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SPRING MUDFLOWS AT WRIGHTWOOD, SOUTHERN CALIFORNIA

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SUMMARY

The Wrightwood area in the San Gabriel Mountains of southern California is known as a site of recurring mudflow activity. The community of Wrightwood is built on the coalesced fans of Sheep, Acorn and Heath Creeks, and the fan deposits are probably chiefly of mudflow origin. Historically, mudflows there have been observed in association with three climatic conditions: (1) short period of high-intensity rainfall during the summer dry season (thunderstorms); (2) periods of heavy rainfall during the October–March winter season, when most of the year's rain and snow fall; and (3) thaw of the winter snow pack. The mudflow activity associated with heavy rainfall has generally been of only a few hours or at most a few days duration. Mudflow activity associated with spring thaw has been of longer duration, as much as several weeks. At various times in the past, mudflows generated by all three conditions have inundated homes and highways in the Wrightwood area, which is now defended by a flood control levee system.

During May and June, 1969 the rapid melting of a heavy snow pack resulted in a 40-day period of mudflow activity in Heath Creek. All flows originated in the steep upper reaches of Heath Creek, where steep ravines are incised in the toe of a large active landslide. Direct observation by the authors showed that flows formed when small masses of debris fell or slid from the surface of the landslide mass into the steep channel. Some of the masses were fluid enough to continue downstream without interruption; others stopped in the channel until remobilized by added meltwater or the passage of a mudflow from a higher altitude. Both processes resulted in discrete 'slugs' which continued down the steep ravine, through an alluviated canyon, to a fan where most of the debris was deposited.

The activity may be described as a spring mudflow cycle, within which three stages were observed in a gradational sequence. A waxing stage began with sporadic short-duration mudflows, during which the lower alluviated canyon floor of Heath Creek was aggraded. A climactic stage of larger mudflows at more frequent intervals and of longer duration was characterized by the incision of a single, narrow, U-shaped channel in the alluviated canyon floor, and transportation of debris as much as 2 miles (3.2 km) from the source. A waning stage followed as meltwater supply decreased; short-duration flows backfilled the U-shaped channel and spilled over the banks, again aggrading the alluviated canyon floor.

The Wrightwood area of southern California (Fig. 1) has been the site of recurring mudflows. Three climatic conditions have given rise to mudflows: (1) high-intensity, short-duration summer rainfall which produces short-duration, single flows; (2) exceptionally heavy, warm fall seasonal rains which produce short-duration mudflows;
and (3) rapid melting of an exceptionally thick winter snow pack which produces long-duration mudflow activity, commonly lasting a number of weeks. In this locality, the latter condition is best known (Sharp & Nobles 1953; Morton 1970) and is the only kind considered in this paper. Most of our data are based upon observation and samples collected during a 40-day period of spectacular mudflow activity in the spring of 1969 and during a period of lesser mudflow activity in the spring of 1973.

Fig. 1.
Index map showing location of Wrightwood.

Fig. 2.
Map showing location of Wright Mountain landslide and Heath Creek.
The source material for the mudflows is derived from an old landslide deposit, the Wright Mountain landslide (Morton & Kennedy 1968), the head of which is 2,500 ft (680 m) above and 1 1/2 miles (2.4 km) south of the community of Wrightwood (Fig. 2). The landslide is composed of intensely fragmented Pelona Schist, a very fissile muscovite-albite-quartz schist.

Wright Mountain landslide fills the upper reaches of Heath Creek Canyon; re-establishment of Heath Creek Canyon through the landslide deposit has been accompanied by renewed lateral and headward landsliding. This secondary landsliding places loose fragmented schist debris in the stream channel to be flushed as mudflows downstream. The stream channel gradient is illustrated in Fig. 3.

During a period of heavy spring mudflows, attendant on the melting of a snow pack, the mudflow activity is best described in terms of a three-stage mudflow cycle (Fig. 4). Early mudflows, constituting a waxing stage, are of small volume and duration and occur mainly in the afternoon hours coincident with the peak time of melting snow. These flows, following braided courses, aggrade the alluviated canyon bottom above Heath Creek alluvial fan (Fig. 4A, 6).

With accelerated thaw, meltwater gradually increases and mudflow activity reaches a main or climactic stage. This stage is characterized by larger, more prolonged mudflows, which continue throughout the day. At the zenith of activity, mudflow activity continues through the night. A single mudflow channel is cut, reaching depths of as much as 25 ft (7.5 m) through older mudflow deposits on the alluviated part of Heath Creek channel (Fig. 4B, 7). With flow confined to a single channel, mudflow debris is deposited at the greatest distance from the point of mudflow origin. In 1969, the distance was 2 miles (3.2 km) and in 1941 it was 15 miles (24 km) (inferred from deposits interpreted as being of mudflow origin by Sharp & Nobles 1953, p. 555–557).

A waning stage reflects decreasing amounts of meltwater as the snow pack is consumed. Mudflows of short duration fill or largely fill the deeply cut mudflow channel, and again aggrade the alluviated part of Heath Creek Canyon in braided deposits (Fig. 4C).

During the waxing and waning stages, individual mudflows come in variable intervals, from minutes to hours apart; individual flows last from 1 to 9 minutes. During the climactic stage, mudflows generally occur at intervals of ½ to 40 minutes and last for up to 30 minutes. Flows with a duration of 4 to 9 minutes were estimated to contain 200 to 900 cubic yards (m³) of mudflow debris.

![Profile of Heath Creek and sample localities.](Courtesy WrightwoodCalif.com)
Fig. 4.

Upper part of the alluviated canyon bottom of Heath Creek.

A. Waxing stage. Mudflows aggrading canyon floor.

B. Climactic stage. Single mudflow channel has been cut to depth of 12 ft (3.6m) in earlier deposited mudflow debris.

C. Waning stage. Earlier cut mudflow channel is now largely filled.
The movement of an individual mudflow was neither steady nor continuous from inception to final deposition. Most mudflows halted at one or more points while in transit. During these stoppages the lower terminus of the flow is a steep bouldery front, 1 to 4 ft (0.3–1.3 m) high and relatively devoid of interstitial fines. Subsequent flows remobilized the temporarily stabilized flows in the climactic stage; during the waxing and waning stages they were overridden by, or diverted, subsequent flows.

Mudflows in the upper part of Heath Creek consisted of flows with blunt, rocky snouts, generally 3 to 4 ft (1 m) in height, composed of well-sorted clasts ½ to 2 ft (0.2–0.7 m) in diameter, with an occasional clast up to 4 ft (1.3 m) (Fig. 5). Behind the bouldery front, the flow passed upstream into laminar-flowing, unsorted-appearing, mud-rock mixture, which in turn passed gradationally upstream into turbulent-flowing muddy water (Fig. 8). The muddy water tended to flush fine-grained debris from the channel bottom, leaving behind cobbles and boulders. Downstream, during a climactic stage, flows tended to merge, giving rise to a more or less continuous flow with interspersed boulder accumulations representing former fronts of individual flows. Just above the depositional site of the climactic flows in 1969, translatory waves one to several inches (25–100 mm) in amplitude were generated within a moving flow and had a velocity about twice that of the flow (Fig. 9). Apparently, similar waves were observed in the 1941 mudflows (Sharp & Nobles 1953, p. 552) and, at a smaller scale, in 1972 flows.

Measured velocities of mudflows in 1969 ranged from 2 to 12.5 ft/sec (0.6 to 3.75 m/sec); one intermittently moving flow averaged a velocity of 2 ft/sec (0.6 m/sec) over a distance of 1 mile (1.6 km). Measured velocities of 1941 mudflows ranged from 4 to 14.5 ft/sec (1.2 to 4.35 m/sec) (Gleason & Amidon 1941, p. 3–4).

Thirty samples were collected from moving mudflows in 1969. The bouldery fronts were too stiff to penetrate with the sampling tool, and most of the rocks in the front were too large to pass into the 4-inch (100 mm) opening of the sampler. As individual mudflows

![Fig. 5. Steep rocky front of an 8-foot-wide (2.4m) mudflow in the alluviated canyon bottom. Note the apparent decrease in sorting up-channel from the mudflow front and the fine-grained mud flowing over and through the rocks at the left side of the flow.](Courtesy WrightwoodCalif.com)
FIG. 6.

Front of 5-foot-high (1.5m) stabilized flow, late in the waxing stage in the lower part of the alluviated canyon bottom.

FIG. 7. Fifteen-foot-deep (4.5m) mudflow channel, climactic stage, cut in mudflow debris deposited during waxing stage. Lower part of the alluviated canyon bottom. Note partly exhumed pine tree in centre of photograph.
passed the sample-sites, the debris/water ratio was highest at the leading fronts, and decreased gradually to the trailing parts, which were nearly as watery as the intersurge stream flow. The average specific gravity of dry mudflow debris is about 2.65. At the upper sample site, the specific gravity of the flowing mud ranged from about 2.13 to about 1.62, corresponding to a range of 85.6% to 59.3% rock by weight (or 69.3% to 38.0% rock by volume). At the lower sample site, the specific gravity of flowing mud ranged from 1.95 to 1.64, corresponding to a range of 77.7% to 68.2% by weight (or 57.4% to 46.1% rock by volume). Median grain sizes in samples of flowing mud ranged from 6 to 0.05 mm at the upper sample site and from 2 to 0.25 mm at the lower sample site. Intersurge stream flow (muddy water) had an average specific gravity of 1.32, containing about 35.4% rock by weight (or 19.5% rock by volume), and median grain sizes of less than 0.25 mm for entrained sediment.

Estimates of Bingham viscosity for 1969 mudflow material ranged from $4 \times 10^2$ to
10^4 poises (computed following the method of Johnson 1970); for the turbulent flowing water following a mudflow the viscosity was about 1 poise. Newtonian viscosities for the 1941 flows were calculated by Sharp & Nobles (1953, p. 552–553) to range from 2.1 × 10^3 to 6 × 10^4 poises. For the 1969 flows their formula indicates a range in viscosity 1 × 10^8 to 6 × 10^4 poises.

References