GLACIAL AND HOLOCENE GEOLOGY OF THE CLARKS FORK-SUNLIGHT CREEK REGION, PARK COUNTY, WYOMING

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INTRODUCTION

During July-August, 1995 a Keck Geology Consortium "sophomore-minority" research project was based at Hunter Peak Ranch, Clarks Fork valley, northwestern Wyoming. Although considerable research on the bedrock of this area has been done by the United States Geological Survey, little attention has been paid to the surficial geology. Our goal was to study the Quaternary geology of six adjacent valleys that were invaded by lobes of the Clarks Fork outlet glacier of the Yellowstone Ice Sheet (Plate 1). Pleistocene glacial processes were followed by Holocene fluvial and mass-wasting activity.

PROJECT PARTICIPANTS

The faculty were Bob Carson (Whitman), Joe Cepeda (West Texas A & M University), and Cheryl Jaworowski (University of Wyoming). The visiting faculty were Bob Newton (Smith), Walt Coppinger and Glenn Kroeger (Trinity), and Cathy Manduca (Carleton, Keck Coordinator).

The students were Nancy Adams and Stacey Robertson (Trinity), David Cuevas (University of Puerto Rico, Mayagüez), Sheilagh Diez and Dottie Metcalf (Whitman), Steve Dornbos (Wooster), Kyle Kolodziejski and James Sneeringer (Beloit), Gari Mayberry (Wesleyan University), Jon Payne (Williams), Christa Placzek (Colorado), and Sara Rosenzweig (Smith).

GEOGRAPHY

Clarks Fork of the Yellowstone River originates near the northeast corner of Yellowstone National Park. It flows generally eastward between the Beartooth Plateau and the Absaroka Mountains before reaching the Bighorn Basin. Access to Clarks Fork valley is from the northeast entrance of Yellowstone National Park via Colter Pass (2443 m); from Red Lodge, MT via Beartooth Pass (3362 m); or from Cody, WY via Dead Indian Pass (2460 m). Hunter Peak Ranch (elevation 1987 m) is near the head of Clarks Fork Canyon.

Between Hunter Peak Ranch and the mouth of Clarks Fork Canyon, there are seven major tributaries to Clarks Fork which rise in the Absaroka Mountains to the west and south (Plate 1). We studied the Quaternary geology of six of these valleys. *Crandall Creek* flows east from divides at the east boundary of Yellowstone National Park. *Lodgepole Creek* originates west of Windy Mountain and empties into lower Crandall Creek. *Reef Creek* winds north around Cathedral Cliffs. *Russell Creek* enters Clarks Fork Canyon east of Sugarloaf Mountain. Sunlight Creek occupies a large valley south of Clarks Fork valley; the Quaternary history of Sunlight Basin was studied during an earlier Keck project (Carson and others, 1995). *Elk Creek* flows into Sunlight Creek in lower Sunlight Basin. Finally, *Dead Indian Creek* empties into Clarks Fork Canyon just northwest of Dead Indian Hill.

The climate of Clarks Fork valley is cool and semi-arid; modern soils contain caliche. Microclimates in the area vary considerably and are dependent on such factors as elevation and aspect. Figure 1 shows temperature, precipitation, and snowfall data for the weather station at Crandall Creek, not far from Hunter Peak Ranch. For a summary of the relation of temperature, precipitation, and snowfall to altitude in the Yellowstone region, see Pierce (1979, Figure 4).

	°F	°C
Mean annual temperature	38.2	3.4
Mean January temperature	18.1	-7.7
Mean July temperature	60.1	15.6
	inches	cm
Mean annual precipitation	14.82	37.6
Mean annual snowfall	86.7	220.1
Deepest snow cover	43.0	109.1

Figure 1. Climatological summary for Crandall Creek weather station, elevation 6710' (2045 m), period 1951-1978 (Martner, 1986, p. 319).

GENERAL GEOLOGY

W. G. Pierce and others of the U. S. Geological Survey have been publishing on the geology of the Clarks Fork region for decades. Our study area is completely covered by 1:62,500 geologic maps (Pierce, 1965; Pierce and Nelson, 1968, 1971; Pierce and others, 1973).

The great variety of lithologies and ages of bedrock has been evident since publication of the first geologic map in the Clarks Fork area (Hague, 1899). The bedrock ranges from Archean plutonic and metamorphic rocks to the Eocene Absaroka volcanics (Figure 2). All Phanerozoic periods except the Silurian are represented in the sedimentary record stretching from Hunter Peak Ranch eastward to the Bighorn Basin. The bedrock geologic units present in the six valleys we mapped are shown in Figure 2.

Clarks Fork Canyon is cut into the Archean crystalline rocks. Ledges of Flathead Sandstone top the crystalline rocks in places. The carbonates of the Meagher Limestone and Pilgrim Limestone are cliff-formers which in places are esplanades bordering Clarks Fork valley; the esplanades are commonly topped by glacial pavement. The Bighorn Dolomite, the Madison Limestone, and the more resistant parts of the Absaroka Volcanic Supergroup are also cliff-formers.

During the Laramide orogeny there was considerable faulting and folding on the north and east edges of the Beartooth Plateau. During the Eocene, rocks above the Cambrian strata broke loose and moved many kilometers southeastward across the Clarks Fork area along the Heart Mountain detachment fault; this "fault" has been studied by W. G. Pierce and others for many decades (see, for example, Pierce, 1980). The last few million years have been dominated not only by glaciation but also by repeated and diverse volcanism in the Yellowstone area.

QUATERNARY GEOLOGY

Cirque and valley glaciers originating in the Beartooths and Absarokas and other mountain ranges coalesced into a mountain ice sheet covering much of the Yellowstone area. A large outlet glacier of the ice sheet flowed down the valley of Clarks Fork, terminating on the floor of the Bighorn Basin to the east. Many of the valleys tributary to Clarks Fork contributed local ice to the outlet glacier, but in a few valleys, where local ice was more limited, the Clarks Fork glacier blocked stream drainages and proglacial lakes formed.

K. L. Pierce (1979) studied the history and dynamics of the Yellowstone ice sheet in northern Yellowstone National Park. One focus of that work was the extent of the outlet glacier along the Yellowstone River during Bull Lake and Pinedale Glaciations. Our research was in the vicinity of the Clarks Fork outlet glacier of the Yellowstone ice sheet. Hilmoe (1980) mapped Bull Lake and Pinedale moraines at the mouth of Clarks Fork Canyon. Another lobe of the Clarks Fork outlet glacier terminated in Sunlight Basin (Dake, 1919; Parsons, 1939). Ballard (1976) determined that catastrophic flooding occurred at the mouth of Clarks Fork Canyon, and suggested that glacial Lake Sunlight was the source for the floodwaters.

Dake (1919) determined that Clarks Fork ice had advanced up Dead Indian, Elk, Sunlight, and Russell Creeks (Plate 1). He found moraines with "granite boulders" in these four valleys, and noted granitics at the head of Lodgepole Creek. Dake (1919) agreed with an earlier conclusion by Hewett (1911) that the ice and/or its moraine along Sunlight Creek dammed a lake.

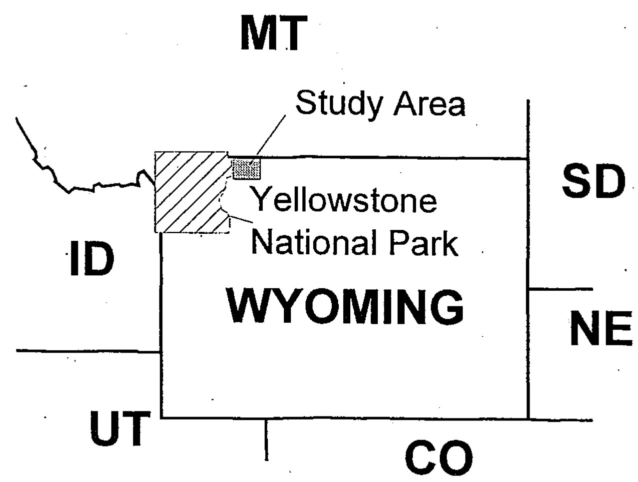
Parsons (1939) discovered that the ice along Lodgepole Creek crossed a divide west of Windy Mountain and descended down Trail Creek, building a moraine near the shore of the lake in Sunlight Basin. He also believed that

<table>
<tr><th colspan="2">AGE</th><th colspan="2">STRATIGRAPHIC UNIT</th><th>LITHOLOGY</th></tr>
<tr><td rowspan="4">Cenozoic</td><td rowspan="4">Tertiary (Eocene)</td><td rowspan="3">Absaroka Volcanic Supergroup</td><td>Trout Peak Fm</td><td rowspan="3">tuffs, breccias, and other volcaniclastic rocks; flows, dikes, and sills; generally andesitic</td></tr>
<tr><td>Wapiti Formation</td></tr>
<tr><td>Cathedral Cliffs Fm.</td></tr>
<tr><td colspan="2">Crandall Conglomerate</td><td>(mostly carbonate clasts)</td></tr>
<tr><td colspan="5">unconformity</td></tr>
<tr><td rowspan="14">Paleozoic</td><td rowspan="3">Mississippian</td><td colspan="2">Madison Limestone</td><td></td></tr>
<tr><td colspan="2">Three Forks Formation</td><td>dolomite, shale, limestone</td></tr>
<tr><td colspan="2">Jefferson Dolomite</td><td>dolomite, dolomitic limestone</td></tr>
<tr><td colspan="4">unconformity</td></tr>
<tr><td>Ordovician</td><td colspan="2">Bighorn Dolomite</td><td></td></tr>
<tr><td colspan="4">Heart Mountain detachment horizon</td></tr>
<tr><td rowspan="6">Cambrian</td><td colspan="2">Snowy Range Formation</td><td>shale, flat-pebble conglomerate</td></tr>
<tr><td colspan="2">Pilgrim Limestone</td><td></td></tr>
<tr><td colspan="2">Park Shale</td><td></td></tr>
<tr><td colspan="2">Meagher Limestone</td><td></td></tr>
<tr><td colspan="2">Wolsey Shale</td><td></td></tr>
<tr><td colspan="2">Flathead Sandstone</td><td>quartzose sandstone</td></tr>
<tr><td colspan="5">unconformity</td></tr>
<tr><td>PRECAMBRIAN</td><td>ARCHEAN</td><td colspan="2"></td><td>granitic rocks, gneiss</td></tr>
</table>

Figure 2. Rock units present in the Clarks Fork area (after James, 1995).

Late Pleistocene Geology of the Clarks Fork-Sunlight Basin Area, Park County, Wyoming

(Plate 1)



Ice limit, Clarks Fork lobe of Yellowstone ice sheet

Moraine, Clarks Fork lobe

CVG Moraine, Crandall valley glacier?

SVG Moraine, Sunlight valley glacier

Ice flow direction, Clarks Fork lobe

CVG Ice flow direction, Crandall valley glacier

SVG Ice flow direction, Sunlight valley glacier

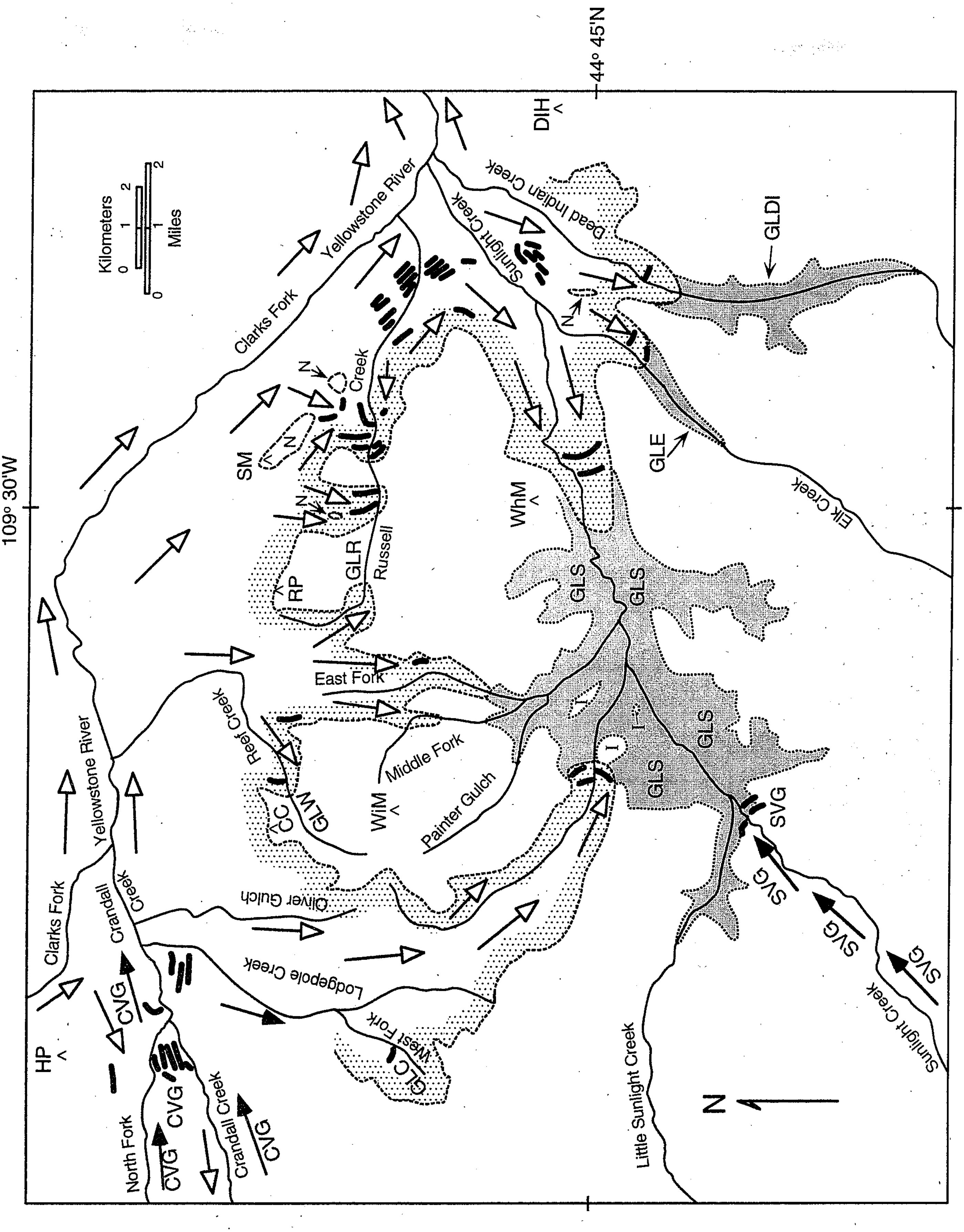
N Nunatak

Large glacial lakes: GLDI, glacial Lake Dead Indian
GLE, glacial Lake Elk
GLS, glacial Lake Sunlight

Small glacial lakes: GLC, glacial Lake Cinderella
GLR, glacial Lake Russell
GLW, glacial Lake Windy

I Island (in glacial Lake Sunlight)

Λ **Mountains:** CC, Cathedral Cliffs, 2850m
DIH, Dead Indian Hill, 2644m
HP, Hunter Peak, 2754m (covered by Clarks Fork lobe)
RP, Russell Peak, 2795m
SM, Sugarloaf Mountain, 2677m
WhM, White Mountain, 2674m
WiM, Windy Mountain, 3128m



109° 30'W
44° 45'N
Kilometers
0 1 2
Miles
0 1 2
Clarks Fork
Yellowstone River
Dead Indian Creek
Sunlight Creek
DIH
GLDI
GLE
Elk Creek
Creek
SM
WhM
GLR
RP
Russell
GLS
East Fork
Reef Creek
Middle Fork
Painter Gulch
CC
GLW
WiM
SVG
Oliver Gulch
Crandall Creek
Lodgepole Creek
West Fork
GLC
Little Sunlight Creek
HP
CVG
North Fork
N

the Clarks Fork ice along Reef Creek crossed a divide east of Windy Mountain and descended a short distance down (the East Fork of) Painter Gulch. Parsons (1939, p. 742) stated that "Only outwash was carried into the valley of Painter Creek." He also maintained that "The Painter and Trail Creek passes are the only low ones between the Sunlight and Clarks Fork valleys" (Parsons, 1939, p. 742).

Based on the presence of fine-grained sediments along Dead Indian and Elk Creeks, Erb (1995) postulated the existence of glacial lakes in those valleys. He established a maximum elevation of 7250' for glacial Lake Sunlight, and argued that the Trail Creek moraine was built when the lake level was lower.

STUDENT PROJECTS

Most of our research focused on a valley-by-valley re-examination of the reconnaissance studies by Dake (1919), Parson (1939), and Erb (1995). Six teams of two students each mapped the surficial deposits in valleys tributary to Clarks Fork and Sunlight Creek (Plate 1).

Christa Placzek and James Sneeringer studied the Dead Indian Creek area, from the head of glacial Lake Dead Indian to Clarks Fork. The extent of the ice-dammed lake is based on lacustrine sediments and ice-rafted erratics well upvalley from the moraine. Probable catastrophic flood deposits near the mouth of the valley indicate that the lake burst through the moraine.

Gari Mayberry and Sara Rosenzweig investigated the valley of Elk Creek from Elk Lakes to Sunlight Creek. Lacustrine sediments and ice-rafted erratics are evidence for a small moraine-dammed lake. The large Elk Lakes slump/earthflow complex is currently active, pushing Elk Creek against a limestone cliff.

Nancy Adams and Dottie Metcalf did field work along Russell Creek. Six lobes of Clarks Fork ice penetrated the valley: one at the head of Russell Creek between a natural arch and Russell Peak, three across the northern side of the valley, one from the northeast across the saddle in Sugarloaf Mountain, and the largest lobe up Russell Creek from the east. The extent of the lobes is marked by erratics and a complex pattern of moraines. Part of the upper valley was ice-free.

Kyle Kolodziejski and Stacey Robertson studied Reef Creek and Painter Gulch from Clarks Fork to Sunlight Creek. One lobe of Clarks Fork ice deposited a moraine across Reef Creek south of Cathedral Cliffs. Another lobe pushed south across the divide into both the East and Middle Forks of Painter Gulch. There is a complex of outwash/kame/alluvial terraces near the confluence of the East and Middle Forks with Painter Gulch.

David Cuevas and Sheilagh Diez investigated Lodgepole Creek, Oliver Gulch, and Trail Creek from Crandall Creek to Sunlight Creek. Lobes of Clarks Fork ice pushed up both Lodgepole Creek and Oliver Gulch, crossed the divide into two forks of Trail Creek, and terminated at a prominent moraine. A large landslide occurred 3 km northwest of the moraine. A variety of drift is exposed along the west fork of Lodgepole Creek, with a moraine complex above glaciolacustrine and deltaic sediments.

Steve Dornbos and Jon Payne did field work along lower Crandall Creek and its tributaries. There was a complex interaction between Clarks Fork ice flowing south and west, and Crandall ice moving east. Granitic erratics indicate that the Clarks Fork glacier penetrated at least 5 km up the valley of Crandall Creek, whereas Absaroka intrusive erratics have been transported by Clarks Fork and/or Crandall ice at least 2 km east of the valley. A mixture of erratics in moraines indicates that the two glaciers met just south of where a huge landslide dammed the North Fork of Crandall Creek.

Mass wasting has been important in all of the valleys. Most of the mass wasting has been slumps and/or earthflows. Many of the large "landslides" appear to have occurred upon deglaciation of the area because of removal of ice support from the valley walls. However, some landslides are active today, including a huge slump/earthflow complex north of Cathedral Cliffs which moved in the wet spring of 1995. Failure is generally occurring in Cambrian shales and old colluvium, but Eocene tuff and Pleistocene lacustrine sediments are also undergoing mass wasting.

In most of the study areas there are surfaces of aggradation underlain by outwash, alluvium, and/or other sediments. These Pleistocene surfaces are the highest of flights of terraces that step down to narrow modern floodplains. In some valleys the streams have incised into the bedrock.

Parts of the forests in the western valleys burned during the Yellowstone fires of 1988. Colluvium production has increased on hillslopes, floods have occurred, and the streams have aggraded in some places and eroded in others.

FUTURE RESEARCH

Our research resulted in the discovery of geologic phenomena and the formulation of hypotheses which invite further investigation. With an ice dam higher than the moraine crests in Sunlight Basin and other valleys, the low slope angles of the moraines suggest subaqueous deposition. The relationship between Ballard's (1976) evidence for catastrophic flooding at the mouth of Clarks Fork Canyon, the probable catastrophic flood deposits just downvalley of glacial Lake Dead Indian, and the former presence of much larger glacial Lake Sunlight is a puzzle. The glaciolacustrine sediments in three valleys may contain enough organic matter for radiocarbon dating to establish the age of the greatest extent of Pinedale ice. The terraces along some creeks may provide a history of a transition from late Pleistocene aggradation to Holocene downcutting and floodplain development. The large ancient and modern landslides will provide more interesting research.

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