CRYOPEDOLOGY—THE STUDY OF FROZEN GROUND AND INTENSIVE FROST-ACTION WITH SUGGESTIONS ON NOMENCLATURE.

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ABSTRACT. Cryopedology is suggested as a suitable name for the sub-science concerned with the study, both theoretical and practical, of intensive frost-action and permanently frozen ground. Sixteen other terms are also introduced and defined. Of these the important ones are pergelisol, permanently frozen ground, and mollisol, the overlying seasonally thawed ground in which intensive frost-action occurs. In areas where this action has ceased, the surface layer has been frost-disturbed or subject to congeliturbation. It is a congeliturbate—a term which includes all varieties of warp, trail, head, Coombe rock, solifluction deposit, Erdfliesse, etc. It is believed that these and the other suggested terms will facilitate discussion of the problems of the Arctic and of the ancient frost-action of periglacial areas.

INTRODUCTION.

STUDY of the action of frost, particularly in the Arctic and in areas having a periglacial[1] climate during the Ice Age goes on apace. However, discussion of the problems involved is handicapped and confused by the awkwardness and inadequacy of available terms. The present paper is concerned with the propriety of introducing some order into the terminology by the adoption of new terms and the modification of certain older ones. All future needs cannot be anticipated but the proposals here made should give a measure of relief.

ACKNOWLEDGMENTS.

I have discussed the questions of nomenclature here considered with many of my advanced students and with a few members of the U. S. Geological Survey. Dr. Herbert E. Wright, Jr., has been helpful. To Prof. Joshua Whatmough and Prof. Serge Elisséef, I am particularly grateful for advice on linguistic difficulties. Figures 1 to 3 are reproduced with permission of the authors and of the editor and publishers of the Geological Magazine.

[1] This term was introduced by Lozinski (1909) for (1) the area adjacent to the border of Pleistocene ice sheets; (2) the climate characteristic of this area; (3) and, by extension, the phenomena induced by this climate even if located outside of the main periglacial zone. The term is now well-established: Cailleux (1942), Zeuner (1945), Bryan (1928), Smith (1936), Denny (1936), Sharp (1942-A).

THE GENERAL PROCESSES.

In our textbooks discussion of weathering and erosion is largely confined to types of activity current in temperate climates. The relatively modest rôle of frost-action in temperate climates can be described with ordinary English words. "Frost" has, according to Webster, several meanings: (1) the act of freezing, applied chiefly to water; (2) the state of the air which occasions freezing; (3) frozen dew or hoarfrost; (4) metaphorically, coldness of temperament, etc. The first two senses are those commonly in use in geological discussions. The word is also a verb, "to frost," in which the meaning is more confused: (1) to frost or freeze vegetation; (2) to cover with hoarfrost and hence (3) to produce a "frosted" or matte surface on cake, metals, or other substances. In order to describe the action induced by freezing and thawing, geological writers have been forced to compound the terms "frost-action" and "frost-work." Webster does not define "frost-action" but the meaning of "frost-work" is given as the pattern of ice crystals on a window pane or other surface.

Thus the general use by geologists of "frost-action," "frost-work," "frost-splitting," "frost-split," "frost-riving," "frost-riven," "frost-heave" and "frost-heaved" is not completely supported by dictionary definitions. However, these terms are all perfectly derived verbal nouns and adjectives of self-evident meaning. There is, however, no way of deriving from these verbal expressions corresponding nouns for the products of the varieties of action that they imply. All that can be done is to use expressions such as "materials produced by frost-action," or "frost-split fragments" or "frost-heaved ground." Experience shows that such roundabout expressions are awkward and inadequate. Several terms have been introduced for particular frost-born products but no satisfactory general terms of wide connotation have yet been brought forward.

THE NEW SUB-SCIENCE—CRYOPEDOLOGY.

The present wave of interest in the Arctic stemming from the recent war, involves studies in both pure and applied science. This new drive will advance knowledge in a field which heretofore has been investigated for its own sake or for application to the problems of the Pleistocene. The construction of roads, airfields and other facilities gives rise to problems new to American engineers and construction men. The extensive experience and studies by the Russians in Siberia have been summarized in the excellent manual by Muller (1945). New studies have recently been undertaken in Alaska by the U. S. Geological Survey and by the U. S. Engineers. This economic interest reinforces and adds a drive which means progress in the study of intensive frost-action and permanently frozen ground.

It appears that a new sub-science is being created and that it deserves a name. "Cryopedology" is proposed (see also Bryan, 1946) as a suitable name, being derived from krúos, κρύος, icy cold, pedon, πέζον, ground or soil and logos, λόγος knowledge. The Greek root "cryo" is familiar in the words cryolite and cryogenic and "pedon" in Pedology or Soil Science.

As thaw as well as freeze is an important factor in all the processes studied, it is unfortunate that the idea of thaw cannot be included without unduly lengthening the term. However, freeze and thaw are ideas so closely joined in our thought that one suggests the other. The term Pedology also is not as extensively used as one would expect because of confusion with Paedology, the medical science of children's diseases and care. Moreover, many soil scientists limit their work to the upper layers produced by soil process (weathering) whereas frost involves very considerable depths below the surface. However, Paleopedology is obviously concerned with weathering to any depth (Bryan and Albritton, 1943) and is thus a model for Cryopedology.

In the remainder of this paper the various processes and phenomena of Cryopedology are reviewed and a set of terms is proposed. The terms should be general in import and allow the retention of local and special terms. So far as new varieties are discoverable, new names may hereafter prove necessary. Local words with local connotations are so useful, particularly in reports of an economic import, that many of these terms should be retained as synonyms. The new terms are compounded so far as possible from familiar roots already established in English usage. They will, therefore, be readily converted into other European languages.

NEED FOR GENERAL TERMS.

Frost-action as a term involves a variety of processes and implied results. There are the phenomena of freezing. As shown by Taber (1929 and 1930) the onset of low temperatures freezes the water in the pores of the ground but there is little resulting expansion. In a body of ground provided with capillary pores and connected to unfrozen water-bearing ground, ice continues to crystallize in layers and masses. Expansion of the frozen layer ensues and results in thrusts in all directions. As the direction of easiest relief of strain is upward, expansion of the ground in that direction is notable and is usually called frost-heave. However, the upward expansion is frequently highly concentrated at spots having the best capillary connections to the best water-supply. There is no common expression for the lateral thrust resulting from expansion although horizontal as contrasted with vertical frost-thrust would sufficiently carry the meaning. As shown by the studies of Taber (1929-1930) and of Beskow (1930) the physics of the process seem at present to require no new terms.

However, the thawing of frozen ground induces new movements. The frozen ground usually contains ice to a volume much greater than the volume of pore space. On melting the grains are separated from each other by films of water and the mass lacks coherence. There results differential and mass flow. Our present knowledge is insufficient to describe all the intricacies of this flow. The objective of many students is to analyze the movements completely. It is certain, however, that if the melt-water can escape, much fine-grained material is carried off. Further the body of melted ground is rearranged by differential movement and, if a gradient exists, there is also a mass flow down slope.

These movements may be arrested by a new freezing cycle and obviously the number of alternations from freezing to melting and their duration and intensity affect the movements. Further, every cold period is accompanied by evaporation of water and ice. The surface of the ground becomes loose and pulverulent. This dry layer also modifies movements on later melting.

The mass movement down slope was named by Andersson (1906) "solifluction" (from *solum*, soil and *fluere*, to flow). His term, not being strictly limited to flow under conditions of freeze and thaw, has been extended to cover soil flow under other conditions. Salomon-Calvin (1929), who restricts solifluction to motion over a base of permanently frozen ground, points out that those who use solifluction as synonymous with "soil flow" need another expression for the process described by Andersson. This new term is here suggested.

Furthermore the movements of material under severe freezing and thawing are not confined to simple mass flow but are more complex. Fine-grained materials are winnowed out so that the surface layer is coarser than the base. Also the coarse and fine components of the surface layer move differentially so as to produce the much studied and highly varied "soil structures."

The down-slope movement of the fine-grained components is presumed to be largely a flow as mud and is called by English writers "sludging." Zeuner (1945) and Muller (1945) propose to call the product of "sludging" by the provincial English word "slud." Whether it is possible to make a distinction between materials which have flowed as labile muds and those washed off and carried off by melt water as held by Salomon and others is uncertain. The present use of "solifluction" and "sludging" implies that a distinction between two types of mass movement can be made.

What can be proved easily is that the surface layer, 1 to 3 feet thick and in places as much as 10 feet thick, has been disturbed and that some of its components have been translated down slope. The nomenclature here proposed emphasizes the disturbance rather than the fact or the method of down-slope movement.

In summation, the easily ascertained effects of intensive frost-action can be assigned to two groups of related processes: (1) the break-up of rock by freezing of water, a familiar process; (2) the differential and down-slope movement of the surface layer. The latter process, although it has been the subject of many studies over the past 30 years and in spite of the pursuit of these studies at an accelerated rate, is still not well understood. Most of the difficulties in nomenclature are in this field of effort. The literature is large. Steche (1934) has listed about 250 papers. The most penetrating review is by Lozinski (1934) and the American literature is increasing rapidly (Sharp 1942-B).

TERMS FOR FROST-SPLITTING.

The break-up of rock by freezing normally requires repeated freezing with intervals of thawing and results in the production of rock spalls and also in the comminution of rock into small grains. These phenomena are referred to as "frost-splitting" or "frost-riving" and the fragments are said to be "frost-split" or "frost-riven." These are good English expressions and unobjectionable. They are paralleled by the German, *Frost-sprengung* and *Spaltenfrost*. The slim crystals of ice which form at right angles to the ground surface are called needle ice, and in German, *Pipkrake*. However, no word is available for the product of frost-splitting either as individual pieces or as a mass. If comminution of rock is as important a process as contended by Bertil Högbom (1914) and by Taber (1943), then a word is necessary.

In compounding a new term, the obvious root is derived from Latin *gelo, gelare*, to freeze, and *gelu*, frost. There are many derivations in English, most of which refer to the formation of a jelly from a liquid, as gelatine, gelatinize, etc. However, "gelation" means to cool from a molten state and "regelation" is familiar as the process of refreezing of ice under pressure. The Latin, *congelare*, to freeze, is familiar in the word congeal, derived through the French, and the prefix *con* blurs the sound of *gel* (*i*) so that the compound becomes distinctive.

Thus for frost-splitting the word *congelifraction* is proposed from *congelare* to freeze and *fractare*, to break. There is then available the noun "congelifract" for the individual fragment produced. If the congelifracts are large, the body or heap of fragments or "spalls" is a rubble of congelifraction. But there are many kinds of rubble and precision is necessary if one is to distinguish between heaps of rubble produced by simple gravitational accumulation in a warm desert, and the rubbles of talus in a cool mountain area where most of the rock spalls are "congelifracts." Further, the comminution of rock into mineral grains by frost-action produces a distinct type of sand and finer fragments. Both large and small congelifracts would form bodies of material to be designated by the term "congelifractate."

TERMS FOR MOVEMENT UNDER FROST-ACTION.

As previously pointed out, the term solifluction is no longer strictly confined to flow under freeze and thaw (Sharpe 1938). A. Heim (1908) for instance has introduced "subsolifluction" for the flow and sliding of soft materials under sublacustrine and submarine conditions.

However, some authors such as the Abbé Breuil (1934) not only use solifluction for the process but also for the product.

Such usage may be justified in French grammar, but is not to be excused in English. Nor can the spelling "solifluxion" common in the writings of English authors be strongly defended. Many English authors use the expressions "solifluction deposit," "solifluction layer" (Zeuner, 1945). Others are slightly confused in their usage. Thus Paterson (1941 p. 5) says in a single paragraph, "Solifluxion 5 indicated a recrudescence of precipitation . . .;" "Subsequent to solifluxion 6 . . .;" "These gravels are capped by a weakly developed solifluxion 7. . . ."

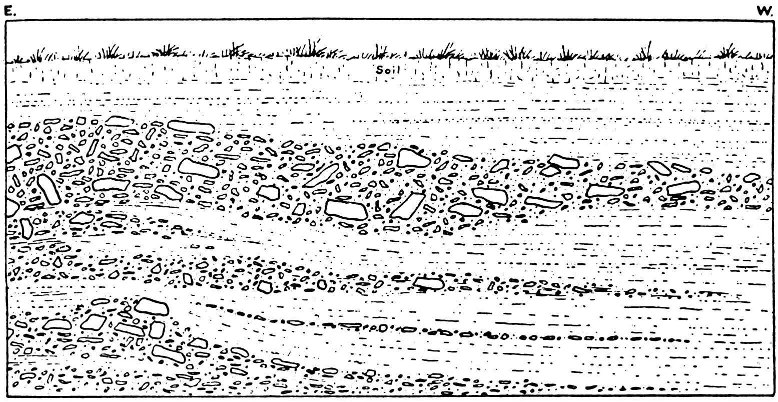

Fig. 1. Section of the Newlay Gravel Pit in Airdale, England, from Dines *et al* 1940. Drawing is without scale but height is about 10 feet. Shows interfingering of congeliturbate with water-laid sand and gravel of outwash terrace.

Here the process, the time involved and the deposit from which the two are inferred are inextricably entangled. Paterson (1941 p. 376) also uses "soliflual" as an adjective and as a noun, and the undefined term "suffosion bursts."

The existence of masses of unsorted material overlying bedrock and the older glacial tills has long been recognized in England. A brief history of thought has recently been published by members of the British Geological Survey (Dines *et al.* 1940). The literature begins in 1788 and from the beginning these deposits of rubble, clay and sand were recognized as formed: (1) by processes no longer in action; (2) as now subject to modern rain wash and weathering; and (3) in places dissected by streams or cut into bluffs by modern wave action.

The term "head" was introduced in 1839 by de la Beche but "Diluvium," "subaerial beds," "masses of detritus," "Angular

Flint Drift," "Angular Drift," 'Coombe Rock," "erratic warp," "warp," "trail," "clay with flints," "Rubble Drift," "Coombe Deposit," "Taele gravels," and "solifluction deposits" are terms used by various authors.

The discussion and illustration of Dines *et al.* are illuminating. In Fig. 1 here reproduced, they show frost-moved rubble interfingered with "late glacial" gravel, sand and silt in Newlay Gravel Pit. "The stony layers are packed with angular fragments of ganister [quartzite] and sandstone up to a foot in length and are obviously derived from a Coal Measures sandstone which crops out on the hillside 300 yards to the south, the slope being about 5°. Some of the ganister fragments show polishing which may be attributed to wind-driven sand."

The relation of frost-formed deposits to the limit of glaciation and to the outwash of the later stage of the New Drift [presumably equivalent to Middle Wisconsin] is shown in Fig. 2.

The frost-moved materials consist largely of rearranged boulder clay. The mappable portions are largely confined to side valleys and two of the patches pass laterally into the outwash gravels extending downstream from the terminal moraines. No frost-moved deposits occur within the glacial limit. Thus it is inferred on these lines of evidence that the mapped bodies were formed in the periglacial climate of the York-Escrick stage.

In the Axe Valley the lithologic character of the frost-moved materials varies with that of the bedrock in such a way as to prove down-slope translation. As shown in Fig. 3, the "head" at the top of the slope where it rests on chalk consists of "pebbly sand and clay" but at the outcrop of the underlying chert beds it changes into "angular chert drift." The content of chert dominates and this term is also applicable down slope in the area of the "upper greensand and Gault" formations which are free of chert, although materials from these rocks are incorporated.

These examples and the studies of many authors in England and Europe prove that deposits attributable to a more intensive frost-action at one or more intervals of the past are common phenomena.

Dines *et al.* (1940) reject the term "warp" which appears to have been introduced in 1847 and 1851 by Trimmer who showed that the surface materials of the hills of Norfolk and Kent were in part derived from the underlying rocks and in part

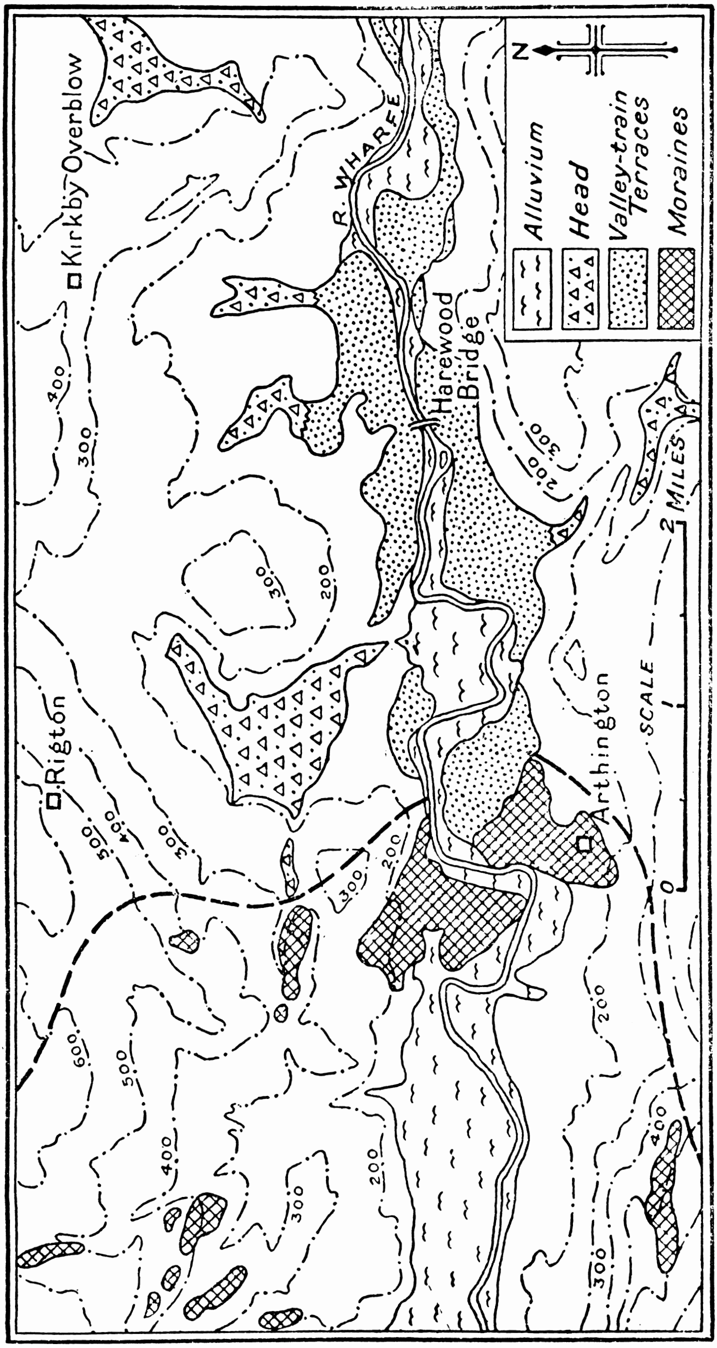

Fig. 2. Sketch map showing relations of the congeliturbate (head) to the valley train terraces of the New Drift in lower Wharfedale, England. Broken line is approximate eastward limit of the final York-Escrick stage of the Newer Drift [Middle Wisconsin]. Blank areas are drift-covered Millstone grit. From Dines *et al.* 1940.

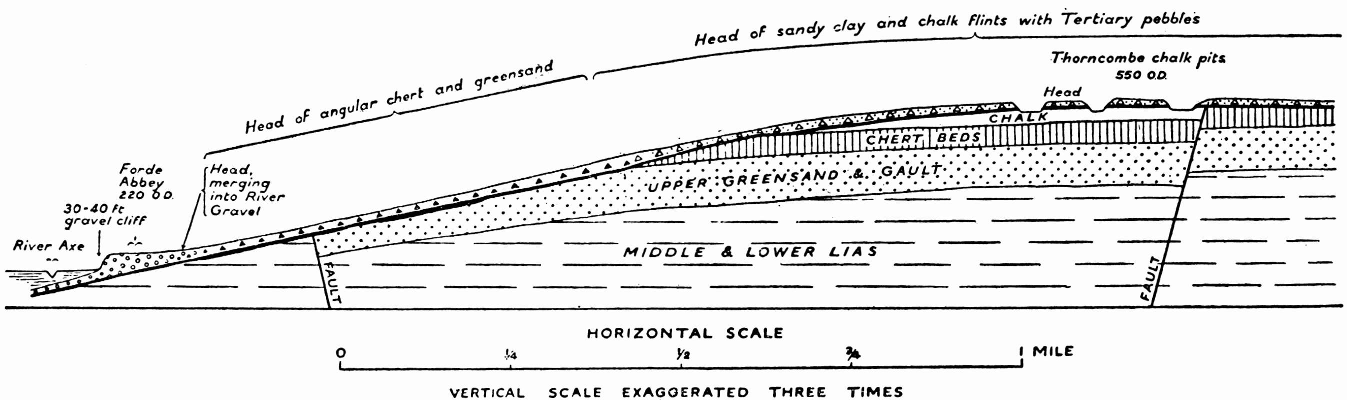

Fig. 3. Distribution of congeliturbate on slope of Axe Valley showing change in lithology with character of underlying rock and transition into outwash terraces. From Dines *et al.* 1940.

transported from up-slope. Fisher (1866) in a well-known paper described the "warp" as a blanket conforming to the slope and the "trail," a term introduced by Fisher, as a deposit in troughs or furrows more or less parallel to the existing minor drainage of the slopes. Dines *et al.* (1941) assert that Fisher considered "warp" or "warp of the drift" the soil derived from "trail." On rereading Fisher's paper it is obvious that he considered the "warp" as earlier than the present soil (p. 554). He considers that the "trail" is not only coarser than the "warp" and obviously derived from up-slope, but it is also older. It has contributed to the formation of the "warp." Fisher refers repeatedly (pp. 562-564) to the "warp" as older than the alluvium of present stream channels. He obviously believed that both materials were due to frost-action. His clearest statement is:

"We have, subsequently, though perhaps not in immediate sequence, a period of extensive denudation, indicated by the furrows filled with materials from the higher grounds, which have travelled in a plastic state, and which I have called "trail." This denudation brought the surface almost exactly to its present form. The period of the formation of the warp succeeded, in which the winter frosts seem to have been more severe than at the present time." (p. 564)

Trimmer (1847 and later) believed that the warp was formed by icy marine waters during the submergence of all of England at the close of the Ice Age. Hence, his use of the word conforms to, or perhaps gives rise to, one of the definitions in Webster: "a slimy substance deposited on land by tides, etc., from which a rich alluvial soil is derived."

Warp has been used in the sense of head by Sanford (1932) and doubtless others in England, but seems to have lost favor. It was introduced into the United States by Bryan (1928) and was subsequently used by Denny (1938) in his brilliant proof of the periglacial formation of frost-developed slopes and rubble masses in the Highlands of the Hudson.

The difficulty with these English terms is their provincial character and lack of distinctiveness when out of context. Each of them, head, warp, trail, etc., is an ordinary word with other and more familiar meanings. "Coombe Rock" is a mixture of fragments of chalk, flints, and other detritus. It and "Clay with flints" are both derived from the Chalk formations of England. They are distinctive but are local lithologic variants of a general phenomenon and confined to England and France. Zeuner (1945) uses "frost soil" as a general term but obviously this compound strains the meaning of both its components. *Frost-boden* (frost soil) has also been used as the equivalent of permanently frozen ground. The German "Erdfliesse," "Brödelerde," etc., are awkward or imply too much. Further, neither the German nor the English terms are readily convertible into other languages.

It is obvious that a word is needed for the process and for the result. A recent coinage by Edelman, Florshutz and Jeswiet (1936) is "cryoturbation" which has been adopted by Cailleux (1942). The word is derived from the Greek, κρύος= icy cold or frost and τυρβάζω= to trouble, confuse or stir up. The root "cryo" is familiar but there are no derivatives of the verb although its equivalent, the cognate Latin *turbare*, is represented in turbine and other words.

An equivalent word can be compounded from the Latin *congelare*, to freeze with *turbare*, to stir up, to produce "congeliturbation." The product of the process of congeliturbation is a congeliturbate. That all varieties of ground moved by frost-action are moved differentially seems established. Thus, all are stirred up or disturbed. Therefore, congeliturbation and congeliturbate should include all varieties of process and all resulting materials.

The surface features of congeliturbation are most easily observed. A large literature has arisen and a very large number of names have been given to these features, mostly in German. Various suggestions have been made for corresponding English terms. Sharp's (1942-B) list of English equivalents is probably the best. He proposes that "soil structures" be used as a general designation to include as varieties: stone nets, stone rings, stone garlands, stone stripes, earth stripes, earth hummocks, and turf-banked terraces. These seven terms include some sixty-three terms in several languages. In cross-sections of congeliturbates, these structures are not usually identifiable. Dücker (1934) has, however, identified stone nets or stone rings in congeliturbates of Late Pleistocene age. Keilhack (1938), Sharp (1942-A) and others have described interdigitation of beds of sands and clay in dumb-bell-like projections. These phenomena Sharp (1942-A) refers to as "involutions," a satisfactory neutral term for the structures (see also Denny 1934). German writers usually call the phenomena "Brödel-strucktur" which implies that they are due to the formation of soil structures according to the Low-Gripp theory. As, however, this theory (Gripp and Simon 1933-34) is still to be proved and is the subject of much doubt (Mortensen 1932; Sharp 1942A and B; and others), all terms involving "Brödel" should be avoided in description and neutral terms such as involution should be favored. A mass of involuted materials is, however, only a variety of congeliturbate.

The down-slope movement of the congeliturbate produces a drag on materials below, resulting in "drag folds" involving the underlying material and the congeliturbate. Such plications are referred to by some English authors as the "underplight" (Dines *et al.* 1940). However, the neutral and descriptive term plication seems adequate and is also applicable to those instances in which the "drag" phenomena involve only the congeliturbate.

The movement of fine-grained materials, mostly the finer products of congelifraction, to the surface is a significant part of congeliturbation. It is essential to the theories of formation of soil structures set forth by Eakin (1916), Högbom (1913), Gripp and Simon (1933-34) and others. This fine material is washed down slope in the yearly period of melting in streams or sheets of water or it may flow as mud. Taber (1943), Poser (1931) and others make much of this process. Insofar as the material flows as mud the process is included in solifluction. The English terms, "sludging" for the process and "slud" for the material, are neither euphonious nor necessary as such material can be referred to as a congeliturbate transported by solifluction or by sheet-wash as the facts indicate.

TERMS ASSOCIATED WITH PERMANENTLY FROZEN GROUND.

The process of congeliturbation is not confined to areas of permanently frozen ground. Salomon (1929) and others have shown that no permanently frozen ground exists in mountain areas where the process is now active in a minor way. However, in the areas of greatest intensity of frost-action of the Arctic, permanently frozen ground is involved. The terms perennially frozen ground and perpetually frozen ground are also in use. These trinomial phrases are all awkward and the equivalent

German and Russian is equally difficult.[2] There has been a movement, mostly among Scandinavian and German authors to introduce *tjaele* or *tjoele*, a Swedish-Norwegian word with equivalent meaning (Beskow 1930; Huxley and Odell 1924). It is, however, a word difficult for non-Scandinavians to pronounce. Muller (1945) in his useful review and analysis of Russian studies of the Arctic has sought the obvious convenience of a single word for permanently frozen ground by coining "permafrost."

"Permafrost" has the merit of being euphonious, but it is an etymological monstrosity, made by contracting "permanent" (through French from Latin, *permanere*) and combining it with the English word "frost," none of whose meanings refer to the ground. It sounds like a trade name for a refrigerator and "permaform" and "permalift" actually exist as the trade names of types of brassieres. There is also a glue named "permacel." These slight crimes might be forgiven, but it is impossible to make a verb or a verbal noun from "permafrost" as "permafrosting" and "permafrosted" imply that a permanent surface or coating has been applied. Hence the act of producing permanently frozen ground cannot be expressed. Further, the term cannot be easily converted into other European languages.

These various objections can be met by a new term which, being compounded from Latin roots already established in English usage, would convey a meaning on its face. Such a word is "pergelisol" from *per*= throughout or continuing+*geli* =*gelare*, to freeze+sol, from *solum*, the soil or ground. In this term the use of the prefix "per" blurs the resemblance to gelatine and other derivatives of *gelare* with the connotation of jelly.

The several modifications and attributes of the permanently frozen ground pointed out by Muller can then be easily made: "subgelisol," "supragelisol." and "dry pergelisol."

One of the great problems of the Arctic is the time and manner of formation of the pergelisol. To what extent is the area now occupied strictly in accordance with modern climate? Johnstone (1930) has recorded frozen ground at depths of 30 feet below the surface and thus obviously below the depth of present day freeze and thaw. It must be fossil. The question is thus raised as to what extent part of the pergelisol may be

[2] German: Ständigen-, dauernden-, und ehigen-Frostböden oder Bödengefrornis; Russian: vechnaya merzlota.

residual from the colder climate of the Pleistocene? The great areas of congeliturbates in periglacial areas imply that pergelisol was also present. Thus future discussion will involve again and again the process of formation of pergelisol. It is suggested that the term "pergelation" be adopted, a word strictly analogous to regelation already a familiar term in glaciology. Muller (1945, p. 21) uses "aggradation of permafrost" in the sense of pergelation as here proposed. For the thawing of pergelisol by natural or artificial means he uses "degradation of the permafrost" an idea which can easily be carried by de-pergelation.

Above the pergelisol lies a layer which thaws each summer and freezes each winter to a degree dependent on the march of temperature and the duration of the seasons. In this layer "frost-action" takes place and hence Muller calls it the "active layer." As thawing cannot occur without previous freezing, it is useless to argue as to which produces the greatest part of the activity involved. The annual thawing of this layer is its prime characteristic and it is consistent that the terminology emphasize this distinction from the pergelisol. In thawing there is usually produced more water than the volume of pore space so that the layer becomes soft and tends to flow. It may, therefore, be termed the "mollisol" from L. *mollere* to make softer, pliable, to melt, and sol=*solum.* The root of this word is familiar in emollient and other words. The act of thawing and softening may, if desirable, be known as "mollition."

The softening of the mollisol is its major characteristic although in well-drained ground where dry pergelisol occurs, melting produces no apparent softening. Whether such areas are large is not known and thus it is at present impossible to evaluate dry pergelisol. However, softening or "mollition" is the common activity and sets in motion the forces which result in congeliturbation. A fossil mollisol is a congeliturbate.

Muller points out that cool or short summers or very cold, long winters lead to failure to melt all the ground frozen the winter before. There thus intervenes between the mollisol and the pergelisol a layer of frozen ground which may persist for one or several years. For this layer he uses the Russian term "perelétok." Offhand there is no objection to adopting this Russian word but the pronunciation, which can be expressed more or less accurately by "pjerelyétok," is difficult. However, by the use of the prefix *inter*, among, between or amid, one can coin "intergelisol" which gives a term that will sufficiently express the likeness of this material to pergelisol and also its situation between the top of the pergelisol and the mollisol.

Muller also introduces the Siberian word "talik" for bodies of unfrozen ground above, within, or below the pergelisol. This

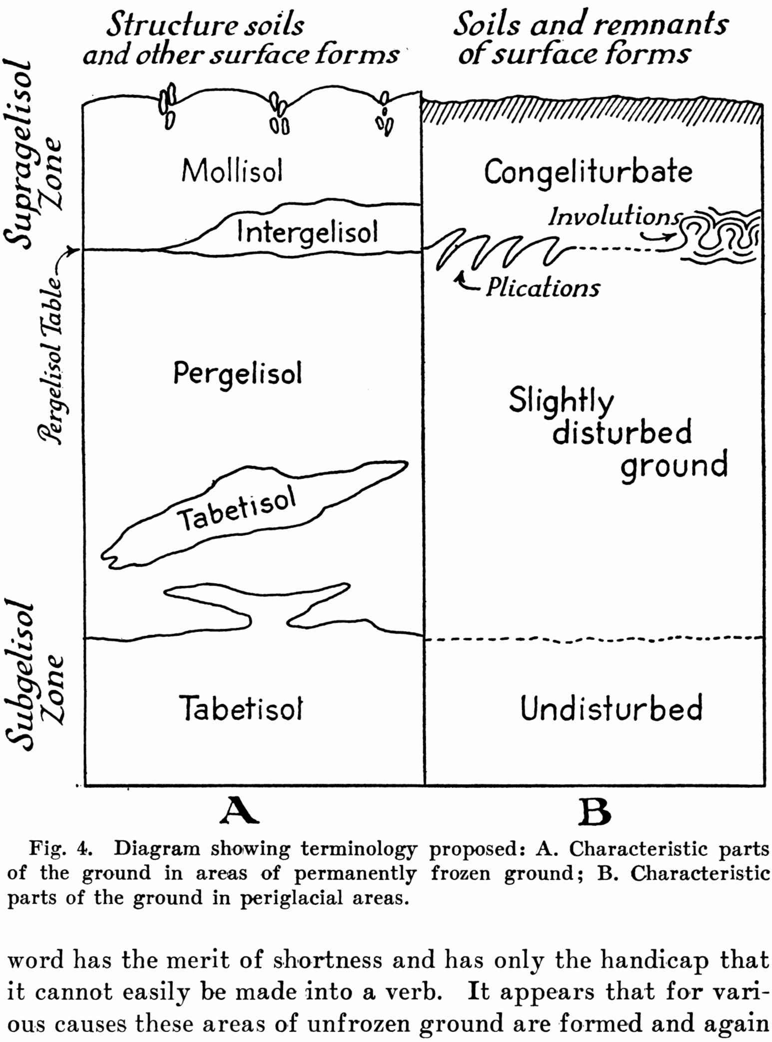

Fig. 4. Diagram showing terminology proposed: A. Characteristic parts of the ground in areas of permanently frozen ground; B. Characteristic parts of the ground in periglacial areas.

word has the merit of shortness and has only the handicap that it cannot easily be made into a verb. It appears that for various causes these areas of unfrozen ground are formed and again are refrozen. The production of "talik" is an idea that will doubtless be discussed and for which a term appears to be desirable. The new term "tabetisol" is here suggested from L. *tabescere*, to melt and sol=*solum*. The root is present in English in tabes, a wasting disease and tabetic, wasting, which is symptomatic of tabes. The production of tabetisol would be expressed by the verb to "tabificate" and the verbal noun, "tabification."

The proposed terminology is parallel for present-day areas of intensive frost-action and for areas where this process was current in the past. The terminology is summarized in Fig. 4.

WIDESPREAD EROSION BY FROST-ACTION.

The idea that landscape can be molded by frost-action and that widespread and extensive reduction of elevation may occur in areas where frost-action is the dominant process is an old one. This idea is indicated by the "equiplanation" introduced by Cairnes (1912A). De Terra (1940) has discussed the problems of the Tibetan plateau and holds that the broad, smooth surfaces are largely the result of long-continued erosion by frost-action which varied in intensity during the Pleistocene fluctuations in climate. Many years ago, Wright (1910) called attention to the smooth upland surfaces of Iceland and southeastern Alaska above which rise peaks and below which deep glaciated gorges are cut. Noting that these uplands were lightly covered by glacial ice during the "ice flood" of the Pleistocene, he conceived of "ice-cap erosion" as an independent high-level process. If the ice covered these highlands only at the maximum of each ice advance, during the rest of the Pleistocene they must have been subject to frost-action with reduction in grade by congeliturbation of the surface accompanied by various forms of solifluction. The overrunning of these areas by ice is incidental, their reduction in slope is, however, as Wright presumed, due to processes unconnected with the fluvial-pluvial cycle of erosion.

Without much doubt Eakin (1916) had a similar idea concerning erosion in the Yukon Valley although his expression is confused. Cairnes (1912 A and B) believed that frost-action, rain-wash and solifluction operate on the relatively smooth and gentle slopes of the Yukon Plateau, but that the material thus eroded from the upperslopes is incorporated in frozen ground on the lower slopes. In this fashion the relief is lowered by erosion above and deposition below without loss of material to the area except through the activity of streams. This process he named "equiplanation." That the complex of processes in congeliturbation contribute the principal load to streams, and constitute the principal and, in many parts of the Arctic, the sole agent of degradation was not part of Cairnes' concept. He seems to have ignored frost-action on the steep slopes of the canyons of eastward flowing streams which dissect the Yukon Plateau. However, Poser (1936) has clear-cut ideas on these matters. He points out that the rivers of East Greenland run only during the melting season. Their activity is closely related to the supply of detritus from the interfluves. The detritus consists of congelifracts of all sizes supplied by rain-wash and solifluction from rock slopes largely mantled by congeliturbates. The rivers carry off the fine congelifractate without difficulty but their broad beds are paved by large congelifracts which are only gradually reduced by congelifraction to sizes small enough to be transported.

These brief references, which might be much extended, indicate that in Arctic and high mountain lands reduction of the land may be largely due to intensive frost-action and concurrent action. Furthermore, similar processes were once at work in the periglacial region as emphasized by Soergel (1921) and others. The land forms are not analizable under the normal "Cycle of Erosion" of Davis. A new term seems necessary and an appropriate coinage would be "cryoplanation" from κρύος, icy cold or ice and plane, through French from L. *planus*, Greek, πλάτος broad. The term would be parallel to peneplanation although without implication that the process had reached or nearly reached completion. We would, however, be able to say that an area is or has been subject to the "Cycle of Cryoplanation" in contrast to areas subject to the "Pluvial-fluvial Cycle."

SUMMARY.

The foregoing suggestions as to terminology are somewhat overpowering in number. They are put forward with due apology and in the hope that these coinages will serve a useful purpose. Those familiar with the complications of Cryopedology will recognize that not all ideas, processes or materials are provided with names. The surface forms of congeliturbation are so numerous that it is doubtful whether Sharp's simplification will meet with unanimous approval. New ideas and interpretations are also in the making and an enlargement of the vocabulary here proposed is inevitable.

The new terms are summarized below:

Cryopedology = the science of intensive frost action and permanently frozen ground including studies of the processes and their occurrence and also the engineering devices which may be invented to avoid or overcome difficulties induced by them.

Cryoplanation = land reduction by the processes of intensive frost-action, i. e., congeliturbation including solifluction and accompanying processes of translation of congelifracts. Includes the work of rivers and streams in transporting materials delivered by the above processes.

Congelifraction = frost-splitting or frost-riving.

Congelifract = the individual fragment produced by frost-splitting.

Congelifractate = a body of *congelifracts*, a mass of material of any grain size produced by congelifraction.

Congeliturbation = frost-action including frost-heaving and differential and mass movements. Includes solifluction, sludging, etc.

Congeliturbate = a body of material disturbed by frost-action = warp, trail, head, Coombe rock, Erdfliessen, Brödelerde, etc. These materials are characterized by surface forms: structure, soils, soil stripes, block-fields, mounds, etc. In places, structures characteristic of the surface forms are recognizable in the congeliturbate.

Pergelisol = permanently or perennially frozen ground = "tjäle" = "permafrost."

Pergelisol table = top of pergelisol.

Subgelisol = zone of unfrozen ground below permanently frozen ground.

Supragelisol = zone above the pergelisol.

Dry pergelisol = material having the requisite mean temperature to be permanently frozen but lacking water content or "dry."

Pergelation = the act or process of forming permanently frozen ground in the present or in the past.

De-pergelation = the act or process of thawing permanently frozen ground.

Mollisol = seasonally thawed ground above the pergelisol = "active layer" of Muller.

Mollition = the act or process of thawing the mollisol.

Intergelisol = perelétok, a layer of frozen ground between the pergelisol and the mollisol, which may persist for one or several years.

Tabetisol = talik, unfrozen ground above, within, or below the pergelisol.

Tabetification = the act or process of forming tabetisol.

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