VOLCANO HAZARDS FACT SHEET

U.S. DEPARTMENT OF THE INTERIOR
U.S. Geological Survey

Experimental Studies of Deposition at a Debris-Flow Flume

Introduction

Geologists commonly infer the flow conditions and the physical properties of debris flows from the sedimentologic, stratigraphic, and morphologic characteristics of their deposits. However, such inferences commonly lack corroboration by direct observation because the capricious nature of debris flows makes systematic observation and measurement of natural events both difficult and dangerous. Furthermore, in contrast to the numerous experimental studies of water flow and related fluvial deposition, few real-time observations and measurements of sediment deposition by large-scale mass flow of debris under controlled conditions have been made. Recent experiments at the U.S. Geological Survey debris-flow flume in the H.J. Andrews Experimental Forest, Oregon (Iverson and others, 1992) are shedding new insight on sediment deposition by debris flows and on the veracity of methods commonly used to reconstruct flow character from deposit characteristics.

Experimental Debris Flows

Debris flows were created by releasing up to 15 m^3 (about 30 tons) of water-saturated sediment stored behind a steel gate at the head of the flume. The sediment consisted principally of poorly sorted sand and gravel as large as 32 millimeters; about 1 percent consisted of mud (particles smaller than 63 micrometers). Following release, the sediment mass rapidly elongated and thinned (Iverson and LaHusen, 1993). Experimental flows typically averaged about 10 centimeters (4 inches) deep, were unsteady and nonuniform, and developed waves that surged rapidly down the channel (Iverson and others, 1992, fig. 1). Wave fronts commonly were less than 10 to 20 cm (4 to 8 inches) deep; interwave flow generally was thinner. The surging nature of the experimental debris flows is not uncommon in natural debris flows. Flow waves have been noted in numerous physiographic settings, and they commonly have periods that range from a few seconds to several minutes or longer.

Deposits From Experimental Flows

Sediment in the experimental flows deposited abruptly at the flume mouth on a smooth, concrete surface that slopes 3 degrees (fig. 1). Deposits typically were less than 50 centimeters (20 inches) thick, generally were unsorted and unstratified, and exhibited morphologic features common to many natural deposits, such as lobate shapes; steep-sided margins; and coarse, marginal ridges known as levees.

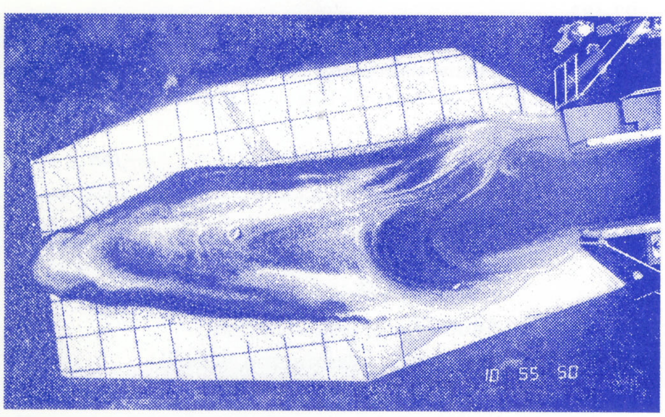

Figure 1. Deposit from saturated flow. Note surface-gravel accumulations (dark patches). A one-meter grid provides scale.

Degree of water saturation can affect debris-flow deposition and deposits. Deposits from clearly unsaturated flows had relatively equant shapes; displayed aspect ratios (ratio of mean deposit width to maximum length) greater than 0.5; and had steep margins. Surface morphology was dominated by subtle to prominent arcuate ridges having relief from a few to several centimeters (fig. 2). These deposits typically formed when successive waves of flow partly overrode and partly shoved forward debris deposited at the mouth of the flume by preceding waves. New material generally was added to the end of the debris fan nearest the source as the locus of deposition migrated upslope from the deposit toe. Distribution of colored tracer particles placed in the source material of an experiment in May 1992 (Costa, 1992) reflects the accumulation pattern of these deposits. Tracer particles placed near the front of the source sediment typically were found near the front and along the margins of the resulting deposit; tracer particles placed near the rear of the source sediment generally were found near the rear of the deposit.

In contrast, deposits from apparently saturated flows typically had aspect ratios less than 0.30, which reflect their elongate shape (fig. 1); low-relief surface morphology; and margins that ranged from steep and blunt to wedge-shaped. Surfaces of these deposits were usually flat, punctuated by inconsistently developed marginal levees, and were marked

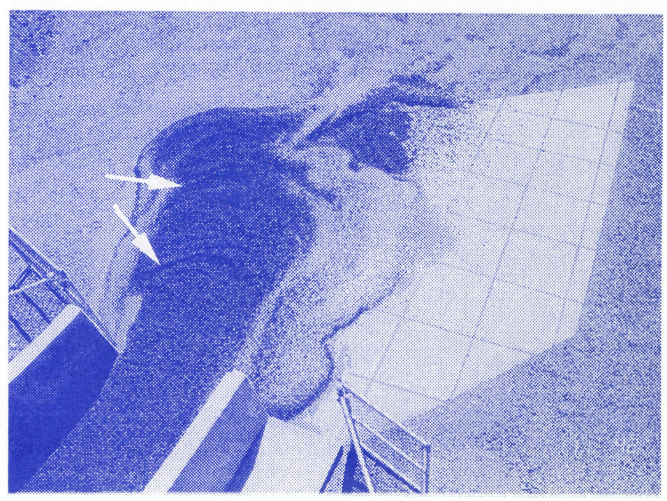

Figure 2. Deposit from unsaturated flow. Note arcuate ridges on surface.

by distinct accumulations of gravels that distinguished the boundaries of individual flow waves. These deposits developed mainly by progressive vertical accumulation of sediment transported by thin, overlapping flow waves (fig. 3).

Despite the variety of surface textures and morphologies, deposit interiors typically were homogeneous. Unlike deposits from normal streamflow, the debris-flow deposits were mostly unsorted, but locally displayed inverse grading whereby particles coarser than about 8 mm were concentrated at or near the surface but generally were lacking near the base (fig. 4). Where gravel accumulated at the surface, the subsurface sediment was more poorly sorted than at the surface, and the mean particle diameter was notably smaller than that at the surface. In the absence of distinct surface-gravel accumulations, deposits were massive, homogenous, and unsorted, and there was little vertical variation in grain size.

To gain additional insight on interior textures and relations among deposits from separate flows, sediments from two flows, released on consecutive days, were allowed to accumulate. A marker layer of distinctive sand was spread across all but an 8 square meter patch of the surface of the first deposit prior to release of the second flow. Upon trenching, it was very difficult to distinguish the separate deposits without aid of this marker horizon (fig. 4). The compound deposit appeared to be homogenous except for well-sorted gravel locally accumulated at the surface, and it could easily be interpreted as the product of a single wave of flow. The marker sand, visible in the foreground and background of figure 4, shows that the lower deposit was not scoured by the second flow and that the deposits of each flow were virtually identical. Despite minor differences in size distributions of the source material, sampling for grain-size variations with depth did not effectively distinguish these deposits.

Particles larger than about 8 mm had well-developed preferred orientations. The longest dimensions of these particles aligned roughly parallel to wave margins. At the toe of gravel accumulations deposited from discrete flow waves, the long axes were oriented roughly perpendicular to the flow direction; along lateral margins the long axes were oriented roughly parallel to the direction of flow. The preferred plane that contained the longest and intermediate axes commonly dipped steeply inward or upslope.

Mudlines preserved along the flume walls recorded passage of the largest wave only. Although each flow developed a series of waves that surged down the channel, only the largest and fastest wave left the preserved peak mudline. Mudlines provided information on the depth and minimum instantaneous velocity of the largest wave only, even if the largest wave represented only a small proportion of the total flow volume; mudlines revealed little about mean flow depth, mean velocity, or mean discharge.

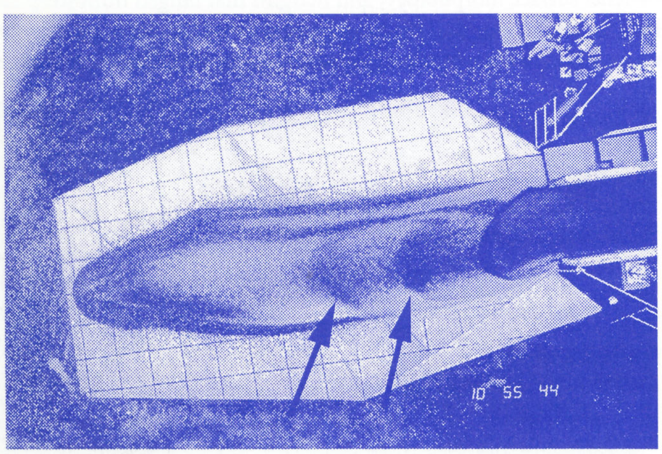

Figure 3. Deposit forming by progressive vertical accumulation of sediment transported by overlapping flow waves. Patches of coarse debris (arrows) identify previous wave margins. Figure 1 shows same deposit 6 seconds later.

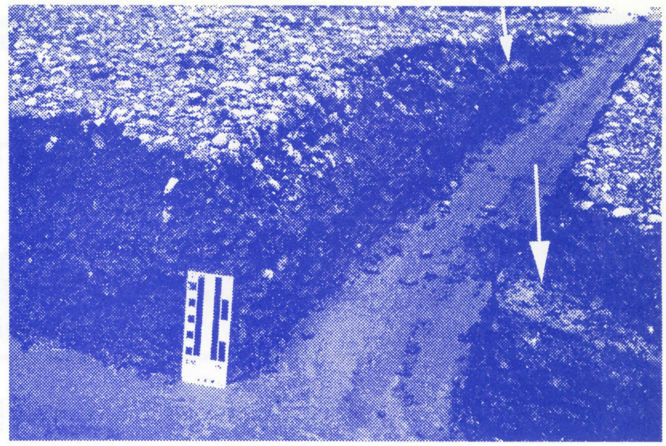

Figure 4. Interior texture of deposit resulting from multiple flows. Note sand horizon (arrows) separating deposits in right foreground and center background. Scale divisions in centimeters and inches.

Conclusions

Results of recent flume experiments indicate that caution is needed in attempts to infer movement behavior, physical properties, or frequencies of debris flows from the sedimentologic, stratigraphic, and morphologic characteristics of their deposits, particularly in near-source depositional environments. Deposition can involve horizontal, sourceward accumulation of debris with modest overlap of subsequent flow waves and (or) progressive vertical accumulation of sediment by overlap of thin, shallow flow waves. Sedimentation by multiple flow waves from a single event, or even by discrete events, may be apparent only in deposit morphology and in sedimentary textures on deposit surfaces. Interior textures of deposits may not faithfully record progressive sedimentation. Few details of flow history are recorded by interior textures of near-source deposits, and individual events may leave little distinguishing evidence. The rapid accumulation of sediment by thin sheets of flow and the inability of interior textures to discriminate discrete pulses of a single flow or even individual flows make computation of physical properties of flow from deposit characteristics questionable.

Interpretations of flow process from analysis of deposit features appear justified based on results of the large-scale experiments. Lobate shapes, steep margins, marginal levees, and unsorted and unstratified textures are characteristic of debris-flow deposits. However, details of the depositional mechanics or of the dynamic and physical properties of flow cannot easily, or accurately, be inferred from deposit characteristics.

Additional Reading

Costa, J.E., 1992, Characteristics of a debris fan formed at the U.S. Geological Survey debris-flow flume, H.J. Andrews Experimental Forest, Blue River, OR: EOS, Trans. Am. Geophys. Union, v. 73, p. 227.

Iverson, R.M., Costa, J.E., and LaHusen, R.G., 1992, Debris-flow flume at H.J. Andrews Experimental Forest, Oregon: USGS Open-File Report 92-483.

Iverson, R.M., and LaHusen, R.G., 1993, Friction in debris flows: Inferences from large-scale flume experiments: Hydraulic Engineering '93, Proc. ASCE Nat. Conf. on Hydraulic Eng., v. 2, p. 1604-1609.

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