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THIN IRON PANS: THEIR OCCURRENCE AND THE CONDITIONS LEADING TO THEIR DEVELOPMENT

DEPARTMENT OF FORESTRY CANADA

by

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INTRODUCTION

The thin iron pans which will be discussed here are those found in soils described as placaquods and placorthods in the soil classification system of the United States Department of Agriculture (18) and as iron pan podzols by the National Soil Survey Committee (15). They are entirely unlike other hardpans, such as ortstein, which are commonly encountered in podzol soils.

First their characteristics, geographic distribution and position in the profile will be described. It will be followed by a more detailed description of the conditions under which they are found in Newfoundland where they are common in a great variety of soils. Consequently, their occurrence here provides a good starting point for a discussion of their origin and the environmental conditions necessary for their development. After this their occurrence under more unusual conditions will be explained.

CHARACTERISTICS

The pan consists of a very thin ribbon, only 1 to 2 mm. thick, with a reddish black to very dusky red (10 R 2/1 - 2/2) colour[1/] and a metallic lustre. It is strongly cemented and impermeable. It overlies a rust red (10 R 4/8 - 2.5 YR 4/8) layer which is up to 1 cm. thick but never cemented. Since the

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1/ The Munsell colour notations are those for moist soils.

rust red horizon is always associated with the cemented ribbon it should be considered as an integral part of the iron pan.

Well-developed thin iron pans have a total iron content varying from 12 to 16 per cent in the upper cemented ribbon and from 2 to 6 per cent in the rust red layer. The iron in the rust red layer can be extracted by either Deb's method (7) or with 0.02 M. EDTA and sodium dithionite (1, 2), but only about 10 per cent of the iron in the cemented layer is extractable with these methods. The pan contains also organic matter; a loss on ignition as high as 13 per cent was measured in some pans but usually it is less than 5 per cent.

The most striking feature of the iron pan is its erratic course through the profile. It will follow a straight course for some distance; then suddenly dip down to a position ten or twenty inches farther down, and as suddenly rise again to another level. Sometimes, the pan shows strange contortions or shows up as an isolated circle well above the general level of the pan. Upon further investigation these often, but not always, prove to be cross sections through tubes of iron pan linked up with the main pan. Boulders and rocks do not alter the position of the pan, but it will leave a distinct mark on them which is often still present on transported material.

GEOGRAPHICAL DISTRIBUTION AND POSITION WITHIN THE PROFILE

The thin iron pans are common in cool climates with a high precipitation. They have been reported often from Scotland (13, 14, 16, 10) and northwestern England (4, 5) but they occur also in Ireland (17), Newfoundland2/, New Zealand (11), Tasmania (18) and in a poorly developed form in Belgium and the Netherlands (20).

They are most commonly found in podzol soils but they occur also under gley soils. Their position in the profile is also by no means fixed. Depending on the environmental conditions it can occur in almost any horizon from the Ae to the parent material, even within one soil type its position may vary as was pointed out before. It may also occur under a gley horizon but it is never found within a gley horizon.

DISTRIBUTION WITH RESPECT TO SOIL TYPE

Most of the reports of thin iron pans have been from podzols on well-drained slope positions where the pan occurs under the Ae, between the humus B and iron B horizons (13, 14, 10), or at the base of or within the plough layer of cultivated soils (4, 17). Crompton (4) described these pans also from shallow peat soils with gleyed eluviated mineral soils.

In Newfoundland the thin iron pans are common in well-drained podzols under maritime heathland dominated by *Kalmia angustifolia*. They occur most commonly between the humus and iron B horizon as they do in many Scottish iron pan soils. In these soils they are most common in areas with

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2/ Chancey, H.W.R. 1951. Report on soil survey work conducted in Newfoundland. Canada Dept. Agric. Unpubl. Rept.

a precipitation of fifty inches or over like the Avalon and Burin Peninsulas and along the south coast, but they are absent in the drier northern and interior parts of the island.

They occur also on soils similar to the peaty gleyed podzol soils of Crompton (5) and under wet iron humus podzols but they reach their optimal development under hydromorphic humus podzols and associated soils under deep peat bogs, from which they have not been described thus far. Under these soils they can be found on the entire island.

These hydromorphic humus podzols (6) may be overlain by a peat layer up to six feet thick. They have a distinct Bh1 horizon with up to fifteen per cent organic matter which grades into a Bh2. An iron ribbon separates the slightly humus enriched lower part of the Bh2 horizon from the underlying parent material which is dry and freely drained. The Ae can also contain considerable amounts of organic material but whereas the humus in the B horizon occurs as coatings over the sand grains, the humus in the Ae horizon consists of small humus particles washed into this layer from the overlying organic horizon.

This whole podzol profile is definitely deficient in iron down to the thin iron pan. In our analyses it contains from 0.1 to 0.03 per cent of free iron. It is always poorer in iron than the unweathered layers under the thin iron pan.

The iron pan i.e. the cemented ribbon and the rust red layer contains an amount of iron equivalent to the amount leached from the overlying mineral soil. This indicates that iron mobilization has actually occurred here.

Once developed the iron pan may cause changes in the overlying profile: a gley horizon[3/] may develop in the depressions of the pan or allochthonous B horizons may develop owing to lateral movement of peat water over the pan. Sometimes the lateral flow of peat water with a high amount of humus colloids may cause the development of a second Bh on top of the iron pan and separated from the normal Bh horizon by a layer with a much lower organic matter content. However, very often it leads to the development of one very thick Bh horizon (Figure 1).

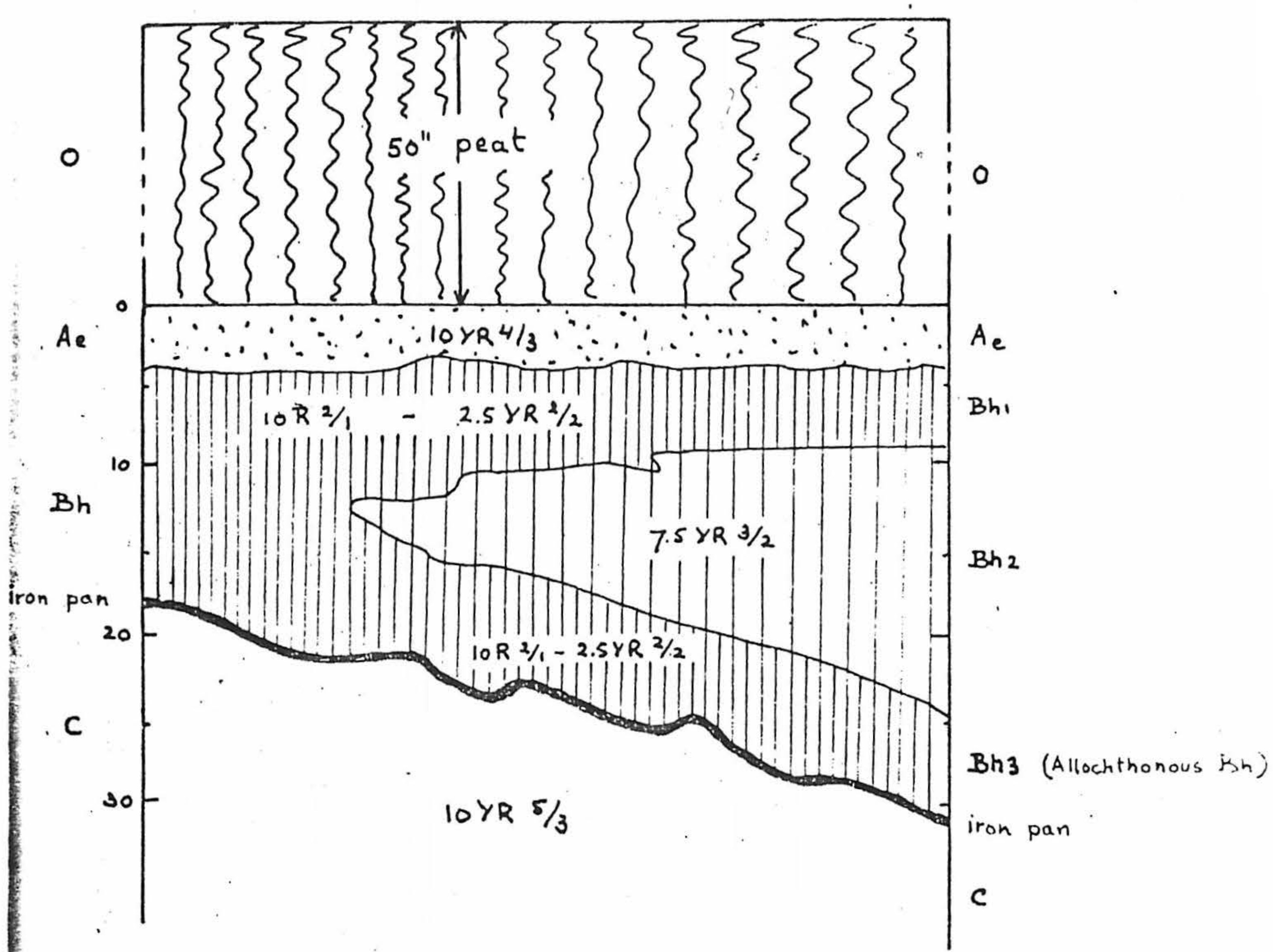
These bog soils are little known because in most soil survey work all peat deposits over one foot thick are mapped as peat bogs. Consequently, the attitude of most pedologists has been to disregard the underlying mineral soil assuming that it is always gleyed. An additional reason is of course the difficulty of studying these soils. Soil pits fill up with water before they are dug and this hampers all further study. It is only when large gravel pits or railroad cuts expose the underlying soils that one can really study them.

GENESIS OF THE IRON PAN

Muir (13) was the first to draw attention to these thin iron pans. Its occurrence between the iron and humus B horizon made him suggest that it developed by gradual cementation of the upper part of the iron B of a normal podzol, once developed it would result in stagnation of rain water and gleying of the upper horizons.

3/ This reduced layer contains an amount of iron roughly similar to that in the parent material

FIGURE 1



Soil Profile Under Peat Bog, illustrating both thick Bh horizon and a second (allochthonous) Bh horizon. Both have developed owing to lateral movement of peat water over the thin iron pan.

Although this explanation may seem adequate for the iron pan formation at the top of the iron B horizon of maritime podzols belonging to the humic podzol great group (15), it obviously cannot explain their occurrence in either the middle of an Ae horizon or down in a C horizon where nothing seems to impede downward percolation of the soil solution.

Proudfoot (17) described thin iron pans from archeological sites where they occurred under cultivated soils. He attributed their formation to intensified podzolization after cultivation. Peat formation was thought to result from subsequent stagnation of rain water on the pan. Intensified podzolization is a vague concept and it is hard to understand why intensified podzolization would lead to such a different type of B horizon development. It also fails to explain why the pan develops in such a variety of horizons rather than in the existing B.

It is interesting to note that wherever these pans occur they are associated with a poorly drained soil underlain by a permeable and freely drained subsoil[4/]. Usually the gleying and saturated conditions above the pan have been attributed to the occurrence of the pan (13, 17) but one should not lose sight of the possibility that the pan is the result of the water saturated surface horizons rather than the cause of it.

Muir (13) mentioned this possibility but it was Crompton (4, 5) who showed the merits of this hypothesis. Given saturated conditions in the surface soil the iron will be easily mobilized as it occurs as ferrous iron which is soluble up to well over pH 9 (12). Consequently most iron will be leached from the wet surface horizons. However, aerobic conditions prevail in the freely drained lower part of the profile and when the ferrous ions

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4/ Once developed thin iron pans persist after drainage. Therefore, thin iron pans can be found occasionally in roadside cuts in dry soils. Upon close examination these soils show evidence of previously existing wet conditions.

reach the air-water interface they will be oxidized. This results in the precipitation of iron in a very narrow zone and ultimately it leads to the development of the thin iron pan.

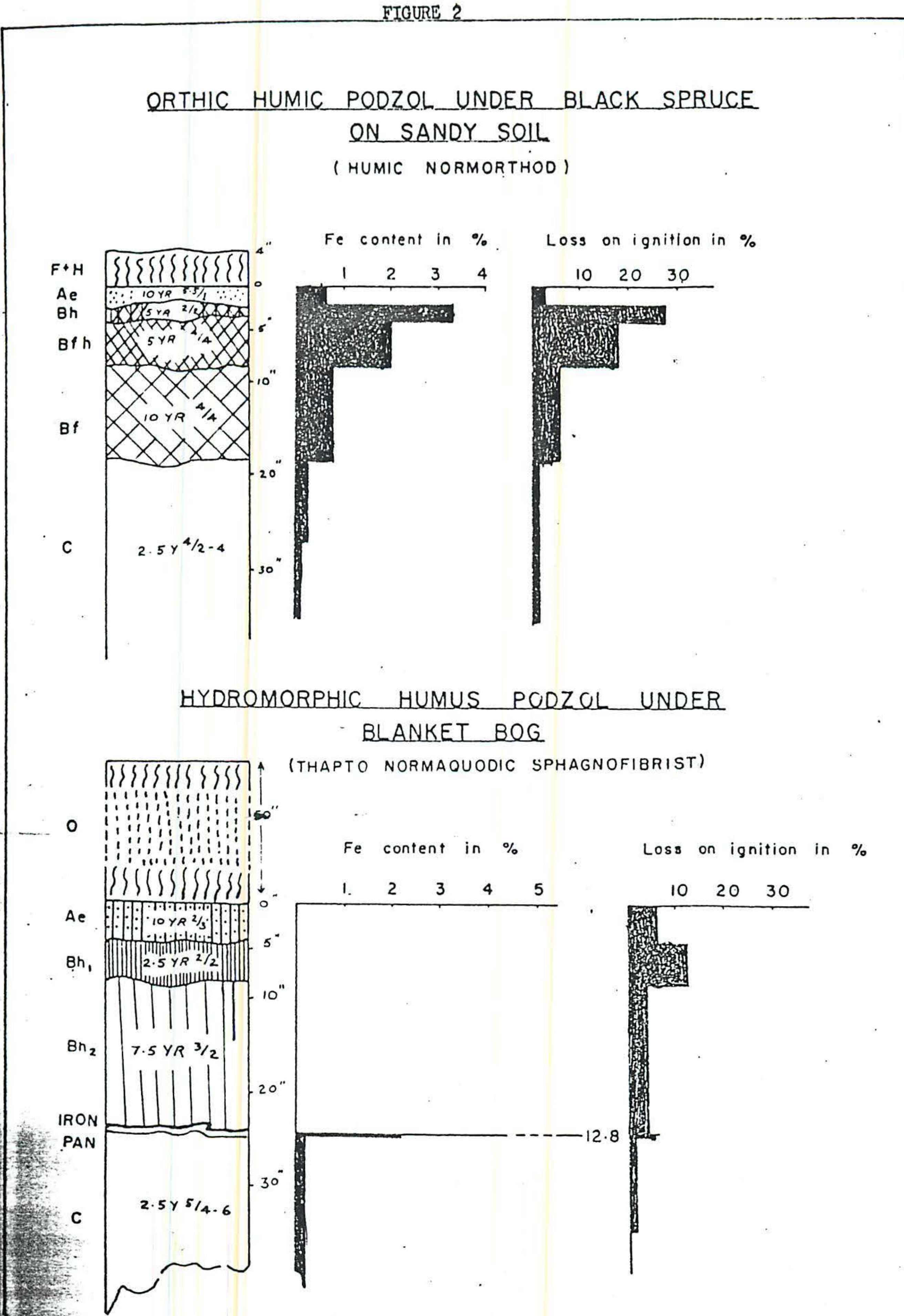
As pointed out later this hypothesis can explain the characteristics of the pan as well as its position in the profile. However it is necessary to describe first the conditions which will cause the presence of a poorly drained surface layer overlying a well-drained and aerated subsoil, and to show that these conditions are not purely hypothetical but actually occur in nature.

In Newfoundland and in other areas with a cold humid climate the decomposition of organic matter is slow. Thick raw humus layers occur commonly but it is particularly pronounced under the Kalmia heath lands in the humid parts of the island. Longterm occupation by Kalmia leads here to the development of ericaceous mor, often over one foot thick. Owing to the high and well-distributed precipitation this layer will remain soggy throughout the year; it acts as a sponge and it will maintain saturated conditions in the mineral soil immediately under it. Blanket bog formation on well-drained positions is also common in areas with high precipitation, and the zone with capillary water hanging under these bogs will keep the upper part of the mineral soil saturated with water.

Thus poorly drained surface soils can occur on otherwise freely drained deposits if the proper climatic conditions occur. The coincidence of the optimal range of thin iron pans with areas with a perhumid climate is of course no proof for this hypothesis on the origin of iron pans as high precipitation will also result in more severe podzolization. But there are many other factors which support the hypothesis.

1. The precipitation at the air-water interface explains why the iron is concentrated in such a thin and well-defined layer.
2. It is consistent with the distribution of iron in the hydromorphic humus podzols. Low levels of iron such as are found in these soils will not occur on well-drained soils but they do occur in many wet podzols (3, 8, 9, 12, 19, 20). Figure 2 shows the difference in iron and organic matter distribution on a well-drained soil and a soil under a blanket bog on essentially similar parent materials. Thus iron removal appears to have occurred under imperfectly drained conditions. That vertical translocation of iron and humus colloids is possible under permanently wet conditions is shown by the fact that the iron in the thin iron pan roughly equals the amount leached from the overlying horizons as well as by the development of a humus podzol in these soils. It is also to be expected since the capillary zone has a maximum thickness which is determined mainly by soil texture. If more water is added it will result in the loss of water from the lower part of the saturated zone (6).
3. The position of the pan depends primarily on the location of the lower part of the saturated zone. This explains why the pan can occur in such a variety of horizons and why it is almost independent of textural changes. Sometimes this saturated layer can be caused by the presence of humus-rich or cemented genetic horizons but if it is hanging from an organic layer its position will depend on climate and soil texture rather than existing profile horizons.
4. The hypothesis accounts also for minor irregularities in the location of the pan since the lower part of this perched saturated

FIGURE 2



Iron and organic matter distribution in dry and wet soil profiles developed in the same parent material zone will vary in depth as a result of textural variations. However, Crompton (4) may well be right when he suggests that the formation of the peculiar contortions which are sometimes found result from a gradual downward movement of the pan due to reduction and solution of iron on the upper surface followed by diffusion and reoxidation at the lower surface.

5. The hypothesis also explains their development under more unusual conditions.

In cultivated soils as described by Proudfoot (17) the disturbance of the natural forest vegetation and the compaction at the plough sole may have led to waterlogging of the surface soil and subsequent pan formation.

The incipient iron pan found in some West European heath podzols (20) are caused by periodical saturation of the very humus-rich black upper part of the B horizon[5/] overlying the normal Bh of the West European heath podzols.

5/ This black layer at the surface of the normal Bh contains bleached sand grains and up to about 20 per cent organic matter which occurs as black humus pellets whereas in a normal Bh the humus occurs also as brown coatings on the soil particles.

CONCLUSIONS

In summary the conditions for iron pan development are:

(a) the existence of imperfectly drained conditions in some part of an otherwise freely drained soil, usually as a result of the presence of a "sponge horizon" either on top of or in the mineral soil.

(b) Downward movement of the soil solution. In spite of the poor drainage vertical percolation of water must be able to take place so that iron can be leached to the area of pan formation. This is the reason for their absence in fine textured soils and soils with a genuine ground water level.

Normally these conditions are fulfilled only on sandy or gravelly soils in perhumid climates but locally they may exist elsewhere.

The iron pans under blanket bogs appear to be a result of primary soil profile development but in most other soils they are secondary formations in existing profiles due to disturbances of the natural vegetation under which the profile developed. Often these changes are the result of anthropogenic disturbances but they may result from repeated natural fires.

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