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Abstract

An impressive record of mass wasting is preserved in the Shadow Valley basin, California, chiefly rock-avalanche breccias and gravity-driven glide blocks. The rock-avalanche breccias show commonly described features including penetrative fragmentation and preserved stratigraphy inherited from their source terrane. Basal contacts may have substantial (5-60 m) relief and a well developed mixed zone. A variety of transport indicators show predominant transport from an eastern source to a western depositional site across a variety of facies. Structural reconstructions suggest that Shadow Valley rock avalanches had unusually long run-outs that are not obviously due to variations in substrate, drop height, or mechanism of avalanche initiation. Many features observed in the Shadow Valley rock-avalanche breccias demonstrate significant internal and basal shear, as well as a prolonged interaction with depositional substrate. As such, the basal contacts were not frictionless, and basal shear stresses probably were transmitted through the breccia mass during transport. If so, then many common features of megabreccia deposits, including long run-out, inherited stratigraphy, and "crackle" or "jigsaw" textures, may be consistent with intergranular actions and collisions. Granular mechanics may be sufficient to produce long run-out and these other features, suggesting that no special mechanism is required to produce Shadow Valley-type deposits. Recent two-dimensional numerical models and new observations of the physics of granular media support this conclusion.

First Page Preview

ROCK-AVALANCHE ELEMENTS OF THE SHADOW VALLEY BASIN, EASTERN MOJAVE DESERT, CALIFORNIA: PROCESSES AND PROBLEMS

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ABSTRACT: An impressive record of mass wasting is preserved in the Shadow Valley basin, California, chiefly rock-avalanche breccias and gravity-driven glide blocks. The rock-avalanche breccias show commonly described features including penetrative fragmentation and preserved stratigraphy inherited from their source terrane. Basal contacts may have substantial (5–60 m) relief and a well developed mixed zone. A variety of transport indicators show predominant transport from an eastern source to a western depositional site across a variety of facies. Structural reconstructions suggest that Shadow Valley rock avalanches had unusually long run-outs that are not obviously due to variations in substrate, drop height, or mechanism of avalanche initiation.

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INTRODUCTION

A number of fundamental geological problems, including erosion, sedimentation, evolution of topography, and hazard assessment, relate to mass-wasting processes and products (e.g., Varnes 1978; Johnson 1984; Shroder 1989; Slosson and Slosson 1989; Schmidt 1994). Two types of mass-wasting, rock avalanches and gravity-driven gliding, have remained particularly enigmatic, in part because of a lack of well understood modern examples, relatively poorly constrained ancient examples, and the limit of useful experimental approaches. Both types of landsliding involve very large rock volumes moving at geologically instantaneous time scales (less than about 10,000 ky), and yet have distinctly different characteristics and mechanisms for initiation and transport (Pierce 1973; Yarnold 1993; Friedmann et al. 1994; Campbell et al. 1995) .

Although a number of studies (e.g., Heim 1932; Shreve 1966, 1968; Pierce 1973; Lucchitta 1979; Keefer 1984; Shaller 1991) have led to mechanical models for initiation and transport of large landslides (e.g., Hsü 1975; Johnson 1984; Melosh 1987; Hauge 1990; Yarnold 1993), there is little scientific consensus on a number of problems, including initiation, transport mechanics and dynamics, deposition, and rheology. The Shadow Valley basin (Fig. 1) in the eastern Mojave Desert, California (Davis et al. 1993; Friedmann et al. 1994; Friedmann et al. 1996) is an exceptional site for the study of mass-wasting processes and products, in particular rock avalanching, gravity-driven gliding, and related deposits. Dozen of megabreccias and several very large (> 50 km^2) intact glide blocks are exposed in transverse and longitudinal cross sections intercalated with various sedimentary and volcanic facies. Many of them have internal markers that preserve internal deformation paths within deposits, and many have well exposed upper and lower contacts. As such, Shadow Valley provides an excellent opportunity to examine ancient examples of large landslides and to learn about their transport history and mechanisms. This paper directly addresses the rock-avalanche deposits; a future paper will address the character and significance of gravity-glide elements (see also Friedmann et al. 1994; Friedmann 1995).

Many features of the Shadow Valley megabreccias match those observed in similar deposits (Shreve 1968; Yarnold 1993; Topping 1993). Importantly, these deposits display a great deal of interaction with their substrate, including injection of clastic dikes, basal mixed zones, and distributed internal shear. Within the uncertainties of structural and paleotopographic reconstructions, they also display the long run-outs characteristic of rock-avalanche deposits. These and similar features are chiefly the product of granular interaction during motion, and it is possible that no other mechanism is needed to produce such features other than the dynamics of granular flow.

DEFINITIONS

A good deal of confusion has evolved in the literature of gravity-driven gliding and rock avalanches. For example, two related terms, *Bergström* and *Sturzström,* have become confused in the literature: rock avalanche is synonymous with *Bergström* as used by Heim (1932) or *Sturzström* as used by Hsü (1975), but not *Sturzström* as used by Heim (1932). To clarify usage in this paper, the following terms will be applied according to the definitions given below.

Megabreccia: a body of rock composed predominantly of pebble- to block-size angular fragments (e.g., Longwell 1951). The term megabreccia has no genetic connotation.

Rock-avalanche breccia: A sedimentary breccia believed to have formed through overland flow caused by catastrophic slope failure. The term implies rapid transport, at least tens of kilometers/hour. By this definition, rock-avalanche breccias are naturally distinct from karst breccias, solution/collapse breccias, volcanic agglomerates, debris-flow conglomerates, gravity-driven glide blocks, and tectonic breccias in sedimentary successions.

Megablock: A large (> 10,000 m^3) block of rock in depositional contact with subjacent rocks. There is no genetic connotation to megablock beyond its sedimentary origin.

Run-out: The distance a rock avalanche travels (L) relative to its vertical drop (H). A key feature of many rock avalanches is that their run-out is larger than that of other mass-wasting deposits (e.g., debris flows, rock falls). *Fahrböschung,* or H/L value, represents a dimensionless parameter whose value is inverse to run-out.

GEOLOGICAL SETTING

The Shadow Valley basin formed above the Kingston Range/Halloran Hills detachment fault in the easternmost Mojave Desert, California (Davis et al. 1993; Friedmann et al. 1996; Friedmann, in press). The basin was active between 13.5 and 7 Ma and filled with 2.5–3.5 km of detritus, as determined by field mapping, measured stratigraphic sections, and a combination of magnetic polarity stratigraphy and $^{40}Ar/^{39}Ar$ geochronology on interbedded ashes. Four unconformity-bounded, informal members constitute the fill, and numerous megabreccias and megablocks crop out throughout the basin (Fig. 2). Specifically, megabreccias are present predominantly in members I and II, the two oldest units, and megablocks are present within all members. These two types of deposit represent 10–15% of the Shadow Valley fill; when combined with lahars and debris-flow conglomerates, mass-wasting deposits account for 30–50% of the basin fill.

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Index Terms/Descriptors

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