HOLOCENE FIRE, CLIMATE & EROSION
IN THE JEMEZ MOUNTAINS, NM
NATURAL AND ANTHROPOGENIC CONTROLS

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2011 Las Conchas Fire: Photo by Kristin Honig, US Forest Service
Fire severity in the Western US has increased in the past three decades

- Increased forest stand density associated with fire-suppression
- As we learn more about how forests respond to climate change, we will have more insight into the future risk of fire in the Western US

*Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming
Source: Jay O’Laughlin, University of Idaho, from National Interagency Fire Center data
How do forests respond to climate change?

- Identify correlations between late Holocene climate change and fire activity
- Northern New Mexico has not yet been studied beyond shorter-timescale tree-ring chronologies and this work aimed to fill that gap

Alluvial studies
- Record of post-fire erosion
- Estimate fire severity
- Longer record than tree rings but lower resolution
- Useful where natural lakes are absent

John Nelson, IDV Solutions
Introduction

- **The Jemez Mountains**: diverse ecosystem, natural resources, and cultural and scientific sites

- **Ponderosa pine and mixed-conifer forests** have been ravaged by extensive severe fires in the last two decades
  - Almost 1000 km², roughly 30% of this middle-elevation range

- Management of this region would greatly benefit from a long-term historical perspective of **fire and climate**

Tree-ring fire history reconstructions

- Low-severity fire regime characterized the ca. 400 years before Euroamerican settlement
- Fuel buildup from fire suppression and grazing
- Increased fire severity in recent years

Therefore, in order to better understand natural variability, climatic influences, and erosional effects of wildfire activity since ~5000 cal yr BP

We identified and radiocarbon-dated fire-related alluvial deposits in the Jemez Mountains
This study was carried out in the 2002 Lakes Fire burn area

- Post-fire hillslope erosion and alluvial-fan sedimentation and incision
- Exposed fan stratigraphy
- Processes commonly associated with fire in the Jemez Mountains
Douglas-fir dominated, north-facing slopes less steep than ponderosa pine dominated south-facing slopes

- Microclimate differences, due to solar insolation differences, may influence geomorphic processes

Therefore, this work also uses fan stratigraphy and geomorphic measurements to test whether post-fire erosion and sedimentation patterns in the Jemez Mountains reflect differing microclimates associated with north and south slope aspects.
Methods

- Alluvial fans in small mountain tributaries contain:
  - Debris-flow
  - Hyperconcentrated-flow
  - Streamflow deposits

- Fires tend to promote erosion:
  - Runoff-generated debris flows and flash floods during summer convective storms of moderate to high intensity
  - These fire-related flows carry burned material from soil surfaces on steep slopes
    - abundant macroscopic angular charcoal, charred litter, and ash that will be preserved within the resulting deposit
Methods

- We described **18** fan sections
  - Identified fire-related deposits
  - Performed grain-size analysis

- We radiocarbon dated **54** fragments of charcoal
  - Provides deposit age
  - Estimated fire severity based on deposit thickness
Fire-related sedimentation events make up 57% of the total thickness of fans. 

North-facing alluvial fans are dominated by fire-related deposits: 77% of the total thickness of alluvial fans. 

South-facing fans are dominated by non-fire related deposits: 61% of the total thickness of fans. 

No particular flow process (e.g., debris flow) dominates either slope aspect. 

North-facing slopes may: 
- Have a thicker cover of relatively permeable, weathered colluvium. 
- Be anchored by a thicker, more mesic forest and understory structure. 
- Not be as susceptible to erosion unless these slopes are impacted by fire. 

South-facing slopes may: 
- Have sparser vegetation, and a thinner cover of colluvium and more exposed bedrock. 
- Produce substantial runoff and sedimentation during intense storms even in the absence of fire. 

Fire has an important influence on hillslope erosion and fan sedimentation in the Jemez Mountains.
Radiocarbon dating results in a probability distribution for each sample.

We sum the sample age probabilities for each year, resulting in an annual cumulative distribution.

Clear peaks in fire event probability:
- More likely that fire activity occurred during these peaks
- "Fading record" effect

Based on the number of samples that contribute to different parts of our record, the most recent 2000 years of our record are best represented.
Most late Holocene fire-related erosional events were relatively minor
  - Consistent with the low-severity burns that dominate the tree-ring record

Larger debris flows also occurred
  - Suggesting at least small areas of high-severity fire
Peaks in fire-event probability correspond with severe regional multidecadal droughts ca. 1800 and 375 cal yr BP.

The late MCA peak in fire-event probability overlaps a severe multidecadal drought 670 – 650 years BP in the Four Corners area.
Late Holocene Fire Activity

- High fire-event probability between 2000 and 500 cal yr BP:
  - Generally occurs during periods of large-scale **climatic variance** as well as periods of **frequent climatic shifts**

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**X**
- Increased El Niño (a) Frequency (b) Variance
- Large-scale precipitation variance
- Dampened precipitation variance

1. Approximate Medieval Climatic Anomaly (MCA) and Little Ice Age (LIA)
2. El Niño Southern Oscillation Records
3. Speleothem Precipitation Record (Central New Mexico)
4. Tree-Ring Drought Record (Southern Colorado)
5. Southwestern US Droughts (Various Sources)
The lack of recorded fire activity during much of the Medieval Climatic Anomaly may have been the result of:

- Dampened precipitation variance
- A change to a more open forest structure and lower-severity fire regime
  - Severe fire in the previous millennia
  - Frequent, severe drought in the Four Corners area

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**Late Holocene Fire Activity**

- Large-scale precipitation variance
- Dampened precipitation variance
- Increased aridity and drought frequency
- Megadrought
- Drought

**Regime Change?**

1. Approximate Medieval Climatic Anomaly (MCA) and Little Ice Age (LIA)
2. El Niño Southern Oscillation Records
3. Speleothem Precipitation Record (Central New Mexico)
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5. Southwestern US Droughts (Various Sources)
Late Holocene Fire Activity

- Lack of exposed and dated deposits older than 5000 cal yr BP
  - Middle Holocene may have seen more severe fires and erosional activity
  - Erosional response after the Lakes Fire was at least locally greater than at any time in the last 5000 yr

- Expansion of this small study area would help us better understand:
  - Local fire-climate-erosional linkages in the Jemez Mountains
  - The degree to which modern climatic warming and anthropogenic impacts have heightened severe fire activity
Thank You

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References

Tree-ring studies & fire-related deposits


Southwestern paleoclimate studies

Medieval Climatic Anomaly and Little Ice Age:

Southwestern droughts:

El Niño Southern Oscillation records:

Tree-ring drought record (Southern Colorado):

Speleothem precipitation record (Central New Mexico):