QUATERNARY GEOLOGY OF THE CLARKS FORK REGION, NORTHWESTERN WYOMING AND ADJACENT MONTANA

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Introduction

During July-August, 1994 a Keck Geology Consortium 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 certain aspects of the glacial, periglacial, fluvial, and mass-wasting processes which have been occurring during the Quaternary. Research was also undertaken on the environmental geology in the vicinity of the abandoned and proposed gold mines north of Cooke City, Montana.

Project Participants

The faculty were Bob Carson (Whitman), Dave DeSimone (Williams), and Eric Leonard (Colorado). Eric Jensen (Carleton, Colorado) was invaluable as a teaching assistant. The visiting faculty were Don Zenger (Pomona), and Carol Mankiewicz and Carl Mendelson (Beloit).

Additional support was provided by three scientists who have spent many years working in the area. Ken Pierce, U.S. Geological Survey, the Quaternary geologist most familiar with glaciation of the Yellowstone area, led a field trip in the Clarks Fork/Sunlight Basin area, and visited often for conferences with faculty and students. Allan Kirk, Crown Butte Mines, led a field trip to the proposed site of a gold mine beneath Fisher and Henderson Mountains, and spent considerable time with the two students doing projects in that area. Kent Houston, soil scientist for Shoshone National Forest, made a presentation on soils in northwestern Wyoming and accompanied five students to soils pits at their research sites.

The students were Katharine Adams and Quinn Kiley (Washington & Lee), Kirby Bean (Whitman), Stephen Boese and Jen Pierce (Colorado), Gail Brinkmeier (Smith), Nelson Erb (Beloit), Mark Hespenheide (Pomona), Adam Love (Franklin & Marshall), and Michael Montag (Williams).

Geography

Clarks Fork of the Yellowstone River originates near Cooke City, MT, and flows southeast and then northeast between the Beartooth Plateau and the Absaroka Mountains (Figure 1). 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, at an elevation of 1987 m, is near the head of Clarks Fork Canyon; the mouth of this deep canyon is at the west edge of the Bighorn Basin. Timberline is at approximately 3000 m. Some forests in Clarks Fork area burned during the Yellowstone fires of 1988.

General Geology

William G. Pierce and others of the U.S. Geological Survey have been publishing on the geology of the Clarks Fork region for decades. The Wyoming portion of our study area is completely covered by 1:62,500 scale geologic maps (Pierce, 1965; Pierce and Nelson, 1968, 1971; Pierce and others, 1973, 1982). The Montana part of our research area has been mapped at 1:24,000 (Elliot, 1979). In addition, Nelson and Prostka (1980), and Elliot and others (1993?) have written on the economic geology of the mining districts in the area.

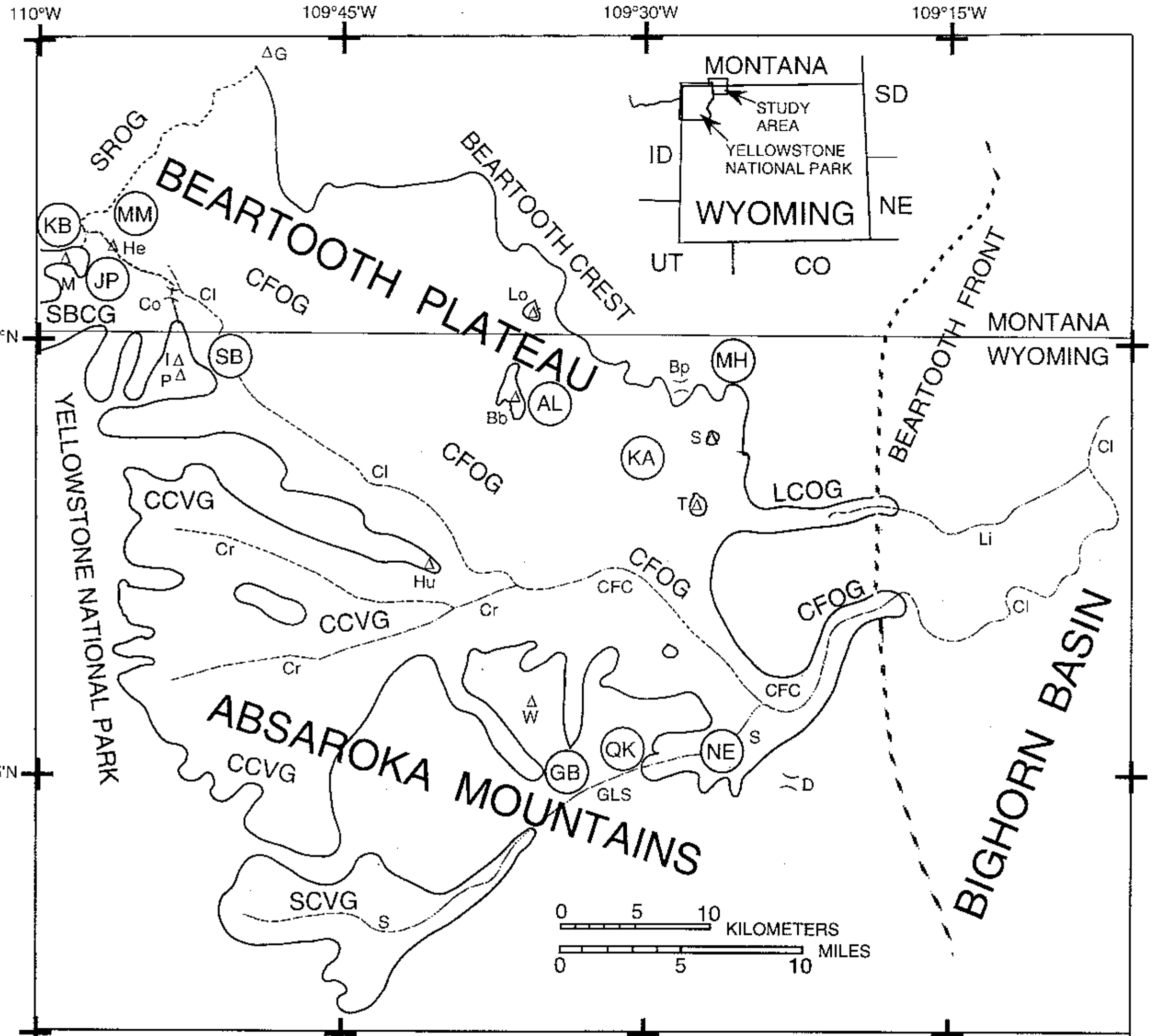

Figure 1. Late Pleistocene glaciers, Clarks Fork region, northwestern Wyoming and adjacent Montana. The approximate extent of ice south of the Beartooth crest and east of Yellowstone National Park is shown. Major glaciers were Clarks Fork outlet glacier (CFOG), Crandall Creek valley glacier (CCVG), Littlerock Creek outlet glacier (LCOG), Soda Butte Creek glacier (SBCG), Stillwater River outlet glacier (SROG), and Sunlight Creek valley glacier (SCVG). Peaks [triangles] are Beartooth Butte (Bb), Granite Peak (G), Henderson Mt. (He), Hunter Peak (Hu), Mt. Index (I), Lonesome Mt. (Lo), Miller Mt. (M), Pilot Peak (P), Sawtooth Mt. (S), Tibbs Butte (T), and Windy Mt. (W). Passes [ )( ] are Beartooth (Bp), Colter (Co), and Dead Indian (D). Streams are Clarks Fork of the Yellowstone River (Cl), North and South Forks of Crandall Creek (Cr), Littlerock Creek (Li), and Sunlight Creek (S). Also shown are Clarks Fork Canyon (CFC) and glacial Lake Sunlight (GLS). The field locations of student projects are indicated with circles: Katharine Adams (KA), Kirby Bean (KB), Stephen Boese (SB), Gail Brinkmeier (GB), Nelson Erb (NE), Mark Hespenheide (MH), Quinn Kiley (QK), Adam Love (AL), Michael Montag (MM), and Jennifer Pierce (JP).

Bedrock in the Clarks Fork area ranges from Archean plutonic and metamorphic rocks (Mueller et al., 1987) to the Eocene Absaroka volcanics (Smedes and Prostka, 1972) (Figure 2). All Phanerozoic periods except the Silurian are represented in the sedimentary record (Ruppel, 1972). During the Laramide Orogeny considerable faulting and folding occurred on the north and east edges of the Beartooth Plateau. Paleozoic sedimentary rocks gravity slid many kilometers southeastward across the Clarks Fork area during the Heart Mountain "thrust fault" event (Pierce, 1980). The last few million years have been dominated not only by glaciation (Pierce, 1979) but also by repeated and diverse volcanism (Christiansen and Hutchinson, 1987) in the Yellowstone area.

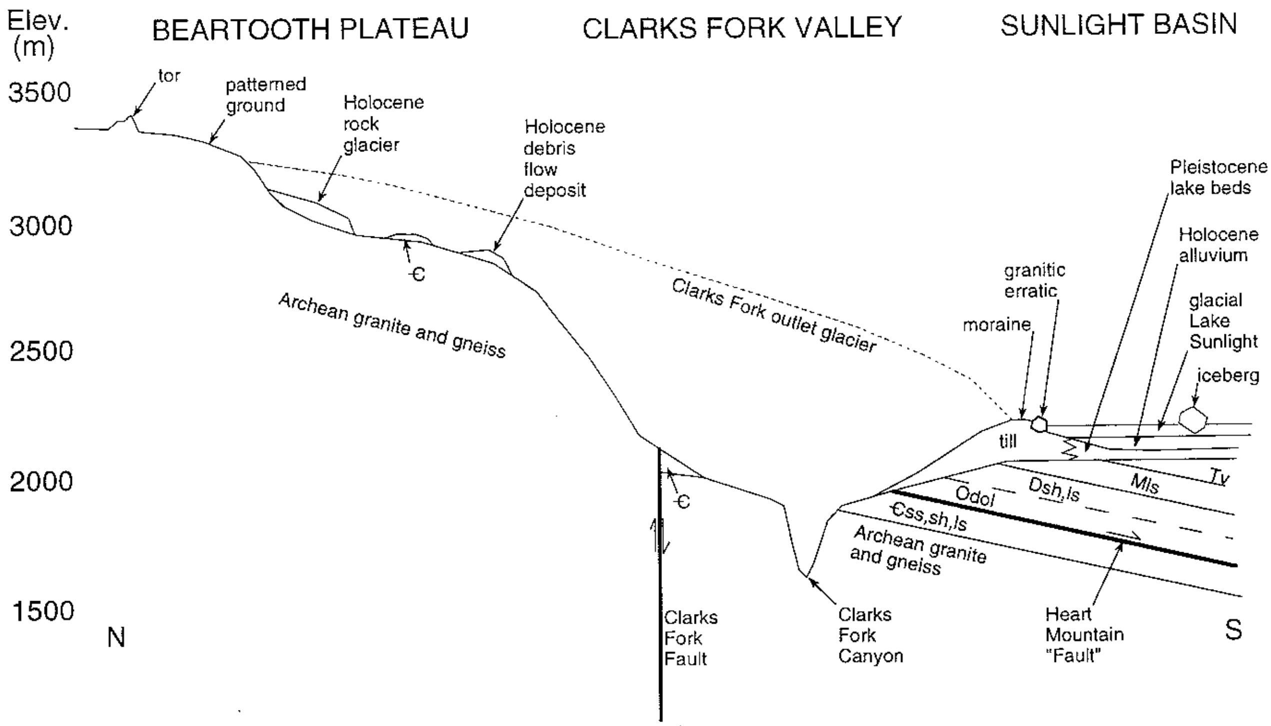

Figure 2: Diagrammatic cross section of the Clarks Fork region.

Quaternary Geology

Cirque and valley glaciers originating in the Beartooth and Absaroka Mountains 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 (Figure 1). 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 (Figure 2). Upon deglaciation mass-wasting occurred from glacially oversteepened slopes, particularly where Cambrian shales outcrop (Figure 3). Streams re-established their drainage systems and locally developed floodplains; both braided and meandering channels are present.

Kenneth 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 (Parsons, 1939) (Figure 2).

The accumulation area for the northeastern portion of the Yellowstone ice sheet was in the Beartooth and Absaroka Mountains. Katharine Adams studied evidence for the former ice cap on the southeastern Beartooth Plateau in an attempt to reconstruct former ice geometry and flow patterns. She mapped glacial striae (preserved mostly below ice-transported boulders), erratic distrubutions, and ice limits on nunataks. Ice thickness could be

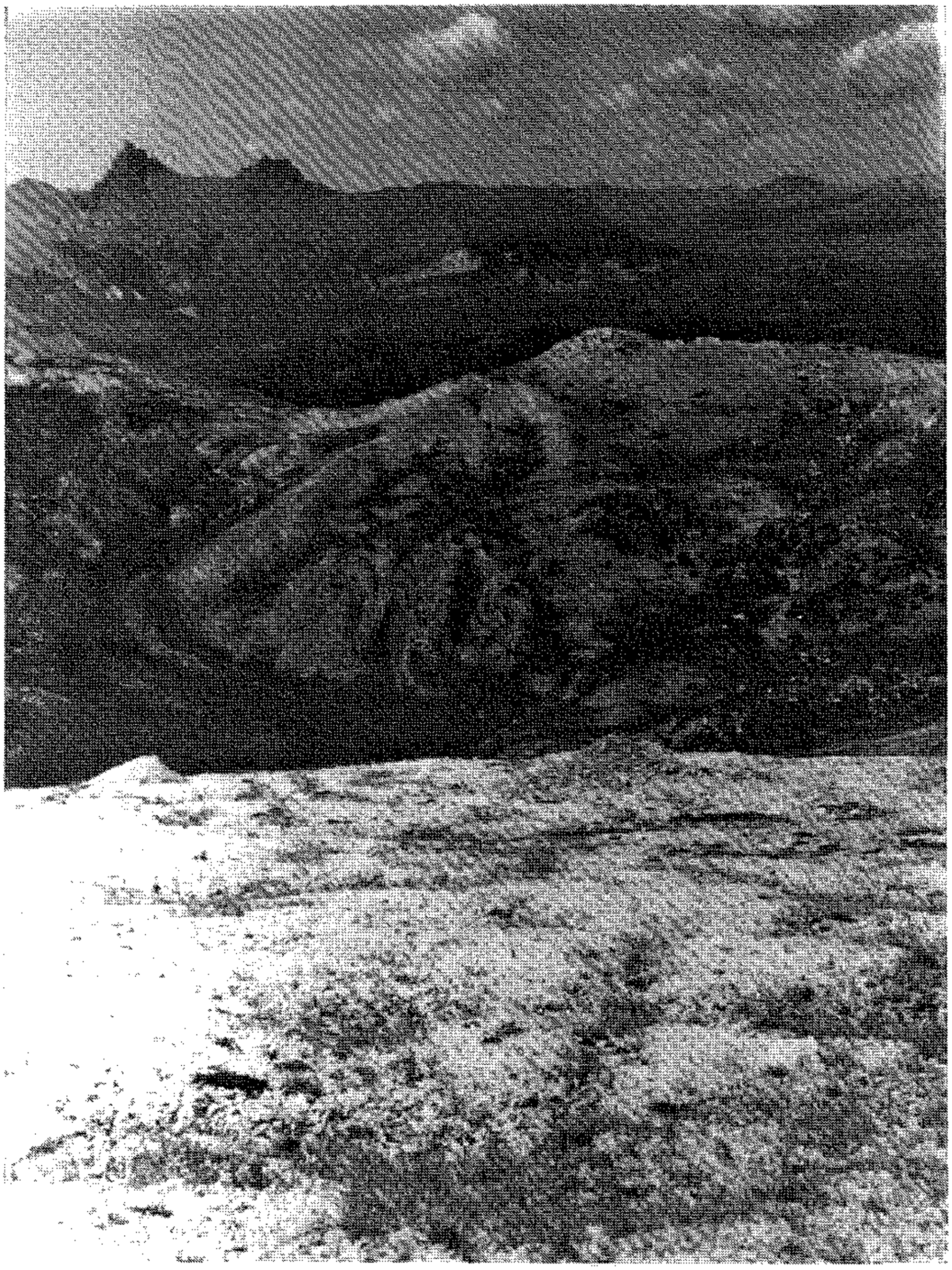

Figure 3: View west from near the summit of Beartooth Butte (3205 m). In the foreground is patterned ground transitional from polygons to stripes in a downhill direction; the underlying bedrock is Devonian shale and carbonates. The nearest ridge, part of Clay Butte (2990 m), is composed mostly of Cambrian shale and limestone, and is subject to debris flows. The distant valley, underlain by Archean granite and gneiss, was occupied by the Clarks Fork outlet glacier. The ridge in the left and center background is crowned by the Pilot Peak (3569 m, left) and Mount Index (3448 m, right) horns; from bottom to top in this ridge are light-colored Cambrian sedimentary rocks (intruded by an Eocene sill), the Heart Mountain "Fault", and dark-colored Eocene Absaroka volcanics. In the right background is the New World mining district near Cooke City, Montana.

estimated at crystalline nunataks such as Sawtooth Mountain, and could be determined accurately where crystalline boulders were deposited on the flanks of sedimentary nunataks such as Beartooth Butte (Figure 1).

The presence of patterned ground and other periglacial features suggests that portions of the Beartooth Plateau were above the ice cap (Figure 2). Wind kept the high Beartooth Plateau and nearby nunataks relatively snow-free. Adam Love mapped and trenched sorted patterned ground in an attempt to test different models of formation. At his two sites there is a transition from polygons to stripes as slope increases. At Beartooth Pass the borders and stripes contain large granitic clasts, whereas on Beartooth Butte there are small stones derived from a shaly limestone (Figure 3).

Mark Hespenheide investigated tors near the east and west summits of Beartooth Pass. He measured fracture orientation and spacing in an attempt to determine the structural control of the location, size, and shape of the tors. He also collected samples for thin-section analysis of the Archean plutonic and metamorphic rocks; one influence on the development of tors may be the differences in mechanical and chemical weathering of the various lithologies.

In places in the Beartooth and Absaroka Mountains cirque glaciers and rock glaciers survived the disappearance of the Clarks Fork outlet glacier at the end of the Pleistocene. Kirby Bean studied active and fossil rock glaciers on the north and east flanks of Miller Mountain. His research included surveying the rock glaciers and digging soil pits in them. The rock supply for the valley-wall or lobate rock glaciers is talus from fractured Absaroka volcanic rocks. Although interstitial ice is locally present, most of the rock glaciers are not active because of insufficient thickness and slope.

Three students had research projects in Sunlight Basin in the Absaroka Mountains. This area was earlier investigated by Dake (1919) and Parsons (1939), who determined that the Clarks Fork outlet glacier advanced up Sunlight Creek and adjacent creeks (Figure 1). The ice and moraines dammed lakes, the largest of which Ballard (1976) called glacial Lake Sunlight (Figure 2). The huge moraines in Sunlight Basin are covered with eolian sand, in one place thick enough to form parabolic dunes.

Nelson Erb mapped the geomorphology and surficial geology of Sunlight Basin, paying particular attention to the limits of the Clarks Fork outlet glacier. Much of his work involved mapping ice-transported and possibly ice-rafted granitic and sandstone erratics in an area underlain by Paleozoic shales and carbonates and Eocene volcanics.

Quinn Kiley studied the terraces along Sunlight Creek from the floor of glacial Lake Sunlight downstream to a postglacial gorge. His goal was to determine the postglacial evolution of the stream. The terraces are cut in thick lodgment till beneath the terminal moraines of the Clarks Fork outlet glacier, and are capped with alluvium. The deep narrow postglacial gorge is located at the mouth of Spring Creek and is cut in Cambrian limestone. A similar postglacial gorge is located beneath the Clarks Fork terminal moraines in the lower valley of Dead Indian Creek.

Gail Brinkmeier investigated the sediments on the floor of glacial Lake Sunlight in an attempt to unravel the geologic history of the lake basin. Most of her field work was a description of the Holocene alluvium and soils exposed in the cutbanks of Sunlight Creek; the channel gravels and overbank deposits are similar to those along the modern creek. She also cored the floodplain, recovering fine-grained (lacustrine?) sediments and peat.

Debris flows and debris torrents occasionally occur along small streams tributary to Clarks Fork and Soda Butte Creek. Such events in 1988 scoured channels and deposited large natural levees. Stephen Boese studied the deposits of debris flows and debris torrents along Index Creek with the goals of determining their frequencies, magnitudes, relation to precipitation, and flow characteristics. Debris flows large enough to dam Clarks Fork occurred about a century ago (based on dendrochronology) and in 1994.

The New World district near Cooke City has experienced mining for precious metals for more than a century. Crown Butte Mines, Inc. has proposed an underground gold mine beneath Henderson Mountain. Two students made investigations regarding environmental geology in the vicinity of the abandoned open pits of the

McLaren and Como deposits.

Mike Montag compared undisturbed sites with areas where reclamation has been attempted; he examined the effectiveness of reclamation efforts to stabilize abandoned mine sites. He attempted to measure differences in erosion (principally by gullying), soils, and water quality. He hopes that his findings on the geomorphology, soils, and geochemistry of the Como Pit will aid in reclamation efforts.

Jen Pierce studied ferricrete deposits in the vicinity of Henderson Mountain with the goal of understanding the geological conditions leading to its deposition. Ferricrete is a conglomerate or breccia cemented by iron oxides; the iron was derived from the oxidation of pyrite in the ore deposits. She attempted to determine the lithologic and geochemical controls for where, when, and why the ferricrete was deposited. The timing of deposition may indicate the relative roles of natural pyrite-rich rock drainage and anthropogenic acid-mine drainage.

Our research turned up many unexpected discoveries: e.g., a sink hole, an active rock glacier, parabolic dunes, peat beneath patterned ground, a debris flow that blocked Clarks Fork of the Yellowstone River during our visit. Also interesting was not finding the expected. We discovered no direct evidence for pre-Pinedale glaciation of the area. We found little surface evidence for lacustrine sedimentation in glacial Lake Sunlight. Based on field work at the mouth of Clarks Fork, Ballard (1976) determined that catastrophic flooding occurred on the outwash plain, and suggested that glacial Lake Sunlight was the source for floodwaters; yet we found no definite evidence in Sunlight Basin for such floods.

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