The Geography of Rockfall Hazards in Glacier National Park, Montana

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ABSTRACT

Glacier National Park, Montana, has a long history of falling rock and rockfall accidents. The recent history of rockfall activities and accidents in the Park is documented here. Rockfalls are frequent in spring and autumn months, when temperatures fluctuate across the freezing point. Summer rockfall activity is primarily associated with heavy rainfall. Hazardous rockfalls may occur on any slope aspect, especially in areas where stratigraphic dip parallels the slope. Numerous accidents from falling rock have occurred, but are spatially concentrated in two major and two minor highway zones, as well as in the backcountry. Visitors to the Park are effectively unaware of the extent and distribution of the hazard. More effective warning signs and informational pamphlets would assist in educating visitors to the Park.

KEY WORDS: rockfall, natural hazards, Glacier National Park, Montana, mass wasting

INTRODUCTION

Popular scenic and natural areas in the United States and other countries frequently include areas of steep terrain and high local relief. Such environments are prone to the hazard of falling rock (e.g. Butler 1982, 1983, Inners and Braun 1988, Williams and Williams 1988). Tourists visiting such locations see signs which declare “Watch for Falling Rock,” “Falling Rock Next Mile,” or similar variations on the theme. However, these same tourists frequently come from great distances and from environments very dissimilar to one of steep slopes with the danger of falling rock; accordingly, they are likely to be unfamiliar with the likelihood of, conditions conducive for, and locations susceptible to falling rock hazards. It is therefore important to document the history of such a hazard to visitors, and to make them aware of the danger. This paper documents the recent history of falling rock and related accidents and damages along roads and trails of Glacier National Park, Montana. It also provides suggestions for improv-
ing visitor awareness of the rockfall hazard.

THE STUDY AREA

Glacier National Park is located in the Rocky Mountains of northwestern Montana (Fig. 1). Terrain is steep and local relief is high, creating the potential for hazardous rockfalls. Two major transportation corridors provide automobile access through and around the Park: Going-to-the-Sun (GS) Road, a narrow, two-lane road which winds through the center of the Park from West Glacier to St. Mary; and U.S. Highway 2, which borders the southern and southwestern flanks of the Park. The former road is only open seasonally, from about late May through late October. U.S. 2 is a year-round major highway link for the northwestern part of Montana. A third road, connecting Babb to the popular Many Glacier region of the Park, is also susceptible to rockfall (Fig. 1). Like GS Road,

![Map of Glacier National Park](image)

Figure 1. Map of Glacier National Park, illustrating rockfall hazard zones along major transportation corridors (shaded Zone 1, GS Road; shaded Zone 2, U.S. Highway 2 Blue Rock section; 3, U.S. Highway 2 Goat Lick section; 4, Many Glacier—Babb Road section). "a," location of Figure 2 and "b," location of Figure 3.
it is open on a seasonal-only basis. All roads mentioned are hard surface roads.

All these roads, but especially GS Road, traverse areas of mountain terrain where steep cliffs tower above the road surface. Along a 12-mile (19 km) section of GS Road, many sections of road were literally carved and blasted out of solid rock (Buchholtz 1976), and cling precariously to the mountainside (Fig. 2). U.S. 2 primarily follows the valley of the Middle Fork of the Flathead River, and so is frequently positioned near the bottom of a deep gorge with steep cliffs immediately adjacent to the highway. Steeply-dipping sedimentary beds parallel the slope in many locations there (Fig. 3). Two major segments of Highway 2, the Blue Rock Cut and Goat Lick sections, are especially vulnerable. The Many Glacier-Babb Road passes directly below towering limestone cliffs for approximately 1 mile (1.6 km). Sections of each road are delineated with typical diamond-shaped road signs stating (specifically, in the case of GS Road) “Watch for Falling Rock 12 Mi.”

One and a half- to two-million visitors per year visit Glacier National Park, nearly all of whom travel on GS Road, the Many Glacier-Babb Road, and U.S. Highway 2 (Hungry Horse News 31 January 1985, 15 January 1986, 14 January 1987). Backcountry trails, where rockfalls may also pose a hazard to visitors, experience about 15,000 overnight users per year (Hungry Horse News 14 January 1987), with a greater but unspecified number of day-use only hikers. In spite of these heavy usages, no indications of hazard frequency are provided the highway tourist by road-sign information—they are simply advised to “watch.” Nor are tourists provided information about

Figure 2. A view of the eastern edge of the 12-mile-long (19 km) rockfall-hazard zone along GS Road. Note the size and proximity of the source cliffs from which rockfalls originate.
the hazard from falling rock in general Park pamphlets handed out upon ar-
ival, or in popular road-guides available
for purchase in the Park (Raup et al. 1983,
Ruhle 1986), so they cannot place the
warning signs into an informed context.
The only literature available to Park vis-
itors which describes rockfalls is aimed
specifically at mountain climbers and
hikers (Larson 1984). It is, however, not
given out at trailheads; it is for sale at
Park visitor centers.

THE GEOLOGIC AND
GEOGRAPHIC SETTING

Rocks bordering the roads and trails
of Glacier Park are relatively weak sedi-
mentary rocks that have been broken up
by faulting and folding during geologic
time (Oelfke and Butler 1985), and which
in many cases have been subjected to
the forces of blasting during construc-
tion. In those hazardous zones marked
by highway warning signs (Fig. 1), the
rocks dip toward the road at angles as
steep as 45-70 degrees (Fig. 3).
The region’s climate is cool, with
damp springs and mild summers. Tem-
peratures fluctuate frequently across the
freezing point during the tourist season,
especially in spring and autumn (Finklin
1986). These fluctuations work in con-
cert with the abundance of moisture to
cause substantial freeze-thaw shattering
of the weak bedrock. Heavy summer
thunderstorms are not uncommon. Ad-
ditional moisture in the form of seeps
along stratigraphic bedding planes fur-
ther lubricates the rocks along dip slopes
and thus exacerbates the hazard.

METHODOLOGY

To compile a history and examine the
geography of rockfall along Park roads
and trails, each issue of the Hungry Horse
News published from 1979 through Oc-
tober, 1989 was consulted. This news-
paper is the weekly chronicle of local
events in and near Glacier National Park,
and includes descriptions of Park acci-
dents resulting from natural hazards. A
chronology of all rockfall occurrences
during the period in question was com-
piled, and their location mapped on
1:24,000-scale topographic maps. From
these maps, rockfall occurrences were
categorized according to slope aspects
(i.e. N, NNE, NE, and so on) from the
newspaper reports which were tabu-
lated from each month of occurrence,
time of day of occurrence, and the na-
ture of damage caused. Older historical
references to accidents and damage
caused by falling rock were also re-
viewed. The results of these data are
summarized in Table 1, and discussed
below.

RESULTS

Seasonality and Meteorologic
Components of the Hazard

Rockfall accidents have been respon-
sible for numerous cases of property
damage and injury, and at least one fa-
tality. Most rockfall accidents occur dur-
ing the late-spring, summer, and early
autumn months; given the seasonal-only
usage of GS and the many Glacier-Babb
Roads and the backcountry trail system,
this is not surprising. More accidents oc-
curred in May and June than in later
months, although July and August are
the busiest of the tourist season. The
greater number in the early portion of
the tourist season illustrates the role of
freezing temperaures and thawings which
destabilize the rocks above the roads.
Fewer such freeze-thaw temperature
fluctuations occur in July and August
(Finklin 1986).

Unfortunately, few data on time of day
of rockfall occurrences exist (Table 1),
effectively precluding generalizations
concerning diurnal variations and time of
highest hazard potential. Rockfall in-
cidents later in the summer are tempo-
 rally correlated with periods of heavy
rainfall. Examples include 11 June 1989,
when 3.25 inches of rain fell within 36
hours and probably caused a massive
rockfall on the Many Glacier-Babb Road
(Hungry Horse News, 14 June 1989a)
some of this rock was “recycled and
used as facing rock on rockwall con-
struction along GS Road; Hungry Horse
News 28 September 1989); 15 July 1989,
when “heavy rain” culminated a 3-day
period of rain and caused extensive
rockfall blockage east of Logan Pass (Hungry Horse News 19 July 1989); and 27 August 1989, when a record-setting frontal storm brought over 4 inches of rain to eastern sections of Glacier Park in less than one week and triggered numerous rockfall accidents (Hungry Horse News 31 August 1989a, b).

Spatial Aspects of the Hazard

Damaging rockfalls occurred on virtually all slope aspects (Table 1). An apparent concentration on south to west exposures is deceiving, because most slopes above GS Road face only south to west, thus a statistical comparison with north- and east-facing slopes is not valid. Where such slope aspects do occur along roads and trails, damaging rockfalls have also occurred.

Many tourists, Park employees, and local residents have been injured by rockfalls on roads and trails in the Park. Employees with several years to decades of experience have been injured or their vehicles damaged, because their duties place them in hazardous positions. Familiarity with the local environment or a home near the natural area does not necessarily reduce the hazard as has been found in other natural areas (Williams and Williams 1988). In an especially ironic case, the editor of the Hungry Horse News and his wife, in the course of covering news events in the Park, barely escaped death when a 76-cm diameter rock plunged through the roof of their car into the backseat and trunk area, spraying them with glass shards and rock debris. A similar case, but occurring through the windshield, destroyed a new government vehicle in 1988, with the passenger escaping with minor bruises. Not so lucky was a female tourist who was the passenger in a car along GS Road in 1962. A large rock
## TABLE 1
Historic and Recent Rockfall Accidents, Glacier National Park

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Slope Aspect</th>
<th>Time of Day</th>
<th>Accident Nature/Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1910</td>
<td>Otato Creek</td>
<td>N</td>
<td>n.d.</td>
<td>Blockage of creek and creation of 2 lakes</td>
</tr>
<tr>
<td>1954</td>
<td>Napi Point</td>
<td>NNW</td>
<td>n.d.</td>
<td>Major rockfall avalanche</td>
</tr>
<tr>
<td>n.d.</td>
<td>GS Road E</td>
<td>S</td>
<td>a.m.</td>
<td>Nearly hit woman in open tour bus</td>
</tr>
<tr>
<td>10/59</td>
<td>U. S. 2 GL</td>
<td>SW</td>
<td>n.d.</td>
<td>Car demolished, 2 injured</td>
</tr>
<tr>
<td>6/62</td>
<td>GS Road W</td>
<td>W</td>
<td>n.d.</td>
<td>Woman killed, car demolished</td>
</tr>
<tr>
<td>5/64</td>
<td>GS Road E</td>
<td>SSE</td>
<td>n.d.</td>
<td>Park employee injured</td>
</tr>
<tr>
<td>5/68</td>
<td>U. S. 2 BR</td>
<td>NNE</td>
<td>early a.m.</td>
<td>Destroyed a power pole, exposing hot line</td>
</tr>
<tr>
<td>3/5/69</td>
<td>U. S. 2 BR</td>
<td>NNE</td>
<td>a.m.</td>
<td>150-ft. wide, 30-ft. high rockfall blocked both lanes, 1 for 6 d.</td>
</tr>
<tr>
<td>7/74</td>
<td>Chief Mountain</td>
<td>NEE</td>
<td>n.d.</td>
<td>Major rockfall avalanche</td>
</tr>
<tr>
<td>6/75</td>
<td>GS Road W</td>
<td>WSW</td>
<td>n.d.</td>
<td>Closure of GS Road</td>
</tr>
<tr>
<td>12/10/78</td>
<td>GS Road W</td>
<td>WSW</td>
<td>n.d.</td>
<td>Closure of GS Road</td>
</tr>
<tr>
<td>5/5/84</td>
<td>U. S. 2 BR</td>
<td>NE</td>
<td>11 p.m.</td>
<td>Car damaged, 30 m of road buried under 2-3 m of rock</td>
</tr>
<tr>
<td>22/5/84</td>
<td>GS Road W</td>
<td>SSE</td>
<td>a.m.</td>
<td>Closure of GS Road</td>
</tr>
<tr>
<td>9/84</td>
<td>Ptarmigan</td>
<td>WNW</td>
<td>n.d.</td>
<td>3-m deep rockslide buried trail</td>
</tr>
<tr>
<td>6/9/86</td>
<td>GS Road E</td>
<td>SW</td>
<td>2 p.m.</td>
<td>Car demolished, 2 people injured</td>
</tr>
<tr>
<td>8/5/87</td>
<td>GS Road W</td>
<td>W</td>
<td>early p.m.</td>
<td>Passenger van dented, tire smashed</td>
</tr>
<tr>
<td>2/8/87</td>
<td>Swiftcurrent</td>
<td>NE</td>
<td>3 p.m.</td>
<td>Hiker struck in head, seriously wounded</td>
</tr>
<tr>
<td>2/5/88</td>
<td>GS Road W</td>
<td>SW</td>
<td>early p.m.</td>
<td>Government pick-up truck struck, $2,300 damage</td>
</tr>
<tr>
<td>18/6/88</td>
<td>GS Road W</td>
<td>SW</td>
<td>n.d.</td>
<td>Car demolished, passenger injured</td>
</tr>
<tr>
<td>8/88</td>
<td>Highline Trail</td>
<td>W</td>
<td>n.d.</td>
<td>Rock broke arm of 14 year old hiker</td>
</tr>
<tr>
<td>26/9/88</td>
<td>GS Road W</td>
<td>SW</td>
<td>early a.m.</td>
<td>Closure of GS Road</td>
</tr>
<tr>
<td>24/1/89</td>
<td>U. S. 2 BR</td>
<td>NE</td>
<td>a.m.</td>
<td>Blockage of 1 lane of traffic for &gt;24 hrs.</td>
</tr>
<tr>
<td>16/2/89</td>
<td>U. S. 2 BR</td>
<td>NE</td>
<td>n.d.</td>
<td>Road blocked &gt;1 hr.</td>
</tr>
<tr>
<td>24/5/89</td>
<td>GS Road W</td>
<td>SW</td>
<td>n.d.</td>
<td>Closure of GS Road</td>
</tr>
<tr>
<td>11/6/89</td>
<td>Many Glacier</td>
<td>S</td>
<td>p.m.</td>
<td>250-ft long, 8-ft. deep rockfall blocked road for over 6 hrs.</td>
</tr>
<tr>
<td>8/6/89</td>
<td>Highline Trail</td>
<td>WSW</td>
<td>early p.m.</td>
<td>Two climbers injured</td>
</tr>
<tr>
<td>15/7/89</td>
<td>GS Road E</td>
<td>SSW</td>
<td>6 p.m.</td>
<td>Several cars damaged, road closed for 12 hr, 1 lane closed 24 hr.</td>
</tr>
<tr>
<td>20/7/89</td>
<td>GS Road W</td>
<td>SW</td>
<td>n.d.</td>
<td>Closure of road for unspecified # of hr.</td>
</tr>
<tr>
<td>27/8/89</td>
<td>Ptarmigan</td>
<td>WNW</td>
<td>n.d.</td>
<td>15-ft. section of trail buried, closed to horse travel</td>
</tr>
<tr>
<td>5/10/89</td>
<td>Highline Trail</td>
<td>WSW</td>
<td>n.d.</td>
<td>Hiker hit in head and knocked unconscious</td>
</tr>
</tbody>
</table>

1Locations east and west of Logan Pass are labelled GS Road E and W respectively. U.S. 2 BR, Blue Rock cut of U.S. 2; U.S. 2 GL, Goat Lick section of U.S. 2.

plunged through the window and door of the car in which she was riding, killing her instantly. Given the history of close-calls on Table 1, it is amazing that so few fatalities have resulted. This can be at least partially attributed to situations where Park officials temporarily closed roads because of the likelihood of rockfall activity (Hungry Horse News 10 May 1989).

**AWARENESS OF THE ROCKFALL HAZARD**

During the summers of 1973 and 1974, this writer was employed as a tour guide/bus driver in Glacier National Park, and drove over 12,000 miles on park roads, mainly GS Road, the Many Glacier-Babb Road, and U.S. Highway 2. Hundreds of Park visitors were entrusted to my care as we drove through rockfall-hazard zones, and yet not once was I informed about, or trained to deal with, the rockfall hazard. At the time, I was completely unaware of past tour bus/rockfall accidents (Brooks 1983) or the likelihood of such an accident. Obviously, then, Park visitors who ride through the hazard zones in their own vehicles or tour buses are probably not familiar with the hazard proclaimed by highway signs.

**SUGGESTIONS FOR IMPROVING VISITOR AWARENESS OF THE HAZARD**

One method for educating the visitor about the rockfall hazard would be to increase the effectiveness of highway warning signs (Horsley 1988), by reducing their ambiguity and forcefully stating the nature of the hazard. Williams and Williams (1988) describe the most effective rockfall-warning signs, determined experimentally, for a natural area in Wales. Glacier National Park officials could adopt their recommendations as to the most effective sign designs, so that visitors will at least perceive that a rockfall hazard truly exists on roads and trails in the Park, and that they enter at their own risk.

Another easily implemented method for educating the public about the rockfall hazard would be the dissemination of literature upon entry to the Park. Currently, as visitors enter Glacier Park, they are provided free informational pamphlets which warn them about the hazards of grizzly and black bears present in the area. Similar information could be provided which informs the casual visitor of the geography of rockfall damage in the Park. Most visitors might ignore such information, as has been found in other studies (Butler 1987, Williams and Williams 1988), but it would assist in alleviating Park liability in case of rockfall accidents. This approach is utilized for the Park grizzly-bear hazard, so its adoption for other natural hazards is simply a logical extension of current management policies.

**REFERENCES**


