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FURTHER OBSERVATIONS ON SOIL FREEZING IN THE PACIFIC NORTHWEST

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Frost observations during the winter and spring of 1949-1950 indicated that pronounced soil freezing conditions existed in the ponderosa pine, lodgepole pine, grass and brush types in eastern Oregon and Washington 2/. Accordingly, a study was designed to determine the occurrence and character of frost under these widespread forest and range types. This paper presents a progress report of observations on soil freezing conditions in these cover types in eastern Oregon during the winter and spring of 1950-51.

PROCEDURE

The area selected for study lies about 15 miles northwest of La Grande, Oregon on U. S. Highway 30. This location was chosen because

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1/ The author's thanks are extended to G. A. Garrison and E. W. Stevenson for assistance in establishing the study plots and observing the freezing conditions throughout the winter and spring of 1950-1951.

2/ Hale, C. E. "Some Observations on Soil Freezing in Forest and Range of the Pacific Northwest", Research Note No. 66, Pacific Northwest Forest and Range Experiment Station, July 1950.

it remained accessible throughout the winter and all the predominant soil and cover types to be investigated were contained within a small area.

All of the soils in the area are of volcanic origin. On untimbered ridge tops a shallow red clay soil has developed over a fractured basalt. This soil supports very little vegetation, most of which is in the form of a poor grass and weed cover. The southeast slopes generally have shallow, brown soils with an open grassland type of cover. The south and southwest slopes commonly have a deep, medium-textured, brown forest soil supporting open stands of ponderosa pine. The north and east slopes are mostly covered with pumice soils. These, it is believed, were derived from volcanic ash, carried by wind from the southwest. They support fairly dense mixed fir and lodgepole pine stands.

The same procedure was followed for establishing the plots and observing the freezing conditions as was used in the 1949-1950 study. Each individual plot consisted of a circular area, approximately one acre in size, wholly within one particular forest or range type. The center of each plot was marked with a tagged tree, stake, or mound of rocks and used throughout the observation period as a reference point from which to locate the actual sampling spots during the periodic observations. When the original plot was established, a pit was dug to the C horizon and the soil profile described. Data on topography, vegetation, and geology were also recorded at this time. Each time the plots were visited during the periodic observations, the soil surface and humus were examined for frost occurrence at paired spots. On the first visit these were located one pace north and south of the plot center; the second time, one pace east and west of the center. This procedure was followed throughout the observation period, increasing the distance from the center by one pace each time the plot was visited so that the soil and snow remained undisturbed where the observations were made.

The periodic observations at each plot included snow depth; depth, type, and location of frost in the soil profile; and soil moisture.

Frost structure was classified into the three general types described by Post and Dreibelbis 3/ in Ohio, as, "concrete," "honeycomb," and "stalactite." "Concrete" frost is characterized by many very thin "ice lenses," small crystals, and an extremely dense structure; "honeycomb" frost has a loose porous structure and permits free vapor movement, while "stalactite" frost structure is characterized by many small needle-like ice crystals aligned vertically and connecting the heaved surface to the soil below. Stalactite frost, when partly thawed and remelted, often has impermeable panes or layers of ice at the base. An additional type recognized in this study was granular frost, found generally in the litter and F horizons in

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3/ Post, F. A., and Dreibelbis, F. R. "Some Influences of Frost Penetration and Microclimate on the Water Relationship of Woodland, Pasture, and Cultivated Soils." Soil Science Society of America, Vol. 7: 95-103, 1942.

the forest and characterized by scattered granules of ice binding the litter and F particles together. Granular frost appears very porous and is easily crushed in the hands. The moisture content of the soil at the surface or below the frost, if the ground was frozen, was estimated by squeezing a small sample of the soil in the hands. The soil was then arbitrarily classified as dry, slightly moist, moist, or wet.

Three study plots were established on the open ridge tops, three on the shallow, brown soils in open grasslands, three in ponderosa pine, and four in lodgepole pine. The descriptive data for each plot are shown in tables I and II. All plots were established in November and visited bi-weekly throughout the winter and spring. Observations were continued until the ground became free of frost and snow and no further freezing was expected.

FINDINGS

During the late fall and early winter the mean temperature remained well above normal. The minimum temperature occasionally went below freezing during the night, but usually remained above 32° during the day. Precipitation was light during this period and considered below normal for the area. Occasionally a trace of snow covered the ground, but this soon disappeared with moderating temperatures. The relation of frost and snow depths to cover types is shown in Figure I. During this early period some concrete frost formed in the surface soil of the lodgepole pine stands, on the north slopes, where the forest canopy was dense enough to protect the ground surface from the sun. This frost remained for several days. Beside this persistent frost, the ground froze at night wherever there was enough moisture in the ground, regardless of cover type. This frost was of a porous type and usually melted by noon. It assumed a stalactite form and heaved the surface soil and grasses into pedestals. Some of these pedestals were as much as two inches high. This condition occurred on both the untimbered (or open) ridgetops in the red basalt soils, and the shallow brown soils having scanty grass cover. Observations, however, indicated that it was most prevalent on the untimbered ridgetops. The brown forest soils in the ponderosa pine stands remained free of frost during this period. This may be attributed to southerly exposure, fair pinegrass cover, and the open character of ponderosa pine stands.

By midwinter the average temperature still remained above normal, although subfreezing and even subzero temperatures were experienced quite frequently. Precipitation, mostly in the form of snow, was above normal for the area. By midwinter the average snow depth on the plots was about 10 inches. This varied from no snow on the windswept, exposed places and near the base of trees where the snow had melted, to well over a foot of snow in drifts. Occasional warm spells followed by subzero weather caused the snow to melt and refreeze with some snow-melt water entering the soil profile and freezing into an impermeable ice

TABLE I
FOREST AND GROUND COVER DATA

Plot No.	Elev. feet	Aspect	Slope %	Forest Cover	Age	Density %	Ground Cover	Density %
101	3,400	NE	3	Lodgepole pine	60	60	Pinegrass Spirea Oregon grape	0-25
102	3,400	E	10	" "	60	80	Pinegrass	10
103	3,400	E	12	" "	60	80	"	15
104	3,400	S	6	Non-forest	-	-	Bluegrass - Bluebunch wheatgrass	10
105	3,400	S	6	" "	-	-	" "	10
106	3,400	S	3	" "	-	-	Bluegrass Cheatgrass	0-15
107	3,500	S	2	" "	-	-	Bluegrass Cheatgrass Bluebunch wheatgrass	5
108	3,500	S	2	" "	-	-	" "	5
109	3,500	-	0	" "	-	-	" "	5
110	3,500	SW	3	Ponderosa pine	150	45	Pinegrass Elk sedge	15
111	3,600	S	6	" "	130	50	" "	15
112	3,500	NE	20	Lodgepole pine Douglas-fir Larch Ponderosa pine	60	75	" "	5
113	3,300	SW	20	Ponderosa pine	100	65	" "	5

TABLE II
SOIL PROFILE DESCRIPTIVE DATA

Plot No.	Humus Type	Drainage	Texture	Horizon Depth (inches)				
				L	F	A	B	C
101	Firm mull	Well drained, deep	Medium	.5	T	.7	20	21+
102	Firm mull	Well drained, deep	Medium	.5	.5	.5	20	22+
103	Firm mull	Well drained, deep	Medium	.3	.5	1.5	20	22+
104	None	Poorly drained	Heavy	.0	.0	.0	11	Rock
105	None	Poorly drained	Heavy	.0	.0	.0	8	Rock
106	Medium mull	Poorly drained	Heavy	T	T	1.0	10	Rock
107	None	Poorly drained	Heavy	.0	.0	T	4	Rock
108	None	Poorly drained	Heavy	.0	.0	T	4	Rock
109	None	Poorly drained	Heavy	.0	.0	T	4	Rock
110	Medium mull	Well drained, deep	Medium	.7	.5	1.3	12	15+
111	Firm mull	Well drained, deep	Medium	1.0	.5	1.0	10	12+
112	Medium mull	Well drained, deep	Medium	.3	.7	1.0	12	14+
113	Medium mull	Well drained, deep	Medium	1.0	1.0	4.0	12	18+

layer just below the soil surface. The lodgepole pine plots still remained frozen throughout the midwinter period. Most of the freezing was of a granular type frost with occasional spots of impermeable concrete frost where the snow was shallow or absent. The untimbered (or open) ridgetop and the open grassland plots were generally free of frost during the mid-winter period. Occasionally one-half inch of concrete frost was found in the surface horizon, but the area of this frozen ground was not extensive. Spotty areas of concrete frost also formed in the ponderosa pine stands during this period, but here again the duration and areal extent of frozen ground was insignificant.

Average temperatures during late winter and early spring still remained above normal, although subfreezing temperatures were experienced nearly every night. Precipitation in the form of snow was heavier than normal during late winter, but early spring precipitation remained about normal. As the snow depth began to decrease, more and more soil freezing occurred, largely the result of the subfreezing nocturnal temperatures. Frost depth in the lodgepole pine stands increased to as much as eight inches where the snow was shallow or absent, and as much as two inches where the snow was deeper. These north exposures were shaded during the day and did not begin to thaw until minimum temperatures began to approach 32° later on in the spring. Impermeable frozen ground could be found in the dense lodgepole pine stands well into April. The untimbered (or open) ridgetop and the open grassland plots continued to have patchy spots of permeable frost where the snow was shallow. Later on, as the snow cover on these flat and southerly exposures melted the surface, soil froze whenever there was enough moisture present and the temperature went below freezing. This frost, however, was of short duration, usually melting by noon, and appeared very porous. Considerable damage occurred to the young grass seedlings, which were showing spring growth during this period, due to continued heaving and settling. This condition continued as long as daily snow melting and nocturnal freezing temperatures existed. In the ponderosa pine stands, concrete frost occurred in the snow-free shady areas well into the spring. However, the areal extent of frozen ground continued to remain small.

By the middle of April no snow or frost existed on any of the plots. Excess ground moisture from snow melt was gone. No further frost observations were made on any of the plots. Soil freezing may still be expected, however, whenever subfreezing temperatures follow spring rains.

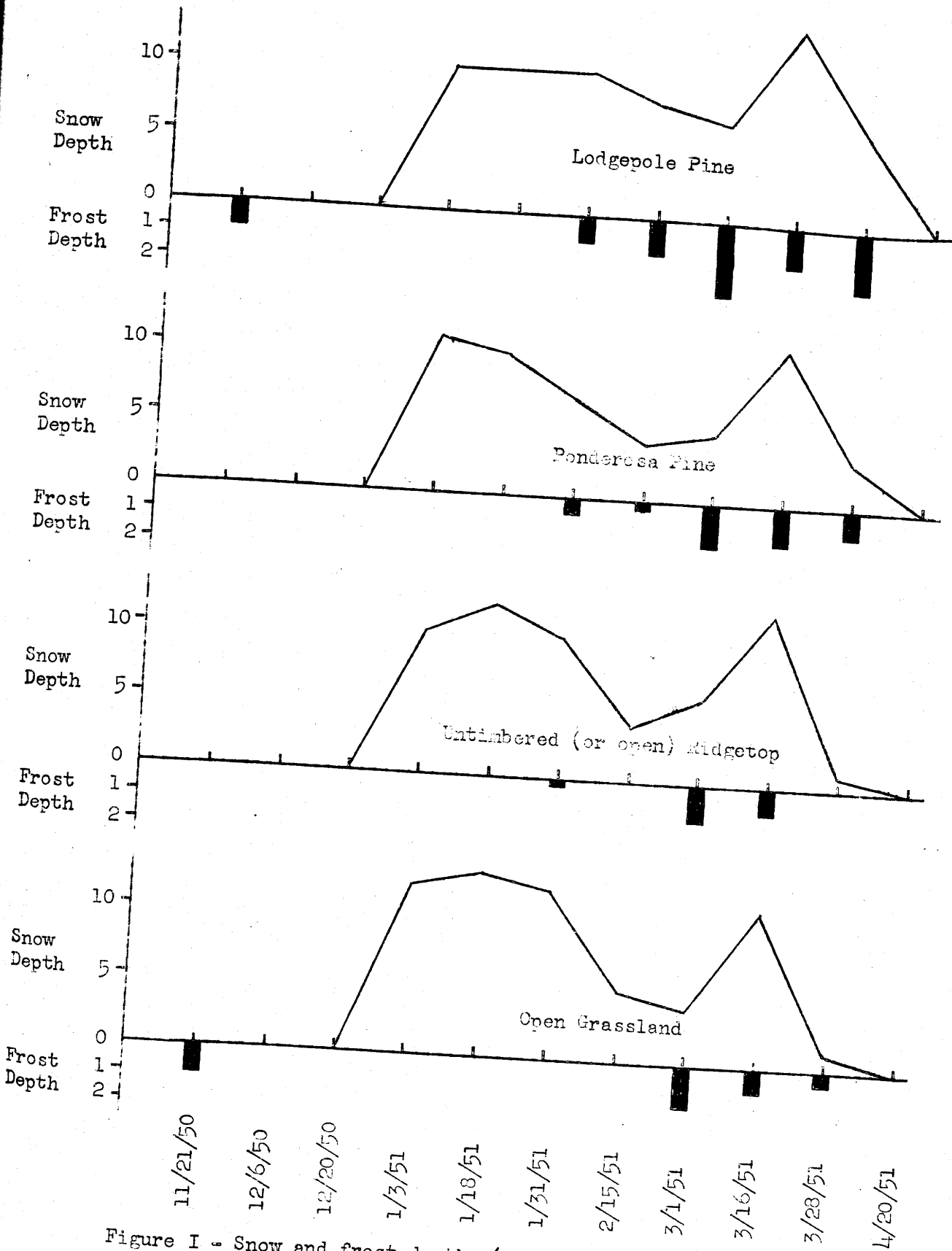

Figure I - Snow and frost depths (in inches) observed during the periodic investigations.

SUMMARY

This study was designed to determine (1) the occurrence and character of frost in the predominant range types of eastern Oregon, (2) the relationship of frozen ground to runoff at the time of the spring melt period, (3) the factors which affect the occurrence and character of frost.

The results of this study can be summarized as follows:

(1) Impermeable frost occurred on all four of the soil-cover complexes at one time or another throughout the winter.

(2) Mixed fir and lodgepole pine stands which predominantly occupy pumice soils on north slopes had more frequent occurrence and longer duration of impermeable freezing than any other soil cover complex studied.

(3) Impermeable freezing was observed least often on south slopes, covered with either open stands of ponderosa pine or grass.

(4) Soil depth and drainage characteristics appeared to be less important than aspect and cover in determining frost occurrence.

(5) Snow depth, which was found to be influenced by aspect and cover, appears to be an important factor in limiting the occurrence and depth of impermeable freezing.

(6) At no time during the entire observation period were there extensive areas of impermeable frozen ground.

(7) Surface runoff over frozen ground was not noticeable, although standing water was present in depressions surrounded by impermeable frost.

(8) Stalactite frost accompanied by frost heaving was most common in early winter and late spring and was usually due to nocturnal freezing. This frost was of a porous type and was usually of short duration. It occurred most commonly on south slopes and shallow soils.

CONCLUSIONS

From this study we can conclude that under normal winter and spring conditions soil freezing takes place in all the predominant soil cover complexes of the range lands in eastern Oregon.

Because of the discontinuity and limited duration of impermeable frost, its effect upon snow-melt runoff under average conditions does not appear to be an important factor hydrologically.