An Investigation of the Origin and Nature of Contraction Fissures in the Vicinity of Grand Forks, North Dakota

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AN INVESTIGATION OF THE ORIGIN AND NATURE OF CONTRACTION FISSURES IN THE VICINITY OF GRAND FORKS, NORTH DAKOTA

by

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for

Geology (420) Senior Thesis

Dr. John R. Reid

May 11, 1964
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Cracks appearing in vegetation-free areas and on level surfaces in the vicinity of Grand Forks, North Dakota were investigated during the winter and spring months of 1964. The width of these cracks was measured to determine if there was any significant change in their size that would correspond to a change in temperature.

It was determined that there is a linear relationship between the temperature and the width of the cracks, and if recording and observing errors could be eliminated, the values would have much more significance in subsequent investigations.

After an extensive review of the literature, several possible means of origin are proposed. It was determined that a correlation exists between these contraction fissures that appear in the frozen soil in the winter months in North Dakota, and similar structures, ice wedges, that are present in the permafrost regions of the world.
INTRODUCTION

The contraction fissures described in this paper are observed in level ground in sub-freezing temperature. This paper will attempt to correlate the genesis and frequency of these fissures with previously reported criteria from the permafrost areas of the world.

Since most of the work thus far performed by those investigating low temperature patterned ground and related phenomena has been in permafrost regions, this is believed to be a logical pattern to follow.

DESCRIPTION OF CRACKS

A brief introductory description of the cracks in question is in order at this point. These cracks appear in vegetation-free areas and on level surfaces. The cracks are as much as 0.5 to 1 cm. in width and are of various lengths often fifty feet or more. They are also randomly orientated. Their depth of penetration varies from several millimeters to more than 30 centimeters.

Following Washburn's (1956) classification of patterned ground, the patterned ground formed by these fractures can be classified as nonsorted polygons. His suggested origin is cryostatic pressure (freezing-induced hydrostatic phenomena). Some linear fissures and some forms of nonsorted polygons might be accounted for by this mechanism, because the cryostatic pressure beneath a downward-freezing layer would deform and fracture the layer if it were sufficiently brittle.
PREVIOUS WORK

Taber (1929, p. 457-458; 1930, p. 314, 317) produced contraction fissures in laboratory experiments by causing withdrawal of moisture to areas of ice formation during freezing. Small-scale, vertical polygonal fissures subsequently become filled with ice and, as the horizontal ice lenses formed concurrently they formed a cellular structure. The withdrawal of water from saturated soils is usually accompanied by the formation of shrinkage cracks as these ice layers build.

The movement of the water to a locus of freezing is explained by their dipolar nature and their migration along the surface of mineral particles under the influence of the difference in dielectric constants of water and ice (Washburn, 1956, p. 848).

As the temperature is lowered below the freezing point ice contracts independently of the orientation of the c-axis of the crystal and independent with respect to the type of ice, whether single or polycrystalline (Butkovich, 1957, p. 9). The grain size does not appreciably affect the values of the coefficient of linear thermal expansion. Ice is, therefore, practically isotropic with respect to thermal expansion in the temperature range 0°C to -30°C. Values for expansion are:

<table>
<thead>
<tr>
<th>°C</th>
<th>0</th>
<th>-5</th>
<th>-10</th>
<th>-15</th>
<th>-20</th>
<th>-25</th>
<th>-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>X10^-6 cm/cm</td>
<td>52.52</td>
<td>51.78</td>
<td>51.33</td>
<td>50.93</td>
<td>50.41</td>
<td>49.77</td>
<td>48.51</td>
</tr>
</tbody>
</table>

With an appreciable ice content, frozen ground will eventually develop frost cracks of tensional origin. Then, as initial
thawing starts at the surface, the cracks normally remain open because of the temperature lag between the surface and the permafrost core. The cracks will remain open unless filled by wind blown particles or water.

This last point is in harmony with the contraction theory proposed by Lachenbruch (1963) which is discussed later in this paper.

Washburn (1956, p. 859) indicates that the forces produced by cryostatic movement may combine with the forces of desiccation, contraction due to low temperature, and differential heaving to form a single continuous system responsible for polygonal patterns. These four processes can represent the end members of a tetrahedron and all possible patterns can be assigned within these boundaries.

**HIGH ALTITUDE FROST ZONES**

In the subnival zone (snow associated) and the high tropical mountains there is no permafrost. There is, however, rhythmic freezing of the ground every night and thawing during the day and ice penetrates only a few centimeters into the soil. Because of this slight penetration, only structure soils of limited dimension can exist, but because of the frequency of freezing there is a frequent movement of soil particles. The daily agitation of the upper soil layers retards the growth of vegetation in these areas. "...In such a process, affecting only the uppermost layers of the ground, the water-retaining ability of the soil and its capillary absorptive capacity are prime prerequisites for structure-soil formation. Other soils dry out too easily on the surface, hindering ice formation" (Troll, 1958, p. 15).
The question arises as to the application of the term "solifluction" to this movement in the upper soil layers which is produced by the short nightly soil freezing. It is concluded that the term is not appropriate because it does not involve movement of water concentrated above the frozen substratum. The structures produced are miniature forms and in some cases are so similar to the larger forms originating over frozen subsoil that there is no distinction made. There is water concentrated through ice formation and fluid movement in the uppermost soil layer, though it is only a short period of time between freezes.

These soil structures are associated with the cohesive colloid-bearing soils and with the water-retaining properties of such soils. The presence of free ions will cause the colloidal substances to coagulate particles of 1-100\(\mu\) into larger particles producing a coarser, looser and more friable structure. (Troll, 1958, p.20).

If there is a shortage of ions (salts), the soil will crumble, due to lack of framework, fill in with fines, and harden. The ionic content of the soil also varies considerably. An example is the enriching of the water with ions and thereby lowering its freezing temperature.

The colloids themselves may swell by absorbing water and developing considerable pressure. The colloids will then expand in the former water-filled pores. This swelling, during the alternating freezes and thaws, can be considered to be the main-spring of soil structure formation.

These soil structures, which are the subject of this investigation, are neither polar nor arctic but are "subnival soil forms"
that occur in all climatic types of earth near the nival range. Their origin is restricted by a strong "morphologically effective" soil frost (Troll, 1958, p. 95). A long lasting winter soil frost such as in North Dakota can have the same effect as permafrost.

PERMAFROST AND FROST HEAVING

R. P. Sharp (1942, p. 417) has described the tundra in the Arctic and sub-Arctic regions as irregular and rough but relatively featureless in its broader aspects. While he was concerned with lenses of ice in the soil, he concentrated on the ground-ice mounds. They are "...low, scattered mounds that interrupt the monotony (and) attract immediate attention. Although the mounds differ in size and shape, most of them are a few feet high, many tens of feet in circumference, and gently rounded or asymmetrical in cross section. ...Mounds a foot or two high and of larger area are barely discernible, and small mounds are hard to distinguish from other minor irregularities of the tundra.

"The ground over most mounds of fairly large size is broken by tension cracks, the largest and deepest of which are near the crest of the upwarp and along its edges. In these places the mounds can be seen to consist of a core of clear ice mantled by a surficial hull, one to three feet thick, of gravel, sand, soil and tundra vegetation. ...The lower surface is essentially flat and the upper surface rounded in the shape of the mound. The ice is clean and fairly clear. A crude vertical columnar structure is discernible as the ice melts..." (Sharp, 1942, p. 417)

These mounds are called "hydrolaccoliths" in Siberia and "ice
mounds" in Alaska and Canada (Sharp, 1942, p. 420). The formation of this structure is attributed to localized updoming caused by the hydraulic forces of ground water after it freezes in such openings.

Another product of differential freezing and thawing is peat knobs in swamps and bogs, and hillocks, commonly called Palsen, in the tundra (Sharp, 1942, p. 420). Here, the frost action has caused an upswelling of fine material. However, they are related in appearance and geographical locale to the ice mounds even though they are of different origin.

The flow of the surficial thawed layer of the tundra is negligible and is not the cause of the ice mounds. The hydraulic force of the ground water is minute and can have only a small hydrostatic head because the thawed tundra is too weak and permeable to permit a significant hydrostatic head to accumulate. The cracking of the surface over the mounds would dissipate whatever pressure might develop.

Therefore, the mounds are attributed to updoming of the surface by the vertical and lateral growth of bodies of ice in the thawed layer above the perennially frozen ground.

The fractured ground at the crest of these mounds shows that they are caused by dynamic upheaval and not by a core of entombed ice of external origin. Tilted plants on the flanks of the mounds and the upwarped soil zones add to the evidence of uplift. "Alternate freezing and thawing with attendant segregation of soil moisture may have been contributory, ... but not dominant. The vertical columnar structure and the planoconvex shape of the ice masses indicate that they grew from the bottom" (Sharp, 1942, p. 421).
The profiles parallel to the slopes have a steeper downslope side, while profiles transverse to the slope and those in flat areas are gently rounded. The shape is due to the maximum growth at the center of seepage and slower lateral development. "The elongation and asymmetry parallel to the slope indicate later progressive growth upslope toward the source of seepage" (Sharp, 1942, p. 421).

LABORATORY RESEARCH

In a closed system, one in which water can neither escape nor be added, as in a laboratory experiment, there is an increase in volume of ice that has been generally assumed to be the result of the amount of water frozen. The cracking and frost heaving and other pressure effects that accompany the freezing of water are the result of the volume change. With one atmosphere of pressure, water freezes at 0°C and expands in volume about 10 per cent (Taber, 1930, p. 304).

Frost heaving is probably in an upward direction because there is less resistance in this direction. Taber points out that this hypothesis is not supported by facts, and his experiments show that all pressure effects due to freezing are due to ice crystal growth. The pressure is developed in the direction of crystal growth only. This direction, in turn, is determined by the availability of water and the direction of heat conduction. When soils freeze under normal conditions the differential pressure of the overburden is a minor factor. The heat involved is the heat of crystallization that is evolved in amount equal to the difference in heat content between solid and liquid. This heat evolution arrests further temperature drop, and the temperature of the mixture of solid and liquid remains constant as long as both phases are present. Further removal of heat
results merely in the crystallization of more liquid until finally the whole mass solidifies; only then does the temperature begin to fall again (Maron and Pratten, 1958, p. 109).

If heat is conducted upward from the bottom of a growing ice layer just fast enough to remove both the heat of crystallization and the heat brought up by the water, the growth of the ice layer will continue. However, if the conduction of heat is faster, the freezing isotherm will move gradually downward and cause ice to form in lower soil voids. The ice layers tend to become thicker at depth because of slower cooling, which is the result of less resistance to the upward movement of water (Taber, 1930, p. 312). Tension cracks may form in soils saturated with water because of this withdrawal of water to form ice layers.

Tension cracks develop near the surface and extend downward in advance of freezing in clays that are extremely impermeable because of their high colloidal content and high percentage of water. These cracks are gradually filled with ice as freezing continues.

Soils that consist of coarse uniform sands and gravels are not subject to frost heaving, or structural formation. Conversely, without moisture, no soil is frost susceptible. The frost susceptibility of a soil is determined under the most favorable moisture supply conditions. Theoretically, the lower the moisture supply, the smaller the maximum heaving pressures and the lower the rate of heave. The frost susceptibility of a given soil is based on the moisture content and the drainage and dissipation of seepage forces are, therefore, most significant. Hydrostatic pressures that supply water to the freezing plane will increase.
the maximum possible pressure and the rate of heaving.

An original rate of heaving may be almost imperceptible, but as the soil becomes weathered and fissured, the rate of heaving may become much greater.

In the closed system the only water available for ice segregation is contained in the soil specimen. The total increase in sample volume upon freezing does not exceed the volume increase of the water that actually freezes. In frost-susceptible soils, however, the increase is larger because free water is being removed from soil voids and concentrated in ice lenses. Some voids are only partially filled, as compared with the closed system specimen, which remains 100 percent saturated. "Water is supplied for ice lens growth from the material directly below the plane of freezing, resulting in a tendency to consolidate this material under the resultant pore water tension. If ice forms within the soil voids as well as in ice lenses as the freezing plane advances, the voids may then be distended again as crystallization occurs. As the plane of freezing advances the material next below goes through the same cycle and the process continues until no more mobile water is anywhere available" (Linell and Kaplan, 1959, p. 115).

Fissures and paths developed by past frost action and the presence of old root holes will result in a "handy" source of moisture for ice segregation.

**RESEARCH PRINCIPLES**

Sanger (1959) has recognized the complexity of predicting the extent or occurrence of frost cracking and heaving. The direct method of studying the interaction between the air and
the ground is a new approach which shows promise but presently lacks the refinement necessary for accurate application.

The required weather data utilized are free air temperature curves, windspeed and direction, cloud cover, duration of sunshine, relative humidity (or vapor pressure) and precipitation. Ground data required are the nature of the surrounding surface, the soil profile, and the thermal properties of the soil. Unless special measurements of heat radiation are made (not a usual procedure), the latitude must be known. Sanger (1959, p. 70) warns that estimating values to replace missing data, or not gathering all required data may cause serious errors.

The principle underlying this procedure is to balance the heat entering and leaving the soil, so as to permit a curve of the surface temperature to be modified to a curve of surface temperature from which the frost penetration can be computed, either by the use of a computer or by a numerical process drawn from known soil condition.

Sanger (1959) points out that, while this method is attractive in principle, it could be quite difficult to apply because of the combining complexities of weather data, soil variability and freezing problems.

Contributing to the quantity of heat present are (1) solar radiation, (2) longwave radiation, (3) convective heat transfer at the ground surface, (4) evaporation, condensation, sublimation and transpiration and (5) conduction in the soil.

The agents causing frost soil formations are summed up by Troll (1958, p. 19) as being: (1) a simple temperature change that produces a change of the specific gravity (convection),
(2) changes in soil volume that result from changes in the condition of the aggregate (freezing and thawing of soil waters), (3) cohesion of freezing soil water (high attraction of water from deeper, unfrozen soil layers), (4) gravity, which tends to equalize the displacement created by volume changes and cohesion, and (5) the swelling that occurs in all colloidal soil constituents, particularly clay and humus.

In any study of the effect and extent of frost action the cooperation of pedologists, soil engineers, physicists, plant ecologists and geologists is needed for full understanding. Frequent and complete field observations are required at different times of the year, and could be supplemented by cold-room studies.

DESICCATION FISSURES

Desiccation cracks (also referred to as sun cracks, shrinkage cracks, fissures and mud cracks) are the product of drying action of the sun, wind and air.

Kindle (1917) reported that rapid drying produced comparatively wide-spaced mud cracks and slow drying gave closely spaced cracks. Later he associated mud cracks with joint planes which he thought were present as closed fissures before the formation of the mud cracks. This "long, straight, smooth edged crack" is similar to the frost cracks observed by this author (Kindle, 1923).

The point in question is, are desiccation cracks and frost cracks genetically related, and if so, to what extent does each affect the other?

Some factors that determine the degree of curling while drying are reported by Longwell (1928). They are the rate of
evaporation, the fineness of the mud, and the thickness of the layer. He states that the influence of the free air temperature is the largest single factor governing the rate of drying as evidence by the fact that curls form most conspicuously during the hot summer months.

This curling of the mud cracks has been experimentally determined by Dow (1964) to be directly proportional to the salt content of the soil. He found that the size of the polygons varied directly with the salinity. The number of polygons formed and their degree of lateral separation varied inversely with the salinity. The upturning at the edges of the polygons occurred when the solutions contained less than 13 percent NaCl. No cracks formed at greater than 20 percent salt concentration.

Laboratory data from two saline profiles near Grand Forks, North Dakota showed the A1 horizon extended from 0 to 22 inches and was mainly silt loam. The profiles were 55 to 75 percent saturated and had a paste pH of 7.2 to 7.8. The soluble ions per liter were: Ca: 36-73, Mg: 39-128, Na: 19-171, SO4: 22-104 and Cl: 38-293, indicating excessive concentration of salts in the upper Red River Valley (Sandoval, et al., 1958, p. 49).

The cracks then will depend upon the chemical composition of the soil in addition to the salinity and this should be taken into consideration when discussing the formation of mud cracks.

**FROST CRACKS**

Polygonal surface markings were thought by Edmonds (1942, p. 91) to be the result of pressure due to expanding of freezing mud and water in cracks. This force, he said, is only effective if the retaining walls are rigid and the mud is still plastic as
it would be during the fall, and spring, when the temperature varies around the freezing point. The primary polygons thus formed are later made smaller by drying cracks.

The expansions and contractions that occur at temperatures other than those near the freezing point do not raise primary polygons. The significance of the freezing point is that, during temperature changes in this range, some of the soil is frozen and rigid and some is in a state of viscous and plastic flow. Therefore, the rigid areas are able to alter the form of surface regions that are still in a plastic state (Edmonds, 1942, p. 87)

FACTORS CONTROLLING CRACKING

In extensive research on desiccation cracks, Corte and Higashi (1960) have summarized mud crack formation according to the following conditions.

The area of cells made by crack patterns has a log normal size distribution and the mean size depends on the thickness of the soil, the bottom material, and the dry density.

The length of the cracks depends on the thickness of the soil in an inverse relationship.

The number of cell sides is also dependent on the thickness. Four-sided cells are most common in a layer greater than 4 mm thick and five or six sided cells predominate at thickness less than 4 mm.

A soil layer on a sand bottom makes larger cells separated by cracks because adhesion at the bottom is very small. The sand attached to the soil bottom "rolls" over the sand below.

The cracking moisture content increases with increasing thickness. It also depends on the dry density of the soil. In
addition, the moisture profile in the soil does not seem to show that cracks start from the surface of the soil. The rupture stress was found to increase with decreased thickness of the soil. As the thickness determines the speed of desiccation, rupture stress is also related to the desiccation speed. However, as Corte and Higashi found, the most important essential relationship must be the one between the cracking moisture content and the desiccation speed. This relationship was derived from the assumption that the cracking starts in the soil when some of the numerous micro-cracks generate near each other and join to form the germ of a crack (Corte and Higashi, 1960, p. 28).

This assumption agrees with the work of Kies, et al. (1950, p. 720), in which he says that the propagation of a fracture is "...essentially and generally discontinuous and consists of the joining up of multitudes of separately initiated components of fracture." The more brittle the substance, the more striking are the effects of speed variations in the "clam shell or conchoidal" markings that are created. The geometrical patterns of parabolas, ellipses and hyperbolas are the result of speed differences between components flowing together, which resemble river systems.

"The over-all velocity of propagation of a crack is governed by the rate and distance at which advance initiations can occur and the rapidity with which subsidiary multiple fractures can be joined up" (Kies, et al., 1950, p. 720). If many of the components join simultaneously, it may be described as explosive fracture.

CURRENT RESEARCH

During the winter of 1963-64, cracks were observed in a
field adjacent to the campus of the University of North Dakota, Grand Forks, North Dakota, to determine the affect of temperature fluctuation on the size of the cracks. The observations were made during the months of February, March and April, 1964, with temperature extremes from -5°F to 62°F.

The cracks were selected in eleven areas around the field, as located on the reference map (fig. 1.), with one to four cracks per area.

These cracks were all open at the start of the project in February. Their initial opening force is believed to have been frost contraction rather than desiccation because these cracks are generally long (often 20 to 50 or more feet) and straight with few branches. Desiccation cracks are easily distinguished because of the multi-polygonal pattern they form and the length of an individual crack is rarely greater than a few inches, as observed by this writer.

Once the measurements were underway, it was more apparent that the critical factor controlling the width of the cracks was the temperature fluctuation.

ICE WEDGES

These contraction fissures in the upper few inches of the frozen ground are similar in nature to the ice wedges in permafrost that appear at depths below the summer thawed zone.

The size of the veins of ice may be one centimeter to several meters wide at the top and taper to a point downward to a depth of from one to more than ten meters. The size of the polygons formed by the intersection of these wedges varies from a few meters to more than a hundred meters (Lachenbruch, 1963, p. 1).
These ice wedges were first discussed by Leffingwell (1915). He observed that fresh cracks that had opened during the winter are exposed during the spring melting. These cracks are filled with water from the melting snow and remain open by a wedge of ice when the temperature drops below freezing again.

In the summer when the ground expands, one of four events can happen: "(1) the pressure may melt the ice, so the crack is closed again; (2) the ground may be elastic enough to absorb the strain; (3) the ground may be deformed and bulged up, either as a whole or locally along the edges of the ice wedge; or (4) the ice may be deformed" (Leffingwell, 1915, p. 642).

If the elastic ground absorbs the strain, the same type of cracking will occur the following winter because there is now an area of weakness. If this happens, there will be a constantly growing body of ice formed at this point.

The cycle of freezing and thawing will cause the formation of cracks in the ice wedge itself and also in the overlying ground. To form an ice wedge 3 meters wide would require 600 years (Leffingwell, 1919, p. 211). If the cracks do not open every year, then the required time would be longer. One thousand years seems to be the age of the largest wedges Leffingwell observed in Alaska.

More recently, A. H. Lachenbruch (1959, 1960a, 1960b, 1963) has made investigations of ice wedges for the U. S. Geological Survey. Road and airfield failure in the permafrost areas of the north are due, in part, to the formation of ice wedges from freezing water in seasonally recurring thermal contraction cracks.

Lachenbruch (1959, Abs.) suggests that the rate of cooling as
well as the total amount of cooling is important in generating the tensile stress that ultimately causes fractures.

Frozen ground has a tendency to contract during the cold winter months and the ice wedges form in response to this thermal tension. The cracks which penetrate the permafrost core are sealed by surface water which enters in the early summer and then freezes when it reaches the permafrost.

**SOURCE OF THE STRESS**

The temperature in the arctic fluctuates about 25 degrees about the mean annual temperature at the surface. At a depth of 20 meters the temperature remains steady and is always within a few hundredths of a degree of the mean (Lachenbruch, 1963, p. 2). When the surface layers dry and contract in the winter, they are restrained by the stable underlayers, and the surface layers are then stretched. As they cool, the layers are contracted causing cracks to develop and widen.

The horizontal thermal strain, the product of the expansion coefficient of the ice content and the change in temperature from its initial value (Lachenbruch, 1963, p. 3).

Therefore, rapid cooling to a low temperature would develop the largest stresses. At the ground surface this value would have the greatest extreme and the greatest thermal tension would develop here. Thus the recurring cracks that cause the growth of ice wedges are initiated at the ground surface.

**FROST CRACKS IN GRAND FORKS, NORTH DAKOTA**

The frost cracks observed in Grand Forks, North Dakota were selected in those vegetation-free areas of an unused field on the west side of the campus of the University of North Dakota. These
areas remained generally snow free during the recording of observations except during periods of snow fall or blowing and drifting snow. The adjacent grassy areas were covered with snow of varying depths the entire time. A few of the observed areas were several inches higher than the surrounding terrain which may, in part, account for their remaining snow free.

The soil is Bearden soil and is rich in calcium carbonate at or near the surface (Larson, 1963, Personal Communication). Eight frozen samples were weighed and then baked and weighed again giving an average frozen moisture content of 20.6 percent.

FIELD OBSERVATION

In selecting the best method of measuring and recording the cracks, it was necessary to ensure that each crack was measured in exactly the same place for each successive observation. To accomplish this, pieces of heavy string were tied to two four-inch nails and the nails were driven into the frozen ground on either side of the crack. The nails were placed far enough apart so as to put a small amount of tension on the string to improve the accuracy of the observations, and to insure that the ground near the cracks was not jarred or in any way disturbed. The string itself would not be frost susceptible and would have a small amount of elasticity which would not affect the movement of the soil.

The cracks were not measured at fixed times but rather when there was a significant change in the free air temperature.

RECORDED DATA

The graphs, of temperature versus width, for the eleven areas observed, all show a definite tendency towards closure with an
increase in temperature. This is the expansion of the ground bordering the cracks and not a shrinking of the cracks themselves, as the cracks are merely an expression of the amount of contraction or expression of the amount of contraction or expansion of the surrounding ground and are only a means of calculating this movement. Keeping in mind that the cracks are related to the movement of the ground, it can be seen from the graphs (Fig. 2 a-n) that the rate of closure is about 1 mm/11° F rise in temperature.

The sharpness of the curves of the plots is probably due to atmospheric conditions, in part, at the time of observation. This could, for example, happen on an extremely cold day after the fissures had opened to a maximum, and then if it warmed up suddenly when the sun came out or a frontal system passed. This would cause a severe lag in the temperature-width graph.

CONCLUSIONS

The graphs of the cracks clearly show a linear relationship between the temperature and the width of the frost cracks. However, because of the irregularities in the plots, many outside factors are assumed to be sources of error. These errors will be summarized later.

It can be stated with some degree of surety, that in a controlled experiment, the temperature-width graph would approach a straight line function.

The temperature of the free air is not as critical as the amount of sunshine hours or the temperature of the upper few inches of the ground. These two alone can retard the initiation or growth of contraction fissures.
Fig. 2 Graphs of Crack Width Versus Air Temperature
The upper few inches of the ground can be compared to the upper few feet of a permafrost region that is subject to thaw in the summer. Although the soil in the top few inches does not always actually thaw so there is standing water, the ground often does become quite pliable, even when the temperature is well below the freezing point, provided there is sufficient sunlight.

Below this thawed surface, the frozen ground behaves similar to permafrost and the contraction fissures penetrate this zone in the same manner as ice wedges in permafrost. Several cracks were observed to extend downward for over 25 cm. while having a surface expression of only 0.3 to 0.8 mm. wide. During periods of rapid temperature fluctuation, these could become filled with water and upon subsequent freezing aid in the further opening of the cracks.

SUMMARY

The frost contraction fissures in this report were studied in an attempt to correlate their genesis and frequency with previously reported criteria from the permafrost areas of the world.

It was shown that the same general structure, a thawed layer and a solid core, was present in both the observed cracks in North Dakota and in the permafrost areas. The only difference this writer can detect is the grand scale on which permafrost is based.

Certainly, many sources of error were inadvertently introduced during the recording of these observations. Not the least of which was the frequency of recording the data. It was pointed out that the surface temperature and the free air temperature
used here are not the same and by assuming they are, is merely compiling errors.

To accurately measure the force of temperature on a soil, it would be necessary to have a continuous-recording measurement device in the area and evaluate these recordings using a complete synoptic weather report. Only in this way could one reasonably hope to eliminate some of the errors. K. R. Everett (1963, p. 1) has described such an instrument called a "linear motion transducer". He explains how such a device can be constructed, and is quite easy to assemble and install in the field and yields very accurate results.

In any further studies of this nature, it is recommended that such an instrument be tried. If care is exercised during construction and installation, little error will result and there will be little disturbance to the environment.

Further, cold-room studies, field observations of subsurface phenomena at different times of the year and cooperative work between the geologist, physicists, soil engineers, pedologists and plant ecologists are necessary for a complete and comprehensive study of frost contraction fissures.

An area near the University of North Dakota that is undisturbed is needed for a study of this nature. The field used for this report has subsequently been converted to an intramural sports field and has had heavy machinery and graders working on it. The Biology Department of the University has acquired a quarter section of land in Oakville township about 12 miles west of Grand Forks on old U. S. Highway #2 (NW 1/4 Sec. 9, T151N, R52W, Oakville Twp., Grand Forks Co.) that was under
consideration for such a study. However, the entire field is covered with vegetation and is totally unsuitable for this type of work.

After an area is located, some criteria worthy of consideration for further study are (1) the effect of permeability of in-place soils within the zone of frost action, (2) the chemical and mineralogical differences between the various strata in the soil profile, (3) the development of more refined or new criteria for frost susceptibility of soils and (4) the effect of the climatic and meteorological elements present.
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