Paper G 14

GLACIATION OF NORTHWESTERN WYOMING INTERPRETED FROM ERTS-1

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ABSTRACT

Analysis of ERTS imagery has shown a number of alpine glacial features can be recognized and mapped successfully. Although the Wyoming mountains are generally regarded as the type locality for Rocky Mountain glaciation some areas have not been studied from a glacial standpoint because of inaccessibility or lack of topographic control. ERTS imagery provides an excellent base for this type of regional geomorphic study. A map of maximum extent of Wisconsin ice, flow directions and major glacial features was compiled from interpretation of the ERTS imagery. Features which can be mapped are large moraines, outwash fans and terraces. Erosional ice features including cirques, large scale "grooves", U-shaped valleys and glacial lakes are useful in delineating glaciated areas. Present-day glaciers and snowfields are easily discriminated and mapped. Glaciers and glacial deposits which serve as aquifers play a significant role in the hydrologic cycle and are important because of the increasing demand placed on our water resources. ERTS provides a quick and effective method for change detection and inventory of these vital resources.

TEXT

During the Pleistocene epoch the largest mass of glacial ice outside of the continuous ice sheet in North America formed in northwestern Wyoming leaving a profound effect on the present-day topography and scenery. In addition the sand and gravel deposits formed by glacial erosion are important sources of construction materials as well as being excellent aquifers. Glaciation also provided numerous natural reservoirs in the form of tarns and moraine-dammed lakes. Rocky Mountain glacial chronology is based on t[illegible] deposits found in the Wind River Mountains of Wyoming. Although glaciation has locally been studied in detail, the region as a whole has not been studied from a glacial standpoint. The large area involved, rugged topography, lack of control and general inaccessibility have discouraged regional investigations. ERTS-1 appeared to provide an excellent base for broad-scale geomorphic studies of this type. This paper presents preliminary

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results of an effort to map glacial geology from satellite imagery using simple techniques and limited ground truth.

Figure 1 is a small scale photomosaic of ERTS-1 MSS-5 imagery in the area studied. The darker area with moderate relief and the prominent lake in the northwest corner of the image is the Yellowstone Plateau. It is bordered on the east by the rugged Absaroka Range and on the south by the Teton and Gros Ventre Mountains. The large northwest-striking structure in the south-center of the mosaic is the Wind River Range. The north-trending ridges and valleys on the southwest margin of the image are the Wyoming Overthrust Belt. All of the images were taken in early fall (1972) and are cloud-free. The imagery was analyzed using basic photo interpretive techniques together with color-additive and stereo viewing.

Overlay maps were compiled outlining the extent of ice at glacial maximum. A simplified and reduced glacial map is presented in Figure 2. Glaciated areas as shown are based on the recognition of one or more glacial features. Glacial landforms can be grouped into erosional and depositional features both which could be recognized on the imagery. Moraines are considered the most diagnostic depositional glacial landform. The Bull Lake and Pinedale type deposits (Wisconsin) were easily outlined on the imagery although they could not be separated where in close contact. These massive looping terminal moraines impound large glacial lakes on the flanks of the Wind River Range (Fig. 1, location A). The Bull Lake and Pinedale tills are not suited for agricultural use because of relief, rocky character and permeability. On the other hand, glacial outwash, fans and valley trains (stratified drift) beyond the former ice margin often contain sufficient matrix to support field crops such as hay and alfalfa. Thus glacial drift could be categorized as till or stratified drift using false-color infrared composites to enhance the vegetation difference. This technique was only successful in the Wind River and Teton Ranges where glaciers advanced out of the mountains onto the basins where vegetation contrasts occur. Terminal and lateral moraines in mountain valleys could neither be reliably distinguished from stratified drift nor from other valleyside surficial deposits except in a few cases where characteristic geomorphic features were recognized. Most of the pre-Wisconsin glacial features have been subsequently destroyed by erosion or covered by later deposits. Remaining exposures are too small to recognize on the imagery. Large gravel-capped mesas or pediments at the mountain flanks and in the basins probably represent erosional cycles of these early glaciations. These pediments or benches appear dark on all bands but are best recognized using a composite of MSS 5 and 7 (Fig. 1, location B).

0 ▬▬▬ 50 miles

Figure 1

ERTS MSS 5 MOSAIC OF NORTHWESTERN WYOMING

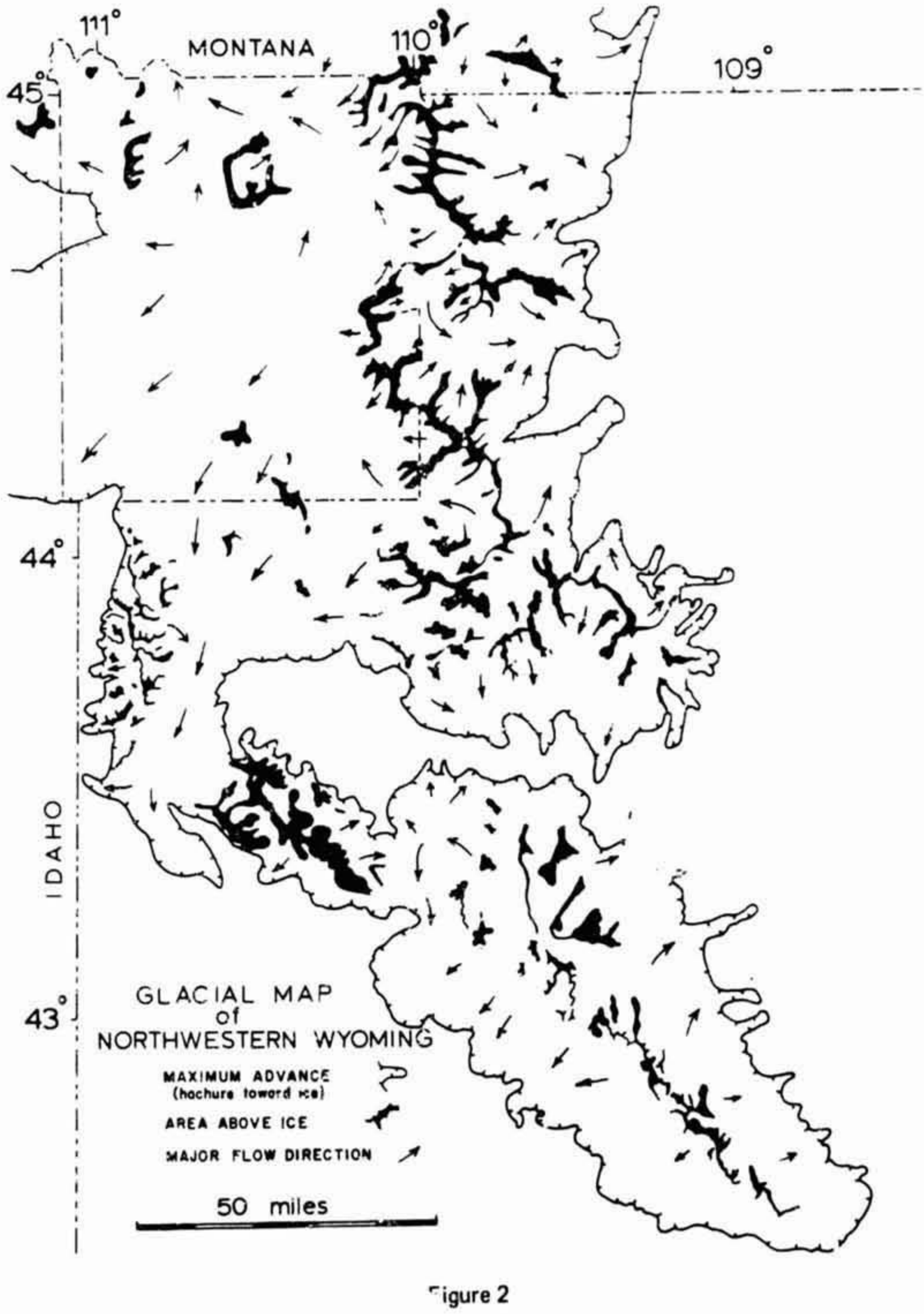
111°
MONTANA
110°
109°
45°
44°
43°
IDAHO
GLACIAL MAP
of
NORTHWESTERN WYOMING
MAXIMUM ADVANCE
(hochure toward ice)
AREA ABOVE ICE
MAJOR FLOW DIRECTION
50 miles

Figure 2

Where massive terminal moraines were absent or not recognizable, glaciated areas were outlined on the basis of glacial topography. Alpine glacial erosion is distinctive and stereoscopic viewing of adjacent ERTS passes facilitated the recognition of U-shaped troughs, cirques, horns, aretes, cols and truncated spurs. Ice limits can be located approximately where valleys change from a U to V shape in cross valley profile. Most of the crests of Wyoming mountain ranges culminate in flat uplands often referred to as high-level erosion surfaces which bevel across the rock structure. Glacial dissection of these surfaces results in the classic biscuit-board topography. Morphology and topography recognized using stereo pairs allowed distinction of the unglaciated areas above the ice (Fig. 2). Color composites enhanced the contrast between tundra vegetation on the erosion surfaces and the bare cirque walls. Glacial tarns distinguished on MSS-7 were useful as indicators of glaciated bedrock.

The glaciated volcanic terrane of the Absaroka Range posed several special problems. Alpine glacial features in the Absarokas are not well-preserved as in the crystalline terrane of the Wind River, Teton or Beartooth Ranges and the glacial cycle is manifest in different forms of mass movements such as landslides and rock glaciers. Because of the absence of moraines and tarns, cirque development and valley morphology were used as indicators of glacial boundaries. Although the Yellowstone Plateau is also a volcanic province, the lower relief has resulted in less intensive mass wasting and more glacial indicators are preserved including moraines, outwash and lacustrine deposits.

Major flow directions (Fig. 2) were mapped using directional criteria such as slope direction and orientation of glacial troughs, U-shaped valleys, and cirque headwalls. Scoured bedrock served as an excellent indicator in some areas. Flow directions in the high Wind River Range were indirectly controlled by the large-scale joint pattern in the Precambrian rocks. These linear joint concentrations represent zones of weakness which were selectively eroded by ice leaving many parallel sets of straight glacial valleys. An excellent example of flow direction recognizable on ERTS imagery is in northern Yellowstone Park (Fig. 1, location C), where ice moving from the Buffalo Plateau can be traced down the valley of the Yellowstone River to Gardiner, Montana. A combination of drumlins, lateral moraines together with scoured bedrock in the form of large grooves and oriented tarns show on the imagery as parallel lines. Linear features are especially well developed on Mt. Everts near Mammoth where ice must have been over 2000 feet deep in order to cover the top of the mountain. Another area where flow direction can be dramatically observed is at the northern end of the Wind River Range where the Green River glacier flowed north out of a huge Yosemite-like valley and made a 120° turn into the Green River Basin after encountering the Gros Ventre Range (Figure 1, location D). The flow indicators in this instance are medial and lateral moraines.

Large glacial outwash channels are visible in the southwest corner of Yellowstone where cascading meltwater scoured many parallel channels (Fig. 1, location E).

Comparison of maximum advance and flow directions interpreted from the imagery indicates there were two major centers of ice accumulation, the Wind River and Yellowstone-Absaroka ice caps. Most of the Wind River ice sheet was restricted to the Precambrian highlands except in perhaps a dozen places where valley glaciers breached the hogback belt and flowed out onto the basins. Ice from the Yellowstone-Absaroka source area flowed in locally complex patterns but generally radiated north down the Yellowstone valley, east to the Bighorn Basin, south into Jackson Hole and west toward the Snake River Plain. The Teton and Gros Ventre glaciers were generally incorporated into the flow of the two major sheets. The Beartooth ice cap was north of Wyoming although south-flowing ice merged with the Yellowstone- Absaroka mass.

In addition to glacial features a number of related or periglacial phenomena were successfully mapped. Large recent mass movements were sometimes recognized. Most often the scar was first detected where the mass separated from the surrounding rock, soil and vegetation. Commonly mass movements exhibit characteristic arcuate fronts and hummocky surfaces depending on the nature and speed of the movement. This characteristic shape was of considerable utility in recognizing these mass movements. Large landslide complexes at Gardiner, Mammoth, Carter Mountain and Togwotee Pass were readily distinguished on color composite images. Slide scars and debris at the famous Gros Ventre and Hebgen Lake rockslides were also apparent. Masses of slow-moving rock debris (rock glaciers) were mapped by using MSS 5 and 7. The largest and most numerous rock glaciers were identified in the cirques of the Absaroka Range. Other periglacial features (with the exception of dune fields) are only distinguishable from low level aircraft imagery. A large belt of dunes south of the Wind River Range may represent glacial eolian deposits. These dunes were mapped and active dunes distinguished from vegetated stabilized dunes by their characteristically high reflectance in all bands.

All of the Wyoming basins depend on the runoff from the mountains for water supply. Permanent snowfields and small glaciers remaining from the Neoglacial stades or "little ice age" are an important part of the hydrologic cycle. Preliminary results indicate snow and ice covered areas can be mapped and monitored using the ERTS imagery. Late summer imagery was successfully used to locate permanent snowfields and small glaciers. Snow is best mapped on MSS 4 while MSS 7 allows better distinction of glaciers from snow cover. The ancient glacial and alluvial deposits serve as important aquifers that retain the meltwater and release it slowly through the summer months. False-color composites were used to map these valley-train or alluvial deposits which in the basins support crops or exhibit greater density of vegetation than the surrounding Cretaceous and Tertiary rocks.

Results of the ERTS investigation were compared with aircraft data and the available glacial maps compiled by conventional techniques. The ERTS map agreed well with the work of Love (1961), Richmond (1964), Richmond and others (1965, 1972), Waldrop and Hyden (1963), and Pierce (1968). Many glacial features visible on ERTS imagery were not recognized until comparisons were made with conventional maps or aircraft imagery. Low-level aircraft imagery was more useful than the satellite imagery where detail was important. In some cases aircraft photointerpretations were superior to field maps. In most cases imagery interpretation was hampered by vegetation. Subtle topographic differences are generally better mapped from imagery than on the ground.

The success of this study demonstrates the utility of ERTS imagery in regional geomorphic studies, especially when inaccessibility is a major factor. Detailed stratigraphy and discrimination of similar tills is not possible but some gross distinctions can be made where units form wide exposures. Snow and ice cover can be easily and quickly mapped and monitored for change using ERTS.

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