Teaching with Catastrophe: Topographic Map Interpretation and the Physical Geography of the 1949 Mann Gulch, Montana Wildfire

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ABSTRACT

Topographic map interpretation is typically taught by "imaginary landscape" or "classic terrain" approaches. This paper details how a "catastrophic approach" involving the August 1949 Mann Gulch, Montana wildfire may be used to teach topographic map interpretation in a university-level *Introduction to Physical Geography* course. The Mann Gulch wildfire erupted from lightning-struck trees to a blowup that killed twelve smokejumpers and one fire and recreation guard as it burned 3000 acres in ten minutes. Two smokejumpers survived by outrunning the fire and one lived by lying in the ashes of his escape fire. The wildfire and its tragic outcome were the culmination of topography, fuels, weather, and human response to calamity. The mix of topographic map interpretation as well as physical geography questions in multiple-choice, explanation, and calculation formats target key steps taken by the fire crew over a ~2 hour period. This approaches' effectiveness stems from its mental and emotional involvement of students as they holistically analyze the landscape and the firefighter's actions within a very real and dynamic setting. Variations of the exercise have been successfully used in three different courses over the past eight years. Numerous other examples of catastrophe could be used to enhance topographic map interpretation in various geography and geology courses.

INTRODUCTION

Topographic maps form the spatial "base" for much of what is taught in physical geography and physical geology. Topographic map interpretation, typically involving scale, coordinate systems, direction, aspect, distance, contour line principles, elevation, slope gradient, and slope morphology, is thus a key component in the education and training of geographers and geologists.

Topographic map interpretation is taught in a variety of approaches including: constructing topographic models (Tucker, 2001); drawing contour lines on clay or rock models (Miller et al., 2000); creating topographic maps of small mounds (Fife, 1995); making topographic maps of imaginary places (Van Burgh et al., 1994); developing scripts for plays acted out on particular landscapes (Van Burgh et al., 1994); using road rallies (Kirchner and Searight, 1989); and emphasizing land development projects (Lacy, 1997). However, the most common approaches in US-published introductory physical geography and physical geology laboratory manuals involve examination of imaginary landscapes combined with subsequent analysis of classic terrain topographic maps (e.g., Christopherson and Hobbs, 2003; Busch, 2000). The downside to the "imaginary landscape" approach is that the topography is not of any particular place thus students may struggle to relate to it. The "classic terrain" approach avoids the pitfall of the imaginary landscape approach by exposing students to real places, often with world-class landforms and landscapes. Because these classic landforms and landscapes typically illustrate the effects of a dominant geomorphic process, students also learn about that particular process as they study the maps. Unfortunately, this topical advantage commonly lacks dynamism (i.e., the landscape appears static on the map) and holism (i.e., one process, typically geomorphic, is emphasized on such exercises while the actual landscape is polygenetic) thus students don't develop an appreciation for the real world applications of their learning.

The objectives of this paper are to demonstrate another approach-catastrophe-to teach topographic map interpretation. The catastrophe used here is the August 1949 Mann Gulch, Montana (located immediately east of the Missouri River and ~25 miles north of Helena in the Helena National Forest) (Figure 1) wildfire in which 12 United States Forest Service (USFS) smokejumpers and one USFS fire and recreation guard were over-run by flames. This event was made popular by the 1952 film *Red Skies of Montana* (20th Century Fox[R]) and Norman Maclean's book *Young Men and Fire* (1992). The Mann Gulch wildfire has received ample attention over the years including song (James Keelaghan's *Cold Missouri Waters* on his 2004 Jericho Beach Music[R] *Then Again* CD), books and monographs (e.g., Gidlund, 1966; Cooley, 1984; Jenkins, 1993; Jenkins, 1995; Useem,1998; Maclean, 2003), government reports (Friedrich, 1951; Rothermal, 1993), magazines and journals (e.g., anonymous, 1949; Hofman and McDonough, 1993; Weick, 1993; Turner, 1999; Maclean, 2004), and websites (Benson, nd; National Smokejumper Association, nda; Wildland Fire Accident Virtual Site, nd). Mann Gulch is the worst USFS smokejumper tragedy to date in terms of lives lost. No other USFS smokejumpers died in flames from the inception of the smokejumpers in 1939 until 1994 when three died in the South Canyon, Colorado fire (Maclean, 1999). No smokejumpers have died since while fighting fire (National Smokejumper Association, nda).

The significance of this paper, and the exercise embedded within, is that it offers an exciting, alternative approach to teaching the very important skill of topographic map interpretation. As shown below, this approach has distinct advantages over the traditional approaches to teaching topographic map interpretation. It has been especially appropriate at Central Washington University (CWU) where a significant number of our students work as wildland firefighters each summer. Tragedy has beset this group as well when CWU students / USFS firefighters Tom Craven and Jessica Johnson died with two other crew members in

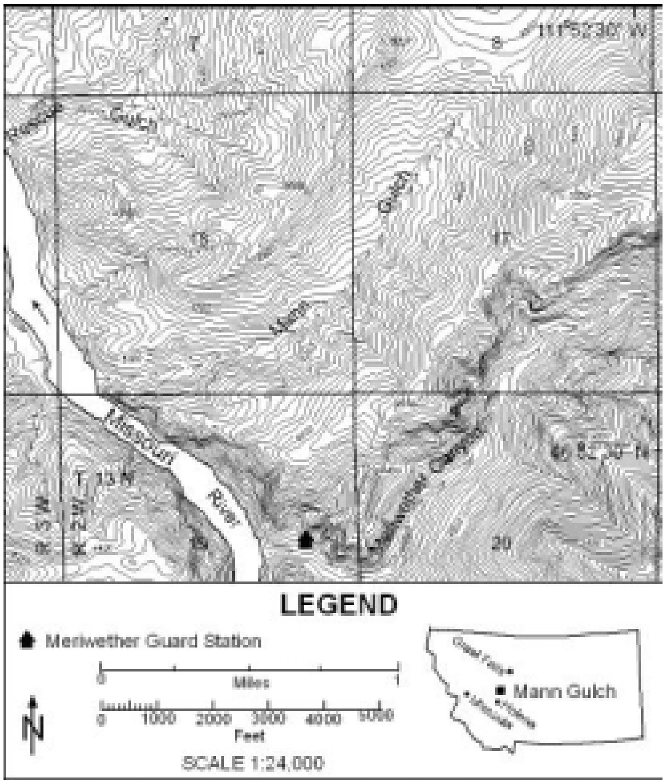

Figure 1. Topographic map of Mann Gulch, Montana watershed and surrounding area. Map sources: Beartooth Mountain, Candle Mountain, and Upper Holter Lake, Montana 7.5' US Geological Survey topographic quadrangles.

Washington's Thirtymile Fire in July 2001 (U.S. Forest Service, nd; U.S. Forest Service, 2001).

LITERATURE BACKGROUND

Using catastrophic events to teach geography and geology - Catastrophe is often taught in geography and geology, either as stand-alone modules or courses (e.g., environmental geology) or to illustrate key points in a particular course (e.g., the 1900 Galveston, Texas hurricane illustrates a devastating hurricane in a physical geography course). Anderson (1987) used the 18 May 1980 eruption of Mount St. Helens to teach introspective writing, interviewing skills, and the relationship between natural, catastrophic events and humans in his human geography course. Anderson's colleagues also wove aspects of the eruption into their physical geography, climatology, and soils curricula in the weeks following the eruption. Others have incorporated catastrophe into their curricula by: promoting a "disaster of the day" approach (Wallace and Hall-Wallace, 2000); combining case studies of actual and fictional disasters with writing assignments to enhance learning (Fryar and Howell, 2001); using Hollywood disaster movies to teach about natural hazards (Furlong and Whitlock, 2003); and linking catastrophic events to scientific data analysis in inquiry-based teaching/ learning (Smyth et al., 2003).

Wildfire as catastrophe - Humans and associated landscapes have been inextricably linked by fire since *Homo erectus* first used it 1.5-2.0 million years ago (Pyne, 2001). Since that time, humans have utilized fire for hunting, eating, socialization, warmth, and safety (Pyne, 2001).

Fire and modern American civilization have a more tumultuous relationship, especially in the American West. While early settlers used fire to their benefit, rising human populations and resulting forest exploitation, combined with the burgeoning conservation movement, led modern cultures to increasingly view fire as a threat (Arno and Allison-Bunnell, 2002). This is especially true in the Intermountain West of the United States (US) where winter wet/summer dry climates create very fire-prone areas (Arno and Allison-Bunnell, 2002). The summer 1910 Northern Rockies wildfires were the culminating events in a catastrophic view toward fire and led to the USFS' Fire Exclusion Policy (Arno and Allison-Bunnell, 2002). Under this policy, the USFS deemed that every fire was to be controlled by 10 a.m. on the day following the initial fire report (Arno and Allison-Bunnell, 2002).

Various states, the USFS, and the media promoted the idea that fire was catastrophic for natural systems as well. Fire prevention and fire education programs sprang up following the turn of the 20th century including "Keep Green" programs in several states (Pyne, 1982). An early 20th century fire prevention poster showed the Grim Reaper simultaneously riding a horse and setting a forest ablaze. The underlying caption stated: "Death Rides the Forest When Man is Careless" (Kaufman, 2004). Walt Disney's 1942 film "Bambi" and the USFS' "Smokey Bear" campaign beginning in 1945, further promoted the idea that fire is a terrible thing for forests and their inhabitants (Pyne, 1982, p. 176; Lutts, 1992; Arno and Allison-Bunnell, 2002).

The "10 a.m. policy" appeared to work. Annual wildfire burn areas generally declined from about 1920 until 1965. Between 1946 and 1978, annual wildfire burn areas were less than 1 million acres (Arno and Allison-Bunnell, 2002). However, the trend since 1965 has generally been one of increasing acreage burned/year, and by 1980, total wildfire-burned area again exceeded 1 million acres. This has led to skyrocketing fire suppression costs. These harsh realities, combined with the recognition of the ecological importance of fire, pushed federal land management agencies to move away from a "war on fire" approach to a "fire management" approach involving more prescribed fire and limited suppression (Arno and Allison-Bunnell, 2002). Unfortunately, the management of initial small wildfires and subsequent explosive growth of those fires at Yellowstone National Park in 1988 dealt a severe blow to the emerging views of fire as necessary and beneficial to Earth systems thus taking us back to a more catastrophic view of fire (Arno and Allison-Bunnell, 2002).

Thus, the view of "fire as catastrophe" has oscillated over time depending on the configuration of society as well as the nature of fires. It is likely that perspectives will continue to vacillate in the future as more homes are built in the wildland-urban interface while managers continue to recognize the significance of fire to ecosystems. Recent US land management policies such as the 2002 Healthy Forest Initiative and the 2003 Healthy Forest Restoration Act are aimed at reducing catastrophic wildfires by improving forest health through thinning and other logging practices (Kaufman, 2004). While the issue of fire as catastrophe is debatable,

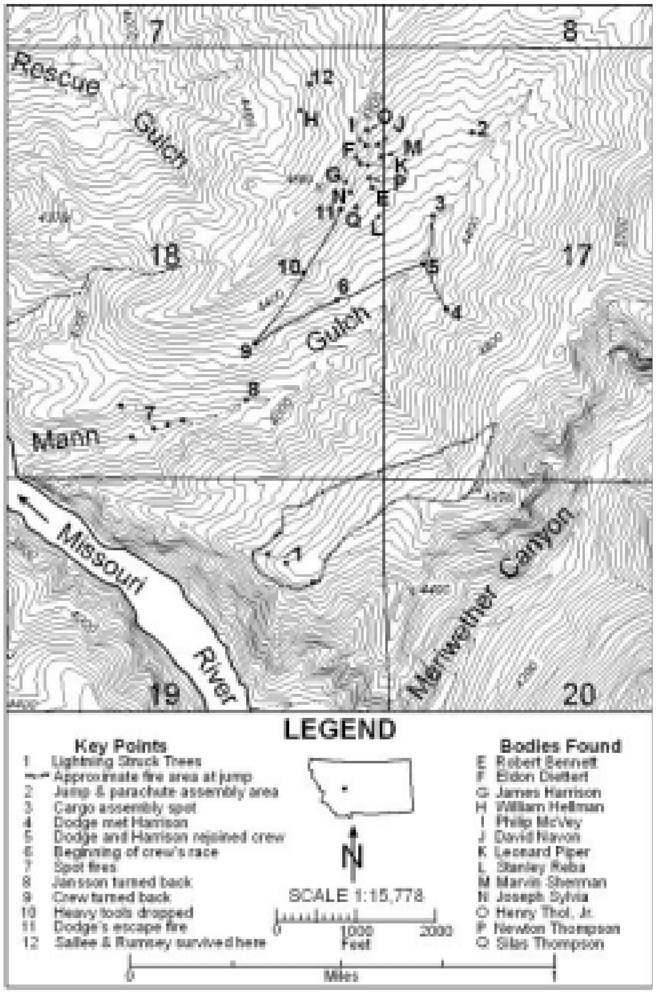

Figure 2. Large-scale topographic map of part of Mann Gulch. Note the: location of the initial fire; parachute and cargo assembly areas; path taken by the smokejumpers; Dodge's escape fire; and the locations of the firefighter's bodies. Map sources: Maclean (1992) and Beartooth Mountain, Candle Mountain, and Upper Holter Lake, Montana 7.5' US Geological Survey topographic quadrangles.

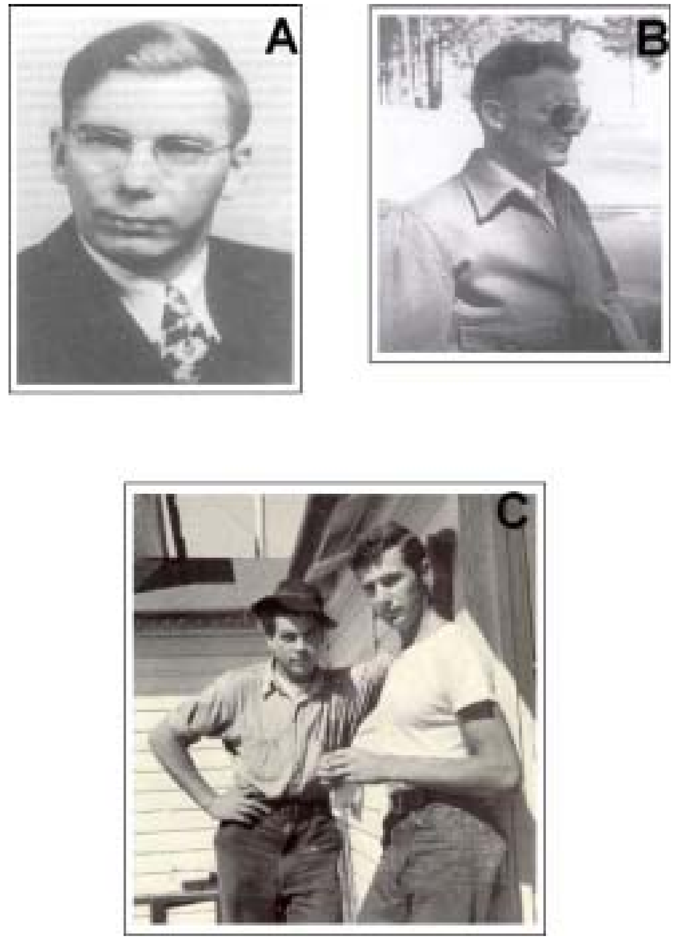

Figure 3. US Forest Service survivors of the Mann Gulch wildfire: A. Robert Jansson; B. R. Wagner "Wag" Dodge; and C. Robert Sallee and Walter Rumsey. Photographs compliments of Helena National Forest, Helena, Montana.

fire is indeed catastrophic when it involves the loss of human life.

AN EXERCISE USING CATASTROPHE

Exercise background - I have used variations of the following catastrophe-based exercise in three courses-*Introduction to Physical Geography*, *Map Reading and Interpretation*, and *Introduction to Geographic Techniques*-within the Geography curriculum at CWU since 1998. Additionally, at least five of my colleagues have used versions of this exercise in those courses.

The exercise presented in this paper has been used in *Introduction to Physical Geography*, a General Education option as well as a required course for Geography majors at CWU. The learning outcomes of this exercise are for students to become proficient at: interpreting and analyzing topographic map characteristics including scale, coordinate systems, direction, aspect, distance, contour line principles, elevation, slope gradient, and slope morphology; using topographic maps to holistically assess the physical geography of a particular watershed; and relating topographic map and physical geography understanding to catastrophic events. The questions within the exercise are aimed at students who have completed more than ~75% of an *Introduction to Physical Geography* course-i.e., weather and climate, water, vegetation, soils, and part of the landforms section have been covered. Questions are mixed with brief sections of text throughout to enhance the drama of the catastrophe as well as enhance student learning (Wickham, 1991; Stokes, 2002). The relatively late inclusion of the exercise into the course means that students are well-prepared to answer the holistic questions. No other science background is expected or necessary for the successful completion of this exercise.

When using this exercise, I first show the location of Mann Gulch on a map (Figure 1), introduce Norman Maclean's *Young Men and Fire* book, and play James Keelaghan's *Cold Missouri Waters* to provide background to the story. I then emphasize that students will need to use their physical geography knowledge, contour line principles (Table 1), a guide to topographic map symbols (US Geological Survey, nd)http://erg.usgs.gov/isb/pubs/booklets/symbols/., a dot grid handout, and the associated maps (Figures 1 and 2) and photographs

Figure 4. US Forest Service victims of the Mann Gulch wildfire. Letters on each photo correspond to Table 2 and to letters in text. Photographs compliments of Helena National Forest, Helena, Montana.

1. All points on any one contour line have the same elevation.
2. Contour line vertical spacing indicates slope steepness-e.g., closely spaced contour lines represent steep slopes while widely spaced contour lines indicate gentle slopes.
3. Contour line horizontal spacing indicates slope uniformity-e.g., non-uniformly spaced or disorganized contour lines indicate an irregular slope.
4. Contour line "V's" indicate presence of ridges and valleys-i.e., contour lines that "V" or "U" upvalley represent valleys while contour lines that "V" or "U" downvalley indicate ridges.
5. Contour line circles indicate hills and basins-i.e., increasing elevations toward the center of a concentric circle indicate a hill while decreasing elevations toward the center of a circle represent a basin. Contour lines are hachured below the outlet elevation to show that the basin is closed.
6. Contour lines and reversing slopes-two contour lines with the same values will be next to each other when a slope reverses itself at a pass or saddle.
7. Contour line intersections-only occur when a map depicts overhanging cliffs.
8. Contour lines never split.
9. Contour lines never simply end.
10. The distance between each adjacent contour line is the contour interval. Every fifth contour line is darker, thicker, and at some location on the map, is shown with an elevation number.

Table 1. Contour line principles essential in interpreting topographic maps.

Table 2 (below). US Forest Service personnel initially involved in Mann Gulch Wildfire, 5 August 1949. All data given as of the time of the fire.

Photo [1]	Name	Age [2]	From [3]	Occupation [4]	Fate
A	Robert Jansson	34	Canyon Ferry, MT	USFS	Lived
B	R. Wagner Dodge	33	Missoula, MT	USFS	Lived
C	Robert Sallee	17	Samuels, ID	Forestry, University of Idaho	Lived
D	Walter Rumsey	21	Garfield, KS	Forestry, Montana State University	Lived
E	Robert Bennett	22	Paris, TN	Forestry, Montana State University	Died
F	Eldon Diettert	19	Missoula, MT	Forestry, Montana State University	Died
G	James Harrison [5]	20	Missoula, MT	Chemistry, Montana State University	Died
H	William Hellman	24	Kalispell, MT	Education, Greeley State Teachers College	Died [6]
I	Phillip McVey	22	Ronan, MT	Journalism, Montana State University	Died
J	David Navon	28	Modesto, CA	Forestry, University of California	Died
K	Leonard Piper	23	Blairsville, PA	Geology, Montana State University	Died
L	Stanley Reba	25	Brooklyn, NY	Forestry, University of Minnesota	Died
M	Marvin Sherman	21	Missoula, MT	USFS	Died
N	Josephy Sylvia	24	Plymouth, MA	Forestry, University of Minnesota	Died [6]
O	Henry Thol, Jr.	19	Kalispell, MT	Undecided, Montana State University	Died
P	Newton Thompson	23	Alhambra, CA	Geology, Pomona College	Died
Q	Silas Thompson	21	Charlotte, NC	Forestry, Montana State University	Died

Notes:
1. Photo refers to letter on individual photos in figures 3 and 4
2. Age information as of 5 August 1949 from Jansson (1065), Cooley (1984), Jenkins (1995), National Smokejumper Association (2004), and Bob Sallee (oral comm., 12 December 2005).
3. Place of residence from Cooley (1984) and Jenkins (1985).
4. Occupation when not a smokejumper or firefighter from National Smokejumper Association (2004).
5. Recreation and fire guard, Meriweather Station, Helena National Forest. All others were smokejumpers
6. Died on 6 August 1949 in Helena's St. Peters Hospital as a result of severe burns incurred in Mann Gulch wildfire.

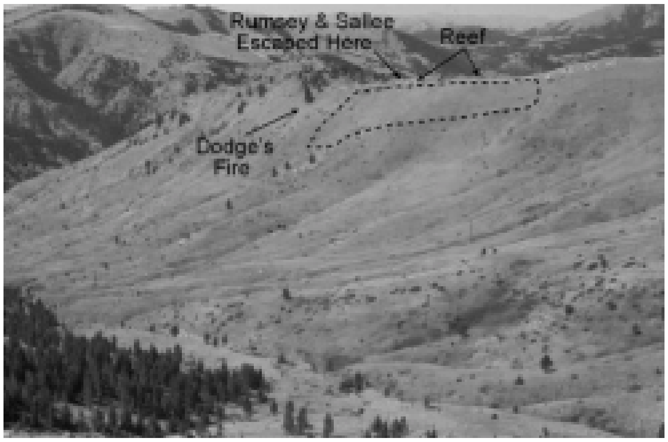

Figure 5. View of Mann Gulch slope: A. on which Dodge survived in the ashes of his escape fire; B. the daunting reef through which Rumsey and Sallee passed; and C. on which all others except Hellman perished (encircled by dashed line). Photo by author in August 2005.

(Figures 3, 4, and 5) to answer the exercise questions. Students are instructed to use the centers of the solid circles on Figure 2 to determine the precise locations of points. This exercise can be completed in several class or laboratory periods, outside of class once the preliminary information is introduced, or in some combination of class, lab and outside. In some academic quarters, I further enhance the holistic character of the exercise by linking it with an earlier exercise where students read and write about contemporary wildfire issues in the western US.

The Fire: Background- The Mann Gulch Wildfire owes its origins to pre-existing conditions as well as events beginning on 4 August 1949. Summer 1948 was cooler and wetter than normal (Western Regional Climate Center, 2005) thus allowing for prolific understory growth and subsequent seed development (Dave Turner, written communication, 19 September 2005). While 1949 area temperatures were slightly cooler than normal, precipitation was less than normal-i.e., 6.6 inches in January-July 1949 vs. 7.9 inches in the January-July 1893-2004 average in Helena. Further, June and July, 1949 precipitation totaled 1.9 inches as compared to the long-term average June and July total of 3.2 inches (Western Regional Climate Center, 2005). Grasses that were plentiful and had grown waist-high in places (Maclean, 1992) with the spring rains were very dry by early August. These pre-existing conditions, combined with an early August heat wave, raised the overall fire danger rating to 74 (on a 100 point scale) at the Canyon Ferry Ranger Station near Helena on 5 August. District Ranger Robert Jansson (Figure 3A) considered this rating in the "explosive" stage (US Forest Service, 1949a). The 1948 designation of part of Mann Gulch into the Gates of the Mountains Wild Area may have further compounded the situation by preventing livestock grazing in the area in 1949 (Maclean, 1992). However, grazing likely was relatively insignificant here because the north side of Mann Gulch was generally too steep and lacked water for cattle (Dave Turner, written communication, 19 September 2005).

Lightning ignited several trees near Mann Gulch during the heat wave late on the afternoon of 4 August (US Forest Service, 1949a) (point 1 on Figure 2). The Mann Gulch wildfire was officially sighted by the Colorado Mountain lookout (located ~29 miles southwest of Mann Gulch) at 12:18 p.m. on 5 August (US Forest Service, 1949a). Ranger Jansson estimated that the fire covered 8 acres when he flew over Mann Gulch at 12:55 p.m. (US Forest Service, 1949a).

The Fire: Questions -

1. What is the representative fraction scale of each of the maps (Figures 1 & 2)? Which has the larger-scale (i.e., shows more detail)?
2. What is the contour interval of each of the maps?
3. Using Figure 1, determine the location of the junction of Mann Gulch with the Missouri River in US Public Land Survey coordinates to the nearest 1/4 of a 1/4 of a 1/4 section.
4. The initial fire started on a ridge / in a valley (circle one).
5. Is the terrain on which the fire started the type of terrain you would expect to be struck by lightning? Explain.

The Crew: Background - Sixteen smokejumpers, plus spotter, assistant spotter, photographer, pilot and co-pilot, departed the USFS Missoula Smokejumper Base (Figure 1) in a C-47 aircraft at 2:30 p.m. on 5 August (US Forest Service, 1949a) for the Mann Gulch wildfire. Smokejumpers were called in because they could rapidly reach this poorly accessible place and in doing so, could likely extinguish the fire before it could grow significantly in size (Turner, 1999). The smokejumpers ranged in age from 17 to 33, and most were forestry students at Montana State University (now the University of Montana) (Table 2; Figures 3 and 4). The smokejumpers were very healthy, physically fit outdoorsmen with some prior firefighting experience. They were young men determined to succeed and dedicated to the task at hand. Perhaps more importantly, they were men who wanted to test their courage by jumping out of airplanes (Sallee, 1993). Norman Maclean (1992, p. 19) states: "They were still so young they hadn't learned to count the odds and to sense they might owe the universe a tragedy." Nine of the crew were first year smokejumpers while the remainder had jumped for two or more years (US Forest Service, 1949a). Most of the crew had not been on a fire larger than 10 acres before Mann Gulch. Foreman R. Wagner "Wag" Dodge (Figure 3B) at age 33 (Table 2) was the veteran of the crew but had only led one crew on a 100-300 acre fire in 1947 and a 10-100 acre fire in 1948 (US Forest Service, 1949b).

The Jump: Background - The heat and associated convective uplift of the day caused a bumpy flight from Missoula. Smokejumper Robert Sallee (Table 2; Figure 3C) later said several of the jumpers were sick from the flight. One smokejumper became so sick that he did not jump from the plane that day (Sallee, 1949).

Spotter Earl Cooley and Wag Dodge both estimated the area of the fire at the time of arrival (3:10 p.m.) was about 50-60 acres (US Forest Service, 1949). The fire fit within the dotted area surrounding point 1 on Figure 2. The smokejumpers and their cargo had dropped into the area by 4:10 p.m. (US Forest Service, 1949). The plane had to drop its cargo from a higher elevation than normal because of the turbulent air thus the stronger winds aloft had more opportunity to scatter the cargo parachutes. It took 50 minutes for all of the jump gear and cargo to be collected at points 2 and 3 (Figure 2) (U.S. Forest Service, 1949).

The Jump: Questions -

6. Had the crew flown to the fire in the morning, convective uplift and the associated air turbulence would likely have been more / less (circle one). Explain.
7. The smokejumpers assembled their gear and cargo on the north / south side (circle one) of Mann Gulch .
8. The parachute assembly area is generally uphill / downhill (circle one) from the cargo assembly area.
9. In a straight line distance, how far (in feet) was the eastern extent of the initial fire at the time of the jump from the subsequent cargo assembly spot?

Path to Disaster: Background - James Harrison, a US Forest Service recreation and fire guard (Table 2; Figure 4G), hiked up from the Meriwether Guard Station in lower Meriwether Canyon (Figure 1) on the morning of 5 August to see if the lightning strikes he had observed on 4 August had resulted in any fires. Upon locating the fire burning at point 1 on Figure 2. he hiked back to Meriwether Guard Station to report the fire by radio, then returned to the fire where he attempted to prevent it from burning into beautiful Meriwether Canyon (US Forest Service, 1949a; Maclean, 1992).

Soon after the smokejumpers landed, Harrison shouted to them. Dodge left the crew at 5:00 p.m. to meet up with Harrison at point 4 on Figure 2 after telling squad leader William "Bill" Hellman (Table 2; Figure 4H) to make sure the men got something to eat before tooling up and joining him at the fire (US Forest Service, 1949a). At about 5:10 p.m., the crew set off to meet Dodge at the fire. All of the men carried one or more canteens and most carried a small "fire pack" with several days food rations, first-aid kit, extra socks, and other personal items (e.g., paperback book, camera, pencil, and paper). Eleven men were double-tooled with pulaskis (a tool with a combination axe-hoe head) and shovels. One man carried a 5 gallon water can mounted on a backpack while two others carried the two-man crosscut saws (Dave Turner, written communication, 19 September 2005; Bob Sallee, oral communication, 12 December 2005). Even this late in the afternoon it was hot-perhaps over 100°F (Maclean, 1992). When the crew reached point 5 on Figure 2, Dodge yelled to them to stay where they were until he and Harrison could join them.

Path to Disaster: Questions -

10. Assuming that Harrison twice ascended from the Missouri River at the mouth of Meriwether Canyon to the 4976' point atop the ridge separating Meriwether Canyon from Mann Gulch on 5 August, how many total feet of elevation had he ascended prior to meeting Dodge?
11. The stream in Mann Gulch generally flows from east to west / west to east (circle one).
12. Dodge and the crew crossed the bottom of Mann Gulch en route to the fire. A(n) perennial / intermittent / ephemeral stream (circle one) flows in Mann Gulch.
13. With temperatures peaking at around 100oF in the late afternoon of 5 August, relative humidity would have been at its highest / lowest (circle one) of the day. Explain.

The Blowup: Background - When Dodge met Harrison at point 4 on Figure 2, he did not like what he saw of the fire. Their location was at the head, thus in the likely path, of the fire were the winds to increase and cause it to spread (US Forest Service, 1949a). Upon rejoining the crew at point 5 on Figure 2, Sallee recalls Dodge saying they needed to get out of the thick second-growth forest because it was a "death trap" (Sallee, 1951). Dodge directed the men to head to the Missouri River by generally following contours on the north side of Mann Gulch. By "contouring" rather than following the bottom of the gulch down to the river, the men would readily see the fire (US Forest Service, 1949a). At the Missouri River, they could fight the fire from the upwind side and have the river at their backs in case the winds changed direction (US Forest Service, 1949a). Meanwhile, Dodge and Harrison hurried back to point 3 on Figure 2 where they filled their canteens and grabbed some ration packs in anticipation of a long night of firefighting (US Forest Service, 1949a). After rejoining the crew at about 5:40 p.m. at point 6 on Figure 2, Dodge took the lead and Hellman took up the rear of the column as it contoured toward the river (US Forest Service, 1949a). Smokejumper Walter Rumsey (Table 2; Figure 3C) noted "At the time the fire started burning a little more fiercely. We all noticed it. A very interesting spectacle. That's about all we thought about it" (US Forest Service, 1949a, p. 102). Five minutes after rejoining the crew, Dodge could see that spot fires had started on the north side of Mann Gulch and was traveling upgulch toward them (US Forest Service, 1949a).

Soon after Dodge left the crew to join Harrison at the fire, Ranger Jansson began to hike up Mann Gulch from the Missouri River to gauge the extent of the fire and to make contact with the smokejumper crew. He estimated 20-30 mile/hour (mph) winds from the south with gusts to 40 mph at the mouth of Mann Gulch (Rothermal, 1993). Jansson could hear fire-loosened rocks rolling down the slopes and dead tree snags snapping (Jansson, 1949a). He soon noted that the fire was "whirling" and spreading firebrands (i.e., burning debris) to the north causing multiple spot fires, several of which were north of the bottom of Mann Gulch (points 7 on Figure 2) (US Forest Service, 1949a). The fire whirls reported by Jansson (1949a) suggest that the fire had become a "blow-up". A "blow-up" occurs when a fire rapidly transitions from a ground fire to a crown fire and creates its own convective vortex. Fuel, terrain, and wind-the classic fire triangle-are the causes of these brief, but very explosive, events (Maclean, 1999). In Mann Gulch, dry fuels, strong winds, and steep slopes combined with an unstable atmosphere to create the crown fire (Rothermal, 1993) that blew up. A vortex forming in the lee of the high southern boundary of Mann Gulch as the strong south wind blew down the Missouri River Valley may have further helped cause the fire to "crown" and subsequently blow-up thus launching firebrands from the main fire to the north side of Mann Gulch (Rothermal, 1993). Once the spot fires started in the forest near the bottom of the gulch, strong winds deflected from the Missouri River Valley rapidly pushed the flames upgulch (Rothermal, 1993). By the time Jansson turned back about 3300 feet from the river between about

5:20 and 5:30 p.m. (point 8 on Figure 2), crown and ground fires composed of the coalesced fires from north and south of the bottom of gulch were moving upgulch toward him (U.S. Forest Service, 1949a; Maclean, 1992). Rothermal (1993) estimated that the crown fire at this point spread at a rate of about 120 feet/minute (ft/min). After a fire "whirl" narrowly missed him, Jansson started running downvalley (US Forest Service, 1949a). He arrived at the mouth of Mann Gulch only after briefly passing out from a lack of oxygen and the heat of the fire (Jansson, 1949a).

Wildfires in dense timber are generally very hot but burn slowly (Maclean, 1992). Conversely, wildfires in grasses burn very rapidly but with much less heat. Arthur Moir, Jr., Helena National Forest Supervisor at the time of the Mann Gulch wildfire, reported that he knew of at least 35 men who had been burned in grassland fires east of Montana's Continental Divide while only 2 men had been burned in the more timbered areas west of the Divide since 1910 (Maclean, 1992). At the time of the fire, Ponderosa pine and Douglas fir grew on the south side of Mann Gulch while Ponderosa Pine, bunchgrass, and cheat grass occupied the north side (US Forest Service, 1949a).

The Blowup: Questions -

14. Point 9 lies on a northeast / southeast / southwest / northwest - facing slope (circle one).
15. Assuming that the firebrands came from the northernmost tree in the initial fire area shown on Figure 2, how far (in feet) were they thrown during the blowup?
16. Explain the climate reason for the differing vegetation pattern north and south of the bottom of Mann Gulch.
17. A soil O horizon would most likely have been present to burn at point 4 / 10 (circle one). Explain.

The Race: Background - Five minutes after rejoining the crew, Dodge could see that the fire had crossed Mann Gulch and was rapidly moving upslope toward them from 450-600 feet downslope (US Forest Service, 1949a). He realized that the crew could no longer descend to the Missouri River via Mann Gulch and they would need to move quickly away from a fire that was advancing on them by the second. He thus reversed direction at point 9 on Figure 2 and headed the crew upvalley. Now that the fire was below the crew, they were in a very precarious position as illustrated by the old firefighter rule: "Never let a fire get below you on a mountain. Only bears and fires, not firefighters, can run uphill faster than down" (Maclean, 1999, p. 84).

After angling briskly upslope, fully tooled on this hot day, for ~1350 feet to point 10 on Figure 2 (Rothermal, 1993), Dodge ordered the men to drop all heavy equipment. Sallee later estimated that the fire was 225-300 feet behind him when he dropped his crosscut saw (US Forest Service, 1949a). The forest was thinner here with more intervening grass cover thus the advance of the fire accelerated to 170-280 ft/min with flame lengths of 16-20 ft. The main fire was also probably throwing firebrands upgulch (Rothermal, 1993).

Dodge led the men further upgulch into an area that was less forested and more grass-covered than the previous leg of the race. The fire was behind them on the north side of the gulch and had advanced ahead of them on the south side of gulch (US Forest Service, 1949a). At point 11 on Figure 2, Dodge realized that the crew did not have time to make the ridgetop (Figure 5) before being overrun by the fire rapidly approaching from the rear. The fire was moving at 360-610 ft/min here with 24-30 ft flame lengths as a result of the thinner fuels and increased winds (Rothermal, 1993).

At point 11 on Figure 2, Dodge lit clumps of grass on fire at ~5:55 p.m. (Rothermal, 1993) in hopes of creating a burned over, fuel-free zone around which the main fire would burn thus providing a safe haven for the men. When later asked by the Board of Review whether he had been taught to set an escape fire in such a situation, Dodge replied "Not that I know of. It just seemed the logical thing to do. I had been instructed if possible to get into a burned area" (US Forest Service, 1949a, p. 123). The escape fire rapidly burned upslope toward the top of the ridge (US Forest Service, 1949a). Dodge walked into the rapidly growing, burned-over area and beckoned the men to join him. Despite his urging, none of the crew followed him. Perhaps the deafening roar of the fire prevented the men from fully understanding Dodge's intent with the escape fire. When asked by the Board of Review whether the crew members looked at Dodge and his burned area, Dodge replied: "They didn't pay any attention. That is the part that I didn't understand. They seemed to have something on their minds-all headed in one direction" (US Forest Service, 1949a, p. 123). Dodge even recalled one crew member saying: "To hell with this, I am getting out of here" (US Forest Service, 1949a, p. 118). As the roaring inferno neared, Dodge covered his mouth and nose with a canteen-moistened bandanna and lay down in the hot ashes. The main fire hit Dodge's location (Figure 5) "within seconds after the last man passed" (US Forest Service, 1949a). Three violent gusts of superheated air nearly lifted him from the ground (Staff, 1949).

Amazingly, Dodge survived the blasts of the fire literally unscathed. Nearby evidence indicated that surface temperatures of the main fire reached 1500-1800°F (Rothermal, 1993) and that the main fire covered 3000 acres in ten minutes or less (Jansson, 1949b). At ~6:10 p.m., he was able to rise and look at the devastated landscape (US Forest Service, 1949a). Soon after hearing a voice to the east, he discovered crew member Joe Sylvia (point N on Figure 2; Table 2; Figure 4N) who was badly burned. Dodge moved Sylvia to a large rock, removed his boots and gave him his canteen. He then departed to seek medical help for Sylvia (US Forest Service, 1949a).

Two other crew members who ignored Dodge also survived the fire. Sallee, Rumsey, and Eldon Diettert (Table 2; Figures 3 and 4F) were among the first to pass Dodge as he lit the fire. Sallee thought that Dodge wanted the men to follow the edge of his fire up to the ridge crest with Dodge's fire acting to slow down the inferno moving upgulch (US Forest Service, 1949a). Rumsey later testified "I remember thinking it [the escape fire] was a good idea...don't know whether I understood. If I had fully realized it I probably would have gone right in. I kept thinking the ridge-if I can make it. On ridge I will be safe. I went up the right hand side of Dodge's fire" (US Forest Service, 1949a, p. 104). Rumsey reported that he could feel the heat of the main fire on this back as he neared the ridge crest (US Forest Service, 1949a).

Upon reaching the late Paleozoic and Mesozoic marine sedimentary and metamorphic (Robinson and McCallum, 1991) "rimrock" (or "reef") near the top of the ridge, Sallee and Rumsey found an opening and passed through (Figure 5). It is unclear why Diettert did not follow them. His body was later found nearby (point F on Figure 2). Another ~100 yards of running in the head of what is now known as Rescue Gulch (Figures 1 and 2) brought Rumsey and Sallee to a vegetation-free blockfield (point 12 on Figure 2) about 5 minutes ahead of the fire (US Forest Service, 1949a). They survived by moving around the blockfield as the fire approached from different sides (Maclean, 2004). Rumsey later told Jansson "The Lord was good to me-he put wings on my feet, and I ran like hell" (US Forest Service, 1949a, p. 128).

After the fire passed the blockfield, Rumsey and Sallee yelled to see if anyone else was alive. Upon hearing a voice from about 90 feet to the west, they discovered squad leader Hellman (US Forest Service, 1949a, p. 81) who had been badly burned atop the ridge but made it over the north side of the ridge (US Forest Service, 1949) (point H on Figure 2). As they tried to comfort Hellman, Rumsey and Sallee soon heard Dodge shouting at the top of the ridge. Upon meeting, Dodge and Sallee decided to descend to the Missouri River for medical help for Sylvia and Hellman. Rumsey stayed to care for Hellman (US Forest Service, 1949a). Sylvia was left alone in the hot, smoky hell of Mann Gulch.

The Race: Questions -

18. At the subsequent inquiry, Dodge was asked why he didn't lead his men directly from point 9 to the ridgetop. This is a logical question as the route is surely shorter than the one he chose. Why do you think he didn't choose that route? Explain.
19. Based on Earth-Sun relationships at this latitude, the slope at point 10 should have been hotter / cooler (circle one) than the slope at point 4. Explain.
20. How far (in feet) did the men hike upslope from point 9 to 11 in their work clothes and heavy boots on this very hot afternoon? Recall, they dropped their packs and fire fighting tools at point 10.
21. How much elevation (in feet) did the men gain from point 9 to 11?
22. What is the slope gradient (%) from point 9 to 11?
23. The slope from point 9 to 10 is generally steeper / gentler (circle one) than that from point 10 to 11.
24. The rocks of the slope are primarily quartzites. All other factors equal, quartzite should result in more steep / gentle slopes than shale.
25. Aside from the noted elevations, explain how the contour lines show you that Rumsey and Sallee crossed a ridge rather than a valley as they ran from the fire.
26. What is the likely origin of the blockfield on which Rumsey and Sallee survived (point 12)? Explain.

The Aftermath: Background - Dodge and Sallee reached Meriwether Guard Station at about 8:50 p.m. after hiking down Rescue Gulch and flagging down a boat. By 11:30 p.m., Jansson and Sallee were leading a rescue party, including two doctors, up Rescue Gulch. The doctors treated Hellman and Sylvia with plasma and morphine, and dressed their wounds. Soon after daylight on 6 August, both were carried on stretchers to the mouth of Mann Gulch where they were transported by boat and subsequently by ambulance to St. Peters Hospital in Helena (Hawkins, 1950). Both died later that day of massive third degree burns (65-85% of their bodies) and heat-induced damage to their respiratory systems (US Forest Service, 1949a).

All other members of the crew-Robert Bennett, Eldon Diettert, Phillip McVey, David Navon, Leonard Piper, Stanley Reba, Marvin Sherman, Henry Thol, Jr., Newton Thompson, and Silas Thompson, as well as James Harrison (Figures 2 and 4; Table 2)-perished immediately in the fire. The sites in which their bodies were recovered are marked as points E-Q on Figure 2. Death likely came very rapidly to these men as the result of suffocation due to consumption of oxygen by the fire (Hawkins, 1950).

Even with the help of a light rain, it took 450 men six days to control the Mann Gulch Wildfire. By that time, the fire had burned 5000 acres (Hanson, 1949), killed 13 men, and changed the lives of crew members, friends and families forever. Foreman Wag Dodge lived little more than five years after the Mann Gulch tragedy, only to die of Hodgkins Disease (Maclean, 1992; National Smokejumper Association, ndb). Ranger Bob Jansson died in 1965 after a long period of poor health (Jansson, 1965). Dodge and Jansson each carried the weight of responsibility to their graves-Dodge for the men and Jansson for the 5000 acres lost (Weltzian, 1995). Smokejumper Walt Rumsey died in 1980 in an airplane accident (Maclean, 2004). As of December 2005, Bob Sallee is the lone survivor of the Mann Gulch catastrophe.

The fire was a wake-up call to the USFS and their elite smokejumpers. In its aftermath, crew discipline training, equipment research and development, and fire behavior research increased (Turner, 1999). The Mann Gulch wildfire also changed the way the USFS firefighters approach fires. The 10 Standard Fire Orders and the 18 Watch Out Situations were developed in 1957 (National Interagency Fire Center, nd) as a result of Mann Gulch and other tragic fires (Maclean, 1999) and now govern wildland firefighter practices. Despite the lessons learned at Mann Gulch, fire continues to be catastrophe-i.e., 14 wildland firefighters (including three smokejumpers) perished under similar conditions at Storm King Mountain in Colorado in 1994 (Maclean, 1999).

The fire also had dramatic impacts on the health of the watershed. A thunderstorm on 11 August 1950 dumped at least 1 inch of precipitation in approximately 45 minutes on the Mann Gulch area (Friedrich, 1951). The result was tremendous rill and gully erosion on the burned thus largely vegetation-free slopes, and subsequent deposition as debris fans at the mouths of channels (Friedrich, 1951).

The Aftermath: Questions -

27. Carefully trace the drainage divide (i.e., watershed boundary) outlining the Mann Gulch drainage on Figure 1. Recall from class the definition of a drainage divide.
28. From your outline of the Mann Gulch watershed, describe its shape. Explain how this shape may have influenced the behavior of the fire.
29. Assume that the entire watershed above 3700' elevation burned in the wildfire. Much of this area burned in about 10 minutes! Using a dot grid, calculate the number of Mann Gulch watershed acres burned in the fire.
30. Explain why burned areas within the Mann Gulch watershed eroded much more than adjacent

unburned areas during the August 1950 thunderstorm.

Exercise Aftermath - The I*ntroduction to Physical Geography* exercise shown above involves 30 questions, two-thirds of which are focused on topographic map principles and one-third of which deal with physical geography, all woven into a historic, catastrophic event. Questions are split equally between multiple choice, explanation, and calculation formats. The content and format of the questions prepares students to achieve all three student learning outcomes-i.e., proficiency in topographic map skills, holistic physical geography analysis, and relating maps and physical geography to catastrophe. Achievement of the student learning outcomes is assessed through grading of the exercise, a subsequent examination, and sometimes, a subsequent classic terrain exercise. Qualitative assessment of student learning over time reveals that students learn topographic map skills at least as well with this exercise as they do using the imaginary landscape and classic terrain approaches. Further, the holistic analysis of a dynamic, real world event is advantageous to the traditional approaches. The catastrophe approach also reaches students on deeper mental and emotional levels than the imaginary landscapes or classic terrain approaches, especially given that the students are of approximately the same age as the smokejumpers. Unintended consequences of this approach include an enhanced sense of recent western history and its relationship to fire and firefighting, and a renewed interest by some students in reading popular literature. The exercise has also had unexpected, far-reaching effects. One geography alumnus became a wildland firefighter partially because of the exercise. Another former student who is now a wildland firefighter is using a version of the exercise to teach fellow firefighters topographic map interpretation skills.

From an instructor's standpoint, the primary negative aspect of this exercise is the large amount of grading associated. Students complain that the exercise is too time-intensive (i.e., it requires at least three hours to complete thus it cannot be completed within a standard two-hour laboratory period) and the holistic nature of the exercise requires that students recall what they learned earlier in the course.

SUMMARY/CONCLUSIONS

Eight years of practice has shown that the catastrophe approach is an exciting and effective alternative to the classic terrain and imaginary landscape approaches of teaching topographic map interpretation in introductory and intermediate geography courses. This approach is also appropriate for adding additional questions regarding the physical geography or geology of the area. With slight modification, this exercise may be readily adapted to a variety of other university-level geography and geology courses, as well as middle and high school courses.

While I used the 1949 Mann Gulch wildfire as the event highlighting the catastrophe approach, numerous other examples exist including other wildfires (e.g., Hult, 1960; Maclean, 1999), the effects of storm events in a variety of settings (e.g., Hult, 1960; Krakauer, 1997; Junger, 1998; Larson, 1999; Laskin, 2004), as well as polar ice- (e.g., Alexander, 1999;), volcanism- (e.g., Winchester, 2003; Parchman, 2005), flood - (e.g., McCullough, 1968), and earthquake- (e.g., Thomas and Witts, 1971) related catastrophes. All are riveting catastrophes rooted in the geosciences and written as popular literature. Such approaches offer much promise, especially when accompanied by Hollywood film clips or song.

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