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Base from U.S. Geological Survey 1:24,000 Hagerman, Idaho, 1949 (revised 1992).

Slope Map and Locations of Irrigation-induced Landslides and Seepage Areas, Hagerman Fossil Beds National Monument, Idaho

by

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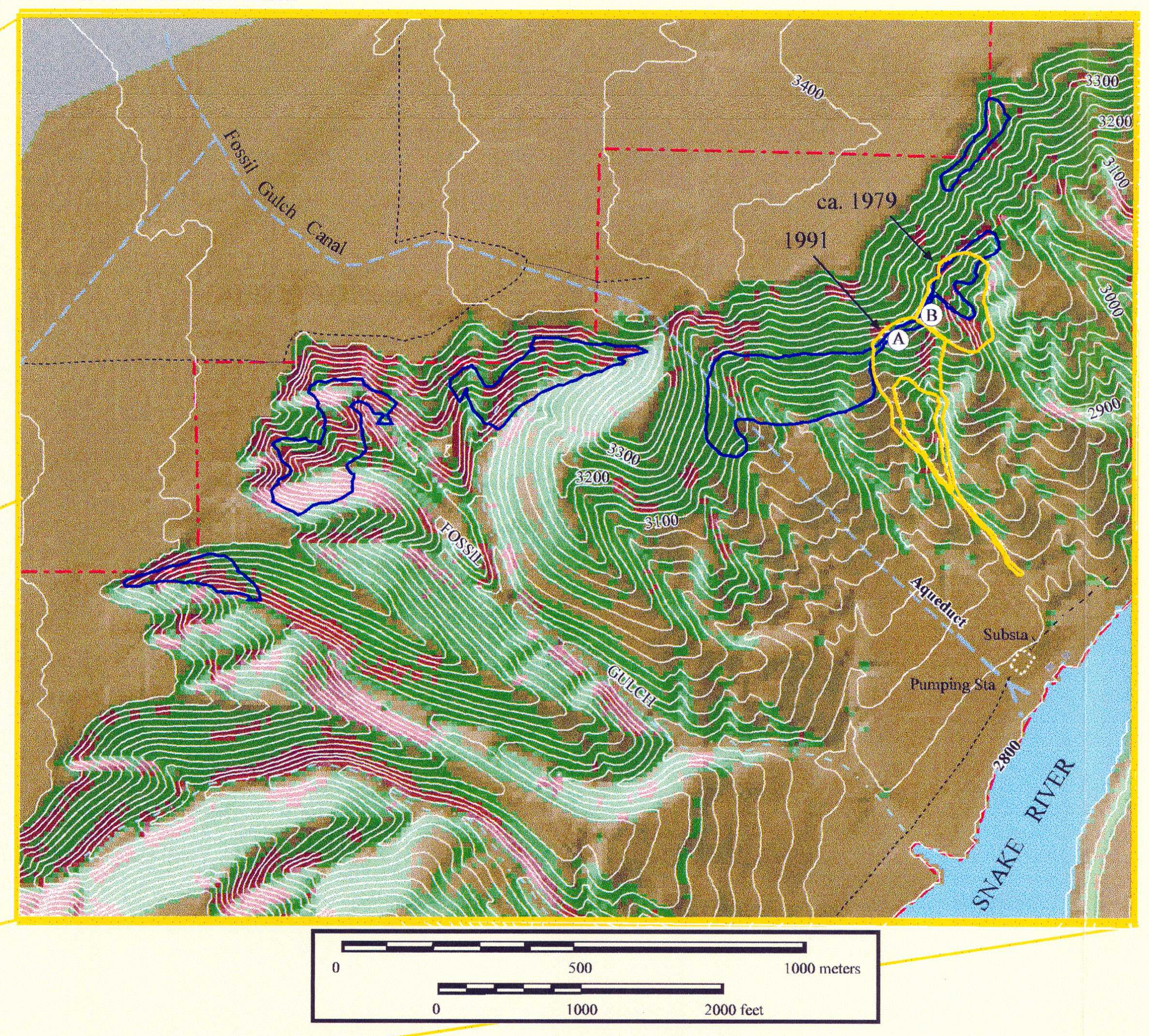
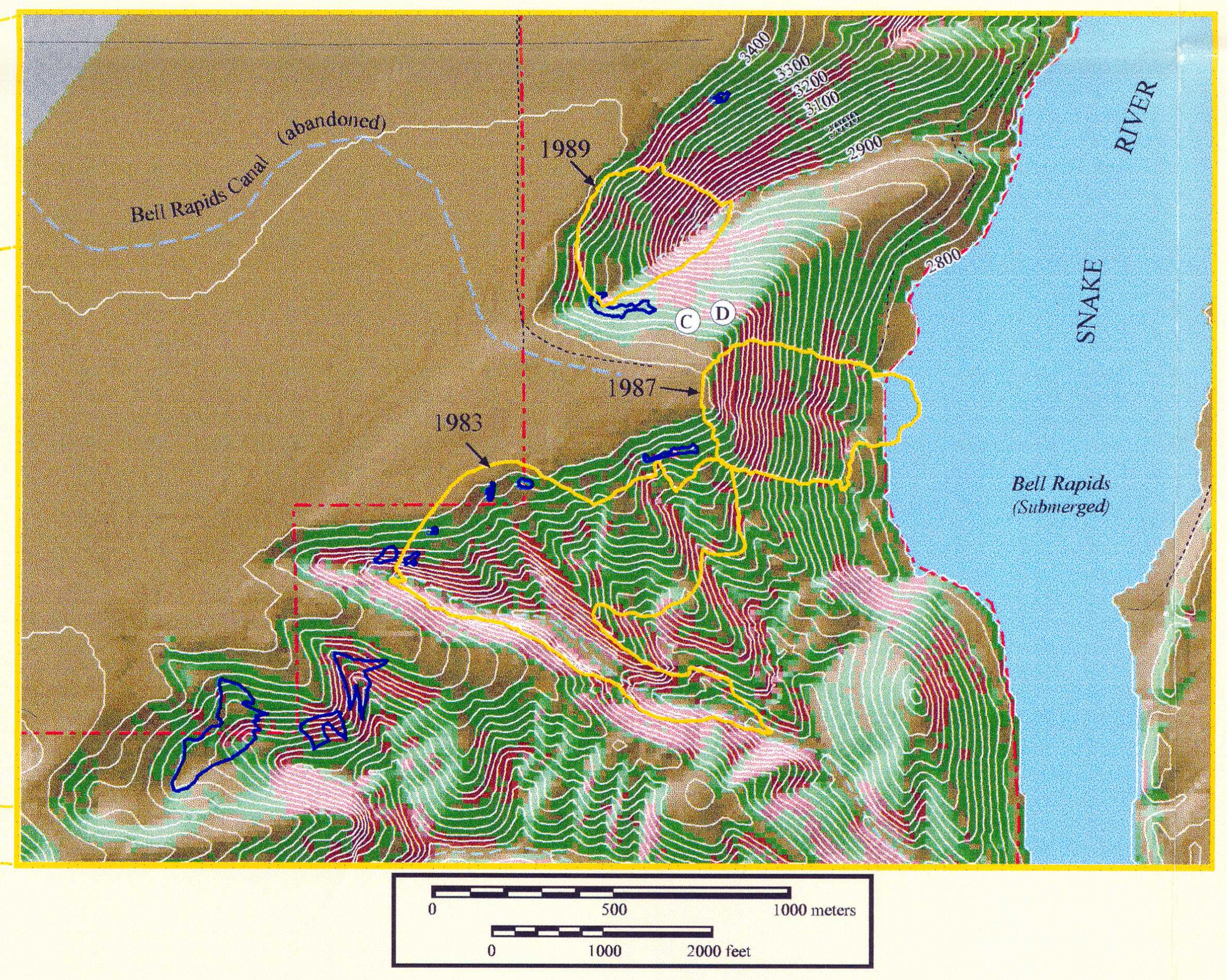
Fossil Gulch Area.



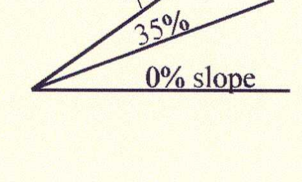
Bell Rapids Area.



EXPLANATION

SLOPE CATEGORIES

(percent of slope)



0 to 35% (shades of brown)

70% plus (shades of red)

35 to 70% (shades of green)

Seepage area (as indicated by vegetated areas visible in 1993 aerial photographs)

1983

Irrigation-induced landslide (date shown is the reported year of initial large-scale movement)

Sampling Locations

- Ⓐ FGS-1 through FGS-5 (Fossil Gulch area)
- Ⓑ FGN-1 (Fossil Gulch area)
- Ⓒ BR-1 (Bell Rapids area)
- Ⓓ BR-2 (Bell Rapids area)

CONTOUR INTERVAL 25 FEET

Table 1. Summary of material properties of samples from the Fossil Gulch and Bell Rapids landslide areas

Sample No.	Description[1]	Gradation			Dry Unit Weight (pcf)	Atterberg Limits			ASTM Classification	Strength Parameters[2] Peak		Ultimate	
		%Sand (4.76-0.075 mm)	%Silt (0.075-0.005 mm)	%Clay (<0.005 mm)		LL	PL	PI		Ø (degrees)	C (psi)	Ø' (degrees)	C' (psi)
FGS-1	Sandy SILT	29	60	11	80	43	30	13	ML	26	11	25	7
FGS-2	Clayey SILT	9	60	31	85	52	27	25	CH	22	18	10	7
FGS-3	Silty CLAY	5	47	48	81	68	31	37	CH	28	8	11	1
FGS-4	Carbonaceous CLAY	3	5	92	69	109	48	61	MH	12	13	7	2
FGS-5	Fine SAND	96	4	--	77	Non plastic			SP	34	1	31	1
FGN-1	Clayey SILT	15	43	42	83	51	22	29	CH	23	4	16	5
BR-1	CLAY	--	12	88	78	94	33	61	CH	19	14	13	6
BR-2	SILT	9	86	5	81	Non plastic			MH	32	1	--	--

[1] All samples are from in-place exposures of the Glenns Ferry Formation with the exception of sample no. FGN--1 which is from part of an old landslide deposit (Malde and Powers, 1972) now incorporated in the 1991 Fossil Gulch area landslide.

[2] Effective-strength parameters based on consolidated-drained direct-shear tests on saturated samples.

INTRODUCTION

Landslides caused by irrigation have occurred in semiarid-to-arid regions of the interior plateaus of western North America since the late 1800's. Typically, the landslides occur on steep slopes underlain by fine-grained sediments that have low shear strength when wetted (Schuster and others, 1987). This map and accompanying table provide basic geotechnical data concerning recent irrigation-induced landslides and slope stability at Hagerman Fossil Beds National Monument, Hagerman, Idaho. The Monument is located in an arid region of south central Idaho, about 48 km (30 mi) northwest of the city of Twin Falls. Mean annual precipitation at Hagerman is approximately 23 cm/yr (9 in/yr). Currently, irrigation water is pumped up the bluffs from the Snake River via a 1.2-m (4-ft) diameter pipeline at the north end of the Monument. After reaching the plateau above the bluffs, the water enters the Fossil Gulch canal and is then distributed via sprinkler systems to extensive potato, sugar beet, and bean fields. Prior to 1987, the Bell Rapids canal, located in the central part of the Monument, was also used for irrigation. However, that canal was abandoned in 1987 when a landslide destroyed facilities that supplied the canal with water. To compensate, irrigation water is piped south from the Fossil Gulch canal to areas previously serviced by the Bell Rapids canal. During the period 1983-1991, major landslides developed at the Monument along the steep, 500-ft-high bluffs overlooking the Snake River (see inset maps). The landslides occur predominantly in poorly consolidated, fine-grained, floodplain deposits of the Tertiary age Glenns Ferry Formation. The floodplain sediments consist mostly of a repetitious sequence of nearly flat-lying silt, sand, and clay beds that are typically less than 1 m thick. Detailed descriptions of the floodplain deposits have been given by Malde and Powers (1962; 1972), and Bjork (1970). Massive landslide movements are characterized by slumping and sliding of large blocks of the silt, sand, and clay beds that subsequently disintegrate and continue moving downslope as coalescing earthflows. As of 1995, the movements have involved an estimated 3 million cubic meters of material.

Local slumping, sliding, earth fall, and rock fall, especially along the high, steep headwalls at the tops of the slides continue to slowly enlarge the slide areas. In addition, minor mudflows are occasionally generated, consisting of a fluid mixture of water and mostly fine-grained slide debris. The mudflows move rapidly down drainageways that lead to the Snake River. The slope failures threaten the safety of individuals working in or traversing the Monument area and the scientific value of world renowned fossil resources present in the geologic strata. Also, structures and other property in the path of the failures may be at risk. An example, is the 1987 landslide in the Bell Rapids area (see inset map) that severely damaged the Bell Rapids irrigation pumping station, a pipeline, and related facilities. Due to continued instability, many areas within, adjacent to, and downslope of the existing landslides are hazardous. In addition, steep slopes in seepage areas that have not failed may be unstable and are considered potentially hazardous.

Previous observations indicate that the slope movements are directly related to irrigation water that has seeped from the canals located on agricultural lands above the bluffs (Young, 1984; Riedel, 1992). The canal seepage travels downward in the subsurface to a perched aquifer and then flows laterally to the bluff face where it forms seeps that wet or saturate large volumes of sediments at and below the points of discharge on the slopes (fig. 1).

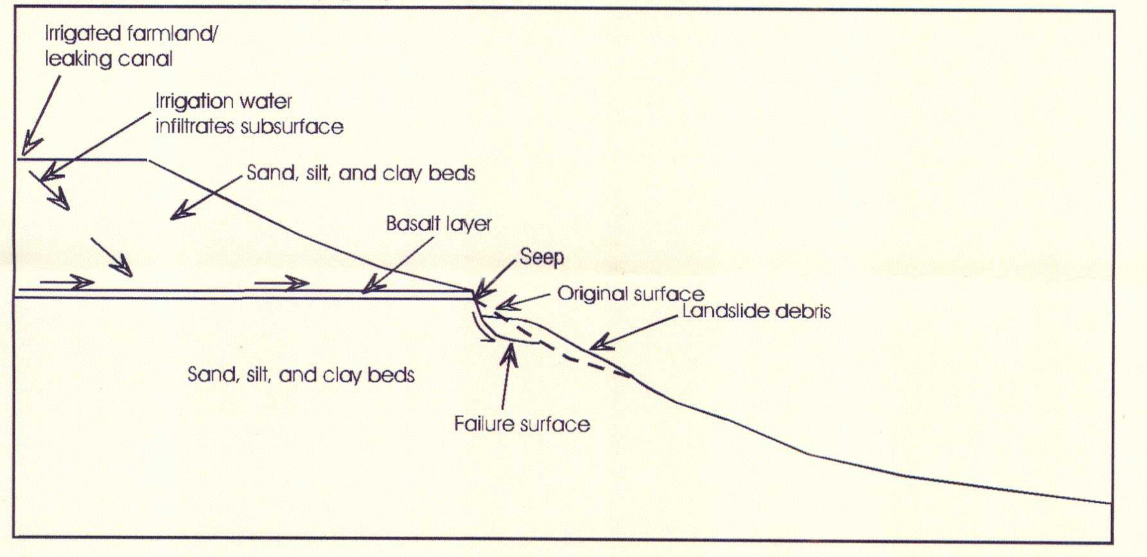


Figure 1. Generalized bluff profile depicting the 1991 Fossil Gulch area landslide and conditions that led to the failure.

The seepage and resulting addition of water to previously dry or unsaturated sediments promotes slope instability and landsliding in two principal ways: 1) by reducing the shear strength of the sediments that support the slope, and 2) by increasing the overall driving force that tends to cause failure. The driving force may be increased by the added water weight and possibly by seepage forces caused by flow of water through the sediments. Shear strength may be reduced by increased pore-water pressure and by the destruction of bonds or cementing agents that bind the soil particles. Slope steepness is an additional important factor that controls slope stability. Other factors being equal, the steepest slopes are the most susceptible to failure.

WHAT THIS MAP SHOWS

This map consists of a shaded relief model of the Hagerman 7 1/2' topographic quadrangle with categories of slope steepness and locations of seepage areas and irrigation-induced landslides superimposed. Other smaller, recent landslides located along steep slopes adjacent to the Snake River are not shown. The map divides the Monument into areas with slopes of 0-35 percent (0-19°), 35-70 percent (19-35°), and steeper than 70 percent (35°). The map is based on pre-landslide (1949) topography. Therefore, the contours and slope categories within the landslide boundaries do not reflect topographic changes produced by the landslides. However, the slope information shown for the area of the landslides is useful for identifying the categories of slope that were involved in the failures. As shown, nearly all of the irrigation-induced landslide activity occurred in slope areas steeper than 35 percent (19°). The map shows the relationship between canal, seepage, and landslide locations and can be used as a general guide to relative slope stability. Slopes outside the landslide areas that are considered most likely to fail are those that are within or immediately adjacent to seepage areas and are steeper than 35 percent. Least likely to fail are those slopesless than 35 percent that are not affected by seepage. However, due to generalizations of the basic data, the method of map preparation, and variations in local conditions, the map cannot be used to interpret stability of specific local areas.

MAP PREPARATION

A Digital Elevation Model (DEM) of the Hagerman 7 1/2' topographic quadrangle with a grid spacing of 10 m (30.5 ft) was used to develop the map. Delta 3D (Infotec Development, Inc.), a GIS software product, was used to edit, display, and analyze the DEM data and related vector information. The shaded relief model with slope categories, contours, and area boundaries was subsequently imported into CorelDraw (Corel Corporation) for further editing, addition of text, and formatting. Landslide- and seepage-area locations are based on field mapping and air-photo interpretation by Alan Chleborad and photogrammetric mapping by Jim Messerich, both with the U.S. Geological Survey. Aerial photographs used in the study were flown in 1976 (black and white, 1:30,000), 1992 (black and white, 1:12,000), and 1993 (color, 1:6,000).

MATERIAL PROPERTIES

Samples of fine-grained sediments from the Fossil Gulch and Bell Rapids areas were tested for index properties and strength characteristics. The tests were conducted for the purpose of obtaining data helpful in predicting the engineering behavior of the materials. Index tests included Atterberg limits, gradation, and dry density. Strength parameters (friction angle and cohesion values) were determined from consolidated-drained direct-shear tests on saturated samples. One carriage reversal per direct-shear test was performed to estimate ultimate or residual strength parameters. The tests were performed by Golder Associates, Inc., and Advanced Terra Testing, Inc., Lakewood, Colorado.

The samples were collected in September 1994. Sampling consisted of digging (0.6-0.9 m) 2-3 ft. below the surface of an outcrop with hand tools to expose in-place materials and then extracting small block samples from the individual beds. The block samples were then carefully wrapped and taped to preserve their natural state during transport to the laboratory. Samples FGS-1 through FGS-5 are from beds of the Glenns Ferry Formation exposed in the main scarp of the 1991 landslide in the Fossil Gulch area. Sample FGN-1 is fine-grained material from Holocene age landslide debris (Malde and Powers, 1972) that is incorporated in recent slide activity in the 1991 and ca 1979 landslide areas. Samples BR-1 and BR-2 are from an exposure of the Glenns Ferry Formation located between the 1987 and 1989 Bell Rapids area landslides. Those sampled beds are also exposed in the main scarps of the 1987 and 1989 slides (see explanation and inset maps for sampling locations).

Test results are shown in Table 1. Material properties ranged from non- plastic, essentially cohesionless fine sand or silt with peak friction angles as high as 34° to highly plastic clays with residual friction angles as low as 7°. Only samples FGS-1 through FGS-4, that were wetted in-place by seepage, had natural water contents higher than their plastic limits. Samples FGN-1, BR-1, and BR-2 that were not wetted by seepage had natural water contents well below their plastic limits. Because a limited number of surface samples were tested, it is unknown to what degree they are representative of all the fine-grained sediments involved in the failures.

It was noted, in the field, that the clay-rich beds in the main scarp of the 1991 slide were the source of thin coatings of slickensided clay that covered large areas of an exposed failure surface. Apparently, the clayey material is sheared from the clay-rich beds during the failure process and deposited on the sheared surfaces of adjacent silt or sand beds. This process may have the effect of significantly lowering the shear strength along a failure surface as shearing progresses.

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