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The field tradition in mountain geomorphology

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ABSTRACT

Fieldwork has a long and honored tradition in mountain geomorphology, and justifiably so. Many features and processes present in mountains occur at fine to very fine spatial scales that simply do not lend themselves well to analyses via remote methods. The nature of the sampling of data in mountain environments also constrains the use of computational techniques, such as GIS, in favor of on-site data collection. In addition, when one is present in the field in mountains, the dynamic nature of the landscape often provides unexpected rewards that could not be planned for in a campaign of remote analysis. These aspects of scale, sampling, and serendipity make on-site fieldwork still the preferred method for geomorphological research in mountain environments. Several examples of features occurring at fine spatial scale that could only be effectively examined in the field are presented in this paper, as well as examples of data sampling occurring at fine scale. I also illustrate several instances where being on-site, at a specific unexpected moment, in the dynamic mountain environment provided scientific insight that could only be obtained through the serendipity of being there. Why continue to conduct geomorphological fieldwork in mountains? "Because the mountains are there"!

1. Introduction

The field tradition in geomorphology has been nowhere more evident than in the realm of mountain geomorphology. The steep slopes, changing and often challenging weather, and numerous hazards present would seem to argue for the adoption of remote data collection methods not subject to the limitations of field accessibility, hazardous conditions, and the vagaries of weather (although passive optical remote sensing is also very weather-dependent). And indeed, technological advances in remote sensing, geographic information systems, and geochronology are enhancing knowledge of mountain processes and the chronological development of mountain landscapes (*c.f.* Bishop and Shroder, 2004). Nonetheless, mountain geomorphology will continue to maintain a powerful tie to its field-based roots for at least the three reasons that are the focus of this paper. These reasons include two that are intertwined: the nature of the data collected by many mountain geomorphologists and the scale of data at which the geomorphic processes of interest operate. The third reason is serendipity, invoking the timing and nature of geomorphic processes operative in mountain environments. I examine each of these reasons in sequence and provide examples from my own work and from the literature to illustrate their significance in maintaining the field tradition in mountain geomorphology.

2. The nature and scale of data collected

Many of the phenomena studied in mountainous environments by geomorphologists are small, i.e., at a fine scale. Because of the scale, many of the samples of those phenomena that are collected are also collected at a fine scale, in a manner that necessitates field data collection. Examples include the scale and sampling of tree-ring data; soils and paleosol data; sediment collection in ponds for analysis of organic matter, texture, sedimentary structures, and pollen and other macro- and microfossils; fine-scale processes in alpine tundra; short-term changes in travertine terraces; fine-scale rock spalling and erosion associated with fire; and the zoogeomorphic impacts of animals. Each of these examples is examined in the following paragraphs.

2.1. Tree-ring data and data collection

Tree-ring data are typically collected using increment borers, unless special permission is given for collection of cross-cut or wedge samples (Shroder, 1980; Butler, 1987; Stoffel and Bollschweiler, 2009). Samples for dendroclimatic and dendrogeomorphological analysis are commonly collected in mountain environments to reconstruct past climates or to reconstruct histories of hazardous geomorphic processes. Tree-ring samples are the quintessential field sample requiring in-the-field presence (Stoffel et al., 2010). Hundreds of increment core samples may be required for dendrogeomorphic reconstructions, each sample gained through painstaking increment borer insertion and extraction of cores. Individual tree age, individual tree records of geomorphically induced damage, climatic reconstructions,

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information on past insect and pathogen outbreaks, and forest age structure are common examples of data extracted from tree rings. This data and method of sampling, or sawing of cross-cuts and wedge samples, are not likely to be replaced in the foreseeable future.

2.2. Pollen and other micro- and macrofossil collection

The sampling of pollen for paleoenvironmental reconstruction is, again, not restricted to mountain environments; but pollen sampling in mountains often provides some of the most accurate visions of past vegetative realms and corresponding paleoclimates. Pollen as well as other micro- and macrofossils (such as tree needles, seeds, and insect remains) are typically collected from lake bottoms with the use of piston samplers; they can also be sampled from buried sediments in former lakebeds (Butler, 1985) (Fig. 1). Packrat middens in dry mountains in western North America are also sampled painstakingly and meticulously on-site. Carbon dating of charcoal and organic remnants, not to mention sediment collection for cosmogenic radionuclides, also potentially offer insights on timing, environmental constraints, and rates of processes. What they *cannot* be is sampled remotely. Like with tree-ring sampling, manual collection in the field provides the only meaningful option now and in the foreseeable future for collecting information on past environmental conditions in mountain environments.

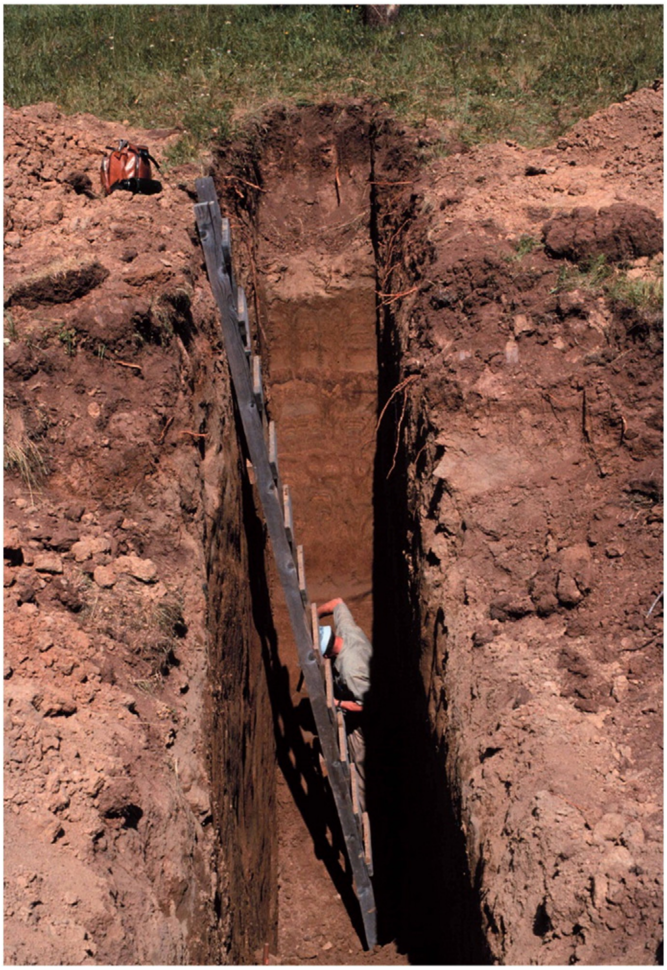

Fig. 1. Pollen and paleosols data were collected from this 3.5-m-deep pit in meadow sediments entrapped behind a recessional moraine in the Lemhi Range of Idaho. These forms of data for paleoenvironmental reconstruction must be collected in the field.

2.3. Soils and paleosols data and data collection

Although ground penetrating radar and other geophysical methods, such as tomography, can provide some information on subsurface conditions, soils and paleosols data collection in mountain environments (and elsewhere!) are likely to continue to depend upon intensive fieldwork (Benedict, 1970; Birkeland et al., 2003; Schmid et al., 2009) (Fig. 2). Sampling of horizons in a profile usually requires careful excavation, unless one is lucky enough to find a profile in a stream- or roadcut, followed by meticulous note-taking and field data collection for color, texture, particle size, organic matter, nutrients, and other variables. Paleosols similarly may often only be revealed through excavation (Fig. 1) and painstaking field recording and sampling. Fieldwork remains a hallmark of soil and paleosol studies in mountain environments.

2.4. Processes in the alpine tundra

In many locations in the alpine tundra, active needle ice and subsurface frost sorting create microfeatures such as miniature stripes, frost boils, and other geometric patterns (Pérez, 1992a; Wilkerson, 1995; Sawyer, 2007; Butler et al., 2009; Pérez, 2009). Measuring the rate and direction of movement of individual clasts, as well as the amount of vertical heaving, needs to be accomplished at a very fine scale (Fig. 3). Repeat terrestrial laser scanning (TLS) and point-cloud generation for creation of micro-scale digital elevation models can be used to analyze the direction and rates of clast movement over time (Hodges et al., 2009; Schürch et al., 2011; Smith et al., 2012; Barneveld et al., 2013), but such scanning nonetheless necessitates a presence in the field. Remote monitoring is simply too expensive, and equipment is not likely to survive the rigors of year-round emplacement in such harsh conditions. Analysis of vertical heave and burial (Wilkerson, 1995; Sawyer, 2007) requires insertion of probes (such as wooden dowels, nails, or rods) and subsequent field revisits to measure the amount of upheaval (Fig. 4). Although technological advances, such as point-cloud generation, are aiding in making the analysis of clast movement quicker and easier, the basis for such studies continues to be meticulous, in-field data collection.

The analysis of another process operative in alpine tundra that requires fieldwork is studying turf exfoliation, or *Rasenabschälung*, defined as "a denudation process active in periglacial areas which destroys a continuous ground vegetation cover by removing the soil exposed along small terrace fronts" (Pérez, 1992b, p. 82). Soil is removed by the processes of needle ice action, dessication, and deflation; collapse of overhanging terrace edges; surface runoff; soil piping and throughflow; and rainsplash (Pérez, 1992b; Butler et al., 2004). I have been monitoring soil piping and throughflow as a factor in turf exfoliation at the Divide Mountain site described in Butler et al. (2004) for almost 10 years through the process of repeat photography. Several pipes are apparent (Fig. 5) in the soil beneath turf cover at this tundra site, and over the period of observation the sediment beneath the turf overhang has been removed via throughflow beneath the overhang; the greatest amount of sediment removal occurred between observation periods in 2005 and 2007 (Fig. 5a, b). Documentation of such fine-scale processes in the alpine tundra will remain the purview of fieldwork for the foreseeable future.

2.5. Travertine terraces in Yellowstone National Park, Wyoming

In Yellowstone National Park, Wyoming, USA, the National Park Service provides visitors with informational pamphlets that describe, in general terms, the nature of the geothermal features of the Park (National Park Service, 2007). Those pamphlets do *not* describe, however, the changing nature of these landforms, although it is well known that geothermal landforms undergo changes in physical appearance over periods of time ranging from season-to-season, to