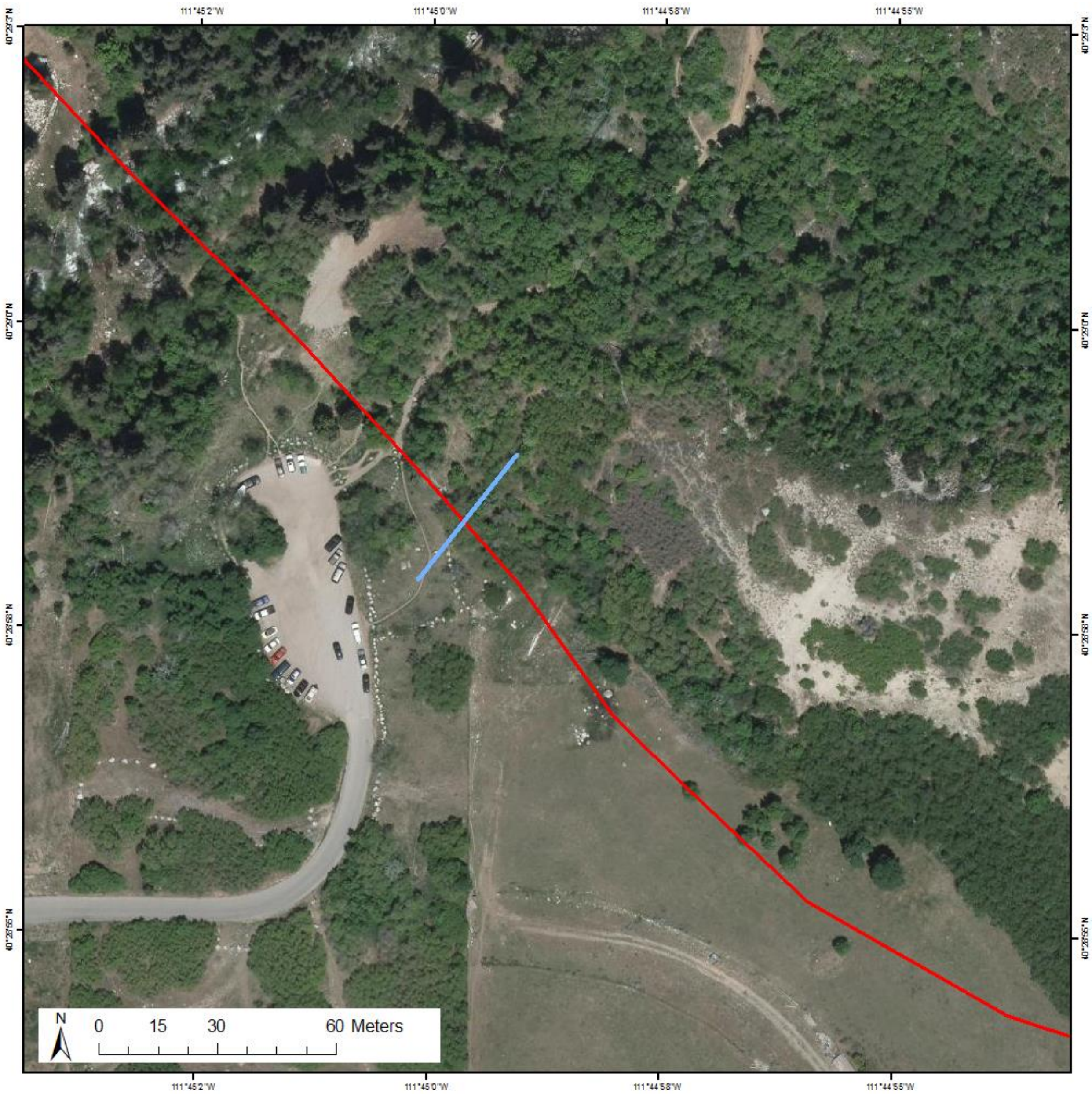

Figure 5. *Alpine backup trench site, near the mouth of Dry Creek Canyon, Utah County, Utah. Proposed trench location shown in blue, fault trace shown in red (modified from Black and others, 2003). This trench site was not excavated. Basemap from Utah Automated Geographic Reference Center (2012).*

SUMMARY AND CONCLUSIONS

The UGS's role of managing field logistics and excavation went very smoothly for this project. Utilizing UGS Geologic Hazards Program staff to assist with fieldwork in both trenches was crucial to the completion of this project. Additionally, the proximity of the UGS office to both sites was convenient for office-related tasks, such as creating and printing photomosaics quickly for trench logging. Utilizing UGS resources greatly contributed to the timely completion of these investigations.

These paleoseismic investigations at Flat Canyon and Alpine are helping to further our understanding of rupture parameters along the central segments of the WFZ. The data from both trenches will be compared with existing Holocene earthquake chronologies for the SLCS, PS, and NS to address the question of whether these segments rupture together or independently. Preliminary results from the Flat Canyon site were presented at the 2014 annual meeting of the Seismological Society of America (Bennett and others, 2014). Preliminary results from the Alpine site were presented at the 2015 annual meeting of the Seismological Society of America (Bennett and others, 2015). The full results of this paleoseismic investigation will be published separately by Scott E.K. Bennett and co-authors.

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