INFLUENCE OF BURNING ON THE SOIL IN THE TIMBER RANGE AREA OF LAC LE JEUNE, B. C.

by

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ABSTRACT

In the forest used as range several problems are encountered: (1) accessibility of ranges and (2) invasion of open or lightly timbered ranges by forest growth.

For many years stockmen have advocated the use of controlled burning to overcome these problems. However, at present the value of fire for range improvement in this region is not definitely known. Experimental burns have been made to study the effect of fire on vegetation, but little or no work has been done to determine the effect of fire on the soil in such forest range areas.

Accordingly, this investigation was initiated in order to determine to what extent soil characteristics in the forest range about Lac Le Jeune have been altered by forest fires.

As a result of forest fires the following changes occurred in the soil of the lodgepole pine, Douglas fir and mixed stands of lodgepole pine, Douglas fir, and spruce forests near Lac Le Jeune.

(1) A reduction in percent porosity of the top 0-3 inches of soil due to the destruction of both the porous organic horizon and the crumb structure of the upper portion of the B_2 horizon. A further reduction was the result of the soil pores being clogged by ash and suspended soil particles.

(2) Increased percentage of capillary pore space of the 0-3 inch layer because of the destruction of the larger pores in the Ao horizon and the compaction of the bare soil by rain.

(3) A decrease in the percentage of non-capillary pore space or air volume in the 0-3 inch layer resulting from the destruction of the Ao with large pores. The compacting effect of rain drops on the crumb structure of the B_2 horizon also aided in decreasing the non-capillary porosity.

(4) An increase in volume weight of the 0-3 inch layer due to compaction and destruction of the less dense Ao.

(5) A decrease in the infiltration rate due to compaction and destruction of soil structure.

(6) An increase in soil temperature at a depth of 3 inches resulting from the addition of charcoal which absorbs heat and the destruction of vegetation and forest litter which normally serve as insulating agents.

(7) An increase in pH of the Ao and in some cases of the A_2 as a result of the release of basic minerals from the ash, and an indication that the basic minerals may be leached downwards to the A_2. The pH of the Ao decreased 3 or 4 years after the fire.

(8) A decrease in the organic matter content of the duff which had not been totally destroyed by fire. Below the Ao no change occurred.

(9) A decrease in the total nitrogen content of the Ao due to volatilization of nitrogen during the fire. No definite trend could be established below the Ao.

(10) An increase in total phosphorous in the Ao because of the release of this element from the litter.

(11) A reduction in the carbonic acid soluble phosphorous in the Ao due to its combination with the excess calcium

to form an insoluble compound. Similiarly a decrease in CO_2 soluble phosphorous occurred in the A_2.

(12) A decrease in CO_2 soluble potassium in the Ao and A_2 resulting from unrestricted leaching. An increase in CO_2 soluble potassium in the B_2 horizon.

(13) An increase in CO_2 soluble calcium in the Ao of recent burns due to the presence of large amounts of calcium in the ash. Apparently 8 or 9 years are required before all the added calcium is leached to lower horizons.

(14) An increase in CO_2 soluble magnesium in the Ao of the recent burns. The content decreased in the Ao of the older burns because of increased leaching.

(15) A decrease in CO_2 soluble nitrates in the Ao. An increase in nitrates in the B_2 is probably a result of increased nitrification at the soil surface followed by considerable leaching.

(16) A reduction in the base exchange capacity of the Ao. An increase in exchangeable calcium in the Ao and A_2. An increase in exchangeable magnesium in the Ao, A_2, and B_2 horizons. An increase in exchangeable potassium in the Ao, A_2, B_2, and B_3. An increase in percent base saturation in the Ao, A_2, B_2, and B_3 horizons.

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INTRODUCTION

Forests occupy 95 percent of the interior of British Columbia with grassland and alpine tundra making up the remainder (136). Most of the drier and more open forested areas are valuable for range purposes and of an estimated 10 to 15 million acres of usable forest range, about 7 million acres are now being grazed (136).

Two of the more important problems encountered in the use of forest range are: (1) accessibility and (2) invasion of open or lightly timbered ranges by tree growth.

In the Douglas Fir zone of the Southern Interior where many stands of lodgepole pine have been killed by bark beetles or by fires, large areas are covered by masses of fallen trees. Such locations are no longer easily grazed because of the inability of stock to move about readily and the difficulty in managing herds. At the same time the routes to more desirable range areas are frequently obstructed by these barriers. How to overcome this problem, serious as it is in some localities, has baffled the ingenuity of Government officials and ranchers alike.

Some of the open or semi-open areas are being invaded by tree growth which causes a reduction in the grazing capacity of forest range. Such an invasion may be the result of heavy grazing or the natural return of trees to areas deforested in the past by repeated fires.

For many years stockmen have advocated the use of controlled burning to overcome such grazing problems. There is little doubt that such a practice provides a means for disposing of unwanted vegetation, but at the same time sets up conditions for accelerated erosion which may result in extreme damage. Experimental burns have been provided on occasion in order to determine the merits of periodic firing but frequently the conclusions have been based largely on appearance of the subsequent vegetation rather than on changes in the soil itself. Thus the data as they appear in the literature are rather contradictory. This investigation was undertaken therefore in an attempt to harmonize these apparent contradictions and to determine specifically to what extent soil characteristics in the forest range about Lac Le Jeune have been altered by forest fires.

REVIEW OF LITERATURE

There is an extensive literature relative to the influence of burning on forest grazing lands and yet the evidence is not conclusive insofar at least as effects on soil are concerned. This is unquestionably due to the difficulty in interpreting observations and in integrating as between the numerous factors contributing to an observed effect.

In order to simplify the presentation the review of literature is being presented under the following headings:
(1) effect on the amount of unincorporated organic matter,
(2) effect on physical properties,
(3) effect on chemical properties, and
(4) effect on soil organisms.

Effect of Fires on the Amount of Unincorporated Organic Material

The effect of fire upon the thickness of the forest floor varies inversely with the intensity and frequency of burning (18). Alway and Rost (1), reported that in the case of severe fires the mineral soil was exposed over extensive areas, and in single light fires the organic layers below the litter were little affected.

According to Anon (3), a series of fires in the Great Dismal Swamp in North Carolina had brought about destruction of peat to a depth of 10 or more feet in places.

In the Adirondacks, Diebold (27), found that as a result of fires the median depth of forest floor in burned areas of the spruce-fir type was only 2 inches as compared to 14 inches in the unburned sites.

Burns (18), observed in New Jersey, almost complete destruction of the unincorporated organic matter.

Donahue (28), stated that in soils under shortleaf and longleaf pine stands the total amount of organic matter was twice as great in areas long unburned as it was where frequent burning had occurred. Summer fires destroyed more organic matter than did spring fires.

On a described loblolly pine burn Elliott and Pomeroy (34), noted that all the surface litter was destroyed. In the places where the fire was the hottest only 50% of the duff and surface root mat was burned. Over most of the area the duff remained intact.

Harper (53), in a study on longleaf and slash pines noted that the dead and live vegetative cover of the soil was removed by fire.

Fires on steep mountain slopes in central Arizona completely burning the needle litter and duff was observed by Hendricks and Johnson (57).

Heyward et al (62), and Heyward (65), described the differences between the organic layers under longleaf pine stands protected from fire for at least ten years and under stands subjected to frequent burning. As a result of frequent burning the Ao vanished on many soils. On areas protected from fire the litter was .75 - 1.5 inches thick, with a gradual transition to an F layer .5 - 1.5 inches thick, which generally rested upon mineral soil. A thin H layer was present in a few spots.

In India, Hole (69), reported that burning of grasslands was injurious owing to the destruction of all humus and organic debris.

Isaac and Hopkins (73), showed that heavy slash fires destroyed 89 percent of the organic matter in the duff layer of western Washington soils.

In pot culture experiments with undisturbed forest soil, Lunt (89), showed that the Ao was removed by burning.

McCulloch (94), stated that fire may destroy as much as 25 tons of organic material per acre.

Minckler (100), reported that in the spruce-fir type at high elevations in the Southern Appalachians, fire has destroyed the organic soil on certain areas removing as much as 2 feet of organic matter and leaving bare rock exposed.

Studies carried out by Rideout (112), on Vancouver Island reveal that over much of the burned sites the duff layer has been completely removed.

Many other workers such as Arend (5), Chapman (19), Copley et al. (22), Fowells and Stephenson (39), Frothingham (42), Heiberg (55), Rowe (113), Worley (148), and Elwell et al (36), although not presenting data did recognize that fire destroyed unincorporated organic matter.

Effect of Fires on Physical Properties

The marked change brought about in the physical properties of soils is largely due to the removal of unincorporated organic material and exposure of the mineral soil fraction to the elements. Lowdermilk (87), stated that if the forest litter was destroyed the consequent exposure of the soil greatly increased the amount of eroded material and reduced the absorption rate of the soil. Suspended particles in run-off water from bare soil filtered out at the surface and thereby sealed the pores and seepage openings into the soil sufficiently to account primarily for the marked differences in the rate of absorption between bare and litter covered soils.

Temperatures during fires.

In a study of fires on the central coastline of New South Wales, Beadle (11) reported that the surface temperature varies from 81 to 213°C. At a depth of one inch the temperature does not exceed 67°C. Under extreme conditions the temperature at a depth of 1 inch exceeds 250°C., while at a depth of 1 foot the temperature is 43 to 50°C. The probable maximal temperature during a severe fire at a depth of 1 inch is 111 - 114°C., at 3 inches 59 - 67°C.

Elpatievsky et al. (35), showed that burning of huge piles of slash in spruce and pine forests in Russia caused temperatures in the upper horizon of sandy mineral soil to rise to

260°C. (500°F.). The depth of penetration of heat into the sandy soil was much greater than into heavy textured soil. In studying the burning of heavy slash of Douglas fir, cedar, and hemlock, Hofmann (68), observed the following temperature extremes; 30 inches above the ground, 850°F.; under 3/4 inch of duff, 120°F.; in mineral soil under 1 1/2 inches of duff, 60°F.; and under 1 inch of exposed mineral soil, 75°F. Isaac and Hopkins (73), while investigating the effects of slash burning on the forest soil of the Douglas fir region recorded a maximum temperature of 1,841°F., just above the duff surface. The maximum temperature 1 inch below the duff was 608°F.

Heyward (66), while studying soil temperatures in the longleaf pine region found that at a depth of 1/8 of an inch to 1/4 of an inch, the majority of readings ranged between 150° and 175°F. These temperatures persisted for 2 to 4 minutes after which they declined rapidly. The maximum temperature reached was 274°F. Soil temperatures at the 1/2 inch depth were much lower than those at 1/8 inch. 195°F. was the highest temperature observed at the 1/2 inch level. At depths of 1 inch only slight increases in temperature were recorded.

Temperatures of burned-over soil.

In comparing soil temperatures of burned and unburned chaparral areas of California, Bauer (10), found the soil temperatures were considerably higher on the burned areas, especially in the summer months. Also in California, Hervey (59), found that burning significantly raised the temperature at the soil surface and also at a depth of 2 1/2 inches.

Investigations by Boyce (14), point out that fire causes the formation of charcoal in the soil. The presence of charcoal brings about the increase in the temperature of the exposed soil. Isaac (72), noted that Douglas fir seedlings were dying on recently burned areas. He stated that blackening of the soil surface due to burning caused greater soil temperatures. Blackening of the soil surface as a result of the addition of charcoal through burning was also found by McArdle and Isaac (93), to give a much warmer soil. With an air temperature of 90°F., the average soil temperature on the surface of yellow mineral soil was 132°F. The average temperature of soil covered with a thin layer of burned duff had a surface temperature of 150°F. McCulloch (94), noted also that fire produces charcoal on the ground. The addition of charcoal is sufficient to raise the surface soil temperatures as much as 15 or 20 degrees above the unburnt soil. The effect of charcoal in raising the soil temperature was also noted by Tryon (139).

Greene (46), observed in the longleaf pine belt that the average maximum temperature on the burned area was 5.5°F. higher than on the unburned area. A study by Harper (53), in the longleaf and slash pine areas showed that the soil temperatures rise slightly higher on a freshly burned area. Wahlenberg's (142), investigations in the longleaf pine belt point out that the spring temperatures to a 3 inch depth were more by 1° to 6°F. on burned soils. Further work in the longleaf pine lands by Wahlenberg et al. (144), revealed that soil temperatures may average as much as 5.5°F. higher for burned soils, possibly largely due to the heat-absorbing capacity of charcoal.

Hensel (58), observed that the burnt grasslands in Kansas at a depth of 1 inch had a mean maximal soil temperature 12.1°F higher than the unburned grasslands. The mean temperature was 4.1°F. higher on the burned areas. At a depth of 3 inches the mean maximum temperature was 3.6°F. higher and the mean minimum temperature was 4.2°F. higher.

Research by Isaac and Hopkins (73), revealed that fire changed the soil's capacity to absorb heat. At an air temperature of 85°F., the surface temperature of yellow mineral soil may rise to 125°F. or higher. The surface temperature of black charred soil may rise to 608°F.

Soil temperatures in areas which had been burnt and in areas under forest were recorded by Kittredge (78). The temperature at the 1 inch depth was 70°F. under forest and 90°F. in a corresponding burned over area.

In the Duke forest, Pearse (103), observed that temperatures on the surface and at the 3 inch depth in a plot burned over at intervals for five years were more extreme than those in an adjacent undisturbed plot.

Phillips (109), studies in the savanna of South Africa showed that higher temperatures occurred during the day in the 0-6 inch layer of fired soil than in the non-fired soil; during the night, temperatures were lower in the burned soil.

Shirley (124), found no difference in surface temperatures between burned and unburned plots in a jack pine stand during the second growing season after a light fire.

An increase in soil temperatures as a result of burning was recognized by Sims et al. (125).

Moisture Relations.

During an investigation of moisture relations in California chaparral, Bauer (10), recorded that on burned areas moisture in the upper soil layers dropped below the wilting percentage during part of the growing season. In the deeper layers, moisture remained above the wilting point throughout the period. California studies by Hervey (59), show that burning did not significantly affect soil moisture during the growing season. Further investigations in the burned chaparral lands of California by Sampson (117), show that the moisture in the upper layer of the soil is apparently depleted more rapidly in burned than in unburned chaparral because of increased evaporation from exposed surfaces and differences in vegetative cover. The level of soil moisture at greater depths was higher in burned than in unburned areas. This was explained by the presumed lack of living plant roots in the lower soil levels of burned areas.

Burns (18), found that annual burning for long periods caused slight increases in field capacity. This increase was probably a result of added charcoal. Tryon (139), also found that charcoal has an affect on moisture relations of soil; it increased the water holding capacity of sandy soil but reduced that of clay.

Garren (43), stated soils of frequently burned longleaf forests show lower soil moisture than comparable unburned soils. Whereas no difference in soil moisture was found by Greene (47), when he compared annually burned plots and unburned plots in longleaf pine forests. Similarly Wahlenberg et al. (144), noted no significant differences in soil moisture between annually burned areas and unburned areas in longleaf pine forests. Heyward (67), also working with burned and unburned longleaf pine forest soils presented data showing that the unburned soils were moist at the 0-2 inch and 4-6 inch depths. In the unburned soils there was as much as 52 percent more moisture in the 0-2 inch depth. Heyward stated that there were no differences in wilting percentage and in moisture-holding capacity between these burned and unburned soils.

Alway and Rost (1), found no significant effect of fire upon the moisture equivalent of the burnt mineral soil.

Work done by Eden (31), in the English heathland demonstrated that moisture in the surface soil of burned areas was less than in unburned soils, whereas in the lower horizons the burned soil was more moist than the unburned soil.

In the Leningrad region, burned soils generally were found to have more moisture than the unburned soils according to studies by Gulisashvili and Stratonovitch (49).

Studies by Hofmann (68), in the Pacific Northwest revealed that fire had a drying effect on the soil. The moisture content of burned soils was reduced in the mineral soil at a depth of one inch and in the mineral soil under 3/4 had 1 1/2 inches of duff. Similarly a reduction in moisture holding capacity and field capacity in the Douglas fir regions was reported by Isaac and Hopkins (73), to be a result of burning.

The moisture contents in soils under forests and under burns 24 hours after a rain were compared by Kittredge (78). Under forest the moisture content was 26.8 % while the soil under burns contained 24.7 % moisture.

Phillips (109), stated that in evergreen forests in South Africa firing conserved moisture in the soil below the 0-6 inch layer but that losses of moisture from the upper 6 inches of burned soil were considerable. However in the savanna type (grassland containing scattered trees) fires reduced the moisture content of the upper 6 inches of soil and did not alter the moisture content of the layers below.

Rideout (112), observed that there was a reduction in the moisture holding capacity of the surface soil immediately following burning.

Texture and Structure

Auten (7), established the fact that forest soils lose their porosity when the litter has been removed by fire. Further studies by Auten (8), in the Ozarks substantiated the foregoing finding. He explained the loss of porosity in the soil as being a result of compaction of the bare surface soil which occurs during rainfall and by the sealing of soil pores as the finer particles are washed downward. Research by Burns (18), in the New Jersey pine barrens showed that burning did birng about a slight compaction of the soil. Demmon (26), in discussing forest fires in the longleaf pine regions stated that the soil surface of the frequently burned longleaf pine areas was considerably more compact than that of adjoining unburned areas. In the Appalachian region, Frothingham (42), found that after a fire the soil became compacted. Garren (43), reported that more massive structure was brought about by burning in the longleaf forests. The frequently burned longleaf pine forest soils had less penetrability than the unburned soils. Heyward and Tissot (63), found that in unburned longleaf pine regions the soil was more penetrated by holes and thus more aerated as compared to the more compact and less porous soil of frequently burned areas. Lunt (88), showed that whenever litter was removed, compaction of the soil occurred. Compaction could result within a period of 2 1/2 years. The effect of ashes in sealing the soil pores after burns in the Rocky Mountains was recognized by Friedrich (40). In a comparison of forest, open, and burned soils, Kittredge (78), observed that in unburned regions the soil had a more porous structure. Kotok (80), noted that forest litter maintained the porosity of the surface soil. Whereas removal of the litter by fire brought about a decrease in porosity. Observations of burns in woodland-chaparral vegetation by Rowe (113), show that burning brings about destruction of surface soil structure due to plugging of soil pores. The effect of highly alkaline ash causing deflocculation of the soil granules was noted by Sims et al. (125). Rain carried the dispersed soil particles into the soil pores causing clogging. As time goes by the soil is compacted to a considerable degree. Trimble and Tripp (138), in describing the effects of fire on soil structure in the Northern Rocky Mountains pointed out that the sun and the rain baked and sealed the unprotected soil surface. The soil was puddled or compacted due to the destruction of the porous organic matter in the upper horizons.

According to Craddock (24), fire reduced the colloidal content of the upper inch of soil in the chaparral regions of California.

Another study in the longleaf pine regions by Heyward (64), showed that unburned soils were one to five times softer than the same soil when burned frequently. Wahlenberg (143), also studying the longleaf pine regions observed that soil protected from fire for 7 years were less dense and more porous than the burned soils.

On the burns on Vancouver Island Rideout (112), revealed that burning brought about migration of colloidal organic matter and clay particles to the subsoil while Godwin (44), observed that varying intensities of burning have had no apparent effect in breaking down soil structure.

Although no data was presented, Isaac and Hopkins (73), stated that burning of slash caused an unfavourable change in the structure of underlying soil.

Failure of teak to make growth was attributed by Laurie (82), to unsuitable physical condition of the burnt over, hard baked soils.

Most of the workers recorded detrimental effects of fire upon the soil texture and structure, however the following investigations contradicted these findings: Edwards (32), in his studies in India found that heat produced good tilth as did Topham (137), in Central Africa. Observations by Ehrenberg (33), revealed that clay soils were more friable and their penetrability was increased when high temperatures and certain conditions were combined. These same beneficial effects were recognized by Jamwal (75), when heavy clay soils were burned.

Sreenivasan and Aurangabadkar (127), reported that on heavy soils after a fire, the clay content of the soil was less than before the heat was applied; the colloids were apparently aggregated by the higher temperatures. Similarly Stepanov (128), noted that baking of small soil particles into lumps was an effect of high temperatures during fires; these lumps could not be broken up by the usual methods of mechanical analysis, indicating that soil texture was changed.

Volume - Weight

Investigations by Auten (7), comparing the volume-weights of burned forest soils and undisturbed forest soils showed that in the upper six inches the burned soil was 25 percent heavier.

Burns (18), reported that annual burning for long periods in the New Jersey pine barrens caused slight decreases in volume-weight and air capacity of mineral soil.

In the longleaf pine regions Heyward (64), reported that the volume-weight of the unburned soils was commonly less than 1 while the volume-weight of the burned soils was between 1.2 to 1.6.

According to Kittredge (78), the volume-weight of the upper two inches of a burned soil was 1.38 while the volume-weight of the upper two inches of the adjacent forest soil was 1.12.

Lunt (88), stated that with removal of forest litter an increase in volume-weight resulted.

Soils in the New Jersey pitch pine plains which owed their existence to fires were reported by Lutz (91), to have higher volume-weights than the soils of the forested regions.

Infiltration Rate

Measurements made by Arend (4), showed that the infiltration rate of loam soils in the Ozark Mountains of Missouri was lowered 38 percent on the average by annual burning. Another study in the Ozarks by Auten (8), showed that burned soils have a reduced capacity for water absorption. The rate of absorption with each successive application of water decreased much more rapidly in the burned soils than in the unburned.

A substantial decrease in the rate of infiltration with annual burning for long periods of time was recorded by Burns (18). An immense reduction in the absorptive capacity of the soil was found by Lovejoy (86), to be a result of forest fires in the North Lake States. Meginnis (97), observed that the soil in an oak forest in Mississippi protected from fire for at least eight years had a much greater absorptive capacity for rainfall than did the soil in a nearby scrub oak area which had suffered damage from logging and frequent fires.

Johnston (77), stated that the infiltration rate of a burned soil in Colorado was 40 percent less than the infiltration rate of undisturbed soil. The infiltration rates of undisturbed forest soil were recorded by Kittredge (78), to be four times that of burned soil. Sims et al. (125), found that the first application of infiltrating water entered the undisturbed forest soil three to four times faster than the water that entered the burnt soil. Upon the fourth application of water, entry was achieved six to t en times faster on the unburned soils than on the corresponding burned soils.

Observations by Rowe (113), in woodland-chaparral vegetation revealed approximately 94 percent reduction in the infiltration capacity of the soil on annually burned plots. Further study in the chaparral lands of California by Sampson (117), demonstrated that unburned soils have infiltration capacities three times that of the corresponding burnt areas.

Several workers presented data which opposed the viewpoint that fire reduced infiltration rates. Work done in California quoted by Madson (95), had definitely shown that denudation through burning does not produce undesirable change in the infiltration capacity of the soil. Studies by Veihmeyer and Johnson (141), also in California revealed that the infiltration capacity of the soil under burned brush was not impaired by burning.

Runoff and Erosion

In California, Lowdermilk (87), stated as did Love and Jones (85), that destruction of the forest litter and the consequent exposure of the soil greatly increased the amount of eroded material and the amount of surficial runoff. Plummer (110), also in California, observed that after a fire a disastrous flood occurred which was the result of a heavy rain falling on the exposed surface. Another study in California by Eaton (30), demonstrated that runoff increases following a severe fire and that the rate of erosion of soil increased as much as 30 times by burning.

Friedrich (40), observed, that a summer thunderstorm falling on an area in the Rocky Mountains which was severely burned a year before, gutted stream channels and carried away top soil. Adjacent unburned areas also in the path of the storm, remained unharmed. In the lodgepole pine of the same area, Trimble and Tripp (138), reported that burning even on gentle slopes brings about sheet erosion as a result of the increased and accelerated runoff.

A decided increase in erosion with either an increase in slope or an increase in intensity of burn was observed in Idaho by Connaughton (21). On steep lower south slopes in Northern Idaho a washing away of the finer loam and soil particles leaving a relatively large proportion of rock and gravel was attributed by Larsen (81), to be a result of fire.

Investigations in Central Arizona by Hendricks and Johnson (57), showed that on slopes in burnt over areas runoff and soil loss occurred, while none occurred on adjacent unburned areas. On the contrary Humphrey (71), in Southern Arizona observed that the burning of velvet mesquite, burroweed, and cholla areas decreased erosion.

Bennett (12), comparing unburned and burned scrub oak woodland in Oklahoma noted that on the unburned plot the runoff amounted to .08 percent of the total precipitation and .01 tons of soil per acre was washed off. Meanwhile on the burned plot runoff comprised 2.43 percent of the total precipitation and the washoff was .15 tons of soil per acre. Sheet erosion according to Arend (4), removed from 0 - 25 percent of the topsoil following annual burning in Missouri. Further studies on erosion and runoff by Kotok (80), revealed that as a result of burning and removing the forest litter; surface runoff on burned plots was 3-30 times that of adjacent unburned areas; erosion on burned surfaces exceeded that from litter surfaces by 50 to 3000 times.

The following investigators noted that burning increased runoff and erosion: Brown (15), in a study of burning a chaparral-covered watershed, Bruner (16), in Arkansas, Copley et al. (22), in the Central Piedmont region, Demmon (26), in the longleaf pine region, Elwell et al. (36), in Oklahoma, Graves (45), Lovejoy (86), in the North Lake States, Lutz (92), in Alaska, McCulloch (94), Pardee (102), Rutledge (115), and Sims et al. (125).

A study by Pechanec and Stewart (104), concluded that soil losses from planned burning were light and that soil movement was accelerated to some extent immediately after burning. On steeper slopes rainfall runs rapidly from exposed soil and carries with it the valuable surface layers. Recurrent burning was found to intensify these losses.

Effect of Fires on Chemical Properties

The literature is contradictory in respect to total nitrogen following burning. The following investigators reported decreases in total nitrogen: Alway and Rost (1), Alway and McMillar (2), Barnette and Hester (9), Bruner (16), Burns (18), Elwell et al. (36), Graves (45), Isaac and Hopkins (73), Kivekäs (79), Leningen (84), Lovejoy (86), Lutz (91), Osborn (101), and Sims et al. (125).

Opposing this conclusion are : Burns (18), Demmon (26), Garren (43), Greene (46), Heyward (64), Heyward and Barnette (61), Lunt (89,90), Rideout (112), Wahlenberg (142) and Wahlenberg et al. (144), who reported increases in total nitrogen. Many of these workers studied fires in the longleaf pine forests of Southern United States where it has been reported that grasses and legumes are more abundant following a fire. Such vegetation is recognized as being able to increase the total nitrogen content of soils.

An investigation in Minnesota by Alway and Rost (1), demonstrated that there was a rise in pH in the top 3 inches of the burned forest soil, in the 4-6 inch section no change was recorded. The release of lime and magnesia in the ash was responsible for the rise in pH. In the burnt forest nitrogen was only .02 percent lower than the corresponding unburned forest.

Alway and McMillar doing further work in Minnesota (2), stated that all nitrogen is lost when organic matter burns. Under some conditions this loss may amount to several hundred lbs. per acre.

The soil on an island with a virgin pine cover was compared by Barnette and Hester (9), with mineral soil on the nearby Florida mainland where the area had been burned almost yearly for 42 years. The loss of nitrogen and organic matter per acre per year on the burned soil was estimated to be 27 lbs. and 2088 lbs. respectively. Samples from the unburned areas had a lower pH than those from the burned areas. The exchangeable lime was higher in the upper one inch and lower below one inch in the burned soil than in the unburned soil.

In New South Wales, Beadle (11), found that fires in eucalyptus forests that had not been burned for over six years did not bring about any marked change in pH or loss-on-ignition of the underlying mineral soil.

A study of fires in Arkansas by Bruner (16), pointed out that woods humus has the capacity to build up and maintain soil fertility by constantly supplying nitrogen, phosphorous, and potassium. By destroying the woods humus, forest fires rob the soil of nitrogen and other nutritive elements.

In a comprehensive study of the effect of fires on the soil in New Jersey, Burns (18), presented data indicating that burning every four years or two annual burns decreased the percentage of nitrogen and weight of nitrogen per unit area. Annual burning for long periods of time brought about increases in pH, organic matter, nitrogen, exchangeable calcium and exchangeable potassium in the A horizon.

No deterioration in nitrogen content was detected by Chapman (19), in samples of mineral soil taken from the upper horizon in annually burned lobolly pine stands.

According to Craddock (24), fire reduced the organic matter content of the upper inch of soil in the chaparral regions of California. Fire increased the amount of nitrate nitrogen when analyzed in a 1:1 water extract solution.

Annually burned longleaf pine soils were found by Demmon (26), to contain slightly more calcium and nitrogen than similiar soils unburned for 10 years or more. Fire also reduced the acidity of the soil.

Investigations by Eden (31), in the English heathland showed that burning brought about no great increase in potassium. An increase in lime in the 0-1" portion was recorded. There was a possible loss of organic matter in the upper 1 inch portion of soil.

Edwards (32), working in India stated that burning vegetation returns to the soil all the mineral elements taken out of the soil by the plants during life. The small volume of ash can as a rule become easily incorporated with the surface layers of the soil and provided that there is no erosion or excessive rainfall, leachings will wash the soluable contents of the ash into the soil.

Elpatievsky et al. (35), noted that the effect of burning was to increase the pH of the surface soil.

The effects of burning pasture and woodland annually in Oklahoma were shown by Elwell et al. (36), to be a loss of nitrogen and the destruction of organic matter.

Research by Eneroth (37), in Sweden demonstrated that the pH values of humus layers on similiar soils are on the average higher in the burned clearing than in unburned clearings. The variations maybe as much as 1 pH unit or more. The change in pH with burning was found to remain stationary for several years after the fire. The CaO content was higher in the upper humus layers from the burned clearings except in the very oldest clearings. On the average the CaO content was higher in the lower humus layers from burned clearings except in the youngest clearing.

Finn (38), burned organic matter that had been placed upon sandy soil and upon loamy soil in boxes. Immediately after the organic material had been ignited the boxes were placed in the open. The pH was changed from acid to alkaline by burning, however at the end of one year the soil reaction had again become acid. As rain fell upon the boxes leaching and the consequent loss of nitrate, calcium and potassium occurred.

Fowells and Stephenson (39), stated that burning and the resulting formation of basic ash materials increased nitrification and resulted in an increase in the soluble mineral constituents of the soil. Fire destroyed the humus layer and some of the humus near the soil surface.

A study by Frothingham (42), in the southern Appalachian region showed that when litter is burned its mineral content is left behind as an ash which is quickly dissipated by leaching and washing out.

In summarizing the effects of fire on the soil in the Southeastern United States, Garren (43), stated that burning results in decreasing acidity, increased nitrogen, increased calcium and organic matter in longleaf pine soils. The return of minerals in ashes and greater growth of legumes and herbs on burned over areas contribute to these changes.

On Vancouver Island, Godwin (44), recorded that burning brought about an immediate increase in available nitrates and a change toward alkalinity in the H^+ ion concentration.

The loss of soil nitrogen with burning was noted by Graves (45).

Burned soils in the longleaf pine region were found by Greene (46), to contain more total nitrogen and more organic matter than the corresponding unburnt soils. These differences were explained by the greater number of grasses and legumes on the burnt areas.

Griffith (48), set up experiments in an effort to separate the effects of slash burning into two classes: (1) effects of the heat of the fire, and (2) effects of the addition of ash. After burning there was an increase of pH in the upper 3 inches of soil which was apparently due to the addition of alkaline ash. Following burning an increase in nitrate was recorded which was also due to the effects of the ash. Fire had no effect on incorporated organic matter or on loss-on-ignition.

Haig (50), recognized that fire destroyed organic matter. Burning immediately released in the ash a considerable quantity of available nutrients. One benefit obtained by burning was the neutraliz ation of organic acids.

A decrease in acidity of the surface layers in a heath soil with burning was recorded by Haines (51). The amount of soluble salts increased immediately after the fire. During the following months these added salts were leached out of the surface soil.

Hardon and White (52), found that burning of slash and the consequent additions of ash changed an acid, base-unsaturated soil to a soil almost base saturated and nearby alkaline in reaction. The amounts of acid soluble potash and phosphoric acid were increased.

The experiments of Heiberg (54), demonstrated that it was unlikely that fire could cause much damage to incorporated organic matter. In another article Heiberg (55), stated that as a result of firing, part or all of the organic matter on top of the soil is destroyed with the consequent release of available minerals from the ash.

In California, Hervey (59), showed that a single burning of annual-plant communities did not significantly affect the amount of organic matter in the top inch of the soil.

According to Hess (60), in Switzerland, where the soil was acid, burned over spots had a much higher pH and more calcium carbonate than unburned spots; the reaction of neutral soils was very little affected by fires.

Investigations by Heyward (64), pointed out that in the burned longleaf pine areas the soil is slightly less acid and has more replaceable Ca^{++} More organic matter and total nitrogen were observed on the burned sites.

Heyward and Barnette (61), noted that soils from burned areas in the longleaf pine region showed pH values ranging from .15 to .48 pH units higher than those of unburned areas. Replaceable calcium totalled as much as 101 percent more than on the unburned soils. Total nitrogen differences were from small changes up to 14 percent more in the areas subjected to burning.

Hosking (70), in a series of experiments demonstrated that when organic matter was heated for a few hours at 100 C° or 212°F appreciable losses occurred. Up to 200°C heating results in essentially distilling off the volatile constituents.

Isaac and Hopkins (73), in a comprehensive study of burning in the Douglas fir region revealed that the burning of slash brought about a pronounced change in the chemical properties of the duff and the underlying mineral soil. The thickness of the duff layer averaged about 1.5 inches. Analysis showed that the duff on the average acre, estimated to total 32 tons, contained approximately 28 tons of organic matter, 594 lbs. of nitrogen, 76 lbs. of phosphorous, 555 lbs. of calcium, and 121 lbs. of potassium. The usual heavy slash fire resulted in almost complete destruction of the duff layer. Burning apparently caused; (1) a loss of 25 tons (89 percent) of the organic matter contained in the duff. (2) a change in duff reaction from pH 4.95 to a pH of 7.6. (3) the escape of approximately 435 lbs. of nitrogen per acre. (4) an increase in the supply of available potassium, calcium and nitrate in the duff and in the 0-3 inch layer. (5) an increase in the weight of water soluble salts in the duff and in the 0-3 inch layer. (6) a decrease in available phosphorous in the duff. The increases in available plant nutrients resulted from the deposition at the surface, in highly soluble form, of part of the nutrients present in the duff. Serious subsequent losses by leaching appeared probable, and (7) an indicated loss of a considerable part of the mineral nutrients contained in the duff, presumably carried off in smoke. Analysis of the duff revealed that there was an increase in the percentage of mineral nutrients due to the loss of organic matter and nitrogen, however because some of the minerals released from the duff were carried away in smoke a decrease in the total quantity of mineral nutrients occurred.

Table lV Reaction of Wind River soil before and after a heavy slash fire. #

Sample	Reaction Before Fire	Reaction After Fire
Duff	4.95	7.6
Mineral soil at a depth of:		
0-3 inches	5.0	6.2
3-6 inches	4.8	5.5
6-12 inches	5.0	4.9
12-30 inches	5.15	5.2

Table V Quantity and Compostion of residue of samples of Wind River soil after ignition.#

Sample	Weight of Ash in terms of Total Weight of Soil Percent	Silicon Dioxide in Terms of Total Weight of Ash Percent	Nutrients in Terms of Total Weight of Soil		
			Phosphorous Percent	Calcium Percent	Potassium Percent
Duff					
Before Slash Fire	13.26	69.5	.115	.81	.177
After Slash Fire	50.96	80.7	.121	1.80	.306

Results of the Neubauer test in which a chemical analysis is made of seedlings grown on a sample of the soil diluted with pure sand shows strikingly that the fire had greatly increased the quantity of calcium and potassium available but had only slightly affected the phosphorous. This agrees with the results of the chemical tests on availability of nutrients.

Isaac and Hopkins (73)

Table VI Quantities of water-soluble salts and of other plant nutrients available in Wind River soil before and after a slash fire.#

Sample	Water Soluble Salts. P.P.M.		Nitric Acid Soluble Salts							
			Before Fire				After Fire			
	Before Fire	After Fire	P	K	Ca	NO_3-N	P	K	Ca	NO_3-N
Duff	1116	1330	4	4	2	0	2	5	5	3
Mineral Soil At a Depth of										
0-3 inches	370	585	0	0	0	1	0	1	2	4
3-6 inches	365	345	0	0	0	0	0	1	0	0
6-12 inches	164	222	0	0	1	0	0	1	0	2
12-30 inches	82	142	2	1	0	0	2	1	1	0

The extracting solution used was .2N nitric acid solution.

Explanation: 0=none; 1=a trace; 2=poor; 3=fair; 4=good; 5=excellent; 6=excessive.

Isaac and Hopkins (73).

Joffe's (76), investigation in the pine barrens indicated that periodic controlled burning reduced acidity in the surface soil.

Kivekäs (79), in Finland found that burning had favourable effects on the chemical properties of mineral soil. As a result of fires the pH increased while hydrolytic acidity and exchange acidity decreased. Although the nitrogen content was lower, exchangeable calcium, exchangeable potassium and available phosphorous were more abundant in burned soil than in unburned soil. These changes occurred at both the 0-5 and 5-10 centimeter depth. Soil fertility evaluated by the growth of oats was at a higher level in burned than in unburned soil.

Research by Leningen (84), in Germany, showed that the burning of forest humus cover results in the loss of nitrogen. It was pointed out that the alkaline ash may have detrimental effects on tree growth. The pure ash produced during the fire consists of approximately 30 percent CaO.

Burning of the forests in the North Lake States was observed by Lovejoy (86), to result in the loss of nitrogen and organic matter.

A pot culture experiment used by Lunt (89), demonstrated that the removal of the Ao by burning tended to increase the amount of available nutrients, total nitrogen and organic matter. Burning of the Ao was responsible for an increase in pH and lowering of the conductivity. Destruction of the Ao by fire resulted in a lowering of the soluble iron and ammonia content.

Lunt (90), in a detailed study of burning in Connecticut, found that with burning the pH of the Ao and A_1 rose. Ammonia nitrogen, available phosphorous, and exchangeable potassium of the Ao were conspicuously absent. It was thought that the phosphate released had been converted to insoluble iron and aluminum phosphates. The exchangeable potassium had been leached out in soluble form. Other tests showed that burning resulted in a higher pH, increase in total nitrogen, increase in organic carbon and available phosphorous in the A horizon. A series of tests made on a podsol - mor type of soil indicated that burning the Ao resulted in an increase in pH, increases in exchangeable calcium, total nitrogen and organic matter content of the A_2 horizon.

According to Lutz (92), nitrogen and organic matter had been destroyed as a result of fires which gave rise to the New Jersey pitch pine plains.

The effect of burning in increasing the pH of the surface soil was noted by Marshall and Averill (96).

Milne (99), favoured burning because the C:N ratio was lowered.

It was found by Osborn (101), that the burning of litter after harvests in South Africa caused a loss of organic matter and nitrogen in the 0-2 inch layer of clay soil and of a loam soil. Perry (107), indicated that burning of a hardwood forest in Pennsylvania brought about a temporary decrease in acidity. Burned soil had lower values for loss-on-ignition than samples from an unburned area. Another study was carried out by Perry and Coover (108), in the same area. Frequently burned areas had lower values for loss-on-ignition but had about the same pH in the A horizon as infrequently burned areas. Burning seemed to bring about an increase in the pH of the B horizon.

A study of burning on Vancouver Island by Rideout (112), revealed a gradual increase in surface soil pH with an increase in exchangeable hydrogen in the subsoils of burned sites. An initial increase in exchangeable base content of the burned surface soil was noted. An increase in magnesium and potassium in the subsoils of burned sites occurred as a result of leaching these elements from the accumulated ash. In the surface of the burned soil an initial increase in phosphorous content was found. The ammonia content increased in both surface and subsurface soils as a result of burning. Increased nitrification and a loss of nitrate by leaching was brought about by fire. An increase in total nitrogen content and a consequent decrease in the carbon: nitrogen ratio of the subsoil.

The effects of charcoal being added to the soil after a fire was recorded by Salisbury (116). Closely associated with the additions of charcoal, an increase in pH, nitrates and carbonates was observed.

In the chaparral regions of California, Sampson (117), recorded that much of the potassium added to the soil in the ash was leached away. Changes in pH were slight. The nitrate content of the upper soil layer of practically all chaparral regions studied was higher on fresh burns.

Schreiner et al. (120), pointed out that nitrogenous materials may be added to the soil as a result of burning.

Experiments by Seaver and Clark (121), showed that the amount of soluble or available material in the extract of a heated soil is increased approximately 6-10 times that of the unheated soil.

The loss of nitrogen by burning and the deposition of a highly alkaline ash on the soil surface after a burn was recognized by Sims et al. (125).

As a result of fire heating a soil Sreenivasan and Aurangabadkar (127), found a lowering of exchange capacity, replaceable calcium, replaceable magnesium and organic matter. Also an increase in total soluble salts, replaceable sodium and replaceable potassium was recorded.

Investigations by Wahlenberg (142), in the longleaf pine regions indicate that organic matter and nitrogen were slightly higher on burned soils. Under protection from fire the soil acidity was greater by from .1 to .5 pH units.

Further studies in the longleaf pine area were carried out by Wahlenberg et al. (144). Mean values for the burned land exceeded those for the unburned land in percentage dry weight as follows: total nitrogen .0028 $\pm$ .0011; loss-on-ignition .180 $\pm$ .1056; and replaceable calcium .0085 $\pm$ .0024.

Effect of Fire on Soil Organisms.

Arend (5), in a study of burning in the Missouri Ozarks found that annual firing caused reductions in microbiological activity.

In Malaya, Corbet (23), studied the effect of burning on soil microorganisms. Plate counts of these organisms from the 1-4 inch layer of mineral soil were made at intervals before and after a fire. The number of microorganisms rose immediately following the fire but a week afterward and for at least nine months thereafter the plate counts fell to the values obtained before the fire.

Düggeli (29), while investigating in Switzerland found that the number of bacteria was not significantly affected by the mixing of spruce ashes into the mineral soil.

According to Fowells and Stephenson (39), burning and the resulting formation of basic ash materials increased nitrification in the soil.

Fritz (41), stated that in the redwood regions fire has sometimes severely baked the top soil and burnt out most of its rich supply of the important macro and microorganisms.

In the frequently burned soils of the longleaf pine regions, Garren (43), found that the soil fauna was scarce.

Freene (47), noted that the bacterial counts were higher on burned soils in the longleaf pine area.

Soils of the unburned areas in the longleaf pine regions were observed by Heyward and Tissot (63), to be riddled with holes and tunnels of small mammals and insects. Such evidence of life was lacking in the frequently burned sites. The Ao of the unburned soils contained 5 times as many microfaunal forms as did the ground cover of burned areas. The top 2 inches of mineral soil, the unburned areas had 11 times more such animals than the corresponding soil depth from burned areas. The groups of soil animals were generally the same in burned and unburned sites. Fires decreased the number of earthworms.

Results of the tests by Isaac and Hopkins (73), with the bacterium Azotobacter chroococcum indicated that burning had overcome a calcium deficiency for the growth of this organism in the soil, either by destroying organic acids, or by depositing calcium in an available form, or by both. Aspergillus made better growth when a burnt soil with its increased supply of nutrients was attacked.

The results of a study by Jamwal (75), in India, indicate that fire, especially a severe one, kills outright all living organisms in the soil. The reduction of protozoa resulted in an increase of nitrification.

Kittredge (78), recorded that in unburned areas there were more holes and channels caused by macroorganisms than in the corresponding burned soils.

A slight decrease in ammonification and a slight increase in nitrification was attributed to forest fires by Kivekäs (79).

In the North Lake States, Lovejoy (86), noted that fire destroyed most of the beneficial organisms leaving the soil inert and unresponsive.

Michaelis (98), reported that fire eliminated rodents which had been threatening a young hardwood plantation with destruction.

Pearse (103), while investigating the effects of burning over litter on soil animals in the Duke Forests found that to a depth of 3 inches many more animals were present in the unburned plot than in the burned plot. During a five year period the number of earthworms in the soil of the burned area decreased by 50 percent. Centipedes, millipedes and ants also decreased in abundance because of fires.

Increases in nitrification because of fires were reported by Remezov (111).

A 70-80 percent reduction in the acitivity of earthworms and burrowing insects was found by Rowe (113), in burned woodland-chaparral regions.

Russell (114), stated that soil heating or partial sterilization which might be expected to kill off living organisms results in an increase in nitrification. The theory is that after heating, the soil fungi which use up more nitrogen in their assimilation processes are suppressed and the bacteria which use up less nitrogen in proportion to the amount they liberate become dominent. Probably the protozoa, enemies of the bacteria are more severely affected by the heat.

The destruction of microorganisms by fire was recognized by Sampson (118).

Schreiner et al. (120), reported that all organisms which normally occupy a fertile soil are killed by heat but nitrogenous materials are thereby liberated and made available.

Sushkina (130), in a comprehensive study of nitrification in forests found that after burning nitrification begins in soils where it has been observed before and greatly increases where it has been going on before burning. Moderate burning of the soil has a more favourable effect on the nitrifying capacity than an intense burning. In cases of moderate burning the capacity for nitrification is evident even immediately after the burning. The effect of burning upon the soil lasts during a period of five years. A running fire will have a more favourable effect upon nitrification than the burning of forest debris gathered in piles.

According to Tryon (139), the charcoal added to the soil during a fire did not affect the abundance of bacteria or fungi.

Wahlenberg et al. (144), found higher bacterial counts on burned soils.

Conclusions from the literature.

In studying the literature relative to the effects of fire on the soil, contradictory reports in the same region have been encountered. It would appear as though a great many factors are involved and that they were not kept constant in all studies. Thus if one of the factors such as; severity of burn, season of year, slope, exposure, texture, structure, climate, vegetation and parent material, differed varying results would naturally follow.

Certain effects of fire on the soil were frequently encountered in the literature. The effects which appeared to be general are summarized below.

1. A goodly portion or all of the unincorporated organic matter is destroyed. The degree of destruction depends upon the frequency and severity of burning.

2. When organic matter is destroyed, nitrogen is lost.

3. Seldom is the incorporated organic matter reduced through burning. Loss may occur when heavy accumulations of slash are burned.

4. Soil temperatures are higher during the day on burned over soils than on unburned soils.

5. Burned soils had a higher volume-weight due to compaction.

6. As a result of compaction these burned soils have a lower infiltration rate.

7. Runoff and erosion is greater in burned areas.

8. Burned soils are more dense and not easily penetrated.

9. The chemical properties of the upper layers of the mineral soil are affected by burning. The pH and the content of available nutrient ions is increased. In the mineral soil organic matter and nitrogen are not greatly affected.

10. Decreases in the abundance of soil organisms is brought about by frequent burning.

11. Fires stimulate nitrification.

EXPERIMENTAL

Geology of the Lac Le Jeune Area.

This area was surveyed by Dawson (25), in 1889 and 1890 and by Cockfield (20), in 1939 to 1944. The observations of Cockfield did not differ significantly from those of Dawson.

Much of the area in the immediate vicinity of Lac Le Jeune is underlain by plutonic rocks (20), which are part of the Coast intrusives formation of Jurassic age. The surface rocks in this area are part of the Central Nicola Batholith which extends north from Nicola Lake and consists largely of granadiorite and quartz diorite. It is partly sheared and in some specimens the quartz appears as a fine mosaic and as interlocking grains. The rock has at many localities a pronounced gneissic structure and the enclosing rocks are sheared and injected with granitic material. Most of the specimens examined under the microscope showed relatively small amounts of orthoclase, with the plagioclase feldspars ranging in composition from oligoclase to labradorite. The ferromagnesian minerals are biotite, hornblende or pyroxene, and in many of the intrusive rocks both biotite and hornblende are present.

Both Dawson and Cockfield recorded extensive areas of basalt in the Lac Le Jeune area. These rocks belong to the Kamloops group and are assigned to the Tertiary period. The Kamloops volcanic rocks comprise a considerable thickness of rhyolites, trachytes, andesites and basalts, together with feldspar porphyries, but the group is very largely composed of basalt and basalt breccia. The rocks show a wide range of colour from white, through various shades of red, pink, mauve, brown, buff, grey, and green to black. They are usually massive and fine grained, but are locally porphyritic and in places coarsely so. Occasionally they are so coarse grained as to resemble fine grained plutonic rocks, though when examined under the microscope small amounts of interstitial fine grained groundmass maybe seen.

Dawson (25), stated that to the westward of Trapp Lake the level of the plateau rises gradually, though irregularly, till the basalt rocks are found in some places at heights exceeding 4000 feet. In this region, to the north of the head of Moore Creek, the edge of the basalts often ceases to be marked by a distinct escarpment, and as the country here becomes thickly wooded their boundary is drawn with less precision than elsewhere.

The author observed several basalt escarpments close to the selected sampling areas. These escarpments reached an elevation of 4,400 feet above sea level. It was noted that the basalts presented bold escarpments facing in a southwesterly direction. As Dawson observed, the other faces were not distinct cliffs but descended gradually to the lower levels.

Dawson and Cockfield both recognized that this region had been glaciated during the Pleistocene. According to Dawson, numerous moraine ridges often parallel to the valley are evident in the upper part of Moore Creek, which is located to the southeast of Lac Le Jeune. The elevation of these ridges is 3500 feet.

In the Meadow Creek valley which drains Lac Le Jeune numerous hillocks and transverse ridges, evidently representing moraines are found. The moraines are partly buried in horizontal deposits which have formed in ponds and marshes. These features are found at an elevation of about 4000 feet.

Lac Le Jeune at the head of Meadow Creek (4177 feet) is held in by more or less degraded moraines which are in part transverse to the valley but also in part parallel to it.

Dawson also stated that the deposits of boulder clay to the south of Chuwels Mountain (6 miles north of Lac Le Jeune) are extensively developed and wide spread.

Glacial striations at the 6000 foot level indicating ice flow in a direction S. 35° E. were found on Chuwels Mountain by Dawson. Cockfield recognized the influence of glaciation in the immediate vicinity of Lac Le Jeune. Striations were noted on Chuwels Mountain some six miles distant and further striations were recorded one quarter of a mile from the lake. As well, drift ridges were located closeby. In the geological report he concluded that the ice advanced from the northwest towards the southeast and south. This direction is borne out by the scattering of blocks of conglomerate across the upland surface from the Iron Mask mine towards Shumway Lake. These erratics presumably came from Eagle Hill near Copper Creek, a distance of twenty miles.

The author while studying the area prior to taking soil samples, observed five glacial erratic conglomerate blocks. Other glacial features such as an esker and moraine ridges damming a lake were recognized near Rossmore Lake which is about four miles from Lac Le Jeune.

The glacial till or drift laid down by the moving ice was the parent material of the soil samples taken for study. This till was light brownish gray in colour, compacted and coarse in texture. The portion passing through a 2 mm screen was classified as a sandy loam. However, the majority of the till was made up of coarse, angular, partially weathered fragments of greenstone, basalt, quartz diorite and grana-diorite.

The geological formations had a pronounced effect on soil formation in the Lac Le Jeune area. In locations where the Kamloops basalt is the bedrock, soils formed from it were brown in colour, shallow in depth and fine textured. Basalt normally contains little or no free silica and upon complete weathering a relatively fine textured soil results. The high base content of basalt makes it more susceptible to weathering than the acidic rocks such as granite. Soils derived from the coast intrusive granitic rocks were grayer in colour, shallower in depth and coarser in texture. Granitic rocks upon weathering release considerable amounts of free silica and thus give rise to coarse textured soils. The glacial till laid down during the Pleistocene contained fragments of greenstone, basalt, grana-diorite, quartz diorite and gabbro. Appreciable amounts of rock flour or finely ground rock fragments were also found in the till. The textures and colours of the soils formed on the glacial till were between those of the soils developed from granite and basalt. The total depth of solum was greater in the soils originating from glacial till than the soils developed divided state of the glacial till, which made it relatively permeable to leaching, more profile development was evident in the soils derived from it. Whereas the bedrock outcroppings of granite and basalt are relatively impermeable to leaching and thus the soil forming processes are initially slow.

Climate of the Lac Le Jeune Area.

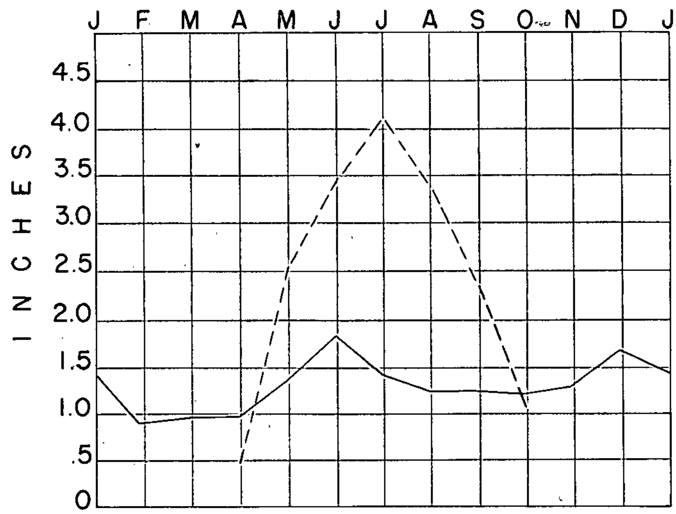
Specific climatic data for this area is unavailable. To provide approximate values of temperature and precipitation two climatic stations with somewhat similar conditions were chosen.

Table 1 Climatic Data for Two Stations Near Lac Le Jeune

Station	Number of Years	Location in Respect to Lac Le Jeune	Altitude	Annual Precipitation (inches)	Annual Temperature
Mamette Lake	34	15 miles west	3200	11.97	37°F.
Knouff Lake	40	40 miles north	3750	15.43	35°F.

From observations and interpretation of climatic data the average annual temperature for Lac Le Jeune would likely be between 35 - 36°F. and the annual precipitation would be in the range of 13 - 15 inches. The estimations made by the Meteorological Division of the Department of Transport (145), closely approximate the above values.

Figure 1. Precipitation and Potential Evapotranspiration Curves for Knouff Lake



KEY:

——— = Precipitation

---- = Potential Evapo-transpiration.

Location and Soils of the Lac Le Jeune Area.

Lac Le Jeune is situated twenty-two miles southwest of Kamloops in the central interior of B.C. The lake is accessible by a class 2 highway. To reach most of the sampling areas about the lake, advantage is taken of the numerous fire guards which have been constructed as an aid in forest fire control.

The soils in the Lac Le Jeune area belong to the Brown Podzolic soil zone. A general description of these soils as taken from Soils and Men (126), is as follows: essentially the Brown Podzolic soil is an imperfectly developed Podzol having in timbered areas an organic mat on the surface and a very thin gray leached horizon just below it -- usually less than one inch thick. The B horizon is largely yellowish brown in colour and has only the beginnings of a dark brown orterde just below the gray A horizon. The total depth of the solum is usually less than 24 inches although it exceeds that depth in places. The climate varies from temperate to cool temperate and humid, but the effective moisture averages less than in the Podzols. Reactions of the soil are moderately to strongly acid and highly leached.

According to Stobbe (129), morphological studies of a Brown Podzolic soil indicate that the profiles are more or less featureless and suggest a gradual decrease in the intensity of soil weathering with depth. He stated that under virgin conditions the Brown Podzolic soils have the following horizons:

Ao - consists of a leaf mat 3/4 - 1 1/2 inches thick, in various stages of decomposition. The upper part is fibrous and brown in colour, while the lower part is greasy and very dark grayish brown.

A_1 - the Ao fades into the A_1 horizon which on the average varies from 1/2 to 2 inches in thickness but it may occasionally reach a maximum of 3 1/2 inches. In some cases the A_1 may be entirely lacking. The A_1 is dark brown to dark grayish brown in colour, very friable and has a weak fine crumb or fine granular structure. The organic matter is usually not as completely mineralized as in case of the Grey-Brown Podzolic and Brown Forest soils and frequently this horizon approaches a loose mechanical mixture of separate organic and mineral particles. Earthworms are not commonly found in this horizon. The reaction is strongly to moderately acid.

A_2- is generally lacking but it may occur as a discontinuous or interrupted horizon. If present it occurs in the form of thin gray streaks, as occasional thicker or deeper pockets or as a somewhat indefinite grayish layer in the lower part of the A_1 horizon. In the latter case it consists of gray particles within the darker soil mass, giving a salt and pepper effect. The A_2 is usually single grained, somewhat lighter in texture than the other horizons and is strongly to moderately acid.

B - the change from the A_2, A_1, or Ao horizon which ever the case may be, to the B horizon is distinct and sharp. As a result the transitional B_1 horizon is generally lacking. The total thickness of the B horizon varies greatly but on the average it ranges from 29 to 30 inches. The upper part of the B is brown, yellowish brown or reddish brown and the colour fades in intensity with depth until it approaches that of the parent material in the lower part of the horizon. The upper part of the horizon, the B_2 is very friable and has dominantly a fine crumb structure but it may also be weak granular or nuciform. In the lower part of the B_1, the B_3, the soil consistence and structure are more variable depending on the nature of the parent material. Textural variations within the B horizons are not significant, nor consistent. The reaction varies from strongly to moderately acid, but it is usually slightly higher in the B_3 than in the upper part of the solum.

C - the change from B_3 to C may be very gradual or it may be, more or less, abrupt in the case of soils developed from compacted till on sloping topography. The parent materials varied from till to alluvial and outwash deposits and have been derived largely from granites, gneisses, schists, slates, and shales. Reaction of these materials is generally moderately to mildly acid, but it may occasionally be strongly acid.

Description of Sampling Areas.

This area is the site of many past fires. The present Forest Service fire map records fires back to 1929. Ample evidence is found of fires which destroyed extensive tracts of forest about the lake approximately eighty years ago.

The soils sampled for study were taken in areas which had been burned in 1943, 1945, 1945 and again in 1951, and 1951. These three fires took place within a period of three weeks in late July and early August. Samples were also taken in unburnt areas adjacent to the burns. Much difficulty was encountered by the author in locating typical mature unburned Douglas fir sites; however, two fairly representative areas were located with mature trees between 350 and 400 years old.

Similiar conditions of slope, exposure, drainage, topography and parent material were maintained throughout the soil sampling sites. The vegetation was nearly the same on all sites except for two burns. These exceptions were the fire of 1945 on a mixed stand of spruce, lodgepole pine and Douglas fir, and the 1943 burn of mature Douglas fir. On the remaining locations lodgepole pine was the dominant tree cover type.

In the 1943 burn of Douglas fir tree cover, two pits were dug and samples taken according to horizon.

Three pits were dug in the 1945 burn of lodgepole pine.

In the mixed stand of spruce, Douglas fir and lodgepole pine which was burned in 1945 two pits were used for study.

Investigations were carried out on two pits in the stagnant lodgepole pine stand burned in 1951. Samples were taken from one pit in the normal stand of lodgepole pine which was burned in 1951.

Two pits were studied in the area of lodgepole pine which had been burned over twice, once in 1945 and again in 1951.

On the unburned 300-400 year old Douglas fir site two profiles were studied.

Three pits were used for sampling in unburned 80 year old lodgepole pine stands.

One pit was dug in the unburned 80 year old stagnant lodgepole pine area.

In the unburned 80 year old stand of spruce, lodgepole pine, and Douglas fir, one pit was studied.

It should be explained that the number of pits studied depended upon how large the sampling area was. If the size of site was limited then the number of pits studied was reduced. The author felt that in these restricted areas the error due to sampling would be very materially reduced and thus the number of samples could be safely decreased.

A profile description for each site is presented in Tables 2 to 11. In instances where more than one profile is taken in an area only one will be described unless there is a significant difference between the replicates.

Table 2: Profile Description of soil under Douglas fir tree cover burned in 1943.

Horizon	Depth	Texture	Colour		Structure	Consistence	Stones	Roots
			Dry	Wet				
Ao	$1\frac{1}{2}$"	Humus	10 yr 4/1 Dark Gray	10 yr 3/1 Very Dark Gray				
A_2	$0-\frac{1}{2}$"	Sandy Loam	10 yr 7/2 Light Gray	10 yr 3/4 Dark Brown	Single Grained	Slightly hard	20%	Some
B_2	$\frac{1}{2}-7\frac{1}{2}$"	Sandy Loam	10 yr 7/3 Very pale Brown	10 yr 5/3 Brown	Fine Crumb Strong	Slightly Hard	40%	Numerous
B_3	$7\frac{1}{2}-12\frac{1}{2}$"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Fine Crumb Weak	Hard	50%	Many
C	$12\frac{1}{2}$"+	Clay Loam	10 yr 6/3 Pale Brown	10 yr 3/3 Dark Brown	Massive	Hard	60%	Few

Profile Development: Moderate

Topography: 4260 feet elevation
2 percent southwest slope

Soil Drainage: subsoil drainage good

Vegetation:
Tree Cover: all original trees fire killed.
8 year old stand of lodgepole pine.
Shrubs: willow, rose, alder, white hardback.
Herbs: fireweed, lupine, twinflower, hawkweed, pine grass.

Table 3: Profile description of soil under lodgepole pine burned in 1945.

Horizon	Depth	Texture	Colour Dry	Colour Wet	Structure	Consistence	Stones	Roots
Ao	$\frac{3}{4}$"	Humus	10 yr 2/2 Very Dark Brown	5 yr 2/1 Black				None
A_2	0-$\frac{1}{2}$"	Sandy Loam	10 yr 5/3 Brown	10 yr 3/3 Dark Brown	Single Grained	Soft	10%	None
B_2	$\frac{1}{2}$-10$\frac{1}{2}$"	Sandy Loam	10 yr 5/3 Brown	10 3/3 Dark Brown	Fine Crumb (strong)	Soft	30%-	Many
B_3	10$\frac{1}{2}$"-16$\frac{1}{2}$"	Loamy Sand	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Fine Crumb (weak)	Slightly Hard	40%	Few
C	16$\frac{1}{2}$ +	Loamy Sand	2.5 yr 7/2 Light Gray	10 yr 4/2 Dark Gray Brown	Massive	Hard	45%	Few

Profile Development: moderate

Topography: 4290 feet elevation
1 percent southwest slope

Soil Drainage: subsoil drainage good

Vegetation: Tree cover: All original trees fire killed
five year old stand of lodgepole pine

Shrubs: rose, sopolallie, willow, dwarf blueberry

Herbs: pine grass

Table 4: Profile description of soil under Douglas fir, spruce and lodgepole pine burned in 1945.

Horizon	Depth	Texture	Colour		Structure	Consistence	Stones	Roots
			Dry	Wet				
Ao	½"	Humus	10 yr 2/2 Very Dark Brown	10 yr 2/1 Black				None
A_2	0-¼"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Single Grained	Slightly Hard	15%	None
B_2	¼-8¼"	Sandy Loam	10 yr 6/3 Pale Brown	10 yr 4/3 Dark Brown	Fine Crumb Strongly	Slightly Hard	25%	Few
B_3	8¼"-13¼"	Loamy Sand	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Fine Crumb Weak	Slightly Hard	45%	Some
C	13¼"+	Loamy Sand	2.5y 7/2 Light Gray	2.4y 5/2 Gray Brown	Massive	Hard	50%	Few

Profile Development: moderate

Topography: 4250 feet elevation
1 percent southeast slope

Soil Drainage: subsoil drainage good
Vegetation: Tree Cover: all original trees fire killed.
6" - 12" high, spruce, lodgepole pine seedlings
Shrubs: Canada dogwood
Herbs: lupine, timber sedge, dandelion, fireweed

Table 5: Profile description of soil under stagnant lodgepole pine burned in 1951.

Horizon	Depth	Texture	Colour Dry	Colour Wet	Structure	Consistence	Stones	Roots
Ao	$\frac{3}{4}$"	Humus	10 yr 2/1 Black	10 yr 2/1 Black				None
A_2	0-$\frac{3}{4}$"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Brown Gray	Thin Platy Medium	Soft	10%	Few
B_2	$\frac{3}{4}$-6$\frac{3}{4}$"	Sandy Loam	10 yr 6/3 Pale Brown	10 yr 4/2 Dark Brown Gray	Fine Crumb Strongly	Slightly Hard	25%	Many
B_3	6$\frac{3}{4}$-17$\frac{3}{4}$"	Clay Loam	10 yr 7/2 Light Gray	10 yr 6/3 Pale Brown	Massive	Hard	30%	Few
C	17$\frac{3}{4}$"+	Clay Loam	10 yr 7/2 Light Gray	10 yr 6/2 Pale Brown	Massive	Very hard	35%	Few

Profile Development: moderate

Topography: 4250 feet elevation
slight southwest slope

Soil Drainage: subsoil drainage fair

Vegetation:
- Tree Cover: all original trees fire killed
  $\frac{1}{2}$" - 1" high lodgepole pine seedlings
- Shrubs: rose
- Herbs: pine grass, fireweed, twinflower.

Table 6: Profile description of soil under lodgepole pine burned in 1951

Horizon	Depth	Texture	Colour Dry	Colour Wet	Structure	Consistence	Stones	Roots
Ao	1"	Humus	10 yr 2/1 Black	10 yr 2/1 Black				None
A_2	0-½"	Sandy Loam	10 yr 6/3 Pale Brown	10 yr 3/2 Very Dark Gray Brown	Single Grained	Soft	30%	Few
B_2	½-9½"	Sandy Loam	10 yr 5/3 Pale Brown	10 yr 3/3 Dark Brown	Fine Crumb (Moderate)	Slightly Hard	40%	Many
B_3	9½-15½"	Loamy Sand	10 yr 6/3 Pale Brown	10 yr 4/2 Dark Gray Brown	Fine Crumb (weak)	Slightly Hard	45%	Some
C	15½"+	Loamy Sand	10 yr 6/3 Pale Brown	10 yr 4/2 Dark Gray Brown	Massive	Hard	55%	Few

Profile Development: moderate

Topography: 4270 feet elevation level

Soil Drainage: subsoil drainage good

Vegetation: Tree Cover: all original trees killed; small lodgepole pine seedlings

Shrubs: rose, white hardback

Herbs: pine grass, lupine, fireweed

Table 7: Profile description of soil under lodgepole pine burned in 1945 and again in 1951.

Horizon	Depth	Texture	Colour Dry	Colour Wet	Structure	Consistence	Rocks	Roots
Ao	½"	Humus	7.5 yr 4/2 Dark Brown	10 yr 2/2 Very Dark Brown				None
A_2	0-¼"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 3/3 Dark Brown	Single Grained	Loose	20%	Few
B_2	¼-7¼"	Sandy Loam	10 yr 6/3 Pale Brown	10 yr 4/3 Dark Brown	Fine Crumb Moderate	Soft	35%	Some
B_3	7¼-13¼"	Loamy Sand	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Fine Crumb Weak	Slightly Hard	48%	Some
C	13¼"+	Loamy Sand	2.5y 7/2 Light Gray	10 yr 4/2 Dark Gray Brown	Massive	Hard	54%	Few

Profile Development: moderate

Topography: 4200 feet elevation
3 percent southwest slope

Soil Drainage: subsoil drainage good

Vegetation:
Tree Cover: all original trees were fire killed
1" high lodgepole pine and aspen seedlings
Shrubs: alder, willow
Herbs: fireweed, dandelion, twinflower, goatsbeard, timber sedge, strawberry

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Table 8: Profile description of soil under 300-400 year old Douglas fir.

Horizon	Depth	Texture	Colour Dry	Colour Wet	Structure	Consistence	Rocks	Roots
Ao	1¾"	Humus	10 yr 4/2 Dark Gray Brown	10 yr 2/1 Black				Many
A_2	0-¾"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Single Grained	Slightly Hard	15%	Many
B_2	¾-7¾"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Fine Crumb Strong	Slightly Hard	40%	Numerous
B_3	7¾-17¾"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Fine Crumb Weak	Slightly Hard	45%	Many
C	17¾"+	Loamy Sand	10 yr 7/2 Light Gray	2.5y 5/2 Gray Brown	Massive	Hard	55%	Few

Profile Development: Moderate

Topography: 4290 feet elevation
3 percent southerly slope

Soil Drainage: subsoil drainage good

Vegetation:
- Tree cover: Douglas fir dominant, some lodgepole pine
- Shrubs: sopolallie, willow, dwarf blueberry, kinnikinnick
- Herbs: pine grass, strawberry, twinberry, lupine, timber milk vetch, timber sedge, yarrow, arnica

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Table 9: Profile description of soil under 80 year old unburned lodgepole pine.

Horizon	Depth	Texture	Colour Dry	Colour Wet	Structure	Consistence	Rocks	Roots
Ao	1½"	Humus	7.5yr 3/2 Dark Brown	5 yr 3/3 Dark Reddish Brown				Many
A_2	0-½"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Single Grained	Slightly Hard	15%	Some
B_2	½-7½"	Sandy Loam	10 yr 6/3 Pale Brown	10 yr 4/3 Brown to Dark Brown	Fine Crumb Strong	Slightly Hard	35%	Numerous
B_3	7½-15½	Sandy Loam	2.5y 7/2 Light Gray	10 yr 4/2 Dark Gray Brown	Fine Crumb Weak	Soft	45%	Many
C	15½"+	Loamy Sand	2.5y 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Massive	Hard	50%	Few

Profile Development: moderate

Topography: 4290 feet elevation nearly level

Soil Drainage: subsoil drainage good

Vegetation:
- Tree Cover: lodgepole pine dominant, willow
- Shrubs: rose, dwarf blueberry, red alpine blueberry, kinnickinnick, white hardback, alder.
- Herbs: pine grass, lupine, fireweed, twinflower, timber milk vetch, hawkweed, strawberry.

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Table 10: Profile description of soil under 70 - 80 year old, unburned, stagnant lodgepole pine.

Horizon	Depth	Texture	Colour Dry	Colour Wet	Structure	Consistence	Rocks	Roots
Ao	2"	Humus	10 yr 4/1 Dark Gray	10 yr 3/1 Very Dark Gray				Many
A_2	0-¾"	Sandy Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Thin Platy Strong	Soft	10%	Some
B_2	¾-7¾"	Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Fine Crumb Strong	Slightly Hard	25%	Numerous
B_3	7¾-14¾"	Clay Loam	10 yr 7/2 Light Gray	10 yr 5/2 Gray Brown	Massive	Hard	30%	Few
C	14¾"+	Clay Loam	10 yr 6/2 Light Brown Gray	10 yr 4/2 Dark Gray Brown	Massive	Very Hard	35%	Few

Profile Development: moderate

Topography: 4250 feet elevation flat

Soil Drainage: subsoil drainage fair

Vegetation:
- Tree Cover: stagnant lodgepole pine
- Shrubs: dwarf blueberry, rose, kinnikinnick
- Herbs: pine grass dominant, twinflower, strawberry, fireweed, wintergreen.

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Table 11: Profile description of soil under 70-80 year old, unburned, mixed stand of lodgepole pine, Douglas fir and spruce.

Horizon	Depth	Texture	Colour Dry	Colour Wet	Structure	Consistence	Rocks	Roots
Ao	2"	Humus	10 yr 4/4 Dark Brown Yellowish	10 yr 3/4 Dark Brown				Few
A_2	0-½"	Sandy Loam	10 yr 7/2 Light Gray	10 yr 5/3 Brown	Single Grained	Slightly Hard	15%	Few
B_2	½-8½"	Sandy Loam	10 yr 7/3 Very Pale Brown	10 yr 5/3 Brown	Fine Crumb Strongly	Slightly Hard	25%	Numerous
B_3	8½-12½"	Sandy Loam	10 yr 7/3 Very Pale Brown	10 yr 5/3 Brown	Fine Crumb Weak	Slightly Hard	45%	Some
C	12½"+	Loamy Sand	10 yr 6/3 Pale Brown	10 yr 4/2 Dark Gray Brown	Massive	Hard	50%-	Few

Profile Development: moderate

Topography: 4250 feet elevation
3 percent southeast slope

Soil Drainage: subsoil drainage good

Vegetation: Tree Cover: lodgepole pine, Douglas fir, spruce

Shrubs:

Herbs: twinflower

Morphological Features.

The organic horizon of the unburned soils is an incompletely decomposed mor type (56). In all profiles studied the F or fermentation layer is dominant while the H or humified layer and the L or litter layer seldom attain measurable thickness.

In studying the ash grey leached layer considerable variability is encountered. There is such a horizon in all the profiles sampled for chemical study. However, it is possible in some instances to move fifteen feet from a profile with an A_2 and find a profile with this horizon lacking. In other cases a short distance away from a studied soil sampling site $1\frac{1}{2}$ inch thick A_2 horizons are found. Under field conditions the leached layers are somewhat lighter than indicated by the colour descriptions. Although considerable care was exercised in sampling, small portions of organic material and B_2 were included in the samples because of the difficulty in sampling such a shallow horizon. In some areas the A_2 is somewhat compacted and has a definite platy structure. As a rule the A_2 is slightly compacted and structureless.

The next horizon, the B_2, represents a sharp and distinct break between the A horizons and the B horizons. In the Lac Le Jeune area there is not any evidence of a transitory B_1 horizon. The B_2 horizon of all profiles studied is a pale brown to a light brown gray in colour. This horizon tends to be a pale brown under lodgepole pine and unburned Douglas fir the colour is usually a light brown gray. In all the profiles studied the texture of the B_2 is a sandy loam. Usually the B_2 is friable and has a fine crumb structure. Burning tends to alter the structure in the top two inches of the B_2. The burned upper portion of the B_2 becomes massive while the lower portion retains its crumb structure.

The B_3 horizons of all the profiles were a light gray or a light brown gray in colour. It is less aggregated than the B_2 and has a weak crumb structure. This horizon is not as friable as the B_2 as it tends to be more compacted and massive.

A light gray glacial till is the parent material or C horizon of all the profiles studied. The till is compacted and remained relatively unweathered. In the C horizon the following sub-angular rocks occur: granite, basalt, greenstone, and gabbro. Free lime accumulations are not observed in the C horizon.

In all the profiles studied drainage is unimpaired except for the relatively impervious C horizon.

METHODS OF ANALYSIS

A. Physical Properties.

Determination of Soil Texture:- All samples were passed through a 2 mm sieve preparatory to analysis. The proportion of rocks and fine material was determined at each site. Each soil sample was textured by hand. As a check on the accuracy of this method two profiles were selected and mechanical analyses were carried out on the fine soil fraction by the Bouyoucos method (13). The values obtained using Bouyoucos's procedure were interpreted by means of the textural triangle (140). A comparison of the two methods is found in Table 12.

Determination of Non-capillary porosity, Capillary porosity and porosity:- Soil cores to a 3 inch depth were taken in duplicate from beneath each of the 10 varying vegetative covers. Non-capillary porosity was determined on a tension table after the method of Leamer and Shaw (83). Capillary porosity was measured by weighing the core when all the non-capillary moisture had been extracted and then weighing the core after it had been oven-dried. The difference in weight between the two weighings represents capillary porosity. The percent porosity was found by determining the weight of the fully saturated core and subtracting from this value, the oven-dry weight of the core. This value represents pore volume. By dividing the pore volume of the brass core, the percent porosity can be obtained.

Determination of Volume Weight:- The brass cylinders used for taking cores have a known and approximately equal volume. Volume weight is found by dividing the nearly constant volume into the oven-dry weight of the soil core.

Determination of Infiltration Rates:- The procedure followed was that of Burns (18). Water infiltration measurements were made in the field with two replicates being carried out at each site. After the unincorporated organic debris was removed from the soil surface a steel cylinder, 20 cm. high, having cross-sectional area of 100 square centimeters, was driven into the soil to a depth of 10 cm. A piece of muslin placed on the soil surface inside the cylinder prevented disturbance of the soil particles. One liter of water was added, and the time required for it to pass into the soil was recorded.

Determination of Soil Temperature:- A Weston soil thermometer was used to take six replicate readings at a depth of 3 inches. These values were obtained for the soil beneath each of the 10 varying vegetative covers.

B. Chemical Properties.

Determination of pH:- Distilled water was added to the dry sieved soil and thoroughly mixed until a soil paste was obtained as recommended by The National Soil Survey Committee (134). The prepared soil paste was allowed to slake for twenty minutes and then the pH readings were determined using a Beckman potentiometer.

Determination of Organic Matter:- The organic matter determinations were carried out by the wet combustion procedure as outlined by Peech et al. (106). One major modification was the use of the more stable ferrous ammonium sulphate in the place of ferrous sulphate.

Determination of Total Nitrogen:- Total nitrogen was determined by the modified Kjeldhal method (6).

Determination of Total Phosphorous:- For the measurement of total phosphorous the perchloric acid method outlined by Shelton and Harper (123), was used.

Determination of Carbonic Acid Soluble Plant Nutrients:- The method used for extracting the plant nutrients was a modification of the CO_2 extraction procedure used by Wilcox (147), and the system recommended by the National Soil and Fertilizer Research Committee (133). Details of the procedure used is as follows:

(a) A unit consisting of two sets of six 500 c.c. erlenmeyer flasks fitted with two hole stoppers and the appropriate glass tubing was attached in series to a tank of liquid CO_2. As a result of the arrangement in series, the contents of each flask was thoroughly and constantly agitated.

(b) Mineral soils were mixed with distilled water in the ratio of 1:2 or in the case of organic soils and Ao horizons a ratio of 1:12 was used.

(c) Activated carbon was added to each soil and distilled water mixture. Peech and English (105), advocated in their procedure of extracting readily soluble minerals the use of 1/4 gram of activated carbon for each 10 grams of mineral soil and the use of 1/2 gram of carbon for each 10 grams of organic soil used. It was found necessary to add carbon to ensure that the filtrates be colourless for colourimetric analysis.

(d) CO_2 was passed through the mixtures in a steady stream at the rate of approximately 60 c.c. per minute for one hour. Each flask was manually shaken at ten minute intervals.

(e) The whole was filtered by suction through Whatman No. 5 filter paper immediately after the one hour treatment with CO_2.

The method used for determining carbonic acid soluble phosphorous, potassium and calcium was essentially that outlined by Wilcox (146). Carbonic acid soluble magnesium and nitrate were found by approximately the same methods as used by Peech and English (105). Minor deviations from the above procedures were necessary in order to adopt them for use with the Hilger biochemabsorptiometer.

Determination of Exchange Capacity and Exchangeable Bases:- The normal ammonium acetate method as described by Schollenberger and Simon (119), was used to determine the exchange capacity and exchangeable bases. It was decided that two profiles should be so studied to see if there was any striking change. The two profiles selected represented the two most extreme cases in the study, one was an unburned lodgepole pine site and the other profile selected was the lodgepole pine severely burned in 1945 and burned again in 1951.

RESULTS AND DISCUSSION

Texture was relatively uniform throughout all the soils studied. Since texture was determined to aid in classification only, no relationship between texture and burning, if any, was sought. The comparison between Bouyoucos's method of mechanical analysis and hand texturing indicates that hand texturing is sufficiently accurate for the purpose in mind.

In the majority of the sites sampled, the percent porosity decreased with burning. With repeated burning illustrated by the burns of 1945 and 1951 a substantial reduction in percent porosity occurs. The decrease was from 68.25 to 52.50 percent porosity. On the other hand an increase in porosity was observed in the 1943 burn of Douglas Fir tree cover. This may be a result of the beneficial action on soil structure of the grasses which became more abundant after burning. An explanation for the increase in porosity in the stagnant lodgepole pine burn of 1951 might be the addition of considerable amounts of foliage from the dead trees. Such an addition to the Ao may have resulted in a greater depth of porous Ao. In the remainder of the samples burning decreased porosity. This reduction in porosity is probably due to destruction of the very porous organic mat resulting in exposure of soil to the elements and the breakdown of the fine crumb structure by fire. A further reduction in porosity results from clogging of soil pores by suspended material.

Burning produced a substantial increase in the percentage of capillary pore space in all the cores studied. Such an increase is partially explained by the reduction of porous litter, the destruction of soil aggregates and the consequent washing in and plugging of the larger soil pores with ash. The alkaline ash may cause dispersion of soil particles which may in turn be carried into the soil pores finally filling the larger voids. With removal of the Ao the top 0-3 inches of soil will normally include more mineral soil which has finer pores than the relatively open organic horizon.

As a result of fire the amount of non-capillary porosity was reduced in all the samples. The removal by fire of the porous Ao which contains many large pores will thus bring about a marked reduction in the percentage of non-capillary porosity. In the burn of 1945 and again in 1951 the non-capillary porosity was reduced the most, from 22.08 percent in the unburned area adjacent to the burn, to 9.85 percent in the burned site.

The data indicated that burning brought about an increase in volume weight of the 0-3 inch layer. All the cores investigated showed substantial increases in volume weight. The greatest increase was from .390 for the unburned mixed stand of lodgepole pine, spruce, and Douglas fir to .990 for the corresponding area burned in 1945. These increases are the result of compaction of the surface soil by rain and the inclusion of more of the dense mineral soil in the 0-3 inch layer.

Burning greatly altered the rate of infiltration on all the sites studied. The greatest reduction occurred in the 1943 Fire. In the 1951 Fire little or no effect was observed. Apparently more than two years are necessary to affect infiltration rates. As the time required for entry of water increased with the age of the fire, it would appear that the length of exposure to the elements is the controlling factor in decreasing infiltration rates. Exposure of the bare surface soil results in compaction and destruction of soil structure which greatly affects infiltration rates.

Soil temperature at a 3 inch depth indicated that burned over soils were warmer. The warmest soil was the area burned in 1945 and 1951. The value obtained for this area was 70°F. as compared to 54°F. for a comparable unburned location. Apparently with the removal of the Ao and with the falling of the dead trees the soil has lost its insulating agents and the ground is subject to more rapid changes in and greater extremes of temperature. The 1951 burn of lodgepole pine and stagnant lodgepole pine did not result in as large a change in temperature as did the older burns. Much charcoal was observed on the soil surface in the 1951 fires but the shade of the still standing dead trees probably reduced the amount of radiation reaching the charcoal.

All the recent burns brought about positive increases in the pH of the Ao. The greatest increase in pH occurred in the 1945 and 1951 burn. The pH values rose from pH 4.5 to pH 7.45 in the Ao of these samples. Increases in the A_2 were observed in several of the samples. One increase was recorded in the lodgepole pine burn of 1945 where the pH rose from 4.65 to 5.3. Another rise in pH of the A_2 was found in the burn of 1945 and 1951 where the pH rose from 4.92 to 6.03. No changes in pH of the A_2 occurred in the burn of 1951. It would thus appear that several years precipitation is essential to carry down the minerals before the pH of the A_2 rises. With two burns the Ao is so reduced that the ash becomes partially incorporated with the A_2 and thus a rise in pH is registered. With the change in vegetation from Douglas fir to either lodgepole pine or a mixed stand of lodgepole pine, Douglas fir and spruce a substantial decrease in pH of the Ao and A_2 was found. Lodgepole pine foliage is more acidic than that of Douglas fir (131), and it could possibly bring about a reduction in pH by increasing the intensity of leaching of the soil minerals. The values obtained indicate that the pH of the burned soils will decrease 3 to 4 years after the fire.

Analysis of the various profiles indicate that burning decreases the percent organic matter in the remaining duff but did not bring about any change below the Ao. It is observed that in all samples a great reduction in the percent organic matter of the Ao occurred with burning. An example of the effect of fire is the reduction from 26 percent organic matter in the Ao to 5 percent organic matter in the Ao of the lodgepole pine sites burned in 1945 and 1951. Since no marked changes were found below the Ao, it appears that the fire temperatures in this area were not sufficiently warm to destroy incorporated organic matter.

Burning had little or no effect on total nitrogen below the A_2. In the Ao and A_2 horizons there are decreases and increases in the total nitrogen content. Total nitrogen decreased in the Ao of the mixed stand of lodgepole pine, spruce and Douglas fir which was burned in 1945. In the A_2 of the same burned soils the total nitrogen content increased. Such an increase may be the result of increased bacterial activity after the fire or it may be due to the removal of the more soluble nitrogenous salts to the lower horizons. Total nitrogen content is lowered in the Ao of the Douglas fir area burned over in 1943. There is no change in the A_2. an increase of .03 percent is observed in the B_2 horizons which is probably a result of stimulated bacterial activity and leaching. In the Ao of the lodgepole pine burned in 1945 and 1951 decreases of up to 80 percent were recorded. Losses of total nitrogen occurred in the Ao of the soil under lodgepole pine which was burned in 1945. The effect on the A_2 of the soil in the same burn varied. In one pit a decrease in total nitrogen in the A_2 resulted while in another sampling area an increase in the A_2 was found. A reduction in both the Ao and A_2 occurred in the lodgepole pine burn of 1951. Increases in total nitrogen were found in the Ao of the stagnant lodgepole pine burned in 1951.

Burning was responsible for an increase in total phosphorous in the Ao of most of the soils studied. The Ao horizon of the Douglas fir area burned in 1943 had a decrease in phosphorous. A decrease in total phosphorous of the Ao horizon was found in the soils under a mixed stand of lodgepole pine, Douglas fir and spruce which had been burned in 1945. An explanation for the decrease in total phosphorous for these burns might be the loss of phosphorous in the smoke as described by Isaac and

Hopkins (73), or it could be a result of the wind blowing the ash and top soil as recorded by Pechanec and Stewart (104). A trend indicating that burning of lodgepole pine in 1945 only and in 1945 and again in 1951 resulted in an increase of total phosphorous of the A_2. Rainfall probably carried some of the soluble phosphorous down to these lower horizons. With the exception of the example mentioned the results below the Ao varied to such an extent that no conclusion could be made as to the effect of fire on the total phosphorous content in the subsoil.

The carbonic acid soluble phosphorous content of the Ao horizon was greatly reduced as a result of burning. The only sample not demonstrating such an effect was one site in the 1951 burn of stagnant lodgepole pine. The reason for no decrease in the availability of phosphorous at this site may have been due to the absence of excessive amounts of calcium. According to Thorne and Peterson (135), CaO induced alkalinity will greatly reduce the availability of phosphorous. Teakle (132), demonstrated that phosphate concentration in the soil solution was greatly reduced as pH values rose from 4.5 to 6.5. All the samples studied except one site in the 1945 and 1951 burn of lodgepole pine and one site in the 1951 burn of stagnant lodgepole pine showed a decrease in availability of phosphorous in the A_2. The effect of fire varied in the B_2. The availability of phosphorous decreased in the B_2 of the Douglas fir burn in 1943, the lodgepole pine burn of 1945, the 1951 burn of lodgepole pine and the stagnant lodgepole pine burn of 1951. No change in the availability of phosphorous in the B_2 was observed in the remaining samples. The age of the burn appeared to have some effect on the degree of change in availability of phosphorous in the Ao horizons. Recent burns did not appear to have as much effect on availability as the older burns. Possibly several years must pass before all the released calcium in the ash can react with the released phosphorous. A comparison of carbonic acid soluble phosphate and total phosphorous reveals that in the Ao of the unburned soil approximately 25 percent of the total phosphorous is available while in the burned Ao horizons very little of the total phosphorous is available. Similiarly Bujakowsky (17), observed that the normal organic horizon contained 20 times as much soluble phosphorous as did the mineral soil. Burning thus appears to decrease the portion of total phosphorous which is available.

CO_2 available potassium decreased in the Ao of all but one sample studied. The Ao of one sample of the stagnant lodgepole pine burned in 1951 did not have a decrease. The data indicates that the potassium released in the ash must be readily soluble and easily leached. Increases in potassium content of the A_2 did not follow a given trend. Eight of the samples studied showed a decrease in CO_2 soluble potassium. The remaining four samples had an increase in potassium. Increased leaching following the removal of vegetation by the fire, apparently removed most of the potassium beyond the A_2. In the B_2 horizons the potassium content increased in all but two samples. Although the B_3 horizons were not studied, it is possible that the potassium in the two exceptions had been leached to greater depths. The accumulation of potassium in the subsoil after a burn is in agreement with work done by Rideout (112).

An increase in the content of CO_2 soluble calcium in the Ao horizons of recently burned soils was found. Decreases in the amount of calcium in the Ao of the burns in 1943 and 1945 occurred. The largest decrease was recorded in the 1943 burn while but a slight decrease was observed in the 1945 burns. It appears that after 8 or 9 years all the added calcium is leached to lower horizons or is utilized by the new ground cover. The values obtained for the A_2 varied considerably. Five of the samples showed an increase in calcium content while the remaining seven samples showed decreases. In the more recent burns as in 1951 the calcium content in the B_2 horizons did not change to any extent. In the burns of 1943, 1945, 1945 and 1951 increases in four of the samples and decreases in the remaining five samples were found. The samples indicating an increase in the B_2 were probably receiving calcium which had been leached from the Ao and A_2 horizons. Decreases in the calcium content of the B_2 may have resulted from increased leaching due to the removal of ground cover by fire.

CO_2 soluble magnesium showed some variability in the A_2 and B_2. There was a trend to an increase in magnesium of the Ao horizon in the recent burns of 1945 and 1951 and 1951. The content of magnesium decreased in the Ao of the older burns in 1943 and 1945. Excessive leaching probably removed the added magnesium to the subsoil.

The values for CO_2 soluble nitrates showed a decrease in the Ao of the burned soils. In the A_2 horizon the results were varied. From the data it is indicated that eight out of the twelve burned soil samples showed an increase of nitrates in the B_2 horizon. Possibly after the burn nitrification was was stimulated at the soil surface but with considerable leaching the nitrate was carried to the subsoil.

The comparison between the twice burned profile 1945 and 1951 and the adjacent unburned profile indicated that there was some reduction in the base exchange capacity in the Ao. No substantial change was observed below the Ao. Exchangeable calcium was greatly increased in the Ao and slightly increased in the A_2 of the burned soil. The content of exchangeable magnesium rose in the Ao, A_2, and B_2 of the burned soil. Increases in exchangeable potassium were found in the Ao, A_2, and B_2, and B_3 of the burned profile. According to the data the percent base saturation increased in the Ao, A_2, B_2, and B_3 of the burned site.

CONCLUSIONS

As a result of forest fires the following changes occurred in the soil of the lodgepole pine, Douglas fir and the mixed stands of lodgepole pine, Douglas fir and spruce forests near Lac Le Jeune.

(1) A reduction in percent porosity of the top 0-3 inches of soil due to the destruction of both the porous organic horizon and the crumb structure of the upper portion of the B_2 horizon. A further reduction was the result of the soil pores being clogged by ash and suspended soil particles.

(2) Increased percentage of capillary pore space of the 0-3 inch layer because of the destruction of the Ao horizon and the compaction of the exposed soil by rain.

(3) A decrease in the percentage of non-capillary pore space or air volume in the 0-3 inch layer resulting from the destruction of the Ao with its large pores. The compacting effect of rain drops on the crumb structure of the B_2 horizon also aided in decreasing the non-capillary porosity.

(4) An increase in volume weight of the 0-3 inch layer due to compaction and destruction of the less dense Ao.

(5) A decrease in the infiltration rate due to compaction and destruction of soil structure.

(6) An increase in soil temperature at a depth of 3 inches resulting from the addition of charcoal which absorbs heat and the destruction of vegetation and forest litter which normally serve as insulating agents.

(7). An increase in pH of the Ao and in some cases of the A_2 as a result of the release of basic minerals from the ash. There was an indication that the basic minerals may be leached downwards to the A_2. The pH of the Ao decreased 3 or 4 years after the fire.

(8) A decrease in the organic matter content of the duff which had not been totally destroyed by fire. Below the Ao no change occurred.

(9) A decrease in the total nitrogen content of the Ao due to the volatilization of nitrogen during the fire. No definite trend could be established below the Ao.

(10) An increase in total phosphorous in the Ao because of the release of this element from the litter.

(11) A reduction in the carbonic acid soluble phosphorous in the Ao due to its combination with the excess calcium to form an insoluble compound. Similiarly a decrease in CO_2 soluble phosphorous occurred in the A_2.

(12) A decrease in CO_2 soluble potassium in the Ao and A_2 resulting from unrestricted leaching. An increase in CO_2 soluble potassium in the B_2 horizon.

(13) An increase in CO_2 soluble calcium in the Ao of recent burns due to the presence of large amounts of calcium in the ash. Apparently 8 or 9 years are required before all the added calcium is either leached to lower horizons or utilized by succeeding vegetation.

(14) An increase in CO_2 soluble magnesium in the Ao of the recent burns. The content decreased in the Ao of the older burns because of increased leaching.

(15) A decrease in CO_2 soluble nitrates in the Ao. An increase in nitrates in the B_2 is probably a result of increased nitrification at the soil surface followed by considerable leaching.

(16) A reduction in the base exchange capacity of the Ao. An increase in exchangeable calcium in the Ao and A_2. An increase in exchangeable magnesium in the Ao, A_2 and B_2 horizons. An increase in exchangeable potassium in the Ao, A_2, B_2, and B_3. An increase in percent base saturation in the Ao, A_2, B_2, and B_3 levels.

APPENDIX

	Popular Name	Scientific Name
Trees:	Aspen	Populus tremuloides
	Douglas fir	Pseudotsuga taxifolia
	Lodgepole pine	Pinus contorta
	Spruce	Picea engelmanni
Shrubs:	Alder	Alnus sitchensis
	Canada dogwood	Cornus canadensis
	Dwarf blueberry	Vaccinium caespitosum
	Kinnickinnick	Arctostaphylos uva-ursi
	Red alpine blueberry	Vaccinium scoparius
	Rose	Rosa spp
	Sopolallie	Eleagnus canadensis
	White hardhack	Spiraea lucida
	Willow	Salix barclayii
Herbs:	Arnica	Arnica cordifolia
	Dandelion	Taraxacum officinale
	Fireweed	Epilobium angustifolium
	Goatsbeard	Tragopogon pratensis
	Hawkweed	Hieracium albiflorum
	Lupine	Lupinus articus
	Pine grass	Calamagrostis rubescens
	Strawberry	Fragaria glauca
	Timber sedge	Caren conncinoides
	Timber milk vetch	Astragalus serotinus
	Twin flower	Linnaea borealis
	Wintergreen	Pyrola secunda
	Yarrow	Achillea millefolium

Table 12: COMPARISON OF THE RESULTS OBTAINED BY THE BOUYOUCOS METHOD OF MECHANICAL ANALYSIS AND HAND TEXTURING.

Map Number	Site Description	Method	Horizon A_2	Horizon B_2	Horizon B_3	Horizon C
8	1945 Burn of Lodgepole Pine	Bouyoucos	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand
		Hand Texturing	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand
9	Unburned Lodgepole Pine	Bouyoucos	Sandy Loam	Sandy Loam	Loamy Sand	Loamy Sand
		Hand Texturing	Sandy Loam	Sandy Loam	Sandy Loam	Loamy Sand

TABLE 13: THE EFFECT OF FIRE ON THE NON-CAPILLARY POROSITY, CAPILLARY POROSITY, PERCENT POROSITY AND VOLUME-WEIGHT OF THE SOIL.

MAP SITE NUMBER	DESCRIPTION	NON-CAPILLARY POROSITY	AVERAGE	CAPILLARY POROSITY	AVERAGE	PERCENT POROSITY	AVERAGE	VOLUME WEIGHT	AVERAGE
1	1943 Burn of Douglas fir	22.75 27.93	25.34	45.45 36.67	41.06	68.40 65.00	66.70	.680 .712	.696
3	Douglas fir Unburned	32.13 34.13	33.13	30.37 31.75	31.06	62.70 66.20	64.40	.548 .523	.535
5	1945 Burn of Mixed Stand	12.60 16.01	14.30	46.95 40.81	43.88	59.80 56.70	58.25	.985 .996	.990
7	Unburned Mixed Stand	29.24 40.15	34.69	32.94 30.09	31.51	59.30 70.40	64.85	.573 .357	.465
8	1945 Burn of Lodgepole pine	22.28 22.82	22.55	42.47 36.39	39.43	65.00 59.40	62.20	.620 .680	.654
9	Unburned Lodgepole pine	29.12 36.58	32.85	30.15 34.76	32.45	59.00 71.50	65.25	.541 .445	.493
10	1945 Burn of Lodgepole pine	17.02 15.64	16.33	40.87 40.00	40.43	57.40 55.80	56.60	.889 .821	.855
12	Unburned Lodgepole pine	19.59 24.57	22.08	39.18 32.63	36.40	69.00 67.50	68.25	.735 .563	.649
# 14	1945 and 1951 Burn of Lodgepole Pine	9.01 10.69	9.85	42.12 42.90	42.51	51.20 53.80	52.50	1.050 1.223	1.136
# 15	1951 Burn of Lodgepole pine	19.47 32.44	25.95	42.89 38.06	40.47	63.60 70.50	67.05	.967 .704	.835
18	1951 Burn of Stagnant Lodgepole pine	36.38 35.51	35.94	43.77 34.01	38.89	74.50 69.50	72.00	.774 .493	.633
19	Unburned Stagnant Lodgepole pine	29.71 35.92	32.81	41.88 34.13	38.00	71.80 70.20	71.00	.424 .356	.390

COMPARE WITH MAP SITE 12.

TABLE 14 THE EFFECT OF FIRE ON THE RATE OF WATER INFILTRATION AND SOIL TEMPERATURE

	MAP SITE NUMBER	DESCRIPTION	RATE OF INFILTRATION MINUTES	AVERAGE IN MINUTES	SOIL TEMPERATURE AT A DEPTH OF 3 INCHES
	1	1943 Burn of Douglas fir	118 105	111	64°F
	3	Unburned Douglas fir	29 36	32	58°F
	5	1945 Burn of Mixed Stand	60 72	66	66°F
	7	Unburned Mixed Stand	24 18	21	55°F
	8	1945 Burn of Lodgepole Pine	24 23	23	62°F
	9	Unburned Lodgepole pine	19 14	16	53°F
	10	1945 Burn of Lodgepole pine	45 31	38	59°F
	12	Unburned Lodgepole pine	13 18	15	54°F
#	14	1945 and 1951 Burn of Lodgepole pine	112 60	86	70°F.
#	15	1951 Burn of Lodgepole pine	17 18	17	63°F.
	18	1951 Burn of Stagnant Lodgepole pine	42 31	36	58°F.
	19	Unburned Stagnant Lodgepole pine	18 12	15	52°F.

Compare with Map Site 12

TABLE 15 THE EFFECT OF FIRE ON SOIL pH

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE	B3	AVERAGE	C	AVERAGE
1 2	1943 Burn of Douglas fir	5.80 5.60	5.70	5.60 5.20	5.40	5.80 5.70	5.75	6.20 6.00	6.10	6.45 6.20	6.32
3 4	Unburned Douglas fir	5.80 5.35	5.57	5.90 5.40	5.65	5.95 5.82	5.88	6.20 6.05	6.12	5.90 6.02	5.96
5 6	1945 Burn of Mixed Stand	5.46 5.15	5.30	4.88 5.10	4.99	5.55 6.08	5.81	5.92 6.45	6.28	6.2 6.4	6.30
7	Unburned Mixed Stand	4.80	4.80	4.75	4.75	5.62	5.62	5.9	5.9	6.65	6.65
8	1945 Burn of Lodgepole Pine	5.20	5.20	5.3	5.3	5.95	5.95	6.15	6.15	6.45	6.45
9	Unburned Lodgepole Pine	4.70	4.70	4.65	4.65	5.30	5.30	5.46	5.46	5.45	5.45
10 11	1945 Burn of Lodgepole Pine	5.80 5.50	5.65	5.40 5.42	5.41	6.15 5.8	5.97	6.25 6.15	6.20	6.32 6.25	6.28
12	Unburned Lodgepole Pine	4.50	4.50	4.92	4.92	5.45	5.45	5.95	5.95	6.25	6.25
# 13 14	1945 & 1951 Burn of Lodgepole Pine	7.70 7.18	7.44	6.30 5.76	6.03	5.82 6.00	5.91	6.30 6.05	6.17	6.35 6.55	6.45
15	1951 Burn of Lodgepole Pine	6.65	6.65	5.45	5.45	6.29	6.29	6.10	6.10	5.90	5.90
16	Unburned Lodgepole Pine	5.05	5.05	5.62	5.62	6.10	6.10	6.32	6.32	6.60	6.60
17 18	1951 Burn Stagnant Lodgepole Pine	6.22 6.25	6.23	5.10 5.35	5.22	5.60 6.35	5.97	5.85 6.2	6.02	6.0 6.1	6.05
19	Unburned Stagnant Lodgepole Pine	4.20	4.20	5.05	5.05	5.70	5.70	5.95	5.95	6.1	6.1

COMPARE WITH MAP SITE 12

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TABLE 16 THE EFFECT OF FIRE ON THE ORGANIC MATTER CONTENT OF THE SOIL (IN PERCENT).

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE	B3	AVERAGE	C	AVERAGE
1 2	1943 Burn of Douglas fir	19.69 12.30	15.99	1.28 .39	.83	.79 .60	.69	.30 .21	.25	.45 .19	.32
3 4	Unburned Douglas fir	56.68 46.01	51.34	.96 1.31	1.13	.50 1.12	.81	.30 .50	.40	.33 .18	.25
5 6	1945 Burn of Mixed Stand	11.33 11.47	11.40	1.13 .53	.83	.30 .37	.33	.10 .12	.11	.06 .09	.07
7	Unburned Mixed Stand	19.35	19.35	.79	.79	.44	.44	.22	.22	.06	.06
8	1945 Burn of Lodgepole Pine	21.66	21.66	1.31	1.31	.52	.52	.10	.10	.06	.06
9	Unburned Lodgepole Pine	73.92	73.92	1.24	1.24	.58	.58	.15	.15	.09	.09
10 11	1945 Burn of Lodgepole Pine	6.61 11.20	8.90	.94 .94	.94	.53 .42	.47	.15 .16	.15	.08 .12	.10
12	Unburned Lodgepole Pine	26.57	26.57	1.08	1.08	.34	.34	.15	.15	.04	.04
# 13 14	1945 & 1951 Burn of Lodgepole Pine	5.42 5.78	5.60	.86 .99	.92	.75 .68	.71	.20 .09	.14	.12 .07	.09
15	1951 Burn of Lodgepole Pine	18.23	18.23	1.41	1.41	.83	.83	.26	.26	.17	.17
16	Unburned Lodgepole Pine	29.60	29.60	1.06	1.06	.59	.59	.12	.12	.11	.11
17 18	1951 Burn Stagnant Lodgepole Pine	17.79 21.41	19.60	1.37 .87	1.12	.71 .92	.81	.28 .48	.38	.11 .30	.20
19	Unburned Stagnant Lodgepole Pine	29.43	29.43	1.23	1.23	1.06	1.06	.46	.46	.30	.30

COMPARE WITH MAP SITE 12

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TABLE 17 THE EFFECT OF FIRE UPON TOTAL NITROGEN IN THE SOIL (IN PERCENT)

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE	B3	AVERAGE	C	AVERAGE
1 2	1943 Burn of Douglas fir	1.150 .750	.95	.165 .090	.127	.130 .072	.101	.080 .035	.057	.082 .043	.062
3 4	Unburned Douglas fir	2.390 1.340	1.86	.180 .079	.129	.089 .053	.071	.074 .046	.060	.060 .027	.043
5 6	1945 Burn of Mixed Stand	.506 .770	.638	.097 .059	.078	.037 .048	.042	.021 .014	.017	.010 .014	.012
7	Unburned Mixed Stand	.807	.807	.040	.040	.044	.044	.023	.023	.021	.021
8	1945 Burn of Lodgepole Pine	.800	.800	.088	.088	.073	.073	.100	.100	.034	.034
9	Unburned Lodgepole Pine	1.200	1.200	.069	.069	.058	.058	.024	.024	.024	.024
10 11	1945 Burn of Lodgepole Pine	.454 .579	.516	.113 .094	.103	.064 .061	.062	.045 .038	.041	.051 .034	.042
12	Unburned Lodgepole Pine	.678	.678	.094	.094	.075	.075	.029	.029	.021	.021
# 13 14	1945 & 1951 Burn of Lodgepole Pine	.168 .061	.114	.080 .096	.088	.034 .083	.058	.057 .045	.051	.015 .042	.028
15	1951 Burn of Lodgepole Pine	.990	.990	.107	.107	.086	.086	.039	.039	.035	.035
16	Unburned Lodgepole Pine	1.096	1.096	.164	.164	.117	.117	.080	.080	.081	.081
17 18	1951 Burn Stagnant Lodgepole Pine	.784 2.80	1.792	.030 .101	.065	.076 .080	.078	.023 .071	.047	.021 .018	.019
19	Unburned Stagnant Lodgepole Pine	.651	.651	.054	.054	.109	.109	.073	.073	.049	.049

COMPARE WITH MAP SITE 12

TABLE 18 THE EFFECT OF FIRE UPON THE TOTAL PHOSPHOROUS IN THE SOIL (IN PARTS PER MILLION)

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE	B3	AVERAGE	C	AVERAGE
1 2	1943 Burn of Douglas fir	16.32 6.20	11.26	42.86 22.85	32.85	156.37 157.93	157.10	90.82 149.24	120.03	182.72 90.68	131.70
3 4	Unburned Douglas fir	48.91 18.73	33.82	93.11 75.94	84.52	113.01 105.42	109.21	71.70 122.60	97.15	180.41 188.80	184.65
5 6	1945 Burn of Mixed Stand	17.16 17.62	17.39	85.07 86.59	85.83	200.93 235.30	218.11	180.57 189.65	185.11	220.03 242.08	231.05
7	Unburned Mixed Stand	42.74	42.74	165.02	165.02	241.22	241.22	198.98	198.98	198.63	198.63
8	1945 Burn of Lodgepole Pine	35.45	35.45	167.00	167.00	247.06	247.06	201.88	201.88	184.02	184.02
9	Unburned Lodgepole Pine	33.04	33.04	49.71	49.71	96.83	96.83	135.55	135.55	187.08	187.08
10 11	1945 Burn of Lodgepole Pine	149.86 68.83	109.34	108.37 116.59	112.48	226.01 180.31	203.16	90.69 68.05	79.37	126.34 131.93	129.13
12	Unburned Lodgepole Pine	19.94	19.94	75.56	75.56	462.51	462.51	65.29	65.29	90.68	90.68
# 13 14	1945 & 1951 Burn of Lodgepole Pine	57.35 81.25	69.30	85.18 110.58	97.88	243.99 332.08	288.03	97.51 100.40	98.95	119.67 88.93	104.30
15	1951 Burn of Lodgepole Pine	81.14	81.14	146.31	146.31	274.59	274.59	176.77	176.77	257.47	257.47
16	Unburned Lodgepole Pine	21.66	21.66	20.16	20.16	26.37	26.37	55.16	55.16	36.72	36.72
17 18	1951 Burn Stagnant Lodgepole Pine	38.14 70.54	54.34	78.31 83.25	80.78	136.21 333.24	234.72	192.62 157.39	175.00	354.48 264.24	309.36
19	Unburned Stagnant Lodgepole Pine	18.67	18.67	157.75	157.75	244.40	244.40	135.39	135.39	198.93	198.93

COMPARE WITH MAP SITE 12

TABLE 19 THE EFFECT OF FIRE ON THE CO_2 SOLUBLE PHOSPHOROUS IN THE SOIL. (PARTS PER MILLION.

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE
1 2	1943 Burn of Douglas fir	15.92 5.76	10.84	2.57 2.04	2.30	.51 .82	.66
3 4	Unburned Douglas fir	47.72 18.57	33.14	3.98 3.30	3.64	2.06 2.05	2.05
5 6	1945 Burn of Mixed Stand	1.93 7.71	4.82	.10 .71	.40	.51 .51	.51
7	Unburned Mixed Stand	40.07	40.07	2.24	2.24	.50	.50
8	1945 Burn of Lodgepole Pine	19.07	19.07	.62	.62	.82	.82
9	Unburned Lodgepole Pine	32.45	32.45	1.76	1.76	1.64	1.64
10 11	1945 Burn of Lodgepole Pine	1.06 3.65	2.35	.82 .72	.77	.51 .30	.40
12	Unburned Lodgepole Pine	19.03	19.03	1.23	1.23	.30	.30
# 13 14	1945 & 1951 Burn of Lodgepole Pine	10.01 1.52	5.76	1.94 .51	1.22	.51 .30	.40
15	1951 Burn of Lodgepole Pine	17.64	17.64	.62	.62	.42	.42
16	Unburned Lodgepole Pine	20.85	20.85	.84	.84	.61	.61
17 18	1951 Burn Stagnant Lodgepole Pine	20.04 16.61	18.32	.73 .63	.68	.93 .72	.82
19	Unburned Stagnant Lodgepole Pine	17.50	17.50	.31	.31	1.06	1.06

\# COMPARE WITH MAP SITE 12

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TABLE 20 THE EFFECT OF FIRE ON THE CO_2 SOLUBLE POTASSIUM CONTENT OF THE SOIL. (PARTS PER MILLION)

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE
1 2	1943 Burn of Douglas fir	22.86 25.47	24.16	8.75 10.20	9.47	8.23 10.79	9.51
3 4	Unburned Douglas fir	31.31 34.00	32.65	15.20 13.41	14.30	5.67 8.23	6.95
5 6	1945 Burn of Mixed Stand	4.93 12.66	8.79	3.06 2.29	2.67	12.20 3.06	7.63
7	Unburned Mixed Stand	34.84	34.84	14.80	14.80	6.92	6.92
8	1945 Burn of Lodgepole Pine	23.36	23.36	9.91	9.91	15.48	15.48
9	Unburned Lodgepole Pine	49.44	49.44	8.28	8.28	5.64	5.64
10 11	1945 Burn of Lodgepole Pine	3.45 6.72	5.08	3.33 9.23	6.28	3.32 5.63	4.47
12	Unburned Lodgepole Pine	14.16	14.16	8.21	8.21	3.92	3.92
# 13 14	1945 & 1951 Burn of Lodgepole Pine	9.48 1.52	5.50	17.66 3.83	10.74	6.18 8.22	7.20
15	1951 Burn of Lodgepole Pine	25.97	25.97	13.06	13.06	7.72	7.72
16	Unburned Lodgepole Pine	28.31	28.31	8.92	8.92	11.65	11.65
17 18	1951 Burn Stagnant Lodgepole Pine	17.61 21.72	19.66	15.10 13.80	14.45	14.05 14.67	14.36
19	Unburned Stagnant Lodgepole Pine	20.10	20.10	15.29	15.29	10.60	10.60

COMPARE WITH MAP SITE 12

TABLE 21 THE EFFECT OF FIRE ON THE CONTENT OF CO_2 SOLUBLE CALCIUM IN THE SOIL (PARTS PER MILLION).

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE
1 2	1943 Burn of Douglas fir	26.16 26.58	26.37	20.09 15.36	17.72	24.69 17.73	21.21
3 4	Unburned Douglas fir	46.97 31.99	39.48	24.37 19.34	21.85	22.42 24.70	23.56
5 6	1945 Burn of Mixed Stand	9.65 14.87	12.26	9.20 4.59	6.89	13.78 8.42	11.10
7	Unburned Mixed Stand	13.06	13.06	4.59	4.59	10.18	10.18
8	1945 Burn of Lodgepole Pine	24.14	24.14	14.87	14.87	22.46	22.46
9	Unburned Lodgepole Pine	24.70	24.70	10.87	10.87	14.62	14.62
10 11	1945 Burn of Lodgepole Pine	13.57 12.90	13.23	5.38 10.77	8.07	17.40 11.52	14.41
12	Unburned Lodgepole Pine	9.63	9.63	13.86	13.86	14.71	14.71
# 13 14	1945 & 1951 Burn of Lodgepole Pine	113.87 42.65	78.26	10.74 17.66	14.20	7.72 15.41	11.56
15	1951 Burn of Lodgepole Pine	46.38	46.38	18.02	18.02	19.06	19.06
16	Unburned Lodgepole Pine	17.54	17.54	19.68	19.68	22.40	22.40
17 18	1951 Burn Stagnant Lodgepole Pine	20.31 44.09	32.20	18.74 16.27	17.50	22.02 16.35	19.18
19	Unburned Stagnant Lodgepole Pine	18.48	18.48	18.98	18.98	16.70	16.70

COMPARE WITH MAP SITE 12

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TABLE 22 THE EFFECT OF FIRE ON THE CONTENT OF CO_2 SOLUBLE MAGNESIUM IN THE SOIL. (PARTS PER MILLION).

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE
1 2	1943 Burn of Douglas fir	34.13 9.41	21.77	8.75 4.08	6.41	10.28 5.65	7.96
3 4	Unburned Douglas fir	15.28 14.10	14.69	7.60 6.96	7.28	9.79 10.03	9.91
5 6	1945 Burn of Mixed Stand	2.68 7.49	5.08	2.81 1.53	2.17	6.94 4.59	5.76
7	Unburned Mixed Stand	7.84	7.84	4.59	4.59	4.58	4.58
8	1945 Burn of Lodgepole Pine	13.76	13.76	6.26	6.26	5.95	5.93
9	Unburned Lodgepole Pine	23.60	23.60	4.91	4.91	6.92	6.92
10 11	1945 Burn of Lodgepole Pine	6.12 5.37	5.74	2.30 9.49	5.89	5.88 9.73	7.80
12	Unburned Lodgepole Pine	9.63	9.63	9.75	9.75	9.80	9.80
# 13 14	1945 & 1951 Burn of Lodgepole Pine	31.63 8.12	19.87	15.86 11.26	13.56	9.01 9.24	9.12
15	1951 Burn of Lodgepole Pine	19.79	19.79	7.83	7.83	7.94	7.94
16	Unburned Lodgepole Pine	12.31	12.31	12.60	12.60	12.36	12.36
17 18	1951 Burn Stagnant Lodgepole Pine	8.12 20.44	14.28	6.76 5.30	6.03	12.75 6.02	9.38
19	Unburned Stagnant Lodgepole Pine	4.40	4.40	5.79	5.79	7.95	7.95

COMPARE WITH MAP SITE 12

83

TABLE 23 THE EFFECT OF FIRE ON THE CONTENT OF CO_2 SOLUBLE NITRATE IN THE SOIL (IN PARTS PER MILLION)

MAP SITE NUMBER	DESCRIPTION	Ao	AVERAGE	A2	AVERAGE	B2	AVERAGE
1 2	1943 Burn of Douglas fir	.432 .088	.260	.237 .081	.159	.515 .596	.555
3 4	Unburned Douglas fir	.715 .688	.701	.073 .134	.103	.103 .483	.293
5 6	1945 Burn of Mixed Stand	.051 .055	.053	.051 .030	.040	.051 .089	.070
7	Unburned Mixed Stand	.342	.342	.131	.131	.039	.039
8	1945 Burn of Lodgepole Pine	.926	.926	.313	.313	.376	.376
9	Unburned Lodgepole Pine	1.017	1.017	.062	.062	.389	.389
10 11	1945 Burn of Lodgepole Pine	.063 .080	.071	.061 .082	.071	.255 .297	.276
12	Unburned Lodgepole Pine	.158	.158	.143	.143	.609	.609
# 13 14	1945 & 1951 Burn of Lodgepole Pine	.274 .038	.156	.358 .583	.470	.710 .416	.563
15	1951 Burn of Lodgepole Pine	.108	.108	.073	.073	.672	.672
16	Unburned Lodgepole Pine	1.390	1.390	.1730	.1730	.154	.154
17 18	1951 Burn Stagnant Lodgepole Pine	.216 .127	.171	.156 .127	.141	.421 .446	.433
19	Unburned Stagnant Lodgepole Pine	.298	.298	.305	.305	.175	.175

COMPARE WITH MAP SITE 12

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TABLE 24 THE EFFECT OF FIRE UPON THE BASE EXCHANGE CAPACITY, EXCHANGEABLE BASES, AND THE PERCENT BASE SATURATION OF A LODGEPOLE PINE SOIL BURNED IN 1945 and 1951.

MAP SITE NUMBER	DESCRIPTION	HORIZON	EXCHANGE CAPACITY IN MILLIEQUIVALENTS PER 100 GRAMS OF OVEN DRY SOIL	EXCHANGEABLE CALCIUM IN MILLIEQUIVS. PER 100 GMS. OVEN DRY SOIL.	EXCHANGEABLE MAGNESIUM IN MILLIEQUIVS. PER 100 GMS. OVEN DRY SOIL.	EXCHANGEABLE POTASSIUM IN MILLIEQUIVS. PER 100 GMS. OVEN DRY SOIL.	PERCENT BASE SATURATION
12	UNBURNED LODGEPOLE PINE	A_o	49.00	13.55	4.32	1.04	38.5
		A_2	11.00	3.76	1.21	.22	47.1
		B_2	10.00	3.10	.96	.12	41.8
		B_3	7.20	3.08	2.83	.17	85.8
		C	4.50	2.01	1.16	.18	96.6
13	1945 AND 1951 BURN OF LODGEPOLE PINE	A_o	31.00	24.43	5.50	1.07	100.0
		A_2	10.00	4.05	1.92	.37	63.4
		B_2	8.64	2.44	1.36	.25	72.8
		B_3	5.10	2.60	1.97	.32	95.8
		C	3.80	2.25	1.26	.18	97.1

FIGURE 2. AN OUTCROP OF COAST INTRUSIVE GRANITICS NEAR ROSSMORE LAKE

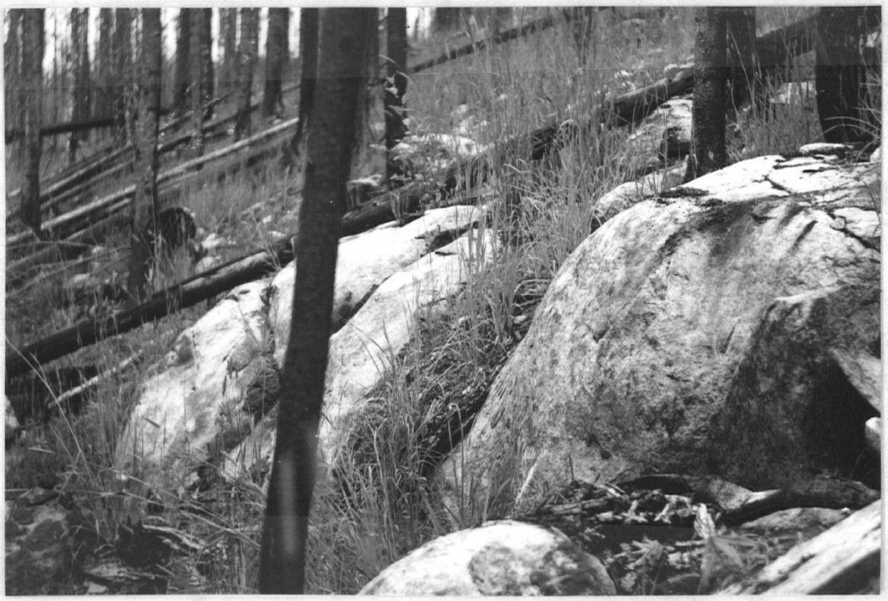


FIGURE 3. COAST INTRUSIVE GRANITIC OUTCROP NEAR LAC LE JEUNE.

FIGURE 4 TERTIARY BASALT AT ROSSMORE LAKE

FIGURE 5 TERTIARY BASALT FORMING A DISTINCT ESCARPMENT AT ROSSMORE LAKE

FIGURE 6. A TRANSVERSE MORAINE NEAR ROSSMORE LAKE

FIGURE 7. A DEGRADED MORAINE DAMMING LAC LE JEUNE

FIGURE 8. A MORAINE ROUGHLY PARALLEL WITH LAC LE JEUNE

FIGURE 9. ROSSMORE LAKE IS MORAINE DAMMED.

FIGURE 10. A GLACIAL ERRATIC CONGLOMERATE BLOCK NEAR ROSSMORE LAKE

FIGURE 11. A GLACIAL ERRATIC CONGLOMERATE BLOCK NEAR LAC LE JEUNE

FIGURE 12. KETTLE-LIKE DEPRESSIONS IN A TRANSVERSE MORAINE NEAR ROSSMORE LAKE

FIGURE 13. AN ESKER NEAR ROSSMORE LAKE

FIGURE 14. A ROCK DRUMLIN LOCATED 11 MIIES FROM LAC LE JEUNE

FIGURE 15. A ROCK DRUMLIN 12 MILES FROM LAC LE JEUNE

FIGURE 16. 1943 BURN OF DOUGLAS FIR

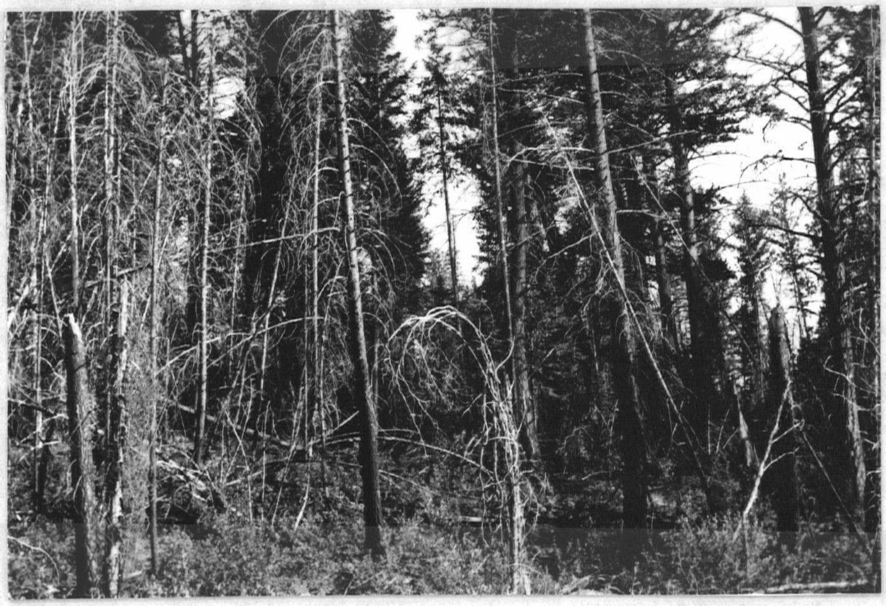


FIGURE 17. UNBURNED DOUGLAS FIR

FIGURE 18. 1945 BURN OF MIXED STAND

FIGURE 19. UNBURNED MIXED STAND

FIGURE 20. 1945 BURN OF LODGEPOLE PINE

FIGURE 21. UNBURNED LODGEPOLE PINE

FIGURE 22. 1945 BURN OF LODGEPOLE PINE (COMPARE WITH FIGURE 21).

FIGURE 23. 1945 and 1951 BURN OF LODGEPOLE PINE. (COMPARE WITH FIGURE 21).

FIGURE 24. 1951 BURN OF LODGEPOLE PINE

FIGURE 25. UNBURNED LODGEPOLE PINE

FIGURE 26. 1951 BURN OF STAGNANT LODGEPOLE PINE

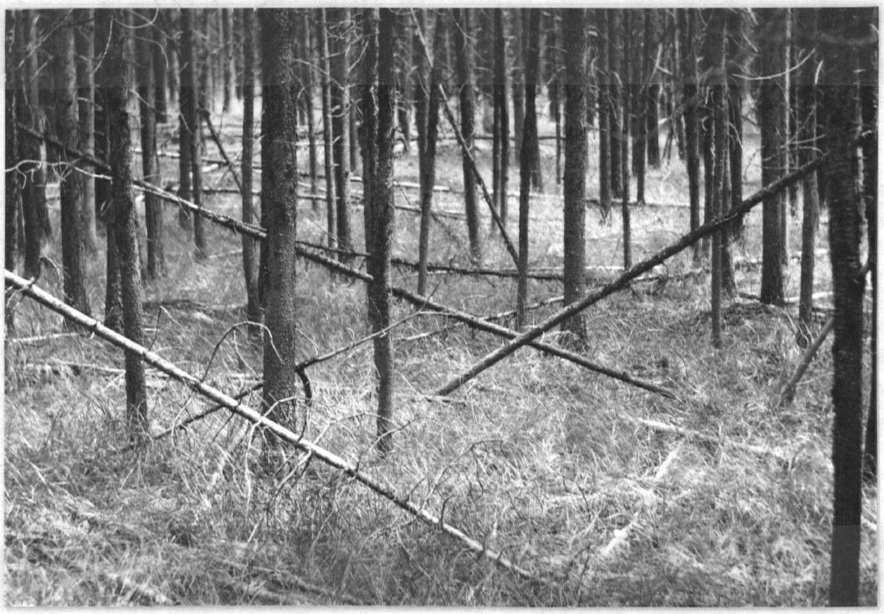


FIGURE 27. UNBURNED STAGNANT LODGEPOLE PINE

FIGURE 28. THE STEEL CYLINDER USED FOR DETERMINING INFILTRATION RATES

FIGURE 29. A WESTON SOIL THERMOMETER

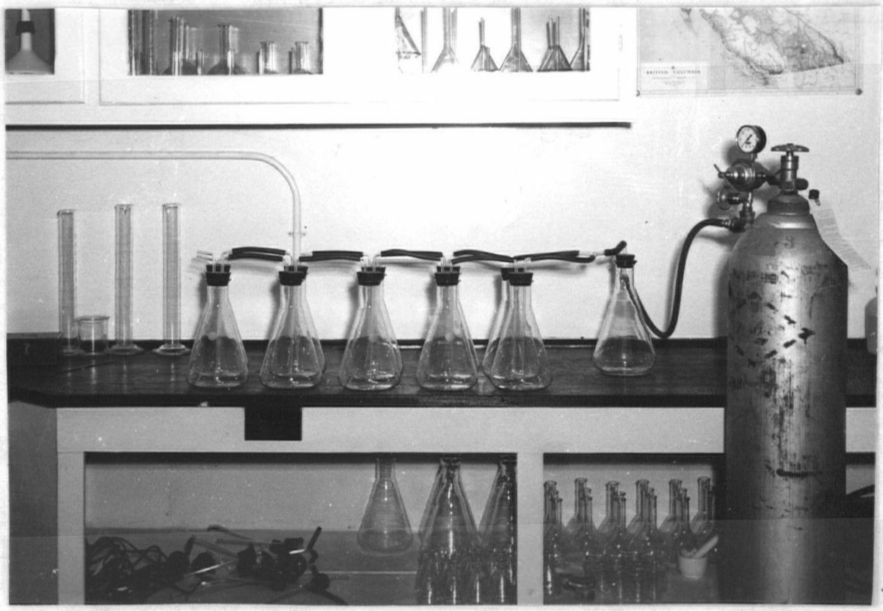
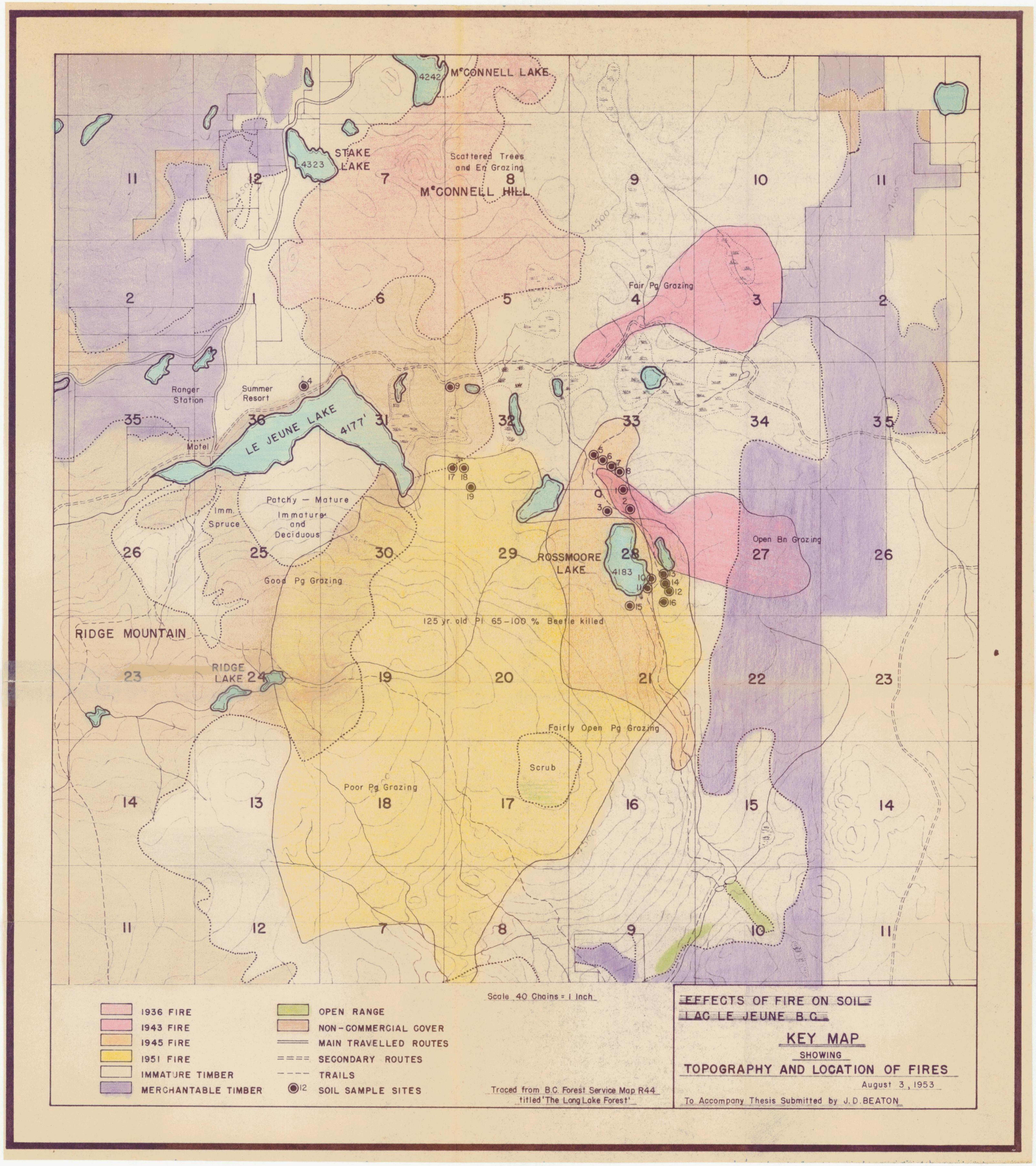


FIGURE 30. THE APPARATUS USED FOR DETERMINING CO_2 SOLUBLE MINERALS.



McCONNELL LAKE
4242
STAKE LAKE
4323
Scattered Trees and En Grazing
McCONNELL HILL
Fair Pg Grazing
Ranger Station
Summer Resort
Motel
LE JEUNE LAKE
4177'
Patchy — Mature
Imm. Spruce
Immature and Deciduous
Good Pg Grazing
ROSSMOORE LAKE
4183
Open Bn Grazing
125 yr. old Pl 65-100 % Beetle killed
RIDGE MOUNTAIN
RIDGE LAKE
Fairly Open Pg Grazing
Scrub
Poor Pg Grazing
4500
1936 FIRE
1943 FIRE
1945 FIRE
1951 FIRE
IMMATURE TIMBER
MERCHANTABLE TIMBER
OPEN RANGE
NON-COMMERCIAL COVER
MAIN TRAVELLED ROUTES
SECONDARY ROUTES
TRAILS
12 SOIL SAMPLE SITES
Scale 40 Chains = 1 Inch
Traced from B.C. Forest Service Map R44 titled 'The Long Lake Forest'
EFFECTS OF FIRE ON SOIL
LAC LE JEUNE B.C.
KEY MAP
SHOWING
TOPOGRAPHY AND LOCATION OF FIRES
August 3, 1953
To Accompany Thesis Submitted by J.D. BEATON

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