Available online at www.sciencedirect.com
ScienceDirect
Geomorphology 96 (2008) 247–249
GEOMORPHOLOGY
www.elsevier.com/locate/geomorph

Editorial

Introduction to the special issue on debris flows initiated by runoff, erosion, and sediment entrainment in western North America

Debris flows are one of the most hazardous types of landslides in mountainous areas of western North America because they are fast moving and can occur with little warning. Field observations and existing literature indicate that three primary types of non-volcanic debris flows affect areas of western North America (Fig. 1): 1) debris flows that mobilize from landslides (i.e., "slides" using the Varnes, 1978 classification) and travel over the surface of the hillslope, often flattening vegetation and leaving a thin veneer of deposits (e.g., Ellen et al., 1988), 2) debris flows that mobilize from slides that then erode and entrain hillslope and channel materials (e.g., Jakob et al., 2000), and 3) debris flows that initiate from surface-water runoff that erodes and entrains hillslope and channel materials (e.g., Larsen et al., 2006). A variation of the third type of debris flow results from glacial outburst floods (e.g., Jackson et al., 1989) or failures of dams (e.g., O'Connor et al., 2001). Seven of the eight papers in this special issue focus on the third type of debris flow, and one (Hungr et al.) focuses on the second type. As reflected by the papers in this issue, the third type of debris flow has been documented in areas burned by wildfire, and in semi-arid to arid regions with sparse vegetation and an abundance of exposed bedrock, including parts of the intermountain west and southern California. In these settings, overland flow is an important part of the hydrological response of hillslope materials to rain storms. The first and second types of debris flows (i.e., those that initiate primarily from slides) are frequently described in wetter, more temperate regions with abundant vegetation, where rainfall occurs at low-to-moderate intensities over long durations, and overland flow is rare (e.g., the Coast Ranges of California, Oregon, Washington, and British Columbia).

The initiation processes and hazard implications for debris flows that are generated through runoff and erosion, rather than by failure of discrete slides, are poorly understood. Traditional analyses of slope stability used to assess slide prone areas are inappropriate for areas that are susceptible to debris flows generated through runoff and erosion. In addition, an important characteristic of these debris flows is an increase in volume through entrainment of sediment as they progress downslope. Thus, these debris flows are able to travel longer distances down channels and across gently sloped fans compared to debris flows that do not entrain sediment (Godt and Coe, 2007). The topic of sediment entrainment is of interest to many debris flow researchers throughout the world as illustrated by recent field, experimental, and modeling studies (e.g., Rickenmann et al., 2003; Cannon et al., 2003; Berti and Simoni, 2005; Hungr et al., 2005; Iverson et al., 2005; Stock and Dietrich, 2006).

The papers in this special issue represent recent advances in understanding debris flows that initiate by surface runoff and increase in volume through entrainment of sediment. Most of the papers were presented in a topical session at the annual meeting of the Geological Society of America in Salt Lake City, Utah in 2005. Five papers focus on debris flows in areas burned by wildfire, and three papers focus on debris flows in unburned areas. The papers are organized into four groups and are presented in the following order: 1) initiation studies, 2) entrainment and volumetric studies, 3) predictive methods, and 4) mitigation issues.

Two papers are included in the initiation group. Cannon et al. documented storm rainfall conditions that produced debris flows in 93 basins burned by wildfire in Colorado and southern California and developed empirical intensity–duration rainfall thresholds for flash floods and debris flows from burned areas in different geologic settings in both states. Coe et al. used data from rainfall, soil moisture, and simulated surface

0169-555X/$ - see front matter. Published by Elsevier B.V.
doi:10.1016/j.geomorph.2007.05.001

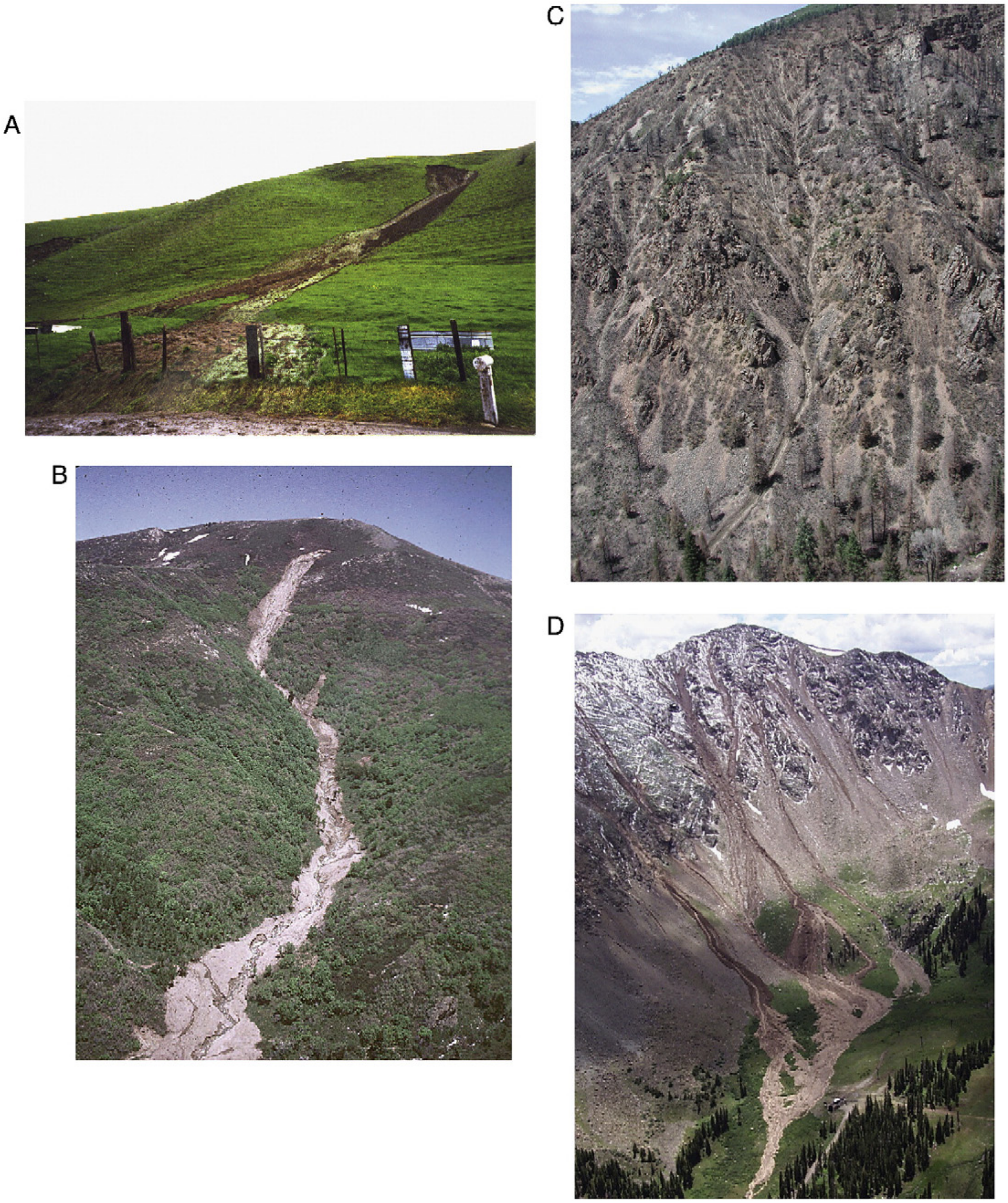

Fig. 1. Examples of types of debris flows in western North America. A) slide that mobilized into a debris flow and flowed over the ground surface in Alameda County, California. Relief visible in photograph is about 80 m. Photograph by Julie Cannon, an adjacent property owner, February 1998. B) slide that mobilized into a debris flow and entrained hillslope and channel material near the head of Ward Canyon east of Bountiful, Utah. Relief visible in photograph is about 380 m. Photograph by Ed Harp, US Geological Survey, June 1983. C and D are both examples of debris flows initiated by surface water runoff. C) debris flows generated from a burned basin near Glenwood Springs, Colorado. Relief visible in photograph is about 350 m. Photograph by Andrea Holland-Sears, USDA Forest Service, 2002. D) debris flows near the unburned Arapahoe Basin ski area in the alpine zone of the Front Range of Colorado. Relief visible in photograph is about 550 m. Photograph by Ed Harp, US Geological Survey, July 1999.

water discharge from six debris flows to develop rainfall and discharge thresholds for the initiation of debris flows in an unburned, bedrock-dominated basin at Chalk Cliffs, Colorado.

Three papers address sediment entrainment and volumetric issues. Gabet and Bookter examined debris flows that occurred following a wildfire in Montana and found that the volumes of flows grew exponentially with drainage area and that volume bulking was accomplished primarily through entrainment of material from channel banks. Santi et al. studied the rates of sediment yield for debris flows in 46 basins burned by wildfire in the western US and found that channels were much more important sources of sediment than hillslopes. Morton et al. compared debris flow histories in two adjacent unburned basins in the San Bernardino Mountains of southern California and found that the larger basin produced more water-rich, higher velocity debris flows.

Two papers describe predictive methods for debris flows. Gartner et al. used rainfall, physical property, burn severity, and morphometric data from debris flows in 56 recently burned basins in the western US to develop a set of empirically-based regression models to estimate the volumes of debris flows in six different geographic regions and geologic settings. Hungr et al. investigated the use of regional magnitude–frequency relationships for debris flows in British Columbia and found that the magnitude of debris flows in variable terrain was heavily influenced by local slope length. Because of this influence, they indicate that regional magnitude–frequency relationships would underestimate magnitudes of debris flows in areas with relatively high relief and overestimate magnitudes in areas with relatively low relief. They recommend several alternatives to regional magnitude–frequency curves for local risk assessments.

One paper describes an approach for mitigating potential hazards from debris flows from recently burned areas. DeWolfe et al. documented various debris flow mitigation treatments in a recently burned area in Colorado and evaluated the effectiveness through a review of technical literature and modeling of debris flow volumes in adjacent treated and untreated basins.

In closing, we would like to thank all of the authors and referees for their diligence, thoroughness, and patience during the process of compiling and editing this special issue. We would especially like to thank Jack Vitek, the Geomorphology special issues editor for the Americas, for his encouraging and insightful suggestions during the editing of this volume.

References

Berti, M., Simoni, A., 2005. Experimental evidences and numerical modeling of debris flow initiated by channel runoff. Landslides 2, 171–182.

Cannon, S.H., Gartner, J.E., Parrett, C., Parise, M., 2003. Wildfire-related debris flow generation through episodic progressive sediment bulking processes, western U.S.A. In: Rickenmann, D., Chen, C.L. (Eds.), Debris-Flow Hazards Mitigation: Mechanics, Prediction, and Assessment. Millpress, Rotterdam, pp. 71–82.

Ellen, S.D., Algus, M.A., Cannon, S.H., Fleming, R.W., Lahr, P.C., Peterson, D.M., Reneau, S.L., 1988. Description and mechanics of soil slip/debris flows in the storm. In: Ellen, S.D., Wieczorek, G.F. (Eds.), Landslides, Floods, and Marine Effects of the storm of January 3–5, 1982, in the San Francisco Bay Region, California. U.S. Geological Survey Professional Paper, vol. 1434, pp. 63–112.

Godt, J.W., Coe, J.A., 2007. Alpine debris flows triggered by a 28 July 1999 thunderstorm in the central Front Range, Colorado. Geomorphology 84, 80–97.

Hungr, O., McDougall, S., Bovis, M., 2005. Entrainment of material by debris flows. In: Jakob, M., Hungr, O. (Eds.), Debris-flow Hazards and Related Phenomena. Springer, Berlin Heidelberg, pp. 135–158.

Iverson, R.M., Logan, M., Denlinger, R.P., Lahusen, R.G., 2005. Transformation of water floods to debris flows: large-scale experiments. Geological Society of America Abstracts with Programs 37 (7), 35.

Jackson Jr., L.E., Hungr, O., Gardner, J.S., Mackay, C., 1989. Cathedral Mountain debris flows, Canada. Bulletin of the International Association of Engineering Geology 40, 35–50.

Jakob, M., Anderson, D., Fuller, T., Hungr, O., Ayotte, D., 2000. An unusually large debris flow at Hummingbird Creek, Mara Lake, British Columbia. Canadian Geotechnical Journal 37, 1109–1125.

Larsen, I.J., Pederson, J.L., Schmidt, J.C., 2006. Geologic versus wildfire controls on hillslope and debris flow initiation in the Green River canyons of Dinosaur National Monument. Geomorphology 81, 114–127.

O'Connor, J.E., Hardison III, J.H., Costa, J.E., 2001. Debris flows from failures of neoglacial-age moraine dams in the Three Sisters and Mount Jefferson wilderness areas, Oregon. U.S. Geological Survey Professional Paper 1606, 1–93.

Rickenmann, D., Weber, D., Stepanov, B., 2003. Erosion by debris flows in field and laboratory experiments. In: Rickenmann, D., Chen, C. (Eds.), Debris Flow Hazards Mitigation: Mechanics, Prediction, and Assessment. Millpress, Rotterdam, The Netherlands, pp. 883–894.

Stock, J.D., Dietrich, W.E., 2006. Erosion of steepland valleys by debris flows. Geological Society of America Bulletin 118, 1125–1148.

Varnes, D.J., 1978. Slope movement types and processes. In: Schuster, R.L., Krizek, R.J. (Eds.), Landslides Analysis and Control. Transportation Research Board Special Report, vol. 176. National Research Council, Washington, DC, pp. 11–33.

Jeffrey A. Coe*
Susan H. Cannon
U.S. Geological Survey, Denver Federal Center,
Mail Stop 966, Denver, Colorado, 80225 USA
* Corresponding author. Tel.: +1 303 273 8606;
fax: +1 303 273 8600.
E-mail address: jcoe@usgs.gov (J.A. Coe).

Paul M. Santi
Department of Geology and Geological Engineering,
Colorado School of Mines, Golden,
Colorado 80401 USA