RELICT PATTERNED GROUND, BEAR RIVER RANGE, NORTH-CENTRAL UTAH

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ABSTRACT

In the Bear River Range, north-central Utah, thirty-nine widely distributed localities of three acres or larger show a morphology resembling periglacial patterned ground. In the total of 2,359 acres (954 ha) under study, aerial photographs reveal an arrangement of mounds by an alternately dark and light pattern. The mounds are evenly distributed on slopes of less than 10 percent and aligned in beaded stripes on slopes of more than 10 percent. The mounds range from 13 to 66 feet (4 to 20 m) across; the average mound diameter is about 40 feet (12 m). Only regolith is affected by the patterned morphology. The regolith in and between the mounds is derived from the same source, but the parent material varies among different localities.

The location of patterned areas appears to be controlled by temperature and soil. Temperature is the primary factor. Slope aspect, potential insolation, average elevation, and amount of terrain affected correlate for different localities. These factors interact to produce approximately the same average annual, summer, and winter temperatures in patterned ground areas. The patterned ground is located where the controlling temperature coincides with the appropriate soil.

Twenty-two areas of patterned ground are within the boundaries of a recent soil survey. An analysis of the soils suggests that patterned ground genesis is facilitated by soils with significant silt and clay components. Some soils affected by patterned morphology have large amounts of stones and cobbles.

The evidence of erosion subsequent to formation indicates that patterned areas did not originate under present climatic conditions. During Pleistocene glacial periods, the calculated average annual temperature at these localities was 32°F. Differential frost heaving during the cooler periods of the Pleistocene is suggested as the process responsible for the creation of patterned morphology in the Bear River Range.

INTRODUCTION

The region of investigation includes the western part of the Bear River Range and the eastern margin of Cache Valley in north-central Utah (figure 1). The elevation in the study area ranges from 5,000 to 9,998 feet (1,524 to 3,047 m). The Bear River Range consists primarily of Precambrian and Paleozoic rocks broadly folded into a northeast-trending syncline and anticline. Approximately fifty-five percent of the exposed stratigraphic section is composed of carbonate rocks. Cache Valley is a north-trending, rather flat-floored valley that parallels the western front of the Bear River Range.

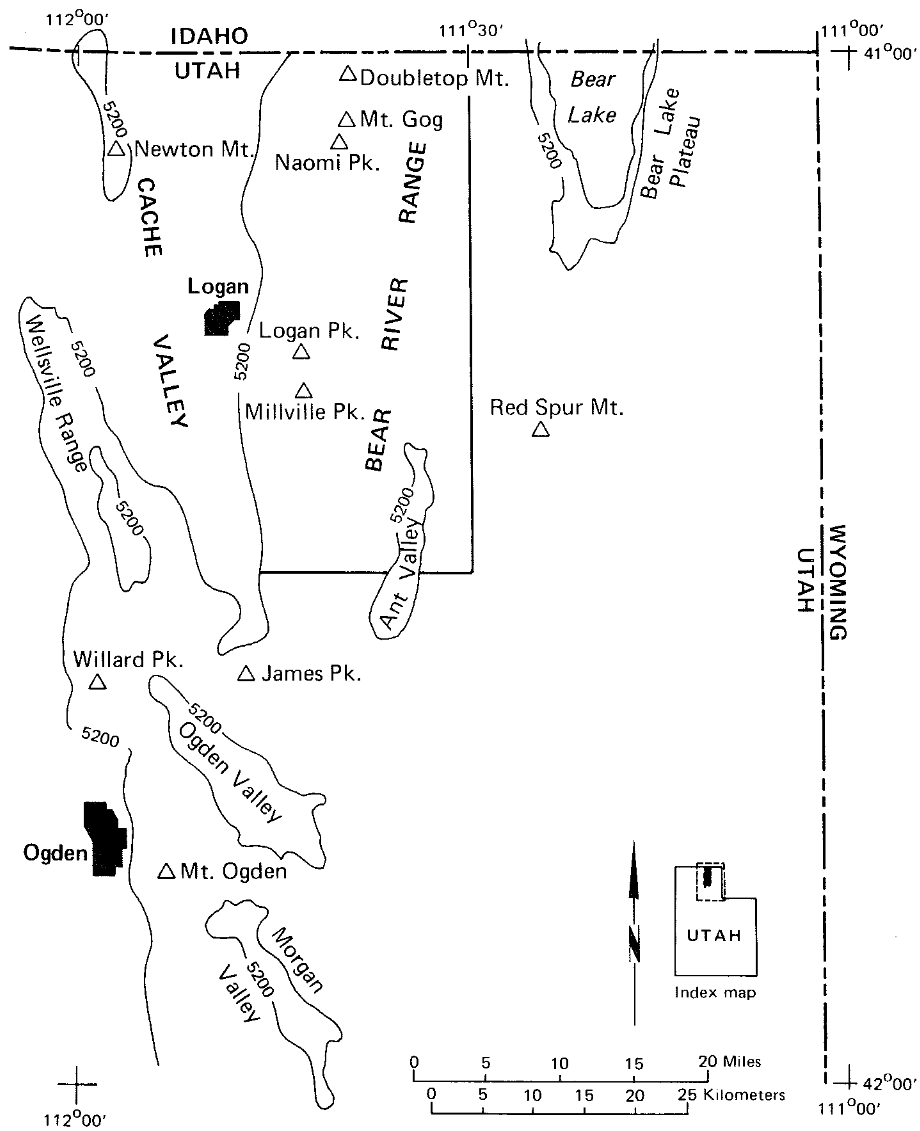

Figure 1. Location of study area in north-central Utah.

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The valley has dropped in relation to the mountains to form a structural graben (Williams, 1948, 1958a). A considerable accumulation of material has been deposited within the valley (Peterson and Oriel, 1970; Stanley, 1972). Except for some isolated outliers of Paleozoic rocks, the eastern margin of Cache Valley consists of exposures of Recent alluvium, Quaternary Lake Bonneville deposits, and Tertiary Salt Lake Formation. The alluvium is generally found near the mouths of canyons. Along the mountain front, the Lake Bonneville deposits are found as lake terraces, and the Salt Lake Formation occurs as pediment surfaces (Williams, 1948, 1958a, 1962).

RELICT PATTERNED GROUND

The patterned ground is found throughout the western part of the Bear River Range and at one area along the eastern margin of Cache Valley (DeGraff, 1975). Within the study area, thirty-nine widely distributed localities show a patterned appearance (figure 2). These features range in size from 3 to 371 acres (1.2 to 150 ha) for a total of 2,359 acres (954 ha). Dark and light tones on aerial photographs reveal the distinctive pattern (figures 3 and 4); it is much less apparent in ground-level observation.

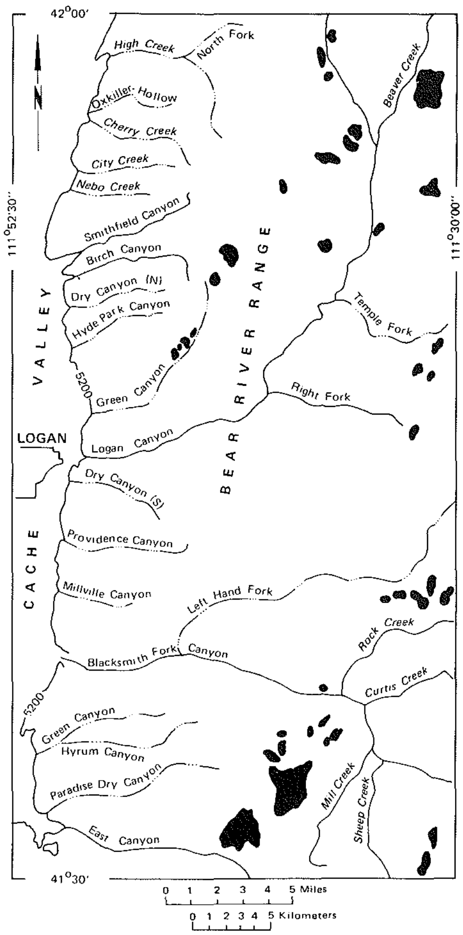

Figure 2. Locations of areas of patterned ground.

When viewed on aerial photographs, the patterned appearance resembles patterned ground features associated with periglacial environments. The term, patterned ground, is defined in the American Geological Institute Glossary (1975) as: "A group term suggested by Washburn (1950) for certain well-defined, more or less symmetrical forms, such as circles, polygons, nets, steps, and stripes, that are characteristic of, but not necessarily confined to, surficial material subject to intensive frost action." The patterned ground in the Bear River Range most closely resembles circles and stripes.

An examination of patterned ground reveals that its appearance results from a distribution of mounds. The mounds are circular to elliptical in plan view. They range between 13 and 66 feet (4 and 20 m) across. The average

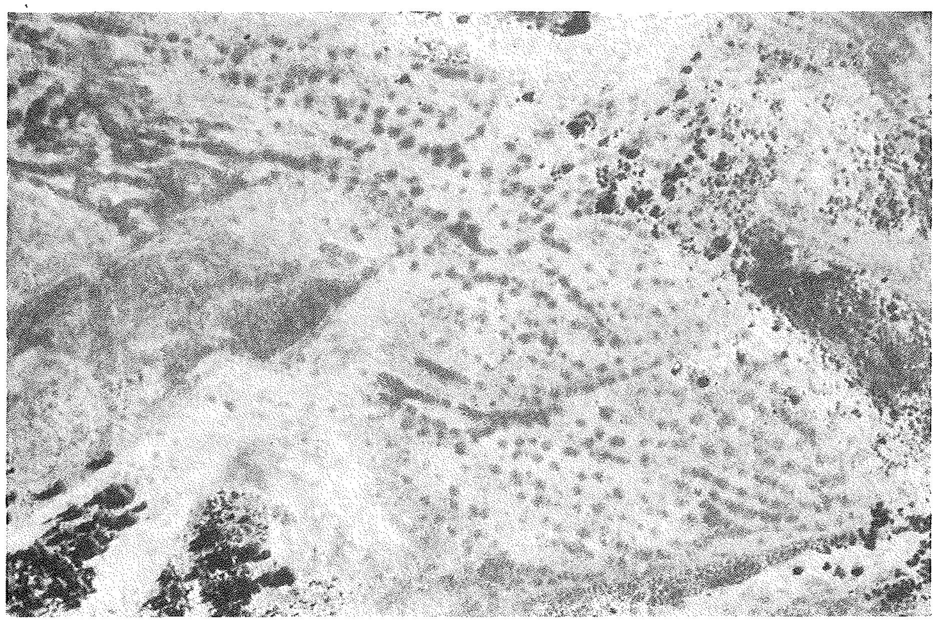

Figure 3. Aerial photograph of patterned ground near East Canyon (EMD-17 88, USDA, Forest Service photograph).

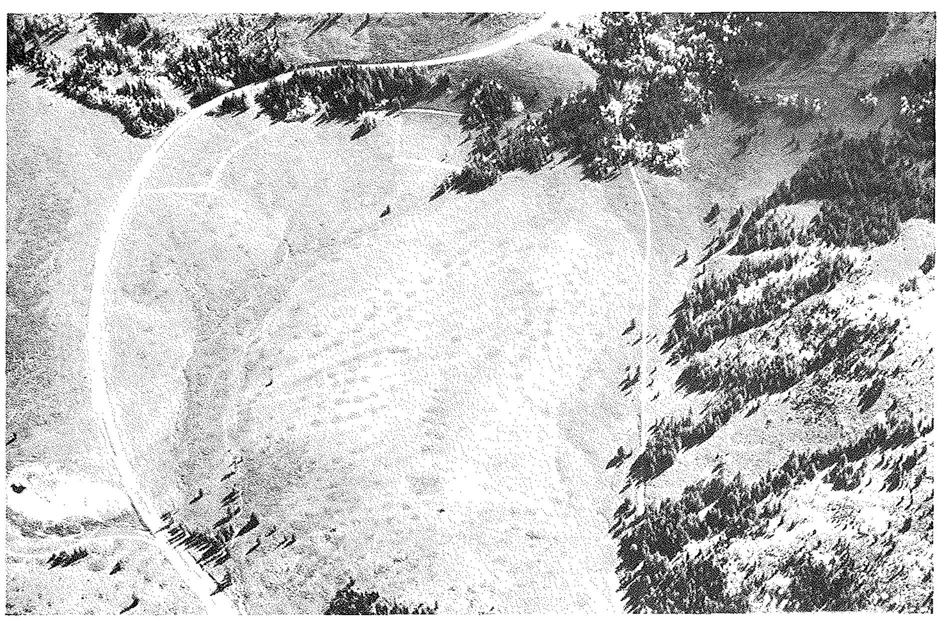

Figure 4. Aerial photograph of part of the patterned ground near Beaver Creek. Photograph taken in spring 1975. Road is U. S. Highway 89. *(photograph courtesy of J. V. DeGraff)*

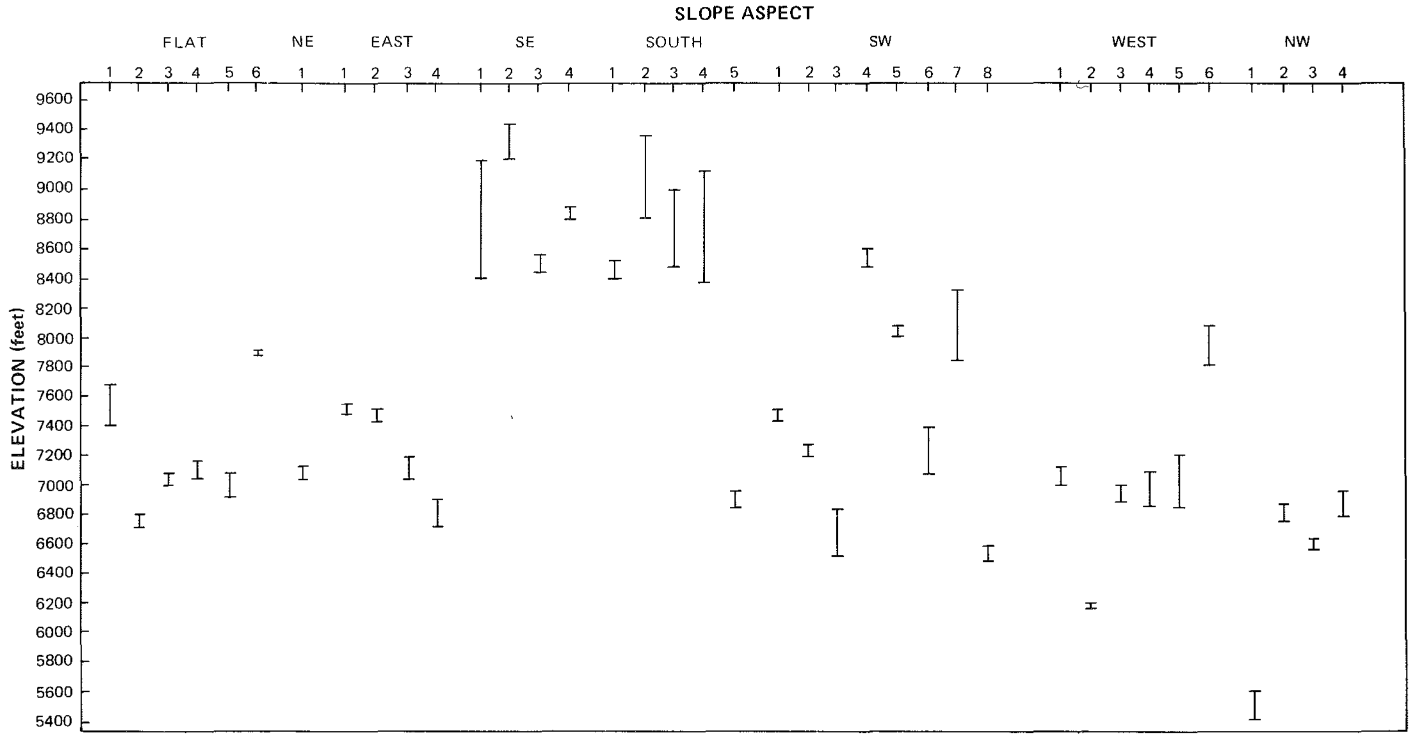

Figure 5. Graph compares the elevation of areas of patterned ground to slope aspect.

diameter is 40 feet (12 m), and total local relief is only 1 to 3 feet (0.3 to 0.9 m). The pattern is accentuated by vegetation. Sagebrush (*Artemesia tridentata*) and grasses generally cover the mounds. Mule ear dock (*Wyethia amplexicaulis*) is the principal vegetative cover in the intermound areas. It is this distribution of vegetation that produces the dark and light tones recognized on aerial photos.

Patterned ground is found through a wide range of elevations, on a variety of slope gradients, and on all slope aspects except north. It is generally on or near the summits of broad ridges, on open upland basins, and on similarly broad, flat, or gently sloping areas. The distribution of mounds is affected by slope. The mounds are evenly distributed on slopes of less than 10 percent. They are aligned in beaded stripes on slopes of more than 10 percent.

Ground observations show that the patterned morphology involves only regolith. Most of the mounds are composed of silt, sand, gravel, and some cobbles. There is little difference in grain-size range between the mound and intermound material. Only one area has coarser intermound material, but this circumstance may result from the flushing out of fine material from low intermound areas during spring snowmelt runoff (Southard and Williams, 1970). The material both in and among mounds appears to be derived from the same source, but the parent material varies among different localities. A variety of rocks including carbonate, conglomerate, quartzite, and mudstone is the parent material. In several areas, the patterned ground involves glacial till or stream alluvium.

PROBABLE ORIGIN

The areas of patterned ground are widely distributed within the study region. There appears to be no consistent relationship between location and factors such as physiographic setting and rock type. Graphic representation of the elevation ranges of patterned ground shows a seemingly random distribution. However, if the elevation ranges are grouped according to slope aspect, a distribution pattern becomes apparent (figure 5).

The elevation data for areas of patterned ground can be evaluated in several ways. The highest and lowest elevation values establish the limits of patterned ground for a particular slope aspect; however, these extreme limits do not necessarily indicate the elevation of most patterned ground on a particular slope aspect. A more representative value is the mean of the midpoints of the elevation ranges. This value better represents the average elevation at which patterned ground is found on a particular slope aspect. A graphic representation of the mean of the midpoints of the elevation ranges and the extreme values shows that distribution of patterned ground is related to slope aspect (figure 6).

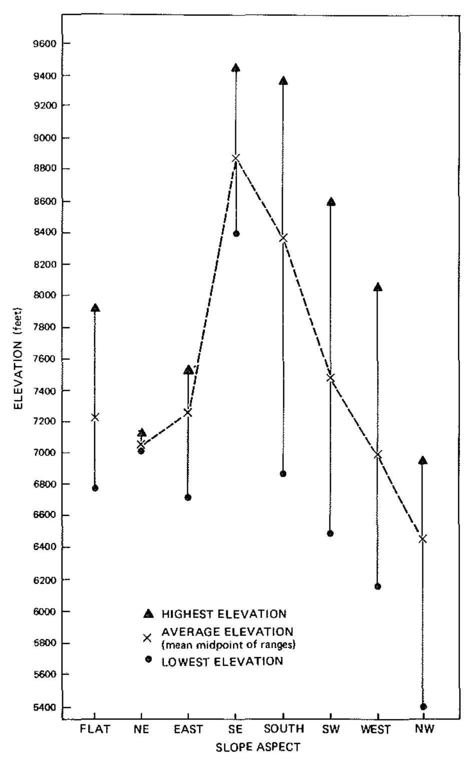

Figure 6. Graph illustrates the relationship between the elevation for the areas of patterned ground and the slope aspect.

The relation between elevation and slope aspect suggests that other factors influenced by the slope aspect may affect the distribution of patterned ground. One factor influenced by slope aspect is solar radiation. To evaluate solar radiation for the patterned ground, values for the average of annual potential insolation were obtained for each area from prepared tables (Frank and Lee, 1966). The values compensate for the latitude and slope of each area. Mean values for all areas on a particular slope aspect were calculated. The values of potential insolation for patterned ground on different slope aspects produces a curve similar to elevation values for different slope aspects (figure 7). It is clear that slope aspect is strongly correlated with the amount of annual potential insolation and the mean elevation for patterned ground.

Among the 2,359 acres (954 ha) of patterned ground, there is a variation in the percentage found on different slope aspects (figure 7). The percentage-of-area curve is similar to the curves for insolation and mean elevation values. The higher values coincide with flat, southwest, and west slope aspects. These higher values probably are related to daily variations in temperature. Higher daily temperatures occur on southwest- and west-facing slopes in the northern hemisphere. If the temperature is near freezing, this attribute of slope aspect increases the number of freeze-and-thaw cycles. In addition, the insulating effect of snow would be less on these slopes. Snow cover would be more readily removed or reduced at the beginning of winter or at the end of spring. Unlike east- or southeast-facing slopes, west- and southwest-facing slopes receive direct sunlight in the afternoon when diurnal temperatures are highest. This results in a greater number of freeze-and-thaw cycles on these slopes. The greater number of freeze-and-thaw cycles probably is responsible for the large total area of patterned ground on these slopes and on flat areas.

In examining the interrelationship of slope aspect, elevation, and insolation, the controlling variable appears to be temperature. Average temperatures can be determined for summer, winter, and annual periods. Dr. E. Arlo Richardson, Climatologist for the Utah State Department of Agriculture, provided the data and formulas necessary to compute these temperatures (oral communication, March 1975). The formulas compensate for differences in slope aspect, elevation, and the general temperature and pressure of the atmosphere. The values for the temperature periods were calculated for each slope aspect. All these temperatures are an average of temperatures in areas facing a particular direction. It is clear that this temperature variation is not directly related to the average of the annual potential insolation received on a particular area (table 1). A graphic representation of the annual, summer, and winter temperatures plotted against slope aspects shows a basically linear relationship for the areas of patterned ground (figure 8). The line generated for a particular time duplicated variations found in the other two lines. There are only minor differences in temperature among different slope aspects during a given time. This variance is visually represented in the graph of seasonal temperatures and slope aspect (figure 8). In addition, statistical analysis of seasonal temperatures confirms the small magnitude of the variation (table 2). The greatest range in temperature is 7.1°F for average summer temperatures. The smallest range in values is 4.3°F for average winter temperatures. Average annual temperatures have a range of 5.6°F. In every case, the small range of temperature is encompassed almost

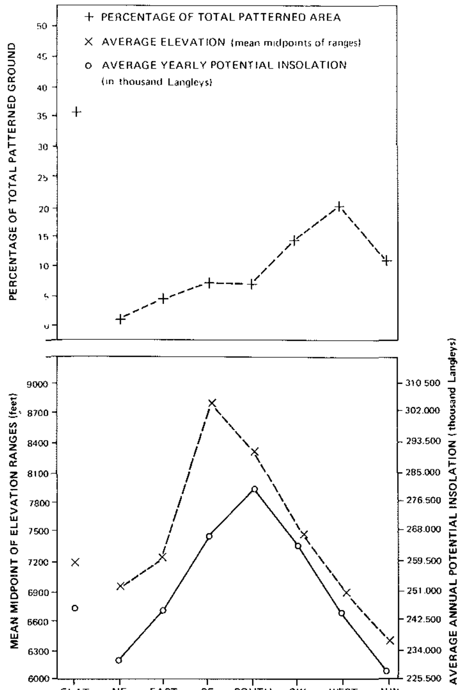

Figure 7. Graph represents the elevation, potential insolation, and percentage of patterned ground on different slope aspects.

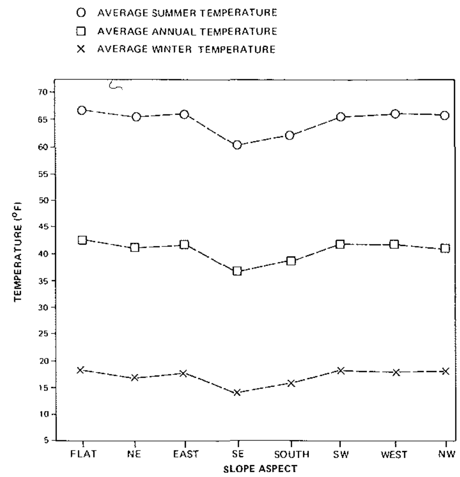

Figure 8. Graph compares the calculated temperature for patterned ground to slope aspect.

Table 1. Comparison of seasonal temperature values and slope aspect.

Slope aspect	Mean winter temperature (°F)	Mean summer temperature (°F)	Mean annual temperature (°F)	Mean annual potential insolation (thousand langleys)
Flat	17.6	67.1	42.4	247.228
Northeast	16.1	66.3	41.0	233.449
East	17.6	67.1	42.4	246.637
Southeast	14.4	61.0	37.9	269.026
South	15.9	63.2	39.8	282.320
Southwest	18.7	67.3	43.3	266.740
West	18.3	68.1	43.3	246.573
Northwest	18.4	68.8	43.5	228.664

Table 2. Statistical values for seasonal temperatures.

Season	Calculated temperature values: Temperature range (°F)	Mean temperature (°F)	Standard deviation (°F)
Winter	4.3	17.1	1.51
Summer	7.1	66.1	2.65
Annual	5.6	41.7	2.00

entirely within one standard deviation about the particular mean. The temperature data illustrate a balance between slope aspect, elevation, and insolation. This balance provides very nearly the same temperature range at each area of patterned ground. Thus, temperature probably is the primary factor affecting the location of patterned ground.

A secondary factor affecting the location of patterned ground is the soil type (DeGraff and Southard, 1976). Twenty-two areas of patterned ground are within the boundaries of a recent soil survey (Erickson and Mortensen, 1974). Patterned ground affects only nine soils among approximately thirty-two found in the study area. These nine soils compose varying amounts of the total soil area (table 3). They represent only 31.9 percent of the total soil in the study area. This predominance suggests that some mutually shared attribute or attributes are conducive to the formation of patterned ground. An examination of the nine affected soils shows that four encompass 84 percent of the patterned areas and 87 percent of the affected acreage (table 4).

An analysis of all affected soils reveals that each area contains a high percentage of silt. The amount generally ranges between 40 to 60 percent. Clay size particles are also present in amounts equal to or greater than 15 percent.

Grain size strongly affects the growth and form of ice in the soil. Silt is particularly susceptible to frost heaving (Penner, 1963). Within the soil the potential for attracting water to the area of freezing increases as grain size decreases (Washburn, 1973). Clay retains higher percentages of unfrozen water at low temperatures than coarser grain sizes (Washburn, 1973). Soils with both high percentages of silt and significant amounts of clay would be prone to frost heaving because of the high matric potential and amounts of available water. In addition, the majority of these soils contains high percentages of stones and cobbles. Studies in areas subject to frost heaving indicate that most frost-heaved stones are in material having a significant amount of fines (Washburn, 1973). It appears that the areas of patterned ground have formed where the temperature factor coincided with soil types prone to frost heaving.

Table 3. The relation of soil series to the areas of patterned ground.

Soil series	Total acreage within soil survey	Percentage of total acreage within soil survey	Number of patterned areas	Acres of patterned area	Percentage of patterned acreage
Yeates Hollow Extremely stony silty clay loam	8,110	6.0	3.0	416	23
Yeates Hollow Extremely rocky silt loam	5,400	4.0	9.0	281	15
Goring Silt loam	5,495	4.1	1.0	19	1
Goring-Obray association	8,440	6.3	5.0	448	24
Obray Silty clay	535	0.4	1.4	465	25
LaPlata-Obray association	4,457	3.3	0.1	11	1
Fitzgerald Extremely stony loam	3,040	2.3	1.0	58	3
Hübner Extremely stony clay loam	1,480	1.1	0.5	102	6
Lucky Star Silt loam	5,900	4.4	1.0	32	2
Total	42,857	31.9	22.0	1,832	100

The genesis of some periglacial patterned ground is believed to be differential frost heaving (Washburn, 1973). This origin is suggested for the patterned morphology in the Bear River Range. This conclusion is based on the morphology of the features and on the control that soil type and temperature have exerted on the location of patterned ground. The temperatures presently associated with the areas of patterned ground in the Bear River Range are too high for active frost heaving. In addition, the areas of patterned ground appear to be inactive. Erosion is currently modifying these areas. This observation is supported by the present field study and a previous investigation (Southard and Williams, 1970). If frost heaving were responsible for the creation of the patterned ground, it must have operated during a cooler period than the present.

Climatic conditions during the Pleistocene would be compatible with active frost heaving in the Bear River Range. Richmond (1965) suggested that the average summer temperature in the northern Rocky Mountains at this time would have been colder by about 17.5°F. The average winter temperature is assumed to have been about the same as present values (Leopold, 1951). Combining these values with the present temperature data provides an approximation of the thermal regime during the Late Pleistocene. The average winter temperature in the areas of patterned ground is about 17.1°F. If the 17.5°F value is subtracted from the currently calculated average summer temperature, the summer temperature during the Late Pleistocene would be about 48.6°F. The resulting average annual temperature would be approximately 32°F in the areas of patterned ground. This value would be very favorable for producing freeze-and-thaw cycles during diurnal temperature variations.

SUMMARY

Based on the analysis of patterned ground in the Bear River Range, a number of points seem clear. The areas of patterned ground are currently inactive forms subject to erosional modification. Their location is closely correlated with certain soils and a narrow temperature range. The soils are highly susceptible to frost heaving because of the high percentage of silt and clay and the presence of stones and cobbles. The temperature is a balance between eleva-

Table 4. Major soil series affected by patterned ground.

Soil series	Number of patterned areas	Percentage of patterned areas	Percentage of patterned acreage	Percentage of all soils affected by patterned ground	Percentage of total acreage within soil survey
Yeates Hollow Extremely stony silty clay loam	3.0	14	23	18.9	6.0
Yeates Hollow Extremely rocky silt loam	9.0	41	15	12.6	4.0
Obray Silty clay	1.4	6	25	1.2	0.4
Goring-Obray association	5.0	23	24	19.7	6.3
Total	18.4	84	87	52.4	16.7

tion, slope aspect, and insolation. Current temperatures are insufficient to create patterned ground. All these points suggest that frost heaving during a colder climatic time is responsible for the creation of patterned ground in these areas. Temperature values calculated for the Late Pleistocene would satisfy the temperature requirement for frost heaving. The subsequent renewed formation of patterned ground may have occurred during the Neoglacial (Williams, 1958b).

The Bear River Range is significantly farther south than the southern limit generally accepted for periglacial activity related to patterned ground formation during the Late Pleistocene (Washburn, 1973). Other investigations in the western Snake River Plain, southeastern Idaho, and in northern Utah have proposed a periglacial origin for features resembling patterned ground (Williams, 1958b; Malde, 1961, 1964; Williams and Southard, 1970). The suggested origin was primarily based on the morphology and composition of the features. The resemblance to recognized periglacial patterned ground is inconclusive. Establishing a periglacial origin based on morphology is difficult to support because of the number of examples that bear a similar appearance but are clearly not periglacial in origin. The pimple mounds of the Gulf Coast region are examples of similarly appearing but nonperiglacial features. Evidence supporting a periglacial origin for patterned ground in the Bear River Range is based on more than a resemblance to recognized periglacial patterned ground. In addition to morphological evidence, the location of patterned ground is clearly controlled by temperature. This indicates that temperature is important in the genesis of the feature. The current temperatures and the observable erosional modification show that formation took place under different climatic conditions. The approximation of Late Pleistocene temperatures favorable to periglacial activity indicates that genesis occurred at that time. Based on this evidence, the relict periglacial patterned ground in the Bear River Range was created during the Late Pleistocene.

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REFERENCES

American Geological Institute, 1974, Glossary of Geology: American Geological Institute, Washington, D. C., 805 p.

DeGraff, J. V., 1975, Inactive patterned ground, Bear River Range, north-central Utah: Geological Society of America, Abstracts with Programs, v. 7, p. 1048.

DeGraff, J. V. and A. R. Southard, 1976, Soils influence on the distribution of patterned ground in the Bear River Range, north-central Utah: Western Society of Soil Science, Program and Abstracts, p. 15.

Erickson, A. J. and V. L. Mortensen, 1974, Soil survey of Cache Valley area, Utah: U. S. Soil Conservation Service and Forest Service, 192 p.

Frank, E. C. and R. Lee, 1966, Potential solar beam irradiation on slopes: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station Research Paper, RM-18, 116 p.

Leopold, L. B., 1951, Pleistocene climate in New Mexico: American Journal of Science, v. 249, p. 152-168.

Malde, H. E., 1961, Patterned ground of possible solifluction origin at low altitudes in the western Snake River Plain, Idaho: U. S. Geological Survey Professional Paper 424-B, p. 170-173.

_____1964, Patterned ground in the western Snake River Plain, Idaho, and its possible cold-climate origin: Geological Society of America Bulletin, v. 75, p. 191-208.

Penner, E., 1963, Frost-heaving in soils, *in* Proceedings, Permafrost International Conference, National Academy of Sciences–National Research Council, Washington, D. C., p. 197-202.

Peterson, D. L. and S. S. Oriel, 1970, Gravity anomalies in Cache Valley, Cache and Box Elder Counties, Utah and Bannock and Franklin Counties, Idaho: U. S. Geological Survey Professional Paper 700-C, p. 114-118.

Richmond, G. M., 1965, Glaciation of the Rocky Mountains, *in* The Quaternary of the United States: H. E. Wright, Jr. and D. G. Frey [editors], Princeton University Press, Princeton, New Jersey, p. 217-230.

Stanley, W. D., 1972, Geophysical study of unconsolidated sediments and basin structure in Cache Valley, Utah and Idaho: Geological Society of America Bulletin, v. 83, p. 1817-1830.

Southard, A. R. and J. S. Williams, 1970, Patterned ground indicates unstable landscapes: Journal of Soil and Water Conservation, v. 25, p. 194-196.

Washburn, A. L., 1973, Periglacial processes and environments: St. Martins Press, New York, 320 p.

Williams, J. S., 1948, Geology of the Paleozoic rocks, Logan quadrangle, Utah: Geological Society of America Bulletin, v. 59, p. 1121-1164.

_____1958a, Geologic atlas of Cache County: Utah Geological and Mineral Survey Bulletin 64, 98 p.

_____1958b, Stone stripes at low altitudes, northern Utah [abstract]: Geological Society of America Bulletin, v. 69, p. 1749.

_____1962, Lake Bonneville: Geology of southern Cache Valley, Utah: U. S. Geological Survey Professional Paper 257-C, 152 p.

Williams, J. S. and A. R. Southard, 1970, Stone stripes at low altitudes in north central Utah and southeastern Idaho [abstract]: American Quaternary Association, Abstracts, First Meeting, p. 152.