A MULTIMETHOD GEOPHYSICAL INVESTIGATION OF THE HILTON CREEK FAULT, LONG VALLEY, CALIFORNIA

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Signature Page

THESIS: A MULTIMETHOD GEOPHYSICAL INVESTIGATION OF THE HILTON CREEK FAULT, LONG VALLEY, CALIFORNIA

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Thank your advisor, your parents, your pets, the people who make your coffee at Starbucks...

ABSTRACT

This is a short paragraph describing the main points of your thesis.

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Chapter 1

Introduction

The Hilton Creek Fault (HCF) is a major range-bounding fault in eastern California. The HCF, which strikes north-northwest, is one in a series of north-trending normal faults that define the eastern escarpment of the Sierra Nevada mountain range. The down-to-the-east geometry of these faults accomodates the upward motion of the Sierran Block to the West and downward motion of the Mono Basin and Owen's Valley, the westernmost grabens of the Basin & Range province, to the East [*Hill*, 2006]. As much as 1600 m of uplift has occurred along the Hilton Creek section of the Sierran rangefront over the past 5 Myr [estimated] [*Rinehart et al.*, 1964].

The HCF, in concert with the Hartley Springs Fault (HSF) to the North, forms a large (15 km) left-step in the Sierran rangefront (Figure **??**). It is at this left step that the volcanic province known as Long Valley developed around 4 Ma during the Pliocene [*Bailey*, 2004]. Although the exact reason for volcanic activity at this location is poorly understood, it is theorized that the volcanism is the result of the crustal transition between the Sierra Nevada and Basin and Range provinces [*Bailey*, 2004]. The Long Valley area has experienced numerous volcanic episodes throughout its history, none more significant than the cataclysmic eruption of the Bishop Tuff at 767 ka [*Hildreth and Wilson*, 2007]. This eruption ejected some 600 km^3 of volcanic material over the course of several days resulting in the collapse of the magma chamber along a ring fault and the creation of the Long Valley Caldera (LVC) [*Hildreth and Wilson*, 2007]. Although partially filled in by Bishop Tuff and post-eruptive sediments, the LVC is a prominent feature on the landscape today as a 17 km by 32 km elongate depression. Magmatism has continued throughout the Holocene as is evident by the many hot springs and young basalt and rhyolite flows that dominate the area.

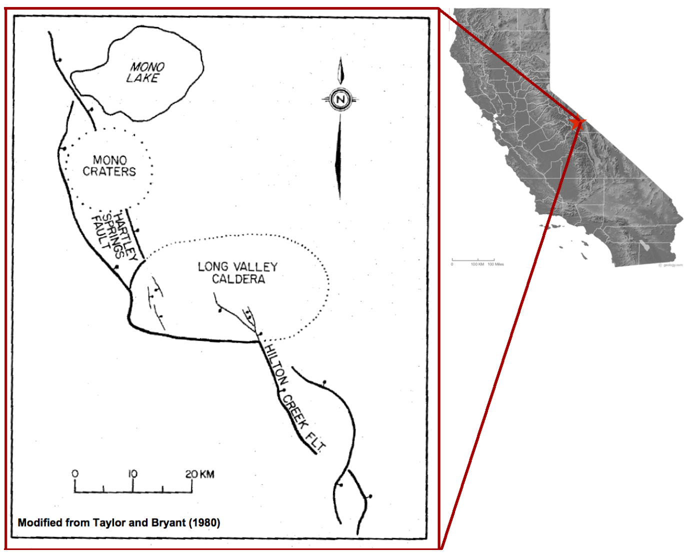

Figure 1.1: Overview map of the Long Valley area. Modified from *Taylor and Bryant* [1980]. **Note: Draw an original figure to replace this**

Current geologic maps of the region denote the HCF as a single strand from its southern terminus at Davis Lake, north to just inside the caldera boundary in the vicinity of US Highway 395, west of Crowley Lake [*Bailey*, 1989; *Hildreth and Wilson*, 2007]. Within the caldera, the fault is denoted as a series of mostly parallel splays left-stepping across the caldera floor to line up with the HSF (Figure 1.2). The total fault length is approximately 22-km [*Berry*, 1997], though the distance to which the fault actually extends into the caldera is subject to significant debate [*Hill and Montgomery-Brown*, 2015]. Early mapping of the region by *Rinehart et al.* [1964] and later by *Bailey* [1974] suggested the HCF extended into the area later occupied by the LVC, but was truncated and buried by the 767 ka Bishop Tuff eruption and subsequent caldera collapse.

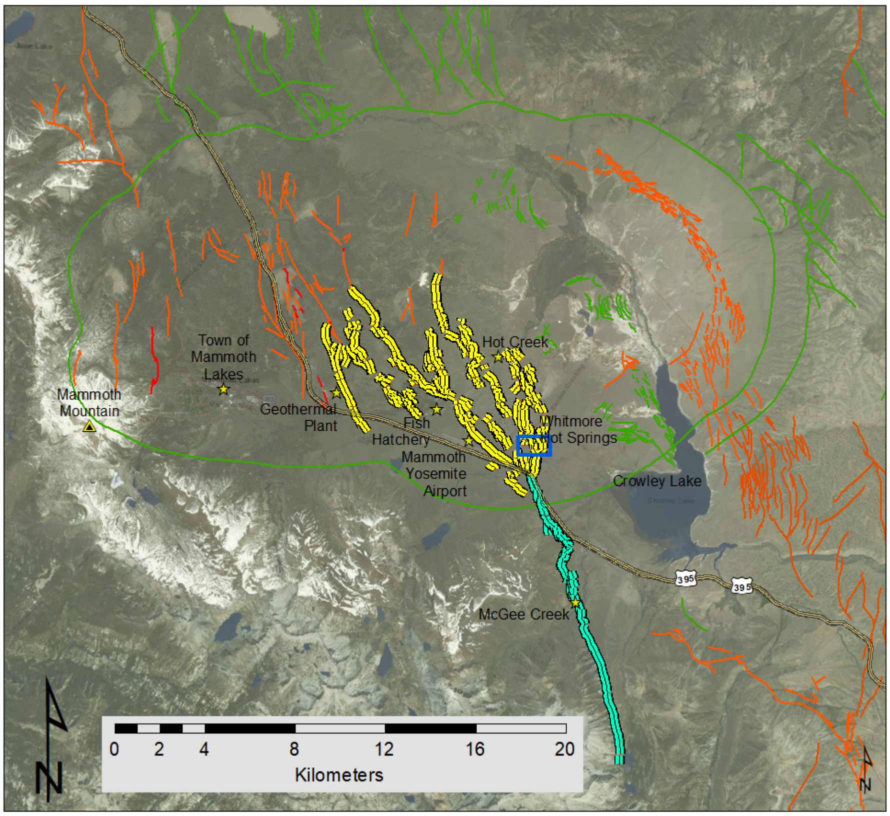

Figure 1.2: Map of Long Valley region indicating HCF fault. **Note: Reduce size of scale**

1.1 Geologic history of the region

Sierra Nevada eastern scarp plus extension of B&R equals volcanoes

1.1.1 Geologic history of the Sierra Nevada range

It’s a pluton. Kind of like a lava lamp, but actual lava.

1.1.2 Geologic history of the Basin and Range province

Stretchy, stretchy...

1.1.3 Volcanic history of the Long Valley Caldera

Erupted 760 ka. Big boom kaboom.

1.2 Geography of Long Valley Region

1.2.1 Description of Long Valley Caldera

Volcanoes, hot springs and faults. Oh my!

Geothermal activity in Long Valley

Hot, hot, hot springs

1.3 Recent activity in region

Shake, shake shake

1.3.1 Pre-1980 research

Yup, there’s a volcano there.

1.3.2 1980 Mammoth Lakes earthquakes

More shake, shake, shake

USGS and CDMG response

Don’t worry, there’s just a volcano under your town

Challenges communicating science to community

Keep vacationing here, please.

1.3.3 Post earthquake changes in caldera

Is this thing going to a’splode?

Increase in uplift rate of resurgent dome

Big, many, much uplift

Recent seismicity

Shaky town

1.4 Description of study area

High desert, plus snow, plus LADWP regulations

1.4.1 Challenges

Insurance

1.5 Motivation for study

I can't think of anything to write here

1.5.1 Intra- and extra-caldera fault characteristics

Description of fault outside of caldera

McGee Creek

Mapping of fault within caldera

1.5.2 Hazard posed by Hilton Creek Fault

Importance of accurate hazard assessment

Hazard studies

Disagreement over potential hazard

1.5.3 Origin of HCF splays in USGS QFFD

Chapter 2

Methodology

Method 'n' stuff.

2.1 Previous applications of topography and magnetism to fault identification

2.2 Total-station and GPS measurement of topography

2.2.1 Equipment used

2.2.2 Data acquisition methods

2.2.3 Data correction methods

2.2.4 Data analysis methods

2.3 Magnetic data acquisition and analysis

2.3.1 Equipment and software used

2.3.2 Data acquisition methods

2.3.3 Data correction methods

2.3.4 Data analysis methods

2.4 UAV/SfM measurement of topography

2.4.1 Equipment and software used

2.4.2 Pre-deployment planning

2.4.3 Data collection methodology

2.4.4 Post-processing methodology

Agisoft Photoscan

Chapter 3

Results

results 'n' stuff

3.1 Correlation of topographic and magnetic anomalies

3.2 Alignment of anomalies to previously mapped fault traces

3.3 Relationship of faulting to hydrothermal features

3.4 Additional evidence for faulting within caldera

3.4.1 Seismic evidence

Chapter 4

Discussion

discussion 'n' stuff

4.1 Application of findings to fault hazard

4.2 Recommended changes to fault maps and hazard studies

Chapter 5

Conclusions

conclusions 'n' stuff

5.1 Recommendations for future studies

We recommend you rename this fault, "Jason's fault". Then when an earthquake happens you can say it was "Jason's fault."

References

Bailey, R. A. (1974), Preliminary geologic map and cross-sections of Casa Diablo geothermal area, Long Valley Caldera, Mono County, California, *U.S. Geological Survey Open File Report*, *74-1007*.

Bailey, R. A. (1989), Geologic map of Long Valley caldera, Mono-Inyo Craters volcanic chain, and vicinity, Mono County, California., U.S. Geological Survey Miscellaneous Investigations Map I-1933, scale 1:62,500.

Bailey, R. A. (2004), Eruptive history and chemical evolution of the precaldera and postcaldera basalt-dacite sequences, Long Valley, California: implications for magma sources, current magmatic unrest, and future volcanism., *US Geological Survey Professional Paper*, (1692), 76 pp.

Berry, M. E. (1997), Geomorphic analysis of late Quaternary faulting on Hilton Creek, Round Valley and Coyote warp faults, east-central Sierra Nevada, California, USA, *Geomorphology*, *20*, 177–195, doi:10.1016/S0169-555X(97)00033-0.

Hildreth, W., and C. J. N. Wilson (2007), Compositional zoning of the bishop tuff, *Journal of Petrology*, *48*(5), 951–999, doi:10.1093/petrology/egm007.

Hill, D. P. (2006), Unrest in Long Valley Caldera, California, 1978 2004, *Geological*

Society London, Special Publications, *269*, 1–24, doi:10.1144/GSL.SP.2006.269.01.02.

Hill, D. P., and E. Montgomery-Brown (2015), Long valley caldera and the UCERF depiction of sierra nevada range-front faults, *Bulletin of the Seismological Society of America*, *105*(6), 3189–3195, doi:10.1785/0120150149.

Placeholder Citation (0), Placeholder Entry.

Ponce, D. A., M. Mangan, and D. McPhee (2013), High-resolution aeromagnetic survey of the Mono Basin-Long Valley Caldera region, California, in *Abstract GP51C-1091 presented at 2013 Fall Meeting, AGU, San Francisco, Calif., 9-13 Dec.*

Rinehart, C. D., D. C. Ross, and L. C. Pakiser (1964), Geology and mineral deposits of the Mount Morrison quadrangle, Sierra Nevada, California, with a section on a gravity study of Long Valley, *U.S. Geological Survey Professional Paper*, *385*.

Taylor, G. C., and W. A. Bryant (1980), Surface rupture associated with the Mammoth Lakes earthquakes of 25 and 27 May, 1980, *Mammoth Lakes, California earthquakes of May*, pp. 49–67.

Appendix A

LaTeX examples

This is a section to test formatting and figure placement in LaTeX.

A.1 Citations

In-line paragraph citation:

As much as 1600-m of uplift has occurred along the Eastern Sierran range front [*Rinehart et al.*, 1964] over the past 5 Ma.

In-line year paragraph citation: Early mapping of the region by *Rinehart et al.* [1964] and later by *Bailey* [1974] suggested the HCF once extended into the area now occupied by the LVC. [*Ponce et al.*, 2013]

This is an empty citation. It is intended to be used as a placeholder until a proper reference can be identified [*Placeholder Citation*, 0]

```
\citep{addReference}
```

A.2 Lists and bullets

Basic list (aka ”itemize”)

- Stuff
- More stuff
- Even more stuff

A.3 Figures

Although partially filled in by Bishop Tuff and post-eruptive sediments, the Long Valley Caldera is a prominent feature on the landscape today as a 17 km by 32 km elongate depression (Figure A.1).

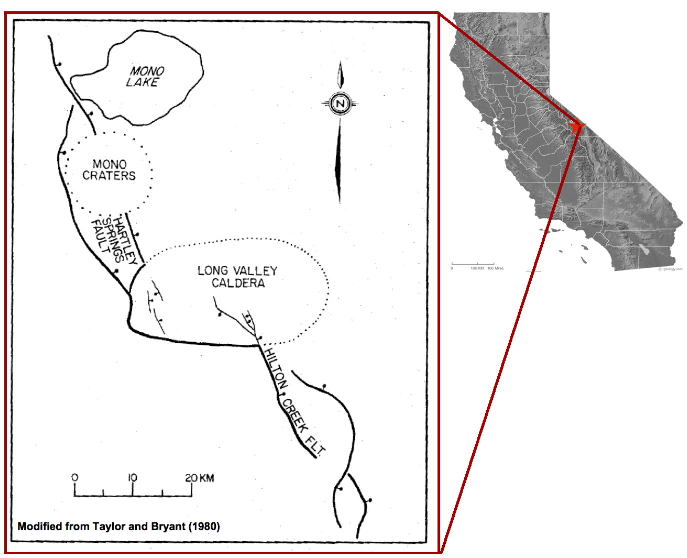

Figure A.1: Overview map of the Long Valley area. Modified from *Taylor and Bryant* [1980].

```
Figure \ref{fig:overview}
\begin{figure}[ht]
```

```
        \centering
        \includegraphics[width=9cm]{figures/overview}
        \caption{caption_text_here \citet{Taylor1980}.}
        \label{fig:example1}
    \end{figure}
```

A.3.1 Code snippet as figure

We can also create a figure that contains Python code (Figure A.2).

```python
def rotate_xy(xPoint, yPoint, x0, y0, angle):
    import math
    # angle in radians

    xDiff = xPoint - x0
    yDiff = yPoint - y0
    xNew = x0 + xDiff * math.cos(angle) - yDiff * math.sin(angle)
    yNew = y0 + yDiff * math.cos(angle) + xDiff * math.sin(angle)
    return xNew, yNew
```

Figure A.2: A Python function to rotate a point *(xPoint, yPoint)* about an origin *(x0,y0)* by *(angle)* degrees.

```
\begin{figure}[ht]
        \centering
            \begin{lstlisting}
    <code goes here>
\end{lstlisting}
```

```
    \caption{caption_text}
    \label{fig:example2}
\end{figure}
```

A.4 Tables

cell1	cell2	cell3
cell4	cell5	cell6
cell7	cell8	cell9

Table A.1: A basic table with multiple rows and columns

```
    \begin{table}[h!]
    \centering
    \begin{tabular}{ |c|c|c| }
         \hline
         cell1 & cell2 & cell3 \\
         cell4 & cell5 & cell6 \\
         cell7 & cell8 & cell9 \\
         \hline
    \end{tabular}
    \caption{A basic table with multiple rows and columns}
    \label{table:example01}
\end{table}
```

A.5 Formatting commands

Float barrier = A command from 'placeins' package. Stops floats from extending beyond a certain point. For ex: Force figures to be placed within a given chapter.

```
\FloatBarrier
```

A.6 Special characters

```
Degree symbol:  360$^{\circ}$
```

Degree symbol: 360°

Italics and Bold: This *part* is in *italics*. This **part** is in **bold**.

A.7 In-Line Commenting

To-Do items will show up in margins of printed document with pointers to todo flag

```
\todo[inline]{Add in-line to-do item here}
\todo{add margin to-do here}
```

Add in-line to-do item here

add margin to-do here

Print list of to-do notes:

Notes

Add in-line to-do item here 19
add margin to-do here 19

A.8 Chapters/Sections

A.8.1 This is a sub-sub-section

No number here - just name

This is a subsection with no section number

```
\subsection*{subsection_title_here}
```

A.9 New Commands

This command places *citation needed* in blue among the text

```
\addcite
```

citation needed

This command indicates an estimated value - useful to insert estimates in the text for later correction and citation

```
\est{2 m}
```

The elevation difference between the points was 2 m [estimated]