QUATERNARY GEOLOGY OF THE ALBION MOUNTAINS, SOUTHERN IDAHO

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INTRODUCTION

Geologic History

The Albion Mountains stretch for 50 km between the Idaho/Utah border on the south and the Snake River Plain on the north. The range is part of the Albion–Raft River–Grouse Creek metamorphic core complex, which exposes some of the most highly extended and deeply-derived rocks of the Basin and Range geologic province (Miller, 1980). Granite, granitic gneiss, schist and amphibolite belonging to the 2.5 Ga Green Creek Complex are the oldest rocks in the range. These basement rocks are unconformably overlain by Proterozoic and Paleozoic sediments that were metamorphosed during crustal thickening in the hinterland of the Sevier orogenic belt (Armstrong, 1968). The highland created by the Sevier orogeny began to collapse and extend during the early Cenozoic. The formerly deep-seated Precambrian rocks were arched into broad domes and structurally unroofed along large-scale low-angle normal faults (Miller and Bedford, 1999). During the Oligocene, the core complex was intruded by several bodies of granite that include the 28 Ma Almo Pluton of the Albion Mountains. Following emplacement of granitic plutons at depths of approximately 10 km, the region experienced rapid uplift. By 10 Ma, a combination of low-angle normal faulting and erosion had exhumed the Almo Pluton, allowing ash flow tuffs from calderas associated with the nearby Yellowstone hot spot to be emplaced on the exposed granite (Miller and Bedford, 1999). During the late Miocene, most of these rhyolitic rocks were translated to the east on low-angle normal faults as the core complex continued to rise (ref). Quaternary uplift of the range has occurred along high-angle range-bounding normal faults. The present shape of the mountains results primarily from the headward erosion of streams that are tributaries of the Raft and Snake rivers on the north and east and Birch and Goose creeks on the west. Headward erosion by Raft River tributaries eventually breached resistant Proterozoic quartzites in the structural domes of the southern Albion Mountains. The Tertiary granite cores of the domes where much more easily weathered, particularly in regions of high joint density and hydrothermal alteration. Streams differentially eroded the weathered granite, leaving behind a spectacular landscape of domes, fins, and spires rising out of broad valleys in the interior of the range. Well-perserved cirques and moraines indicate that the highest peaks of the Albion Mountains, Cache Peak (10,339 ft., 3151 m) and Mt. Harrison (9,265 ft., 2824 m), hosted alpine glaciers during the Pleistocene (figure 1) . Extensive areas of hummocky topography on the flanks of several peaks and ridges suggest that landslides have played an important role in the recent geomorphic evolution of the Albion Mountains.

Figure 1. Independence Lakes occupy a large cirque on Cache Peak.

Human History

The Albion Mountains contain extensive evidence of habitation by native Americans who took advantage of the rich supply of pinyon pine nuts and game animals. European immigrants first became familiar with the area in the 1840s when the California Trail was routed across the southern Albion Mountains. Travelers on their way to the gold fields of central California were impressed by the extensive complex of spires in the valley of Circle Creek, which they named "City of Rocks". The City of Rocks was a local tourist attraction until 1988 when it was included in the National Park system as City of Rocks National Reserve. Visitation increased dramatically with this designation. Six kilometers north of the City of Rocks another group of granite inselbergs known as Castle Rocks is a prominent feature of the valleys of Little Cove and Almo Creeks. The Idaho State Park system recently acquired Castle Rocks and intends to open the area to the public as Castle Rocks State Park in May of 2003.

Previous Investigations

The first comprehensive study of the geology of the Albion Mountains was by Anderson (1931) who noted the glacial features of the high peaks and suggested explanations for the unusual granitic landforms of the City of Rocks. Igneous rocks of the Albion Mountains were first dated by Armstrong (1968) who also subdivided all rocks into formal stratigraphic units. Cunningham (1971) published a detailed description of the geomorphology of the City of Rocks. The entire range was geologically mapped at a scale of 1:24,000 by R.L. Armstrong during the 1970s and early 1980s but unfortunately these maps were never published. Various aspects of the structural geology of the Albion Mountains were the subject of papers by Miller (1980;1983) and Miller and Bedford (1999). Most of the Almo Quadrangle which contains the City of Rocks was recently remapped and is being prepared for publication (Miller et al., in prep). No published studies have focused on the landslides or glacial history of the Albion Mountains or on the geology of Castle Rocks.

GOALS OF THE STUDY

The study had three goals. The first was to obtain information on the geology of Castle Rocks that will directly benefit the proposed state park. The data will be presented to the park as an aid in developing interpretive resources for park visitors and to help park managers make more informed decisions. To achieve this goal, the project strived to gain a better understanding of the processes responsible for the granitic landforms that are the showpiece of the new state park and to recognize geologic features that were exceptional, unique, or fragile.

The second goal was to map and describe geomorphic features resulting from glaciation and mass wasting and to determine the regional extent of these phenomena. The landslide studies seeked to map and date the landslides and explain the conditions that produced them. The glacial landform studies concentrated on the recognition and timing of glacial advances and on mapping the maximum extent of ice during each glaciation.

The third goal was to obtain a record of glaciation and latest Pleistocene and Holocene climate history through the analysis of sediment cores from tarns on Mt. Harrison (Lake Cleveland) and Cache Peak (Independence Lakes).

FIELDWORK

The project commenced on June 22, 2002 when the participants first gathered at our headquarters in Albion, Idaho. The first week was devoted to field trips designed to familiarize the students with both the regional geology and the types of problems that could be addressed. At the beginning of the second week, proposals for individual projects were evaluated and the students were assigned to a project advisor based on their particular interests. During each day of fieldwork, the students traveled to their field sites where they usually worked in groups of two. The equipment involved in obtaining the lake sediment cores required three students to work together on all aspects of those projects. The lake coring team enlisted the help of all project participants to backpack their raft and coring equipment to and from the Independence Lakes. July of 2002 featured the hottest temperatures ever recorded in southern Idaho. This was a particular strain on the three students working in the Castle Rocks area at comparatively low elevations where temperatures regularly exceeded 35° C (95° F).

STUDENT PROJECTS

Niki Bowerman, Dan Cadol, and Paul Bovet ("Team Mud") worked as a closely-knit team to investigate the timing and paleoclimatic implications of the latest Pleistocene and Holocene sediments in the cirques below Cache Peak and Mt. Harrison. Their fieldwork combined geomorphic mapping of late Pleistocene moraines and trimlines with bathymetric surveys and sediment coring of each lake in the two cirques. Detailed analyses of the sediment cores, and climatic reconstructions based on the glacial deposits, provide the first solid constraints on conditions during and after the Pinedale glaciation in this region.

The cirques at both field sites are deep and well developed, having supported the largest two Pinedale-equivalent glaciers in the Albion Mountains. Mapping indicates that the Pinedale-equivalent glacier in the Independence Lakes basin was the largest in the range, covering slightly less than 2 km^2, and extending for 3.0 km at its maximum. The Pinedale Lake Cleveland glacier was roughly half that size, at 1 km^2, and extended for ~2.4 km at its maximum. ELAs at the Pinedale maximum were approximately ~2710 m (8880') and ~2540 m (8320') in the Independence Lakes and Lake Cleveland cirques respectively. By comparing the modern climate at these altitudes to climate conditions at ELAs of modern glaciers around the world, Dan Cadol has been able to establish constraints on the magnitude of climate change since the end of the last glacial age.

Detailed analyses, by Niki Bowerman and Paul Bovet, of several key cores from the largest lakes place constraints on both the timing of the demise of the glaciers, as well as on changes in the environment through the Holocene. The deepest sediments indicate that the glaciers retreated back to the cirques by ~13,000 ^{14}C yr B.P. (~15,600 cal yr B.P.), and disappeared entirely by ~11,800 ^{14}C yr B.P. (~13,800 cal yr B.P.). The stratigraphy, magnetic susceptibility, sediment grain size (Bowerman), and organic carbon content (Bovet) of the cores record a complex post-glacial history, indicating that both sedimentation and plant productivity in and near the lakes fluctuated rapidly on centennial-to-millennial time scales. The causes of these changes remain unclear, but are probably linked to changes in precipitation, seasonality, temperatures, or a combination of all three. The combined results of Team Mud provide the best constraints yet recovered from southern Idaho of Pleistocene deglaciation and Holocene environmental change. These constraints help fill a large gap in knowledge of this intermontane region.

Nick Welty and Jamie Mitchell studied the glaciation of Cache Peak and Mt. Harrison, respectively. Each peak has a summit approximately at modern treeline, but no permanent snowfields. However, each has multiple cirques indicating Pleistocene glaciation, and at least two ages of moraines indicating more than one glaciation. Table 1 compares the glaciation of the two peaks.

Most of the elevation data suggests that Mt. Harrison was colder and/or wetter than Cache Peak, particularly considering the fact that the Independence Lakes cirque on Cache Peak is much larger than the cirque on the northeast side of Mt. Harrison. The most unusual phenomenon about each peak is the difference in size of glaciers of different ages, with pre-Pinedale ice more than twice as extensive as Pinedale ice. In glaciated areas to the northwest, such as the Wallowas (Crandell, 1967) of northeastern Oregon, the size difference between Pinedale and pre-Pinedale glaciers is minimal. Similarly, at the Yellowstone Ice Sheet to the northeast, Bull Lake glaciers are only slightly larger than Pinedale glaciers (Good and Pierce, 1996). The influence of pluvial Lakes Bonneville and Lahontan to the southeast and southwest, respectively, is unknown. The Albion Mountains are relatively isolated from other glaciated portions of the Cordillera; determining the nature and timing of glaciation in the Albion Mountains is important to help understand climatic change in western United States.

Alice Letcher investigated the mass wasting on Mount Harrison and nearby Connor Ridge. About a dozen landslides cover approximately 20 km^2 and are characterized by steep concave scarps, hummocky ground, springs, and local block fields (figure 2). The headwall scarps

Figure 2. Large landslide on the south side of Conner Ridge

are mostly between the elevations of 2350 and 2550 m, with debris toes extending as far as 2 km downslope. The landslides on Connor Ridge occur on dipslopes of about 25°; failure occurred within a schist along the contact of the Archean Green Creek Complex and the Proterozoic Elba Quartzite. Minor areas of reactivated mass wasting on three of the landslides consist of small slumps and earthflows, and have occurred as recently as a few years ago.

Adrienne Hacker, Kathy Hilimire, and Jeremy Laucks worked on projects associated with the proposed Castle Rocks State Park. They had a unique opportunity to gather data within the park before its development and the associated impacts of visitation. Kathy Hilimire conducted a survey of granitic landforms in the proposed park with a special emphasis on locating fragile, unusual, and geologically significant features. She located many fragile features associated primarily with landforms produced by cavernous weathering. It is hoped that park management will actively pursue a

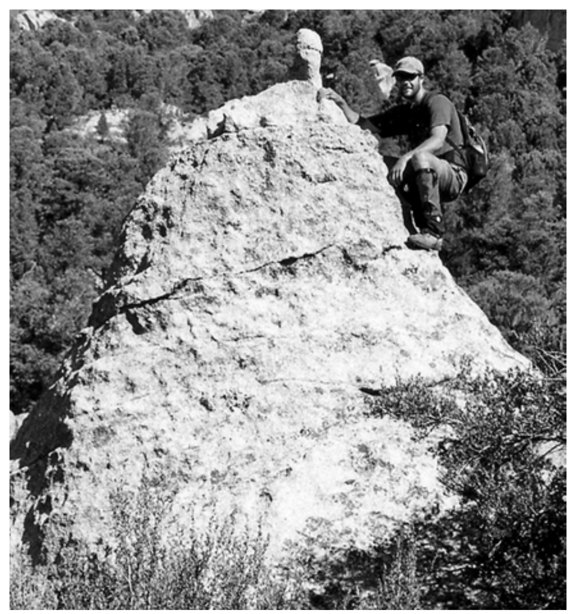

Figure 3. A"pickelhaube" at Castle Rocks

"look don't touch" policy regarding these delicate features. It was discovered that the park contains many examples of large spires with small spikes of granite on their summits. We assigned the term "pickelhaube" (German for "spike helmet") to these features and theorized that they represent the last remnant of a former surface that was reduced via the enlargement of adjacent panholes (figure 3).

Table 1. Data on glaciation from Cache Peak and Mt. Harrison, Albion Mountains, Idaho

CACHE PEAK		mountain	MT. HARRISON	
3152 m		summit elevation	2825 m	
Independence Lakes, 2704-2795 m		lake name(s) and elevation(s), NE cirque	Lake Cleveland, 2519 m	
rock glacier in S cirque		latest glaciation?	moraine in Lake Cleveland	
PRE-PINEDALE	PINEDALE	GLACIATION	PRE-PINEDALE	PINEDALE
1950 m	2450 m	lower ice limit, NE	1795 m	2315 m
5.2 km	3.0 km	glacier length, NE	4.6 km	2.4 km
2315 m	2710 m	approximate ELA*, NE	2105 m	2540 m
	2680 m	S cirque elevation		2615 m
?	2465 m	lower ice limit, S	?	2520 m?
2195 m?	2445 m?	lower ice limit, E	no glaciation?	

Jeremy Laucks concentrated on the large scale geomorphic evolution of Castle Rocks. He studied aerial photographs and surveyed the perimeter of the main cluster of granite inselbergs for evidence of their erosional history. The analysis of features such as flared slopes, pan-holed surfaces, and perched quartzite lag cobbles indicates a complex multi-stage evolution with periods of deep weathering alternating with periods of exhumation. These cycles are almost certainly controlled by the regional variations in climate indicated by the lake core sediments.

Adrienne Hacker studied cavernous weathering phenomena throughout Castle Rocks. The proposed State Park contains many spectacular examples of tafoni produced by this process which are sure to excite the curiosity of visitors. Adrienne surveyed many tafoni within Castle Rocks recording data on their dimensions and location relative to topography and other landforms. She also collected temperature and humidity measurements to compare the climate inside and outside of individual tafone and rock and grus samples to analyze in the laboratory.

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