“Frankly, my dear, I don’t give a dam”

--The Owyhee River

A joint venture of the Pacific Northwest and Rocky Mountain cells of the Friends of the Pleistocene
August 23-26, 2012

Lisa Ely, Kyle House, Cooper Brossy, Liz Safran, Duane Champion, Jim O’Connor
Planned stops and some of the roads that we may travel. Camp is at the BLM Birch Creek Campground.

**Department of Shameless Self Promotion (Project-related papers and publications)**


**Owyhee:** Inspired by the dramatic lava and water interactions, early Paleolithic hominids named this region after the mid-Pacific pile of basaltic lava, first known as Owyhee, then Sandwich Islands, and now Hawaii. Well, that’s not completely true, but we can pretty much say anything since this ‘guide’ has not undergone USGS review and is not approved for publication or distribution. So please don’t cite it. Don’t despair, however, because there’s much better stuff to read and reference. In fact, this “guide” is really just a skeleton, fleshed out by the various (mostly citable) theses and papers that have been completed or are in various preparatory states—most available via the website from which you downloaded this document. Now that the disclaimer is out of the way, we can get to some substance.

**Yeehow:** Owyhee spelled sideways. The Yeehows are colleagues come together in shotgun collaboration. Lisa Ely, Kyle House, and Jim O’Connor trace their interest in floods and landscapes back to the ‘80s and their graduate school days together in Arizona. Liz Safran added needed rigor and perspective. Gordon Grant coined the term ‘extrafluvial’ and solved the problem of too much rigor. We soon figured out that the lava flows were a big part of the story and were bailed out by Kathy Cashman, Duane Champion and Ninad Bondre. Chronology, another can of worms, was alternately confused and confirmed by contributions from Cassie Fenton, Terry Spell, Chris Henry, Brent Turrin, and early K-Ar work by Bill Hart. Of course, much of the work was done by students: Deron Carter, Cooper Brossy, Shannon Othus, Caitlin Orem, Robin Beebee, Scott Anderson, and Rose Wallick among others. NSF provided funding, with additional support (some of it knowingly) from the USGS, Nevada Bureau of Mines, Bureau of Reclamation, GSA, NCALM, and various other sources.

**Why the Owyhee?** Besides being a remarkably beautiful place, the Owyhee River corridor showcases many complications in fluvial systems. Outburst floods from far-off Pleistocene lakes, lava flows filling the canyon, and landslides blocking the river—all serve to give the river alternating cases of fluvialitus interruptus and cataclysmic stream power. What are the key interactions involved with these extrafluvial events and what are the consequences to landscape and valley evolution? We don’t have answers, but we’re at a point where we have some idea at least of what happened, mainly as an outcome of detailed mapping and chronology along the river corridor, extending outward to the volcanic centers that have been the source of many intracanyon lava flows.

**This will be the main focus of the trip**—the story of the lava flows and their interactions with the river corridor. We also dive into the landslides and their effects, locally and regionally. As outlined in Table 1, we’ll generally go from youngest (less than 1 ka?) to oldest (~ 4 Ma) in the sequence of lavas. We’ll spend significant time on Friday looking at the ~70 ka West Crater lava flow and its effects on the river corridor in the Lambert Rocks area. At a couple locations, we’ll discuss the landslide story, which mainly (but not completely) post-dates the major river-invading lava flows and is an important factor controlling the present river character. Pleistocene outburst floods also exert their possible effects on the river.

**Some questions to think about as we move along include:** What are the short and long-term consequences of lava flow incursions into river valleys? Can they significantly affect the fluvial response to regional uplift or base-level fall? Can lava-flow dams generate outburst floods? Likewise, we can ask very similar questions for landslides. And what might be the relation between the fluvial response to lava flows and the incidence and locations of landslides?

Please keep grounded in more mundane but immediately practical issues involved in driving and hiking the Owyhee Canyon country while basking in the purple haze of these esoteric geomorphic questions. It will likely be very hot and perhaps windy, the upland grasses are tinder dry, and heated catalytic converters do ignite fires, as do cigarettes. In addition to fire, rattlesnakes, sharp objects in the road and trail, poison oak, and heat pose significant hazards that we all know about. We’re a long ways from help. Please keep cool, stay on roadways (such as they are), and carry a fire extinguisher, first-aid, spare tire(s) and water.
<table>
<thead>
<tr>
<th>Day</th>
<th>Stop</th>
<th>Location</th>
<th>Stop Emphasis</th>
<th>Presenters</th>
<th>Time (fluid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thursday, Aug. 23</td>
<td>Arrival</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Birch Creek campground</td>
<td>43.2290  -117.4970</td>
<td>This is Camp</td>
<td>Someone should be present to greet you at the bottom of the Birch Creek grade after 6 PM</td>
<td></td>
</tr>
<tr>
<td>Friday, Aug. 24</td>
<td>Depart Camp at 8:00</td>
<td></td>
<td></td>
<td></td>
<td>8:00 AM</td>
</tr>
<tr>
<td>Day 1</td>
<td>1 Coffeepot Crater</td>
<td>43.1457  -117.4618</td>
<td>Introduction, logistics, overview geology, introduce mapping, sequence of lavas</td>
<td>Ely, House, Brossy,</td>
<td>9:00 AM  11:00 AM</td>
</tr>
<tr>
<td></td>
<td>2 Bogus Point (and hike)</td>
<td>43.0710  -117.6795</td>
<td>Lunch, lava flow sequence, paleomag, landslides, lake sediments, West Crater lava flow and dam</td>
<td>House, Brossy, Champion, Safran, Ely, Orem</td>
<td>12:00 PM  5:00 PM</td>
</tr>
<tr>
<td>Saturday, Aug. 25</td>
<td>Depart Camp at 8:30</td>
<td></td>
<td></td>
<td></td>
<td>8:30 AM</td>
</tr>
<tr>
<td>Day 2</td>
<td>1 Hole-in-the-Ground viewpoint</td>
<td>43.1828  -117.5335</td>
<td>Deer Park lava flows</td>
<td>House, Brossy, Champion, Ely</td>
<td>9:30 AM  11:00 AM</td>
</tr>
<tr>
<td></td>
<td>2 Iron Point Viewpoint</td>
<td>43.1369  -117.6589</td>
<td>Lunch, Bogus lava flows, rim gravels, river profile chronology</td>
<td>House</td>
<td>11:30 AM  1:00 PM</td>
</tr>
<tr>
<td></td>
<td>3 Dog-leg viewpoint</td>
<td>43.1184  -117.6925</td>
<td>AM-PM flow, Dog-leg sequence, river profile evolution, lava- and landslide-dam generalizations</td>
<td>House, Champion, Brossy, Ely, Safran</td>
<td>1:30 PM  3:00 PM</td>
</tr>
<tr>
<td></td>
<td>4 Jackson Hole (and hike)</td>
<td>43.1831  -117.6419</td>
<td>Intracanyon lava sequence; perched fan; lava delta</td>
<td>House</td>
<td>3:30 PM  6:00 PM</td>
</tr>
<tr>
<td></td>
<td>Evening; Annual Meeting</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunday, Aug. 26</td>
<td>Depart Camp at 7:30</td>
<td></td>
<td></td>
<td></td>
<td>7:30 AM  10:00 AM</td>
</tr>
<tr>
<td>Day 3</td>
<td>1 The Nipple (from camp)</td>
<td>43.2171  -117.5082</td>
<td>View, Basalt flow, faults, gravel</td>
<td>House, Ely</td>
<td></td>
</tr>
</tbody>
</table>

Our attempt at a schedule. Don't laugh.

Department of Shameless Self Promotion II (Project-related theses)

DAY 1: Friday, August 24, 2012
Today we introduce the regional mapping and chronology, and then examine a lava-dam and lacustrine sequence.

Day 1, Stop One: Coffeepot Crater and Jordan Craters lava flow
Stop Location: Coffeepot Crater interpretative area; Lat. 43.1457; Long. -117.4618
Stop Purpose: Introductions (leaders and participants), outline logistics and overall schedule, summarize history and main objectives of project, general geologic context, describe mapping and outline sequence of main lava flows.
Discussion leaders: all leaders
Key Points:
- Neogene volcanism and basin filling, including massive Miocene rhyolite flows.
- Regional incision probably associated with capture of Snake River 3.8-2 Ma.
- Late Tertiary and Quaternary basalt volcanism, notably Lower Bogus (>1.7 Ma), Bogus Rim (1.7 Ma), Deer Park (>780 ka), Clarks Butte (215 ka), Saddle Butte (145 ka), West Crater (70 ka), Jordan Crater (<1 ka?).
- Stratigraphy, chronology and mapping support history of canyon-filling lava flows and their consequences.

Family portrait of intra-canyon lava flows, showing general relative positions and ages
Preliminary correlation of map units, Owyhee River mapping
Regional geologic map in preparation by House et al. We know this version is pretty much unreadable, but we'll have poster-size printouts on the trip.
Day 1, Stop Two: Bogus Point and hike beyond
Stop Location: Park near Bogus Point (Lat. 43.071; Long. -117.6795); hike out onto West Crater lava flow
Stop Purpose: Lunch with a view, including multiple lavas, Bogus, Saddle Butte, West Crater; discuss paleo-mag and chronology; view and discuss landslides; view and hike West Crater lava dam and resulting lacustrine deposits. Please respect the parcels of private property along the hiking route.
Discussion leaders: Kyle House, Cooper Brossy, Duane Champion, Lisa Ely, Caitlin Orem, Liz Safran

Key Points:
- A complex and not totally determined local history of lava flows entering river corridor from both sides, including the Bogus sequence, Clarks Butte, Saddle Butte, and West Crater.
- Field paleomagnetic studies on these voluminous, monogenetic basalt centers yield typically unique directions of remanent magnetization and polarity as an aid to our geologic mapping and stratigraphic correlation.
- Both the Saddle Butte (145 ka; from west) and West Crater lava flows (70 ka; from east) filled canyons, created long-lived lakes, and ultimately diverted river course first east and then back west.
- Lava flow morphology and stratigraphy reflects interactions with canyon, river and impounded lake.
- Gravel-capped lacustrine deposits associated with West Crater flow span ~70 ka to at least 47 ka, and apparently completely filled the impounded valley.
- Abundant landslides pre-date and post-date the West Crater flow, with several blocking the valley and then breaching.
- Landsliding is promoted by stratigraphy of coherent lava over weak sediment, including lake deposits behind lava dams.

Equal-area diagram of mean directions of remanent magnetization with circles of 95% confidence for lava flows in this study. Samples were collected from lava outcrops near the source vents and within the Owyhee River canyon to validate correlations of isolated lava outcrops with each other and their sources. Directions of magnetization are depicted by the declination (east from true north) and the inclination (closed circles are positive and oriented downward, open circles are negative and oriented upward) from the horizontal (Butler, 1992; McElhinny, 1973). Samples with larger uncertainty were affected by lightning. (from Ely et al., in press, supplementary material)
Saddle Butte 2 (SB2) lava dam at Sand Springs Wash, which is one of the best examples of a lava dam in the field area. Here, the younger SB 2 dam overlies the older Saddle Butte 1 (SB 1) lava flow. The SB 2 dam contains a well-developed lava delta with pillow-laden foreset beds that dip up valley. The surface of the older SB 1 lava is buried by lacustrine sediment capped by fluvial gravel that accumulated upstream of the SB 2 dam.

Cross-section across Owyhee River valley of the Main West Crater (MWC) and Caitlin’s Hill (CH) sections and their relationship to the Owyhee River and other units. From Orem (2010)

Diagram of the Caitlin’s Hill (CH) stratigraphic section with MSH Cy and Cw tephra layers labeled. From Orem (2010)
Geologic map of area of West Crater lava-flow dam and area of day 1 stop 2 hike
DAY 2: Saturday, August 25, 2012
Today we overview some of the older canyon-filling lava flows, discuss river incision and paleo-profiles, and summarize generalizations so far regarding the role and lavas and landslides in Owyhee River valley evolution.

Day 2, Stop One: Hole-in-the-Ground viewpoint
Stop Location: Overlook on southeastern rim of Hole-in-the-Ground landslide complex (Lat. 43.183; Long. -117.5335)
Stop Purpose: Get a view of Deer Park lava flows; see Late Pleistocene through Holocene landslides and discuss chronology; discuss paleoflood history of Owyhee River.
Discussion leaders: Cooper Brossy, Kyle House, Duane Champion, Lisa Ely.
Key Points:
• Paleomag-reversed Deer Park lavas entered Owyhee Canyon by two routes at slightly different times about 780 ka, but with minimal footprint on river corridor.
• Landsliding can persist for many tens of thousands of years at a given location, and river deflection can shift zones of active landsliding across the valley.
• Landslide character can vary spatially within a given landslide complex (e.g. rotational failures vs. earthflows).
• During pluvial periods, some areas that are currently internally drained (e.g., Lake Alvord, Lake Coyote) flowed into Owyhee River system, in part through large paleo-floods.
• Largest flood on Owyhee River in last ~8000 years was 1600 m³/s in 1993.
Preliminary Geologic Map of the Hole in the Ground Reach of the Owyhee River, Malheur County, Oregon

P. Kyle House, Cooper C. Brossy, Duane E. Champion, James E. O'Connor, Liz Safran, and Lisa L. Ely

2012

Map Units

QrW, QrWy, Qrb, Qrg, Qgb, Qgbr, QTg - Older Owyhee River deposits

Qry, Qrbty - Active river bars and low terraces

Qrt - Terrace sequences

Qc - Eolian deposits and colluvium

Qa, Qay, Qai, Qao, QTa - Tributary alluvium

Qr, Qrh, Qrb - Terrace sequences

Qls, Qlsy, Qlsb, Qlsi - Landslides

Qbc, Qbd, Qbr, QTbl - Primary intracanyon basalt lava flows

Qcbs, Qhgs - Lower Pliocene to Miocene sediments and minor volcanic rocks

Qv, Qrv, Qtv - Miocene rocks and sediments

Map projection: Transverse Mercator.
Map datum: NAD83, UTM Zone 11N.
Day 2, Stop Two: Iron Point viewpoint

Stop Location: Lunch with a view overlooking southern rim of canyon across from Iron Point (Lat. 43.137, Long. -117.6589).

Stop Purpose: View Bogus lava flows and rim-top gravels

Discussion leaders: Kyle House

Key Points:
- Bogus lavas are the oldest and most voluminous intracanyon flows on the Owyhee River.
- The lake that resulted from the Bogus lava dam was aerially extensive and led to widespread deposition of several meters of gravel on what is now the canyon rim.
- At ~2 Ma, the Owyhee River valley was relatively broad and flat.
- Rhyolite outcrops form “pinch points” for river canyon and may exert some control over long-term incision rate.

Longitudinal profiles of the Owyhee River and intracanyon lava flows from RK 19 to 76. Lithologic units at the base of the diagram indicate the geologic units that compose the canyon walls at river level. Arrows indicate where lava directly overlies unweathered river gravels or tributary gravels.
Day 2, Stop Three: Dog-leg viewpoint

Stop Location: Overlook along eastern rim of canyon (Lat. 43.118, Long. -117.6925)

Stop Purpose: View a key sequence of erosion surfaces and terraces; discuss chronology of Owyhee River incision; ponder the impact of lava and landslide dams on incision history

Discussion leaders: Lisa Ely, Kyle House, Duane Champion, Liz Safran, Cooper Brossy

Key Points:
- Lava flows provide snapshots of river profiles, thereby tracking long-term incision.
- The West Crater lava dam lingered for at least 25 ka before incision began, and the dam was largely removed in another 35 ka.
- Incision of the West Crater lava dam appears not to have initiated until the impoundment filled with sediment; also apparently the case for the Bogus and Saddle Butte lava dams.
- Despite abundant evidence for lava-water interaction, lava dams on the Owyhee River show no evidence of catastrophic failure. The net effect of intracanyon flows on the river is therefore to inhibit incision.
- Re-incision is relatively rapid once it starts; long-term rates of Owyhee River incision are ~0.2 mm/yr, while incision of individual intracanyon flows can exceed 1 mm/yr
- River re-incision after intracanyon lava flows largely occurs at the flow edges, except where the river is confined by more resistant lithologies.
- This process of re-directing the river exposes the key sequences (coherent lava flows atop weak sediments) prone to landsliding. Landsliding thus extends the geomorphic impacts of intracanyon lava flows beyond the lifetime of the lava dams themselves.
- Landslide dams on the Owyhee River and in eastern Oregon in general are relatively unstable compared to other regions where landslide dams are common. This is due to the relatively large ratio of impoundment to landslide dam volume dictated by the low regional gradient and the landslide character.
- Both lava flows and landslide dams appear to be second-order controls on longitudinal profile evolution in this landscape.

Dogleg Bend terrace sequence and chronology (by cosmogenic radionuclide), recording incision of West Crater lava dam
Cumulative incision of the Owyhee Canyon through time. The valley-filling lava flows have superimposed 300-360 m of additional vertical incision upon the background net regional river incision since the emplacement of the Bogus Rim lava dam at 1.7 Ma.

Table 2. Incision Rates

<table>
<thead>
<tr>
<th>Lava flow/feature</th>
<th>Location (Rb)</th>
<th>Height above river (m)</th>
<th>Mean age (ka)</th>
<th>Incision rate to present (mm/yr)</th>
<th>Incision rate to intermediate points (mm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Bogus lavas</td>
<td>50-73</td>
<td>115-230</td>
<td>1700-2000</td>
<td>0.06-0.16</td>
<td></td>
</tr>
<tr>
<td>Bogus Rim</td>
<td>-53</td>
<td>310</td>
<td>1690 ± 30</td>
<td>0.18</td>
<td>BR to CB = 0.17</td>
</tr>
<tr>
<td>Bogus Rim dam crest</td>
<td>-53</td>
<td>310</td>
<td>1690 ± 30</td>
<td>0.18</td>
<td>BR to WC = 0.18</td>
</tr>
<tr>
<td>Bogus Rim highest overflow</td>
<td>55.5</td>
<td>270</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deer Park</td>
<td>71</td>
<td>210</td>
<td>780 ± 50</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>Saddle Butte</td>
<td>49.5</td>
<td>54</td>
<td>214 ± 9</td>
<td>0.25</td>
<td>CB to WC = 0.33</td>
</tr>
<tr>
<td>West Crater</td>
<td>39</td>
<td>68</td>
<td>69 ± 9</td>
<td>1.2</td>
<td></td>
</tr>
</tbody>
</table>

Note: Abbreviations: BH—Bogus Rim lava; CB—Clarks Butte lava; SB1 and SB2—Saddle Butte 1 and 2 lavas; WC—West Crater lava; T5-T1—terraces at Dogleg Bend, from highest to lowest.

1. Height above river refers to the surveyed height above the water surface at low to moderate discharge, which is ≤2 m above the channel bed in most cases.
2. Weighted mean and representative ages (in parentheses) of the lava flows from Table 1. The ages of the West Crater eroded surfaces and Dogleg terrace boulders are the weighted mean of the cosmogenic 10Be exposure ages on each (Tables DR1 and DR2; see text footnote 1).
3. Incision rates are calculated from the dam crest to the modern river surface unless otherwise indicated. Incision rates within the West Crater dam are based on the elevations of the outer edges of the terrace or strath surfaces.
4. Base of West Crater and Clarks Butte flows are 7.5 m and 45 m, respectively, above the water surface of the modern river; elevations of Dogleg terraces are as indicated in the table.
5. Age of abandonment of Dogleg T5 terrace is based on the mean of the three youngest cosmogenic radionuclide exposure ages of boulders on the strath surface.
6. Dogleg T1 is inundated by high flows from present-day Owyhee River and was not included in incision calculations. Because of the wide range in cosmogenic radionuclide exposure ages of boulders on T1, the age in Table 2 is the mean of only the two youngest boulder exposure ages.
Lava dam impounds river

Slow incision of outlet with local tools

Lake fills with Sediment

Incision enhanced by through-going bedload transport

Episodic downstream aggradation, in part owing to enhanced upstream sediment supply

Fluvio-lacustrine sedimentation

Schematic representation of sequence of events associated with lava-dam incision

Peak discharges from dam failures. Largest and only known lava-dam breach is the Uinkaret lava dam on the Colorado River (Fenton et al., 2004). Floods from breached landslide dams are common and can be large relative to impounded volume. From O’Connor and Beebee (2009)
Comparison of geomorphometric characteristics of Eastern Oregon landslide dams with data sets from New Zealand and a worldwide compilation. New Zealand data are from Korup (2004). Drainage areas for worldwide data are from Ermini and Casagli (2003); other statistics for worldwide data are extracted from Korup (2004). Standard errors on the mean are plotted. Number of dams used for statistics are 16-17 for eastern Oregon, 49-202 for New Zealand, and 83-148 for worldwide data.

Morphometric characteristics of landslide dams, impounded lakes, and upstream catchments were used to compute values of five dam stability indices summarized in Korup (2004): Blockage Index, Dimensionless Blockage Index, Basin Index, Impoundment Index, and Backstow Index. The graphs above show the spread of our data points relative to threshold values reported in the literature. Open circles indicate dams showing evidence of catastrophic failure, solid circles indicate dams lacking such evidence, and the solid triangle indicates a dam showing evidence of long-term stability and catastrophic failure.
Day 2, Stop Four (time permitting): Jackson Hole (and hike)
Stop Location: Park at southwest rim of Jackson Hole; hike down to river level (Lat. 43.183, Long. -117.6418).
Stop Purpose: Spectacular viewing into gorge and hike to intracanyon lava flow exposures; visit perched fan graded to lava flow top; view exposure of lava delta
Discussion leaders: Kyle House
Key Points:
• Tributary valley backflooded with two lava flows separated by lacustrine deposits
• Well exposed Tertiary section
• Access to river to see sub-lava fluvial gravel
DAY 3: Sunday, August 26, 2012
Today an optional (well, everything is optional) early morning hike to “the nipple” to shake the cobwebs loose from last night’s festivities and to gain a spectacular view of the Owyhee River corridor.

Day 3, Stop One: The Nipple viewpoint
Stop Location: Drive or walk from Birch Creek campground upstream, past Birch Creek to near Lat. 43.2210; Long. -117.5127, then climb the slope to the obvious prominence near Lat. 43.2171; Long. -117.5082.
Stop Purpose: River corridor views, including lavas, landslides, and faults; discussion of Birch Creek archaeological investigations.
Discussion leaders: Kyle House, Lisa Ely
Key Points:
• Much more work could be done.

Thanks for joining us, and have a safe and scenic drive home. See you next year!