Surface Fault Scarp Mapping of the Sawtooth Fault, Central Idaho

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INTRODUCTION

This report is an introduction to the digital database of surface scarp mapping of the Sawtooth fault. Mapping data are available as a shapefile and a file geodatabase containing a feature class. Attribute fields were included to coincide with the forthcoming Idaho Geological Survey's Active Fault Database and the U.S. Geological Survey's Quaternary Fault and Fold Database. The attribute fields are described below. Fault scarps were mapped on lidar hillshade and slope basemaps and field checked during summer 2022.

FAULT SCARP MAPPING

We performed a desktop evaluation of lidar and mapped fault scarps in shapefile format at a scale of 1:10,000 using ESRI ArcGIS software. Active fault scarps were identified through desktop analysis of lidar based on geomorphic evidence described by Hansen et al. (1999) and McCalpin (2009). All mapped scarps were evaluated to exclude those formed by nontectonic processes such as erosion, gravitational slope failure, and those related to glaciation and older pre-Quaternary structures.

In general, the Quaternary fault scarps mapped in this study have a consistent geomorphic expression along strike, they are visible across one or more Quaternary deposits (i.e.,

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alluvium, colluvium, glacial) or landform (i.e., alluvial fan, terrace, deglacial surface, moraine), and often increase in size on older surfaces.

In some locations, the Sawtooth fault scarps are intersected, adjacent to, or otherwise near features that fit the description of sackungen (McCalpin, 1999). These features can form due to nontectonic processes or as secondary features in response to an earthquake (McCalpin and Jones, 2021). Their surficial expression can be similar to that of a tectonic scarp, which makes them difficult to differentiate. Following the general geomorphic criteria defined by McCalpin (1999), we classified sackungen as scarps that dip opposite that of the main fault, are relatively short and arcuate, and restricted to a particular aspect of a slope. In general, the Quaternary fault scarps mapped in this study have a consistent geomorphic expression along strike, they are visible across one or more Quaternary deposits (i.e., alluvium, colluvium, glacial) or landform (i.e., alluvial fan, terrace, deglacial surface, moraine), and often increase in size on older surfaces.

All scarps were digitized systematically to ensure the linework represents the base of the scarp and so that the down-dip direction will be correctly indicated when symbolized in mapping software. Scarps were only digitized where they have geomorphic expression. We did not map scarps as inferred or buried where they are not visible in landforms such as active channels, terraces, waterbodies, or other locations. The attribute scheme is based on the Idaho State Geological Survey attribute scheme for fault scarps and is a work in progress (Table 1).

Table 1. GIS Attribute Schema for the Idaho Geological Survey's Active Fault Database

Field Name	Description	Data Type
OBJECTID	Automatic ESRI field	Object ID
Shape	Automatic ESRI field	Geometry
Id	Fault identification number	Long
FaultName	Fault name	Text
source	Source of mapping. Indicates if the mapping was adopted from another source, or what the basis is for new mapping.	Text
Shape_Leng	Length of line feature	Double
FaultAge	Age of fault. Based on historical ruptures, paleoseismic studies, or age of faulted deposits.	Text
SlipSense	Sense of slip. Normal, reverse, or strike-slip (right-lateral or left-lateral).	Text
DipDirecti	Fault dip direction	Text
SlipRate	Slip rate. Based on paleoseismic or neotectonic studies where available. Otherwise based on estimates of offset and age.	Text
Mapper	Name of mapper	Text
Loc_Con	Location confidence. Estimate of the accuracy of the location of the mapped line based on the judgement of the mapper and the quality of the basemap. Assigned categories of Good, Moderate, or Poor.	Text
Interp_Con	Interpretation confidence. Estimate of the confidence of the geologic interpretation of mapped feature based on the judgement of the mapper. Assigned categories of Certain or Uncertain.	Text
FaultNum	Fault number used in U.S. Geological Survey’s Quaternary Fault and Fold Database.	Text
SectionNam	Fault section name used in U.S. Geological Survey’s Quaternary Fault and Fold Database.	Text
FaultZone	Fault zone name used in U.S. Geological Survey’s Quaternary Fault and Fold Database.	Text
StrandName	Fault strand name used in U.S. Geological Survey’s Quaternary Fault and Fold Database.	Text
Synopsis	Synopsis	Text
Location_Comment	Location comments	Text
Geologic_Setting	Description of the fault’s geologic setting.	Text
Geomorph_Expression	Description of the fault’s geomorphic expression.	Text
Age_Youngest_Faulted_Dep	Age of youngest deposit offset by the fault.	Text
Detailed_Studies	Description of detailed studies of the fault, including paleoseismic and neotectonic studies.	Text
IGS_Fault_Code	IGS fault code	Long
System_Code	Fault system code	Long
Structure_Code	Fault structure code	Long
System_Name	Fault system name used in U.S. Geological Survey’s Quaternary Fault and Fold Database.	Text

Structure_Name	Structure name	Text
Compiler_and_Affil	Name and affiliation of the data compiler.	Text
Shape_Length	Length of line feature	Double

LIDAR TOPOGRAPHIC DATA

Two lidar topographic datasets provide freely available public lidar coverage for this project (Table 2). The first lidar dataset is the 2005 Idaho State University (ISU) sponsored lidar collection that provides coverage of two small areas at Redfish Lake and Yellow Belly and Pettit Lakes. The second lidar dataset is part of the Federal Emergency Management Agency (FEMA)-sponsored southern Idaho dataset. It provides extensive coverage of the Sawtooth fault, and it was collected following the 2020 M6.5 Stanley earthquake (Liberty et al., 2021). It covers the 2020 M6.5 Stanley earthquake epicentral area and the Sawtooth Mountain range front south to the Salmon River headwaters. The area around Yellow Belly and Pettit Lakes was not included in the FEMA lidar collection, but the data gap spatially overlaps with the 2005 ISU lidar collection.

The 2005 ISU lidar dataset can be downloaded in digital elevation model (DEM) format from the Idaho Lidar Consortium[4], and the FEMA lidar dataset can be downloaded in point cloud or DEM format from U.S. Geological Survey LidarExplorer[5] or the Idaho Lidar Consortium.

Table 2. Summary of Compiled Lidar

Lidar Project Name	**Sponsor**	**Lidar Collection Date**	**Lidar Quality Level[1] (QL)**
2018 Southern Idaho Lidar QL1	FEMA	2020, Post M6.5 Stanley, ID earthquake	QL1
2005 Sawtooths South	ISU	Oct 2005	QL3

Notes:

1. Lidar QL is defined by USGS (2022). QL1 data has a point spacing of ≤0.35 m and is suitable for a minimum DEM cell size of 0.5 m. QL3 data has a nominal point spacing of ≤1.41 m and is suitable for a minimum DEM cell size of 2 m.

CONCLUSIONS

This dataset depicts surface fault scarp mapping of the Sawtooth fault in central Idaho. Our detailed geomorphic map shows that scarps cut late Quaternary alluvial fan and glacial

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[4] The Idaho Lidar Consortium can be accessed online at https://www.idaholidar.org/.

[5] The USGS LidarExplorer website can be accessed at

deposits for approximately 65 km along the eastern base of the Sawtooth Range. Previous maps of the fault (e.g., Fischer et al. 1992; Kiilsgaard et al., 2006; USGS, 2023) depict the Sawtooth fault as a 60-km-long sinuous surface trace. Our new mapping shows the fault in greater detail, demonstrating a significantly more complex fault zone than previously known. In addition to mapping the Sawtooth fault, we identified, and mapped from lidar two additional previously unmapped, throughgoing scarps that exhibit strong geomorphic evidence for surface faulting. We refer to those features informally as the Cape Horn fault and the Shake Creek fault.

REFERENCES

Berti, C., Anastasio, D.J., and Truxal, S., 2022, New Age and Geomorphic Controls on the Boulder Front Fault, Wood River Basin, Northern Basin and Range Province, Idaho: Geological Society of America Abstracts with Programs. Vol. 54, No. 2.

DuRoss, C.B., Lifton, Z.M., Hatem, A.E., Briggs, R.W., Thompson Jobe, J., Reitman, N.G., Thackray, G.D., Zellman, M.S., Collett, C.M., Gray, H.J., and Mahan, S.M., in review, Unraveling Fault Complexity: Comparing Holocene and Modern Seismicity in the Centennial Tectonic Belt, Idaho (USA): The Seismic Record.

Fischer, F.S., McIntyre, D.H., and Johnson, K.M. 1992. Geologic Map of the Challis 1° x 2° Quadrangle, Idaho. U.S. Geological Survey. Miscellaneous Investigation Series Map I-1819.

Geomatrix Consultants, Inc., 1989, Final report seismotectonic evaluation for Little Wood River Dam site: Technical report to U.S. Bureau of Reclamation, Denver, Colorado, 104 p., 2 pls.

Hansen, K.L., Kelson, K.I., Angell, M.A., and Lettis, W.R. (1999). Techniques for Identifying Faults and Determining Their Origins. Prepared for Division of Engineering Technology Office of Nuclear Regulatory Research. NUREG CR-5503.

Johnson, E.M., 2010, Lacustrine evidence of seismic events on the Sawtooth Fault in the Redfish Lake Drainage, Sawtooth Mountains, Central Idaho [M.S. Thesis]: Idaho State University, 116 p.

Kiilsgaard, T.H., V.L. Freeman, J.S. Coffman. 1970. Mineral resources of the Sawtooth Primitive area, Idaho. U.S. Geological Survey Bulletin 1319-D, p. D1-D174.

Liberty, L.M., Lifton, Z.M., and Mikesell, T.D., 2021, The 31 March 2020 Mw 6.5 Stanley, Idaho, Earthquake: Seismotectonics and Preliminary Aftershock Analysis.

Lifton, Z.M., Zellman, M.S., and Thackray, G.D., 2023, Mapping and Neotectonic Investigation of the Sawtooth Fault, Central Idaho: Collaborative Research with Idaho Geological Survey, Idaho State University, and BGC Engineering, Inc.: U.S. Geological Survey Earthquake Hazard Program Final Technical Report for External Grant Award Numbers G21AP10270, G21AP10271, and G21AP10272, https://earthquake.usgs.gov/cfusion/external_grants/reports/G21AP10271.pdf.

McCalpin, J.P., 1999, Criteria for determining the Seismic Significance of Sackungen and Other Scarplike Landforms in Mountainous Regions *in* Hanson, K.L., Kelson, K.I., Angell, M.A., and Lettis, W.R., Techniques for Identifying Faults and Determining Their Origins. U.S., Nuclear Regulatory Commission. NUREG/CR-5503.

McCalpin, J.P., 2009, Paleoseismology (2nd ed.) San Diego, California. Academic Press.

McCalpin, J.P., and Jones, L.C.A., 2021, The Stillwater Scarp, Central Nevada, USA; Coseismic Gravitational Failure on a 1.200-M-High Range-Front Escarpment, Environmental Engineering Geoscience, Vo. XXVII, No. 4, pp. 377-393.

Mijal, B., 2008, Holocene and latest Pleistocene glaciation in the Sawtooth Mountains, central Idaho [M.S. thesis]: Western Washington University, 62 p.

Reid, R.R., 1963, Reconnaissance geology of the Sawtooth Range: Idaho Bureau of Mines and Geology Pamphlet 129, 37 p., 2 pls.

Shapley, M., Thackray, G.D., Johnson, E., and Finney, B., 2023, Lacustrine evidence reveals spatially and temporally distinct Holocene ruptures on the Sawtooth Fault, Central Idaho, USA. Journal of Quaternary Science, p. 1-16, https://doi.org/10.1002/jqs.3554.

Sherard, C., 2006, Regional correlations of Late Pleistocene climatic changes based on cosmogenic nuclide exposure dating of moraines in Idaho [M.S. thesis]: Western Washington University, 91 p.

Staley, A.E., 2015, Glacial geomorphology and chronology of the Quinault Valley, Washington, and broader evidence of Marine Isotope States 4 and 3 glaciation across northwestern United States: M.S. Thesis, Idaho State University, 177 p. https://geology.isu.edu/thesis.html

Thackray, G.D., Lundeen, K.A., and Borgert, J.A., 2004, Latest Pleistocene alpine glacier advances in the Sawtooth Mountains, Idaho, USA: Reflections of midlatitude moisture transport at the close of the last glaciation. Geology 2004, 32(3), p. 225–228, https://doi.org/10.1130/G20174.1

Thackray, G.D., Rodgers, D.W., and Streutker, D., 2013, Holocene scarp on the Sawtooth fault, central Idaho, USA, documented through lidar topographic analysis: Geology, v. 41, p. 639-642, doi:10.1130/G34095.1.

Tschanz, C.M., Kiilsgaard, T.H., and Seeland, D.A., 1986, Geology of the eastern part of the Sawtooth National Recreation Area, Idaho: U.S. Geological Survey Bulletin 1545-A, p. 17-43, 1 pl., scale 1:62,500.

U.S. Geological Survey (USGS), 2022, Lidar Base Specifications 2022 rev. A. USGS. Accessed online on 11 Aug 2023 from https://www.usgs.gov/media/files/lidar-base-specification-2022-rev-a.

U.S. Geological Survey (USGS), 2023, Quaternary fault and fold database for the United States, accessed June 2023, at: https://www.usgs.gov/natural-hazards/earthquake-hazards/faults.

Williams, P.L., 1961, Glacial geology of the Stanley Basin: Moscow, Idaho Bureau of Mines and Geology, pamphlet 123, 29 p.

Worl, R.G., Kiilsgard, T.G., Bennett, E.H., Link, P.K., Lewis, R.S., Mitchell, V.E., Johnson, K.M., and Snyder, L.D., 1991, Geologic map of the Hailey 1° x 2° quadrangle, Idaho: U.S. Geological Survey Open-File Report 91-340, 1 sheet, scale 1:250,000.