THE SLUMGULLION LANDSLIDE, HINSDALE COUNTY, COLORADO

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The disrupted surface of the Slumgullion landslide. Photo by J.A. Coe, U.S. Geological Survey

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OVERVIEW

This two-day field trip visits the Slumgullion landslide located in the San Juan Mountains of southwestern Colorado (Figure 1). The landslide moves continuously at rates as high as about 7 m/yr, making it an exceptional location for landslide research. The trip will provide opportunities to observe and evaluate the landslide, as well as learn some of the results of research studies performed during the past sixty years. The first day of the trip will include overviews of the landslide and its geologic setting, and the second day will include a hike down part of the landslide. We will see some of the monitoring equipment used to study the landslide and features that indicate the kinematics involved with landslide movement.

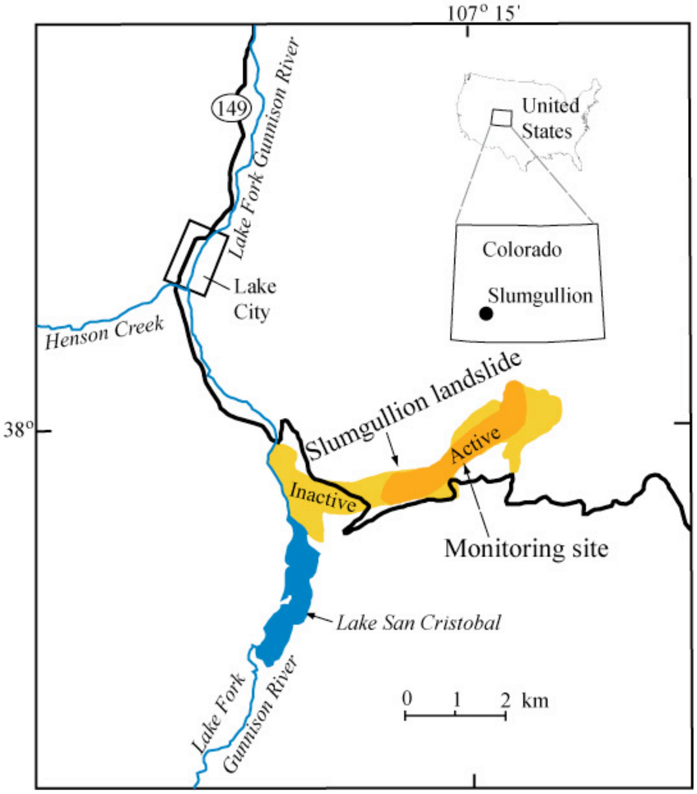


Figure 1. Map showing the location of the Slumgullion landslide (from Schulz and others, 2007).

The Slumgullion landslide (Figure 2) is a translational debris slide (Cruden and Varnes, 1996) and has been described by numerous investigators (for example, Endlich, 1876; Howe, 1909; Atwood and Mather, 1932; Burbank, 1947; Crandell and Varnes, 1960, 1961; Savage and Fleming, 1996; Fleming and others, 1999; Coe and others, 2003; Schulz and others, 2007). The landslide occurs in Tertiary volcanic rocks and consists of a younger, active, upper part that moves on and over an older, larger, inactive part. The entire landslide is 6.8 km long, averages about 400 m wide, has an estimated depth of up to 120 m, and has an estimated volume of 170×10^6 m^3 (Williams and Pratt, 1996). The active landslide (Figures 1 and 2) is about 3.9 km long, averages about 300 m wide, has an estimated average depth of about 14 m, and has an estimated volume of 20×10^6 m^3 (Parise and Guzzi, 1992). Radiocarbon dating suggests that the older, inactive landslide dammed the Lake Fork of the Gunnison River and created Lake San Cristobal about 700 years ago (Crandell and Varnes, 1960, 1961).

Figure 2. View of the Slumgullion landslide. Photograph by J.A. Coe, U.S. Geological Survey.

Summary of Research Studies of the Active Part of the Slumgullion Landslide

In general, the active upper part of the Slumgullion landslide extends, the lower part compresses, and the middle part moves as a plug and has the greatest velocity. This style of movement produces normal faults and tension cracks in the upper part of the landslide (Figure 3) and imbricate thrust faults (Figure 4) and lateral spreading in the lower part of the landslide. The landslide is laterally bounded by strike-slip faults and prominent flank ridges (Figure 5). Low-permeability clay striated by landslide movement is exposed at many locations along these faults. This clay and the continuous movement of the landslide suggest that the landslide may be hydrologically isolated from adjacent areas (Baum and Reid, 2000). Pull-apart basins are common on both sides of the landslide where it widens (Fleming and others, 1996, 1999). At several locations on the lower part of the active landslide, pond sediments are carried downslope while the associated ponds remain stationary. This and other observations (Fleming and others, 1996, 1999) suggest that sub-basal topography strongly controls deformation in the Slumgullion landslide.

Figure 3. Downhill-facing normal fault scarps in the upper part of the Slumgullion landslide. Photograph by J.A. Coe, U.S. Geological Survey.

Figure 4. Imbricate thrust faults in the lower part of the Slumgullion landslide. Photograph by W.Z. Savage, U.S. Geological Survey.

Figure 5. Flank ridges along the southern margin of the Slumgullion landslide (landslide is left of the ridges). Photograph by Giulia Biavati, Università di Bologna, Italy.

The first detailed measurements of landslide movement were begun in 1958 by D.R. Crandell and D.J. Varnes (Crandell and Varnes, 1960, 1961), who established lines of survey markers in the middle part of the active landslide. They found that during the period 1958-1968 movement of up to 6 m/yr occurred in the narrow part of the landslide and that the active toe advanced at about 1 m/yr. From a mapping effort carried out in the early 1990s, Fleming and others (1999) concluded that annual displacement of the active landslide had been about constant during the previous one-hundred years and found that the active landslide consists of several independent kinematic units that can have differing velocities. Coe and others (2003) established a global positioning survey network across the landslide and observed a range of displacement rates of about 6 m/yr among these kinematic units.

Fleming and others (1999) inferred that velocity varies seasonally, presumably due to changes in pore-water pressures, and Savage and Fleming (1996), Coe and others (2003), and Schulz and others (2007) documented seasonally varying velocity through continuous displacement monitoring. Coe and others (2003) established two instrumentation stations to study relationships between landslide displacement, air and soil temperature, snow depth, rainfall, soil water content, and perched ground-water pressure and identified generally direct, positive correlation between ground-water pressure measured at a depth of 2.2 m and landslide velocity. Schulz and others (2007) installed ground-water pressure monitoring devices at depths up to 9.1 m. They found that at these greater depths there was no direct correlation between surface infiltration events and measured ground-water pressures, or between ground-water pressure and landslide velocity. However, they did observe that changes in ground-water pressure inversely correlated with landslide acceleration, suggesting dilatant behavior of shearing landslide debris. They also observed cycles of acceleration, ground-water pressure decrease, and deceleration, suggesting dilatant strengthening and pore-pressure feedback during shear.

Table 1. Field Trip Stops and Topics

Location	Topic	Presenter
Lake San Cristobal Overlook (Stop 1, day 1)	Landslide overview; Lake San Cristobal; geologic setting	Bill Schulz
Slumgullion Landslide Overlook (Stop 2, day 1)	Active landslide characteristics	Bill Schulz
Lower Landslide Walk - Monitoring station to active landslide toe (Stop 3, day 2)	Landslide monitoring; active landslide characteristics	Bill Schulz, Bill Ellis

TRIP ROUTE DESCRIPTION AND MAPS

Our field trip begins and ends in Vail, Colorado, while the focus of the trip is located outside Lake City, Colorado (Tables 1 and 2, Figure 6). Drive time from Vail to the Slumgullion landslide is about 4.5-5 hrs so we will make only 2 stops during the drive, one for a mid-morning break and the other for lunch. Our drive takes us through several geologic provinces, spectacular scenery, and historic towns. We will try to provide some interesting background about these places during the drive. A brief overview of the geologic, historic, and scenic features is given below. Upon our arrival in Lake City, we will stop at our hotel to check in and unload luggage. Then we will drive to the landslide and make 2 stops that provide overviews of the landslide and its geologic setting (Tables 3 and 4). We should return to Lake City about 6 pm. This should allow adequate time for independent exploration of the quaint, historic mining town and dinner. Although limited in number, there are several restaurant choices in town.

To allow ample time to explore the landslide, we will leave the hotel early on Sunday and have a group breakfast. We will be dropped off near the middle of the landslide (Table 5) and will hike down beyond the landslide toe where we will meet the bus. Afterward, we will return to Lake City for a late lunch and then return to Vail. We expect to arrive in Vail between 6 pm and 7 pm.

Figure 6. Satellite image and road map showing field trip route from Vail to Lake City, Colorado (image from Google Maps).

Table 2. Mileage from Start of Field Trip at Vail Marriott Mountain Resort to Lake City.

Mileage	Description
5.8	Leave Vail Marriot Resort heading north on West Lionshead Circle and follow signs to I-70 west. Take I-70 west to exit 171 onto US-24 east.
72.8	Follow US-285 south (continue heading straight) when US-24 splits off to east.
93.8	Turn right onto US-50.
162.6	Turn left onto CO-149.
208.1	Arrive in downtown Lake City at intersection of CO-149 (Gunnison Ave.) and 2nd St.

VAIL TO LAKE CITY HIGHLIGHTS

Our field trip begins the morning of June 8 with a short jaunt west from Vail on Interstate 70 west (Table 2). We then head south on U.S. Highway 24 east (we really do go south, though) toward the town of Minturn. Minturn predates Vail by almost a century and was originally a homestead in the 1800's. In 1887, the Denver & Rio Grande Western Railroad arrived in Minturn, which was named for Robert B. Minturn, a shipping millionaire responsible for raising the money to bring the rails west. We continue south on U.S. 24 through the town of Gilman, perched high on the side of the canyon, and then through the town of Redcliff. Both towns figure prominently in Colorado mining history. We then pass Camp Hale, the WW II training area for the famous 10th Mountain Division of the U.S. Army. Concrete pads for the buildings and barracks are all that remains of this military facility. We then proceed over Tennessee Pass (elevation 10,424 ft) and the continental divide. Leadville is the next large town we pass through. The Leadville Mining District is home to the famous Matchless Mine of "Unsinkable Molly Brown", and also hosts the National Mining Museum. Colorado's highest peak, Mount Elbert (elevation 14,433 ft), is clearly visible just to the southwest of town.

South of Leadville, U.S. 24 follows the northern end of the Rio Grande Rift. The rift formed during the mid-Tertiary uplift of the mountains on either side of the rift. The Arkansas River now flows through this part of the rift. The valley bottom is underlain mostly by glacial outwash deposits, and the upper part of the valley is underlain by moraines and till deposited by glaciers that flowed down from the western peaks. The Collegiate Peaks (Mounts Oxford, Harvard, Columbia, Yale, and Princeton) are west of the Rio Grande Rift and the Mosquito Range is on the east. U-shaped glacial valleys and moraines can be observed along most of the Collegiate Peaks. The northern parts of both ranges are comprised of Precambrian gneiss and schist, and the southern parts are mostly granite.

U.S. 24 passes through the small town of Granite (where granite is exposed along the Arkansas River) and the next large town of Buena Vista, a gateway to Colorado's varied and exciting outdoor recreational activities—mountain climbing, skiing, river rafting and kayaking, mountain biking, hiking, fishing, hunting, fossil and gem collecting, camping and snowmobiling are all easily accessible from this area. If time permits, we are planning a short stop in Buena Vista. With its mild winters, the upper Arkansas River valley is amenable for grazing and hay farming, and cattle and sheep ranching are still actively pursued in this area.

At Poncha Springs we leave the main valley and turn west on U.S. Highway 50, heading upwards to the summit of Monarch Pass (11,312 ft). Monarch Pass Ski Area is located just before the summit of the pass. Originally named Monarch Mountain, the ski area was built in 1939 by Works Project Administration workers. Upon completion of the project, the ski area was given to the city of Salida, which is about 5 miles east of Poncha Springs. Our climb up Monarch Pass follows a formerly glaciated valley upon a Tertiary granite batholith intruded into sedimentary rocks (mostly limestone). We'll pass a large inactive limestone quarry (on the left) and a lead, zinc, and silver mine located above the quarry.

At the summit of Monarch Pass we again cross the continental divide. The valley we follow down from the pass was not glaciated. At the base of the mountain, however, is the terminal moraine of a glacier that flowed down from the north along the Tomichi Creek drainage. We will follow Tomichi Creek from this point to the town of Gunnison. Tomichi Creek and roadcuts along U.S. 50 generally reveal Precambrian igneous and metamorphic rocks, but also some Paleozoic sedimentary rocks. Tertiary volcanic rocks (mostly tuffs) are also common and become more common as we head west.

The next large town we come to is Gunnison, which is a welcome place to stop for a lunch break. The city was named after John W. Gunnison, a United States Army officer who surveyed for the transcontinental railroad in 1853. It is home to Western State College. One of Gunnison's claims to fame is that it is one of the coldest places in the United States during the winter. This is due to its geographical location; it sits at the confluence of two low river valleys between several high mountain ranges from which the cold air descends into town.

On the final leg of our drive we travel a short distance west of Gunnison and then turn south and travel along Colorado State Highway 149. The upper reaches of the Blue Mesa Reservoir can be seen for a short distance along Highway 149. From Blue Mesa to Lake City we enter the San Juan Mountains, which are primarily comprised of Tertiary volcanic rocks. This becomes readily apparent when we drop into the canyon of the Lake Fork of the Gunnison River about 30 miles after leaving Blue Mesa Reservoir. The canyon walls are mostly welded tuffs dissected by vertical columnar joints. The river has eroded through the rim of the Lake City caldera, and a few miles after we leave the canyon we'll reach Lake City and the interior of the caldera. When we drive into Lake City you might notice the valley that we've driven down forks to the right (west) and left (southeast). These forks skirt the edge of the resurgent dome that grew within the caldera; the dome is straight ahead.

As we approach Lake City, the flat-topped mountain to the left (east) is named Cannibal Plateau, which is a bit misleading since Alferd Packer had his meals at the confluence of Deadman Gulch (named after Alferd's former companions) and the Lake Fork, less than a thousand feet from the inactive toe of the Slumgullion landslide. Alferd Packer was one of only two (thankfully – or maybe they never caught the others!) Americans imprisoned for cannibalism. Actually, he claimed he was imprisoned for cannibalism, but he was really imprisoned for murder. During the winter of 1873-1874, Packer was part of a poorly planned expedition through the San Juan Mountains destined for Gunnison. After becoming snowbound, Packer apparently became hungry enough to kill and eat his five comrades. He claimed that one of the men killed the other four while Packer was away searching for food then tried to kill Packer when he returned. Packer claimed to have killed the man in self-defense and had to resort to cannibalism to survive the winter. Packer was convicted of murder in the Hinsdale County Courthouse in Lake City (the big white building that still serves as the courthouse and which is located left of CO 149 at 3rd St.). There has been debate amongst historians regarding the guilt of

Packer, and a mock trial organized by several historians recently found that he was innocent of murder. We'll drive by the site of the massacre on our way to the landslide. The site is on the left just before we cross the Lake Fork (Table 3).

Table 3. Mileage from Lake City to Lake San Cristobal Overlook (Stop 1, day 1).

Mileage	Description
2.5	Leave Lake City (intersection of CO-149 (Gunnison Ave.) and 2nd St.) on CO-149 south. Cross Lake Fork of the Gunnison River. Yellow deposits to right comprise the downstream limit of Slumgullion landslide deposits.
4.1	Drive onto inactive Slumgullion landslide deposits.
4.5	Leave inactive Slumgullion landslide deposits.
5.0	Lake San Cristobal Overlook (Stop 1) is the parking area on the right.

STOP 1. LAKE SAN CRISTOBAL OVERLOOK

This stop provides a view of some of the active part of the landslide (Figure 7), some of the toe of the inactive part of the landslide, and Lake San Cristobal (Figure 8). Also visible from this stop is the general setting of the Slumgullion landslide. Directions to the stop are given in Table 3.

The Slumgullion landslide is located along a flank of the collapsed Lake City caldera. The mountains visible to the west from the overlook were mostly formed during post-collapse resurgent dome building. The landslide occurs within Tertiary volcanic rocks including basalt, rhyolite, and andesite, much of which has been highly altered by hydrothermal activity (Lipman 1976; Diehl and Schuster 1996). The 230-m-high headscarp of the landslide is visible from this stop and exposes faulted, generally flat-lying, interbedded basalt and ash-flow tuff that overlie highly altered andesite and rhyolite (Diehl and Schuster, 1996).

The toe of the active part of the Slumgullion landslide is marked by the light-colored soil, disturbed trees, and an abrupt hill upslope from CO-149. The inactive landslide extends downslope to the valley bottom. The toe of the inactive part of the landslide impounds Lake San Cristobal, which is the second largest natural lake in Colorado. The channel of the Lake Fork of the Gunnison River was completely blocked by the landslide and was subsequently re-established where the toe abuts the opposite valley slope. At the toe, landslide deposits extend about 0.5 km upstream and 0.9 km downstream from the projected landslide margins. Failure of the landslide dam is not expected (Schuster, 1996).

Lake San Cristobal was originally about 4.3 km long but shrunk to 3.3 km long as sediment filled the lake beyond the mouth of the Lake Fork of the Gunnison River. A much smaller sediment fan occurs at the mouth of Slumgullion Creek, which runs along the south flank of the landslide. We crossed Slumgullion Creek just downslope from this stop; the creek flows through a culvert beneath CO-149. The maximum depth of Lake San Cristobal is 27 m and it has a volume of 14×10^6 m^3 (Schuster, 1996).

Figure 7. View of the Slumgullion Landslide from Stop 1. Photograph by W.Z. Savage, U.S. Geological Survey.

Figure 8. View of Lake San Cristobal from Stop 1. Photograph by Giulia Biavati, Università di Bologna, Italy.

Table 4. Mileage from Lake San Cristobal Overlook (Stop 1, day 1) to Slumgullion Landslide Overlook (Stop 2, day 1).

Mileage	Description
1.0	Return to southbound CO-149 (heading the same direction as the drive to stop 1). Slumgullion Landslide Overlook (Stop 2) is the large parking area on the left.

STOP 2. SLUMGULLION LANDSLIDE OVERLOOK

This stop (Table 4) provides a closer view of some of the active part of the Slumgullion landslide than did Stop 1. The active nature of the landslide is readily apparent from this location and is indicated by disturbed soil, hummocky topography, freshly exposed rock and soil, and jumbled orientation of trees on the landslide (Figure 9). Also apparent from this location is a series of flank ridges located along the near margin of the landslide. These ridges are also located along the margins of most of the active landslide. A monitoring station where nearly continuous displacement, groundwater pressure, soil temperature, soil moisture, and climatic conditions have been recorded is visible (but barely discernible) to the northeast and an additional monitoring station is similarly visible to the west. The flatter area located to the west may mark the location where the active part of the landslide emerged from the subsurface and began overriding the ground surface located downslope.

Figure 9. View of part of the Slumgullion landslide from the Slumgullion Landslide Overlook. Photograph by J.A. Coe, U.S. Geological Survey.

Table 5. Mileage from Lake City to Lower Landslide Walk (Stop 3, day 2).

Mileage	Description
6.8	Leave Lake City (intersection of CO-149 (Gunnison Ave.) and 2nd St.) on CO-149 southbound. Parking area for the Lower Landslide Walk (Stop 3) is the wide shoulder of northbound CO-149 (on left while southbound) at the sharp right turn.

STOP 3. LOWER LANDSLIDE WALK

Stop 3 (Table 5 provides directions to the starting point) will involve a several-hour walk down the lower half of the active part of the Slumgullion landslide (Figures 10 and 11). We will cover about 2.5 km on the landslide, gain about 40 m in elevation, and drop about 200 m in elevation. Only our initial ascent (about 40 m elevation over 200 m) and final descent (about 35 m elevation over 300 m) will be off of the active landslide.

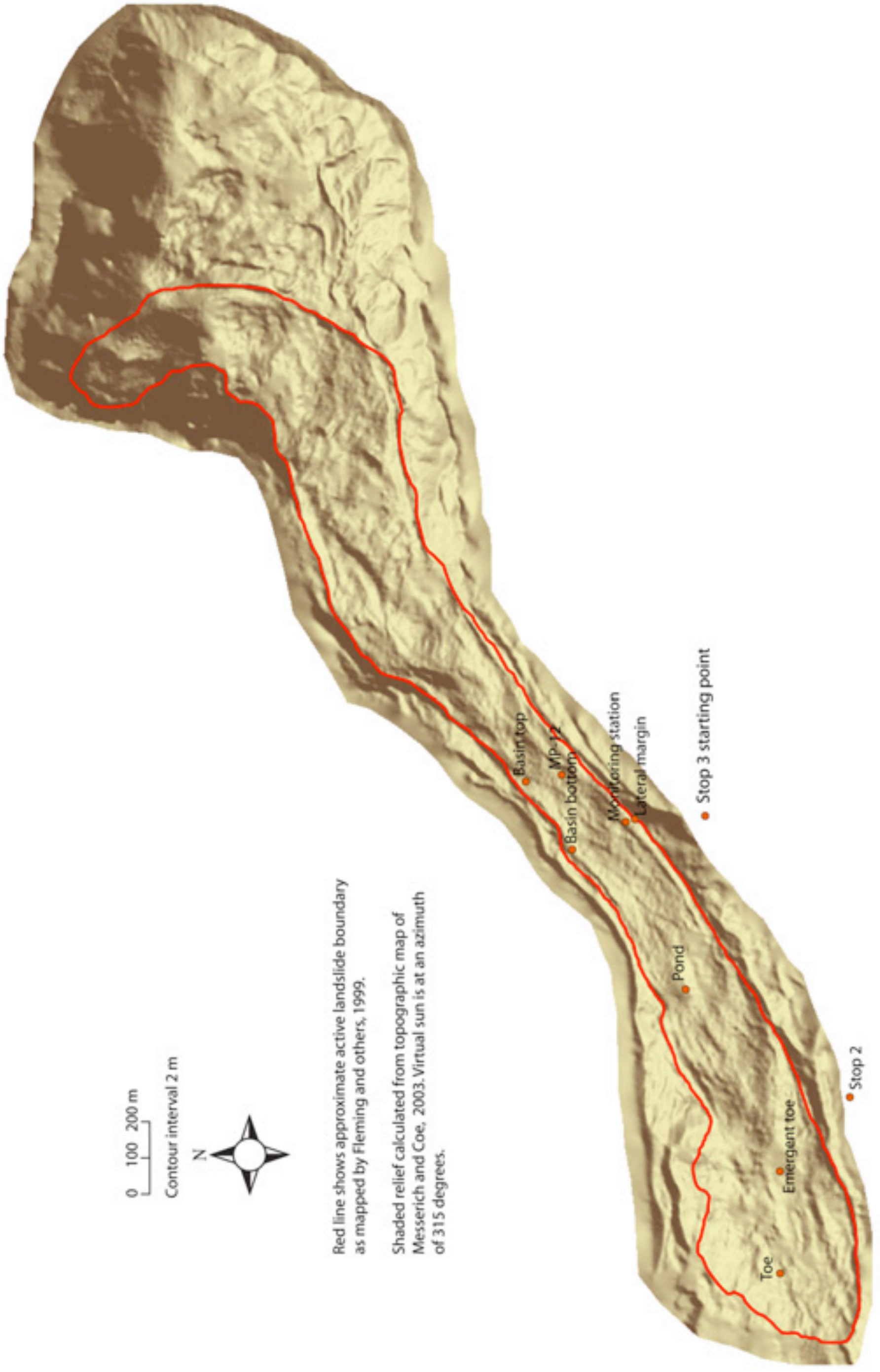
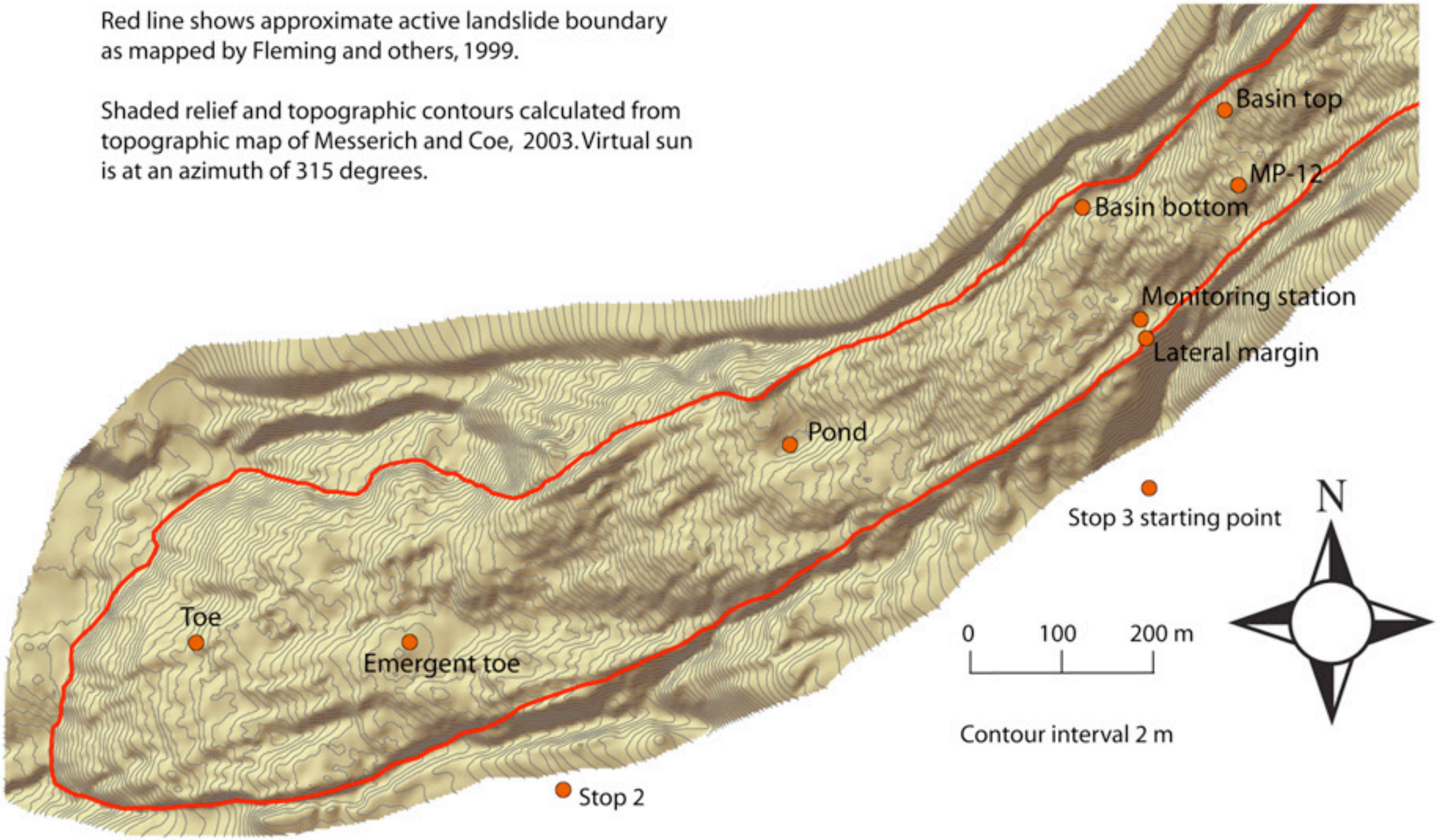


Figure 10. Shaded relief map of the active part of the Slumgullion landslide (outlined in red) showing locations of features that may be evaluated during the field trip. “Stop 3” marks the location of the Stop 3 starting point.


Red line shows approximate active landslide boundary as mapped by Fleming and others, 1999.

Shaded relief and topographic contours calculated from topographic map of Messerich and Coe, 2003. Virtual sun is at an azimuth of 315 degrees.

Figure 11. Map of the lower part of the active Slumgullion landslide (outlined in red) showing locations of features that may be evaluated during the field trip.

Landslide Margin and Monitoring Station

We will cross a few flank ridges as we come onto the landslide (Figures 5 and 12). This is one of the few locations where the boundaries of the active and inactive parts of the Slumgullion landslide are nearly coincident. We should be able to locate an active, discrete strike-slip fault or zone of en echelon fractures marking the active landslide margin (Figure 12). Both forms of ground rupture have been observed at this location and along different parts of these flank ridges. Fleming and Johnson (1989) provide an excellent evaluation of flank ridges formed along landslide margins. Mechanisms proposed to explain the development of flank ridges include helical flow of moving landslide debris, dilation within a shear zone, buckle folds, landslide debris spilling over the landslide margin, and upward intrusion of clay within a shear zone. The series of flank ridges here suggests changing conditions during landslide movement, such as narrowing of landslide debris or changing stress conditions.

This is the location of much of the monitoring performed by the U.S. Geological Survey (Figure 13). Various pieces and types of equipment have been located here periodically for the past several decades. Currently, we measure landslide displacement, positive and negative ground-water pressures, soil and air temperature, rainfall, soil water content, and snow depth (Coe and others, 2003; Schulz and others, 2007). Measurements are made hourly and results are stored on a datalogger. Previous studies in this area included measurements of hydrogeologic properties of landslide debris (Schulz and others, 2007) and of slidequakes associated with landslide movement (Gomberg and others, 1996). Earlier, nearly continuous monitoring of landslide movement was also performed near here using modified tide gauges (Savage and Fleming, 1996) and episodic monitoring using an automatic camera.

Figure 12. View to northeast of southern lateral margin. Photograph by J.A. Coe, U.S. Geological Survey.

Figure 13. Equipment at the monitoring station. Photograph by Giulia Biavati, Università di Bologna, Italy.

Pull-Apart Basin

Pull-apart basins occur in a few places along the flanks of the Slumgullion landslide and are both structural and topographic basins that form to accommodate downhill widening of the landslide (Fleming and others, 1996, 1999). These basins reflect controls on landslide kinematics exerted by lateral boundary conditions. The location of this stop marks probably the most well-developed basin on the landslide (Figures 14-16). It appears that abrupt widening of the landslide here is accommodated by thinning of landslide debris and resultant secondary sliding of adjacent landslide debris that has been oversteepened by the thinning (Fleming and others, 1996, 1999). This conclusion is suggested by the series of crescent-shaped tension cracks and normal faults above the south part of the basin and thrust faults and soft-sediment folding at the bottom of the basin, all of which are subparallel to the overall landslide margin. A pond is generally present at the bottom of the basin and its sediments extend downslope beyond the basin, while basin structural features do not. These features are destroyed at and just beyond the downslope end of the basin during landslide movement. Detailed mapping of this area performed recently and about ten years ago shows that structural features have changed very little in character and location, although the landslide has moved about 40 m through here in the intervening years.

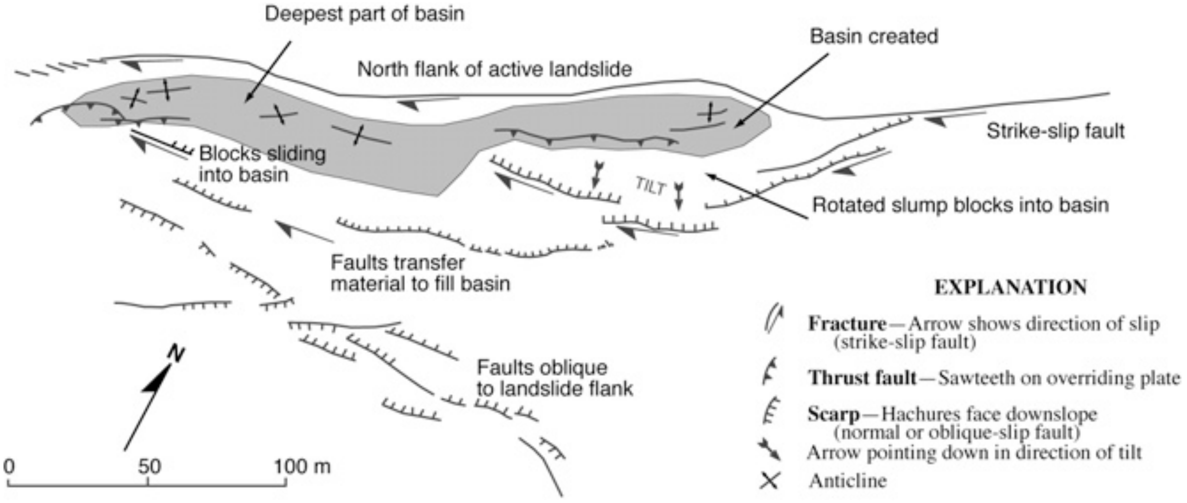


Figure 14. Idealized map of pull-apart basin. From Fleming and others, 1999.

Figure 15. View to southwest of pull-apart basin from its upper end. Photo by J.A. Coe, U.S. Geological Survey.

Figure 16. View to northeast of pull-apart basin from its lower end. Photo by J.A. Coe, U.S. Geological Survey.

Upper Pond

We saw at the basin how lateral boundary conditions appear to affect landslide structural and geomorphic characteristics. At this location we can see how basal boundary conditions apparently also affect landslide characteristics. Observations of this pond (Figure 17) indicate that it has remained generally the same and at the same location for at least the last few decades. During this time, the landslide has moved about 150 m here, or several times farther than the length of the pond. In addition, thrust faults have been observed just upslope from the pond for many years, as have been normal faults at the slope break located just downslope from the pond. We are near the inferred location of the former surface-water divide between Slumgullion Creek and the unnamed creek just to the north (Fleming and others, 1999). Perhaps the landslide overrides this divide and creates the features we see here.

Figure 17. View to the southwest of a pond located on the active Slumgullion landslide. Photograph by J.A. Coe, U.S. Geological Survey.

Emergent Toe

Based on detailed mapping, Fleming and others (1999) concluded that a large area of the landslide headscarp collapsed and resulted in mobilization of the reactivated part of the Slumgullion landslide. This reactivation does not involve the entire length or width of the original landslide, as we have seen, nor does it appear to involve the entire depth. Our stop at the upper pond provided evidence for basal boundary conditions controlling kinematics of the active landslide, and similar conditions appear to occur here. However, rather than overriding a bump in original topography below the landslide, it has been proposed that features here are due to the toe of the reactivated part of the landslide rupturing through the ground surface near here a few hundred years ago. As we'll see when we descend the active toe of the landslide, the landslide is clearly moving along the ground surface at its downslope end. It has been proposed (Parise and Guzzi, 1992) that the location where the landslide originally moved out of the subsurface and onto the ground surface occurred in this area (Figure 18). This change of displacement style is associated with significant changes in the geometry of the base of the landslide. This changing geometry results in the features seen here. Thrust faults occur upslope of the large back-tilted area on which a small pond occurs. Pond sediments extend for at least 250 m downslope from the pond due to displacement of the landslide mass past this location (Fleming and others, 1999). These sediments are well exposed in a gully eroded just downslope (Figure 19). Based on the current rate of landslide movement here, this pond must have persisted for at least the last hundred years (Fleming and others, 1999).

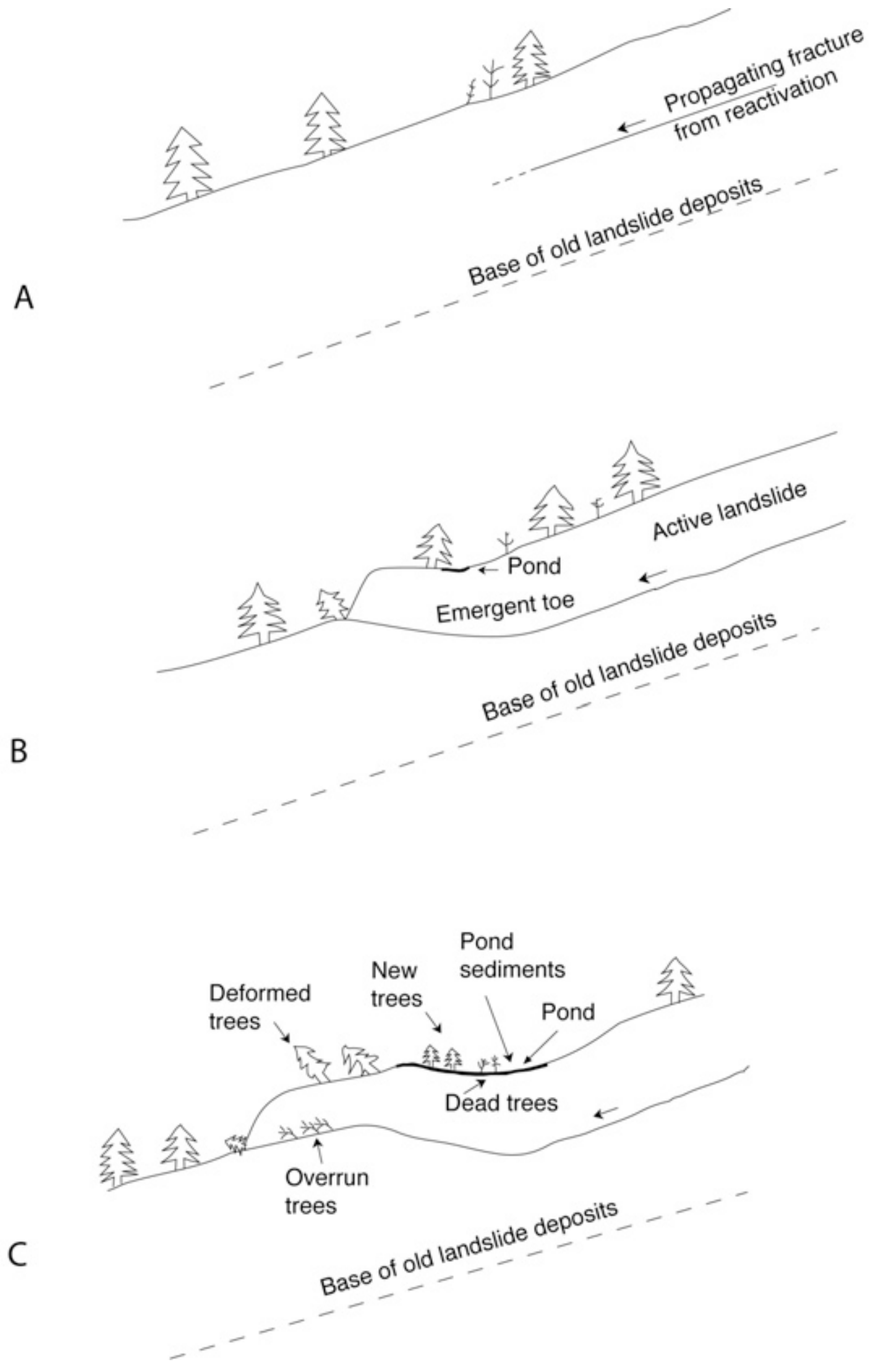


Figure 18. Idealized cross-section showing conceptual sequence of reactivation of the Slumgullion landslide at the location of the emergent toe. From Fleming and others, 1999.

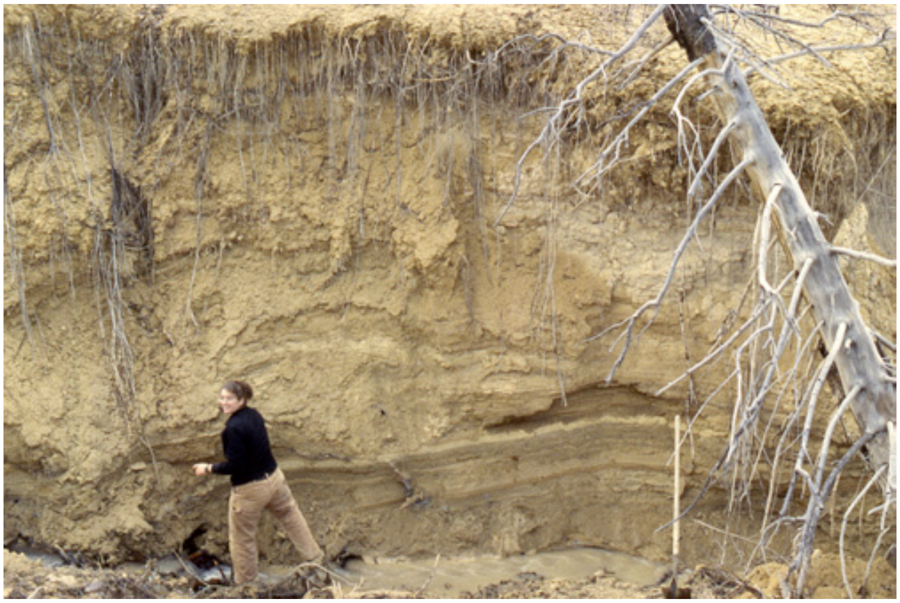


Figure 19. Exposure of pond sediments in the emergent toe area of the active Slumgullion landslide. Photograph by J.A. Coe, U.S. Geological Survey.

Active Toe

The active toe of the landslide is a zone of both transverse spreading and longitudinal shortening (Fleming and others, 1996, 1999). A major strike-slip fault zone extends from the north flank of the landslide through the toe and generally marks the boundary between spreading to the north and downslope sliding to the south (Figure 20). Spreading of the toe north of the boundary even causes trees to split upward from their bases and the separate parts to move away from one another. Surveying of the active toe found that, rather than moving slope parallel as might be expected, points on the ground surface are moving horizontally, indicating that the toe is thickening as it moves (Fleming and others, 1996, 1999). Continuing downslope, the top of the toe becomes nearly flat due to this thickening until a region is encountered where superficial sliding occurs nearly everywhere along the distal end of the toe. This superficial sliding obscures some of the features of the overall landslide as it plows over trees and the old ground surface, but many areas can be found where this overriding is clear.

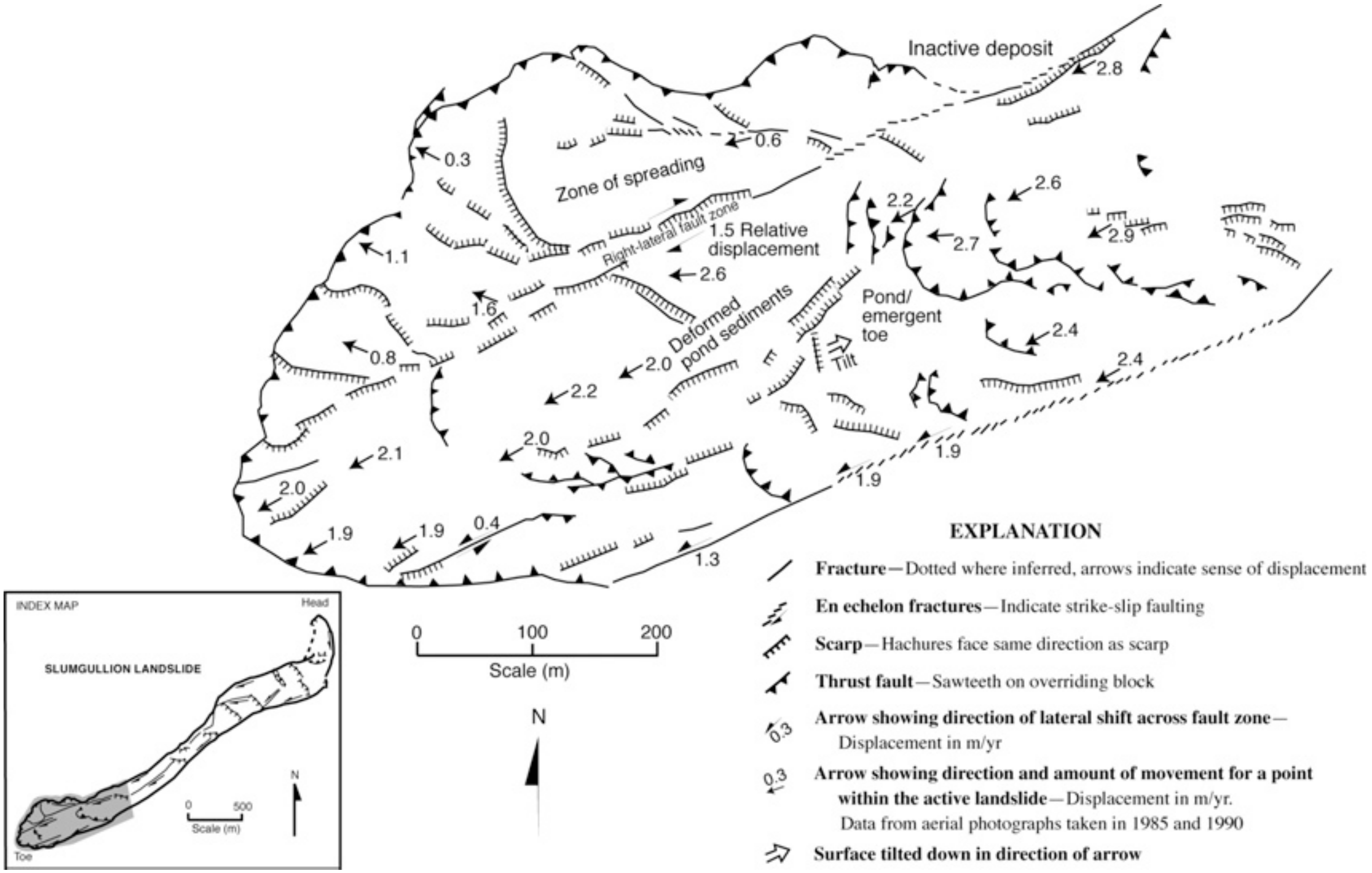


Figure 20. Idealized map of the lower part of the active Slumgullion landslide. From Fleming and others, 1999.

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