KECK GEOLOGY CONSORTIUM

PROCEEDINGS OF THE TWENTY-FIFTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2012
Amherst College, Amherst, MA

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ISSN# 1528-7491

The Consortium Colleges The National Science Foundation ExxonMobil Corporation

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Funding Provided by:
Keck Geology Consortium Member Institutions
The National Science Foundation Grant NSF-REU 1005122
ExxonMobil Corporation

Keck Geology Consortium: Projects 2011-2012
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KECK COLORADO PROJECT: INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
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JAMES N. WINKLER, University of Connecticut
Research Advisor: Will Ouimet

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KECK COLORADO PROJECT: INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO

DAVID P. DETHIER, Williams College
WILL OUIMET, University of Connecticut

INTRODUCTION

Processes in the critical zone, the life-sustaining surficial mantle of the earth, involve the interactions of weathered geologic materials, water, and the biosphere, mediated by atmospheric processes that are controlled by changing climate. Field and laboratory studies provide valuable data about processes in the critical zone and the physical basis for their integration into models of short and long-term geomorphic, hydrologic and biochemical response. The Keck Colorado Project has worked in cooperation with a large interdisciplinary study (Boulder Creek Critical Zone Observatory: Weathered profile development in a rocky environment and its influence on watershed hydrology and biogeochemistry— Suzanne Anderson, PI, Institute for Arctic and Alpine Studies, University of Colorado) of the critical zone. The observatory (CZO) consists of 3 small, instrumented catchments in the Boulder Creek basin, Colorado Front Range: (1) Green Lakes Valley (GLV; el. 3400 m)--a steep, glacially scoured alpine area in the City of Boulder watershed; (2) Gordon Gulch (el. 2600 m)--a forested, montane catchment that exposes isolated bedrock remnants (tors) developed on a surface of low relief; and (3) Betasso gulch (el. 1950 m)--a steep, thinly forested basin that preserves thick regolith in the upper catchment and exposes extensive bedrock outcrops at lower elevations (Fig. 1). After an extensive fire burned 26 km^2 of the Fourmile drainage basin in early September 2010, the Boulder Creek CZO added this area as an additional study site.

The glaciated GLV, low relief surface, and bedrock canyons such as Boulder and Fourmile Creek are developed in granitic and gneissic rocks and are influenced by the strong W-E gradients in elevation, climate and vegetation. Variation in critical-zone development in these different environments has allowed Keck students to test models of weathering and regolith generation, surface-water hydrology, slope evolution and sediment transport in an accessible field setting. Land-use, vegetation and hydrologic response in each CZO catchment also reflect changes produced by activities such as mining, timber harvest and fire over the past 150 years. Keck Colorado field studies have focused on using a variety of techniques to map and characterize spatial relations of near-surface geologic materials and their physical and geochemical properties for each of the study catchments.

SETTING

The Middle Boulder Creek catchment, which includes

Figure 1. View of western margin of Fourmile fire area, looking NW from Sugarloaf (4 November 2011).

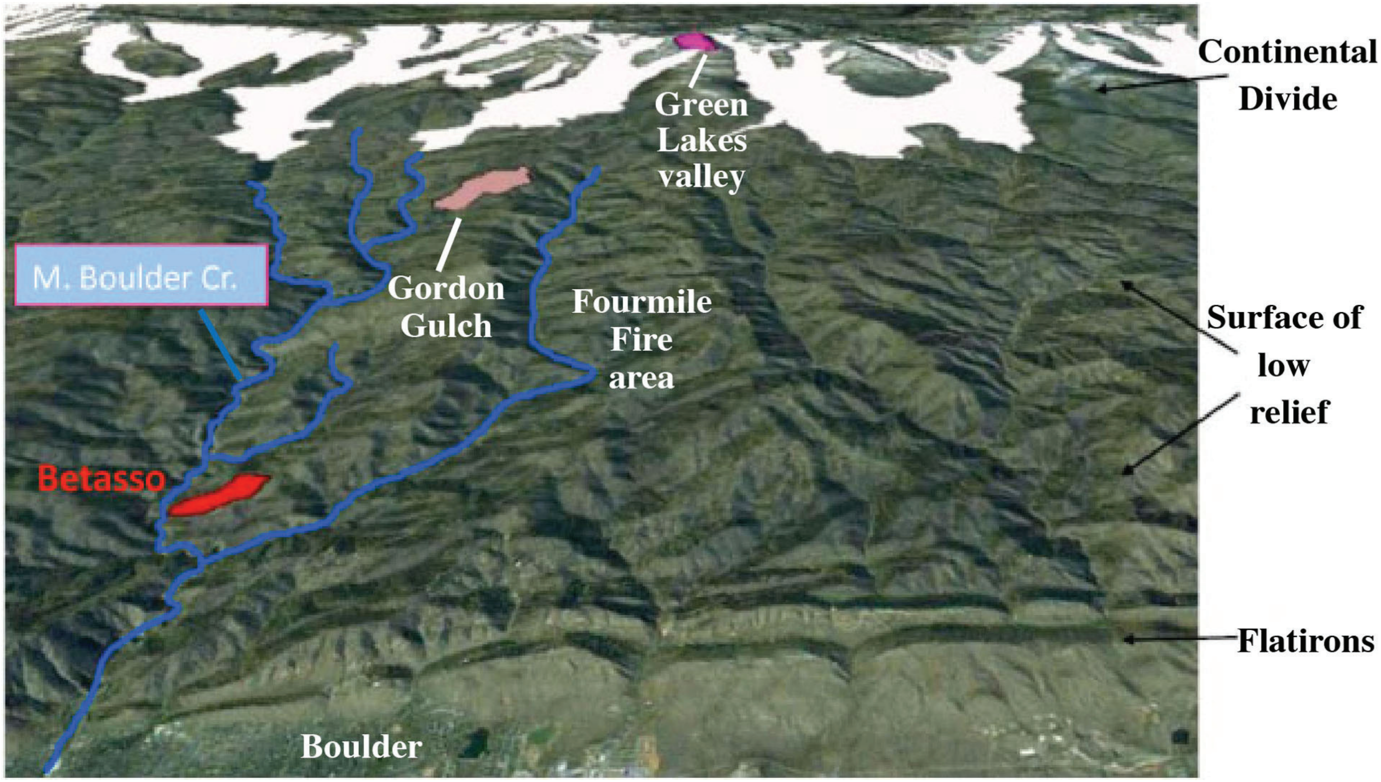

Figure 2. Perspective view looking west across the Front Range from Boulder, Colorado, showing Middle Boulder and Fourmile Creeks and location of Betasso, Gordon Gulch and Green Lakes Valley catchments, Boulder Creek Critical Zone Observatory. White filled area shows approximate extent of latest Pleistocene glaciers (after Madole et al., 1998).

the Fourmile drainage (Fig. 2), extends from the glaciated alpine zone of the Continental Divide east to the semi-arid western edge of the Great Plains. The high-relief zone of cirques and deep, U-shaped valleys in the GLV become shallower eastward through a zone of low relief and relatively low slopes. To the east, valleys deepen into steep, narrow bedrock canyons as they pass knickzones, and flatten to lower channel slopes near the piedmont margin. Small glaciers and late-persisting snowfields (Martinelli; Saddle) dot the alpine zone in the GLV, which exposes bedrock and relatively thin deposits related to the latest Pleistocene Pinedale glaciation and to Holocene erosion. The forested zone of low relief exposes local areas of thick (characteristically 3 to 8 m) regolith, including saprolite and oxidized bedrock, but the weathered mantle is thin in other areas and bedrock crops out at the surface as isolated outcrops termed tors. Low terraces and alluvial fans as thick as 4 m line channels locally. In the vicinity of knickzones and in downstream areas such as Betasso gulch, slopes near channels are steep and fresh bedrock is exposed, whereas areas more distant from channels retain a thicker weathered mantle.

APPROACH

In our fourth project year, we used field mapping and sampling in all three CZO catchments in order to provide basic data about alpine hydrology and geochemistry, bedrock strength and the effects of the Fourmile fire and mining legacy on stream geochemistry. Students supported by the Keck Geology consortium learned field mapping and sampling techniques and initial data reduction, processing and visualization methods in these settings. Students chose from a variety of potential projects in the study catchments; 2011 project topical areas included:

1. Comparison of stream geochemistry in two adjacent snowmelt-rich catchments in GLV
2. Measuring the strength of fresh and weathered bedrock in the three CZO catchments
3. Assessing the effects of the Fourmile fire and mining on stream geochemistry (in cooperation with Sheila Murphy, U.S. Geological Survey)

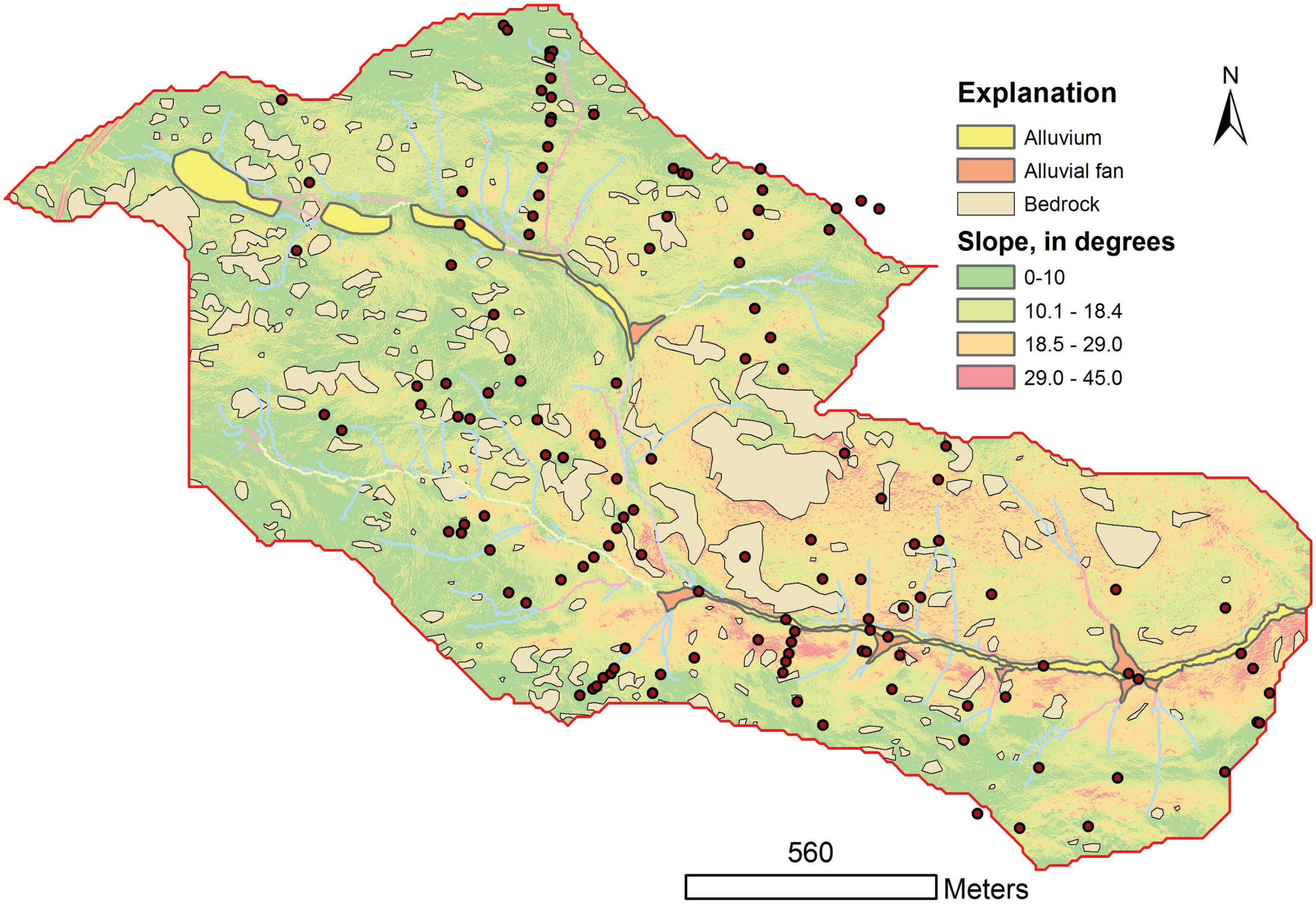

Figure 3. Map showing bedrock, alluvial deposits, alluvial fans and sample sites (red bullets) in Gordon Gulch. Most hillslope areas expose mobile regolith overlying weathered saprolite. 1-m lidar base (Anderson et al., 2012)

We continued our mapping of surficial deposits (Fig. 3), soil chemistry and ^{10}Be-based mobile regolith studies in Gordon Gulch begun in 2009 by James Trotta and continued in 2010 by James McCarthy and Cianna Wyshnytzky, in cooperation with Neil Shea (University of Connecticut M.S. candidate) and investigators from the University of Colorado and the U. S. Geological Survey. The mapping collectively shows that bedrock exposures (tors) comprise about 11% of the surface in Gordon Gulch, and that alluvial fans and several areas of alluvial fill cover about 2% of the area. Most of the gulch exposes mobile regolith 0.4 to 0.8 m thick, which overlies gneissic and granitic saprolite. Nearby catchments appear to expose less bedrock and more mobile regolith. Initial results using meteoric 10Be and soil chemistry suggest that weathering rates are relatively slow and that Gordon Gulch soil and mobile regolith have a residence time on slopes of 0.5 to 5 x 10^4 yr (Wyshnytzky and McCarthy, 2011).

STUDENT PROJECTS

Three Keck students joined Neil Shea, who was supported directly by NSF funding, for field studies in all of the CZO catchments. David Dethier and Will Ouimet supervised students, and field teams frequently joined investigators and graduate students from the University of Colorado. Keck Colorado students worked in pairs on a daily basis and sometimes together when we needed to excavate or fill deep soil pits (Fig. 4).

Short papers elsewhere in this volume report results of the field and laboratory studies in some detail. We summarize and provide brief comments on this

Figure 4. James Winkler (University of Connecticut), Alex Horne (Mt. Holyoke) and Sarah Beganskas (Amherst) in 2.7 m deep soil pit in alluvial fan material, lower Gordon Gulch.

Figure 5. Sarah Beganskas samples surface water and sediment from a stream draining the moderately burned area, Fourmile basin.

research here.

Sarah Beganskas (Amherst) worked on the dissolved and solid-phase geochemistry of streams in the Fourmile burn area (2010) with the assistance of Sheila Murphy of the USGS. Sarah sampled water (Fig. 5) and measured discharge from a representative suite of burned and unburned tributaries along Fourmile and collected sediment from the active channel and from deposits preserved from the debris flows/flood discharge of 13 July 2010. She used GIS techniques to characterize the morphology, burn characteristics and degree of mining disturbance of the tributary catchments and analyzed both the dissolved and extractive chemistry of her samples for major and minor elements.

Alex Horne (Mt. Holyoke) characterized rock strength throughout the Boulder Creek CZO using Schmidt hammer measurements on fresh, weathered, and saprolitic surfaces and fracture-spacing data collected by Alex and by previous Keck students. Most of her measurements are from the bedrock exposures of Gordon Gulch, but she collected a comprehensive suite of values from the glacially polished surfaces of Green Lakes Valley, as well as from the variably altered rocks of Betasso Gulch. Her results suggest that bedrock exposures have similar compressive strength throughout the Boulder Creek area (Fig. 6) and that deeply altered saprolite persists adjacent to rock outcrops except in GLV.

James Winkler (University of Connecticut) compared the geochemical variability and hydrology of Martinelli and Saddle Streams, which drain two small (~0.25 km^2), adjacent catchments in GLV. James' work builds on research carried out by Nel Caine (University of Colorado) as part of the Long-Term

Figure. 6. Alex Horne uses Schmidt hammer to collect measurements of compressive strength from weathered gneissic rocks, Gordon Gulch. Sarah Beganskas records values.

Ecological Research Program (LTER) and on a study initiated by Reece Lyerly, a 2010 Keck student from Furman. Snowmelt in 2011 was unusually high and late, in contrast to the relatively dry summer of 2010. James' results demonstrate that the spatial and temporal variability of geochemistry decreases downstream (Fig. 7.) Streamflow concentrations of Cl, K and NO_3 show evidence of organic control in the Saddle catchment, which supports some subalpine vegetation. Calcium concentrations appear to be controlled by dustfall and by weathering, whereas rock weathering apparently controls Na and Si concentrations in both catchments.

CONCLUSIONS

"Piggybacking" the Keck Colorado Geology Project on the NSF-Boulder Creek Critical Zone Observatory has allowed Keck undergraduates to integrate their projects with the research of graduate and postdoctoral students from the University of Colorado and other research universities. Keck student research has benefitted from the personnel, monitoring efforts, and general level of scientific interest associated with the NSF project. The Boulder Creek CZO has gained from the focused field and laboratory research of the Keck students, their energy, and their collective demonstration of what can be accomplished by the best undergraduates.

Figure 7. James Winkler collects snowmelt from saturated wetlands in the upper Saddle catchment, Green Lakes Valley.

ACKNOWLEDGMENTS

Field studies and measurements in the Boulder Creek area were performed in cooperation with the Boulder Creek CZO Project (National Science Foundation), the USDA Forest Service, and the City of Boulder Watershed and Parks and Recreation Departments. Nel Caine (University of Colorado) and Craig Skeie (City Watershed Manager) guided work in the Green Lakes Valley and Pete Birkeland (University of Colorado) taught us about soils. Suzanne Anderson and Bob Anderson (University of Colorado) shared their knowledge of the Critical Zone and how to study it. Sheila Murphy, U.S. Geological Survey (Boulder) introduced us to the Fourmile fire area and provided valuable guidance and laboratory facilities. We gratefully acknowledge the ongoing cooperation, cogent advice and digging ability of Joerg Voelkel and Matthias Leopold (Technical University of Munich). The hospitality of the Mountain Research Station made

this project possible.

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