MAP SHOWING ALPINE DEBRIS FLOWS TRIGGERED BY A JULY 28, 1999 THUNDERSTORM IN THE CENTRAL FRONT RANGE OF COLORADO

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Abstract

This 1:24,000-scale map shows an inventory of debris flows that were triggered above timberline by a thunderstorm in the central Front Range of Colorado. We have classified the debris flows into two categories based on the style of initiation processes in the debris-flow source areas: 1) soil slip, and 2) non-soil slip erosive processes. This map and associated digital data are part of a larger study of the debris-flow event, results of which we plan to present in a forthcoming paper.

Introduction

On July 28, 1999, about 480 debris flows were triggered by an afternoon thunderstorm along the Continental Divide in Clear Creek and Summit counties in the central Front Range of Colorado. Several debris flows triggered by the storm affected Interstate 70 (I-70), U.S. Highway 6, and the Arapahoe Basin ski area. One flow initiated on the south flank of Mount Parnassus, traveled 2.5 km down Watrous Gulch, deposited about 26,400 m^3 of bouldery debris on I-70, (Alan Chleborad, written communication, 1999) and closed the highway for about 25 hours. Fortunately no injuries or fatalities resulted from any of the debris flows. Additional information on the debris-flow event, and the damage that resulted, is available in a field-trip guidebook published for the Geological Society of America 2002 annual meeting in Denver, Colorado (Coe and others, 2002). We have documented the debris-flow activity in a 240 km^2 area by mapping debris flows from color aerial photography and by inspecting many of the debris flows in the field. This map report and associated digital data present an inventory of debris flows triggered by the July 28, 1999 thunderstorm, but do not constitute a debris-flow hazard map.

The map area is located about 50 km west of Denver, Colorado, and is transected by Clear Creek and I-70. Much of the area is in the alpine zone, defined here as the area above timberline (~3,500 m elevation). Elevations in the map area range from about 2,900 m in the Clear Creek valley to nearly 4,350 m at the summit of Grays Peak. Below timberline, vegetative cover is primarily coniferous forest. Above timberline, hillslope surfaces are either covered with alpine tundra or are unvegetated bedrock and colluvium. There are no glaciers or permanent snowfields in the map area, however the highest north-facing slopes may hold snow well into the late summer. The study area is predominately underlain by Precambrian biotitic gneiss and quartz monzonite, with scattered Tertiary intrusions (Lovering, 1935; Bryant and others, 1981) and associated hydrothermal alteration and mineralization (Tweto and Sims, 1963). The area was glaciated several times during the Pleistocene. Ice of the most recent glaciation (Pinedale age, 14,000 – 12,000 14C yr B.P.) descended to an elevation of about 2,530 m (Madole and others, 1998).

Map Description

Debris flows were mapped from 1:12,000-scale stereo aerial photographs on to the topographic base maps using a Kern PG-2 photogrammetric plotter (Pillmore, 1989). The base maps were created by plotting the Grays Peak and adjacent USGS 7.5-minute quadrangles at 1:12,000 scale from USGS Digital Raster Graphics. The aerial photographs were flown on September 11, 2000, by IntraSearch, Inc. The scale of the photography allowed us to accurately identify debris-flow features as small as about 0.5 m. Each mapped debris flow includes the source area, flow path, and deposits. Debris flows were mapped if their features were fresh, that is, they appeared to have a lighter tone than their surroundings and were not vegetated. During mapping, we frequently consulted aerial photographs flown on October 26, 1999, to help determine the freshness of debris flows. We did not use the October 26, 1999, photos for mapping because some of the debris flows on north-facing slopes above timberline were obscured by snow. Most mapped debris flows were field checked to verify their recency. Once mapped, debris flows were digitized from the 1:12,000-scale maps into an ArcInfo Geographic Information System and reduced to a final map scale of 1:24,000. At 1:24,000 scale, debris-flow features less than about 5 m wide (~ 0.2 mm at 1:24,000) are not visible. The topographic base used for the final map is a seamless digital version of the Grays Peak and adjacent 1:24,000 USGS quadrangles combined with a shaded relief image of a USGS 30 m Digital Elevation Model (National Geographic TOPO! database).

We have classified the debris flows based on the style of initiation processes in the debris-flow source areas. Initiation processes are divided into two broad classes: soil slip (fig. 1; Campbell, 1975) and non-soil slip erosive processes. Soil-slip flows began as small, shallow landslides (generally less than 10 m across and less than 3 m in depth) that subsequently liquefied and flowed downslope. Most soil-slip debris flows formed parallel levees and lobate deposits. Source areas of non-soil-slip flows lacked a discreet landslide scar; and such flows were initiated by concentrated overland flow of water. We observed evidence for two types of non-soil-slip initiation processes in the field, firehose (fig. 2) and rilling processes (fig. 3; Johnson and Rodine, 1984). Firehose processes occurred where bedrock slopes were located above talus deposits. During heavy rainfall, overland flow became concentrated in steep channels and eroded deep gullies in the talus fan heads (fig. 2). Material eroded from the fan head was mobilized as a debris flow. The debris flows left levees along the margins of the gullies and lobate deposits below the talus fans. Rilling processes occurred on steep bare hillslopes mantled with abundant loose angular material (fig. 3). Concentrated overland flow eroded material from these hillslopes leaving rills and gullies in source areas, levees along transport zones, and lobate deposits in deposition zones.

Debris-flow initiation locations were defined as the points farthest upslope for each mapped debris-flow. In many cases, single mapped debris flows have multiple initiation locations, some of which are not visible at 1:24,000 scale. For soil slips, the initiation point was easily identified as the center of the headscarp of the landslide failure. However, for the non-soil-slip category, the initiation locations in the database may represent multiple small rills. The initiation locations of the firehose flows are the highest point in the bedrock channel that appeared freshly scoured in the aerial photographs.

Initiation locations of soil slips are labeled on the map and in the database. However, to show the debris flows clearly, the non-soil slip initiation locations are not shown on the map but are labeled in the database. The non-soil-slip initiation locations are not categorized into the two process types because we were not able to visit and classify all of the source areas in the field.

Two digital data sets are included with this map report. The first data set (fr-dfcl2) contains the debris-flow polygons. A second data set contains the debris-flow initiation locations (fr-dfip). The locations of soil samples collected for particle-size analysis are also shown on the map. We plan to present further details regarding the style of debris-flow initiation, triggering rainfall, and results from the particle-size analysis in a forthcoming paper.

Acknowledgements

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Figure 1. Large debris flow on the west flank of Grizzly Peak. The debris flow initiated as a soil slip that mobilized and flowed downslope. Relief from the foreground to the headscarp of the soil slip is about 400 m. Photograph taken on July 29, 1999. View is to the East.

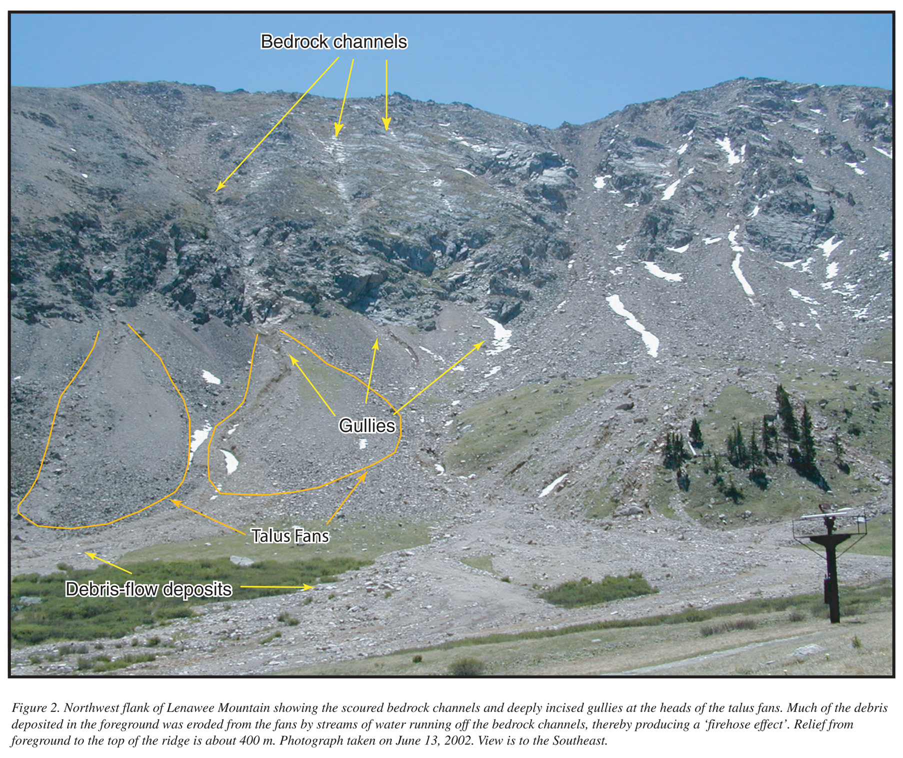
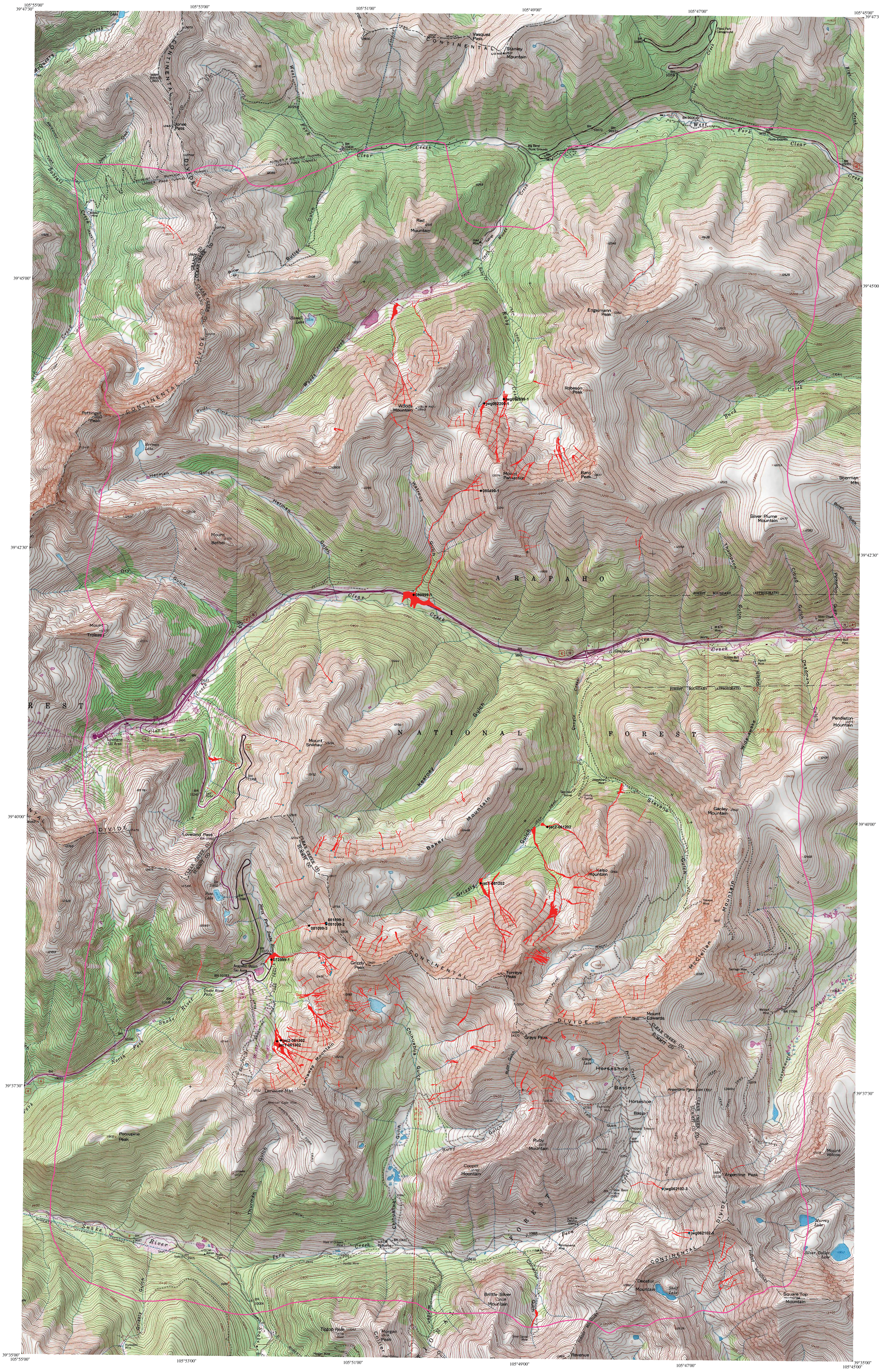
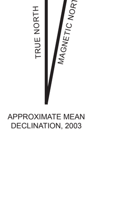
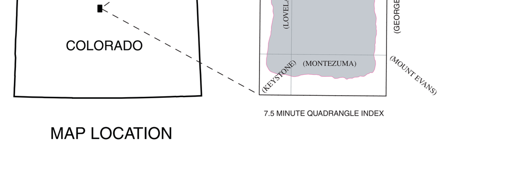


Figure 2. Northwest flank of Lenawee Mountain showing the scoured bedrock channels and deeply incised gullies at the heads of the talus fans. Much of the debris deposited in the foreground was eroded from the fans by streams of water running off the bedrock channels, thereby producing a 'firehose effect'. Relief from foreground to the top of the ridge is about 400 m. Photograph taken on June 13, 2002. View is to the Southeast.

Figure 3. Southwest flank of Mount Parnassus showing the rills in the source area of the debris flow in Watrous Gulch. No obvious landslide sources are present at the heads of the rills. Relief from the channel in foreground to the summit of Mount Parnassus is about 610 m. Photograph taken on August 4, 1999. View is to the Northeast.







MAP LOCATION

0 0.5 1 2 3 4 km

0 0.5 1 2 3 4 mi

Scale 1:24,000

Projection UTM Zone 13

(Contour Interval 40 feet)

EXPLANATION

Debris-flow source area, flow path, and deposit

Soil slip

072999-1 Sample location and identification number particle-size analysis

Study area boundary

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