The Soils of Europe

ILLUSTRATED DIAGNOSIS AND SISTEMATICS

With keys and descriptions for easy identification of the most important soil formations of Europe with consideration of the most frequent synonyms.

by

PROF. DR. WALTER L. KUBIËNA

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS
MADRID - 1953

THOMAS MURBY AND COMPANY
LONDON

No. 4: Simple Key for the Easy Identification of the most frequently occurring European Alpine Soils.

1. Occurring on primitive rock 2

1*. Occurring on limestone or dolomite 10

2. Soil raw, chemically very little weathered, sandy, gritty to gravelly, without formation of distinct humus horizons 3

2*. Soil profile with distinct horizon formation or at least with development of a distinct humus layer 4

3. Occurring in high elevated small snow basins with a snow covering, lasting far into the summer and subsequent waterlogging, under a plant cover of mosses with slight gleying but generally distinct formation of polygon fissures in the frozen stage.

Nival snow basin soil (*rutmark of nival snow basins*), No. 15.

3*. Not occurring in small snow basins.

Alpine silicate raw soil (*rawmark*), type XXI (plate IX).

4. Soil with humus layer, without however an ochre yellow to rust brown coloured B-horizon 5

4*. Soil with ochre yellow to rust brown coloured B-horizon 8

5. Soil occurring in small basins, with anmoor-like humus formation and a bluish grey to greenish grey subsoil generally with many rust flecks.

Alpine snow basin soil (*snow basin anmoor*), No. 19.

5*. Soil without anmoor-like humus formation 6

6. The soil shows the formation of tangel humus (page 36) with generally a strongly developed tangel layer of brown plant remains over a blackish mull-like moder. It occurs in the dwarf shrub region of southern high mountains (plate XII).

Tangel ranker, No. 55.

6*. Soil without tangel humus 7

7. Soil very shallow, particularly on summits within the alpine grass heath region consists essentially of a mat, rich in roots, easily cut like peat, but not waterlogged, which contains more or less loose blackish coloured droppings of small soil animals (plate X).

Eilag ranker, No. 54.

7*. Humus mostly earthy, with good decomposition, humification and good mixture with the mineral substances. The generally dark grey humus layer can reach the thickness of 25 to 40 cm. and more (plate XI).

Alpine mull-like ranker (humus silicate soil), No. (32).

8. Soil without a bleached sand layer, loose, mostly sandy, with low clay formation, however plentiful precipitation of free ferric hydroxide. Profile generally very shallow with strongly reduced, rust brown to ochre yellow (B) horizon. The soil occurs in the grass heath or bunch grass region.

Alpine sod braunerde, No. 82.

8*. Soil profile with distinct bleached sand layer 9

9. Profile generally well developed, subsoil containing distinctly marked usually sepia brown humus enriched layer and an ochre yellow to rust brown iron enriched layer. Soil occurs in the dwarf shrub region.

Sub-alpine iron humus podsol, No. (67).

9*. Profile with usually strongly reduced irregularly running horizons, soil with little chemical weathering, loose, sandy to gritty but frequently with strong tendency to form blackish humus layers, rich in animal droppings.

Alpine sod podsol, No. 91.

10. Soil raw, gritty to gravelly without formation of a definite horizon.

Alpine carbonate raw soil (*calcareous rawmark*), No. 42.

10*. Soil profile with distinct humus horizon formation or at least with development of a distinct humus layer 11

11. Soil profile with humus layer but without an ochre yellow to reddish brown (B)-horizon 12

11*. Soil usually low in humus, with vivid ochre yellow, brown ochre, ochre brown to reddish brown coloured, generally dense, strongly swelling, easily silted-up (B)-horizon. Primarily it occurs as a relic soil on slightly sloping or flat locations on old land surfaces (plate XVIII).

Terra fusca (limestone brown earth), No. 74

12. Soil occurring only in the dwarf pine and dwarf shrub region, with formation of tangel humus (page 36) with strongly developed tangel layer rich in brown plant remains, above a blackish mull-like chalk moder (plate XIV).

Tangel rendsina, No. (39).

12*. Soil not or not only occurring in the dwarf pine and dwarf shrub region. 13

13. Soil of cushionlike form, occurring only in the cushion vegetation region, with a raw humus-like external layer and well humified blackish (mineral deficient) to light grey (mineral rich) inner layer (plate XIII).

Alpine cushion rendsina, No. (38).

13*. Soil occurring primarily in the alpine grass heath region 14

14. Soil striking deep black to brownish black coloured, pitchy, extraordinarily low in minerals, almost always moist but almost never waterlogged, with good humification, primarily occurring on limestone (plate XIII).

Alpine pitch rendsina, No. (37).

14*. Soil mineral rich, generally light grey, only coloured dark grey in transition formations, sandy, with a silted-up structure, in summer completely loose, easily removed by wind.

Alpine protorendsina, No. [3].

No. 5: Universal key for the Identification of the most frequent European Soils, with their Descriptions, arranged after the Natural System.

In the natural system *) soils are not ordered after a single or a few, but after all characteristics (insofar as they are essential) and also after their mutual inter-relations. The decisive characteristics are never settled in advance but arise only from an exact comparison of the different forms. They are never fixed for all soil formations, but undergo a continual change, by which first this, then that group of characteristics becomes the most important. As with all natural systems, the arrangement of soils proceeds form the simplest to the most complex. In this way, groups arise of their own accord corresponding essentially to the natural phases of development. Besides the arrangement according to levels of organization (phase of development) it is however also necessary, for a better overall view, to create larger or smaller closed associations of forms in order to avoid overlapping of the different groups and unprofitable separation of certain members. Thus the entire kingdom of soil formation may be grouped into the following three great ranges of forms or divisions:

Division A, Sub-aqueous or Underwater Soils.

This division is composed of two sub-divisions. The first consists of primitive soil formations *always covered with water and not forming peat,* in which primarily lower plants (algae) serve as parent material for humus formation. They are always characterized by a very simple profile structure in which B horizons are usually completely missing. The possibilities of profile development are limited to (A)C, AC and AG. Further mull humus formation, being the most highly developed humus form, is completely missing in these soils. They are characterized too, by a very low variety of form (which is essentially limited to four main types), further also by low exchange of form i. e. a low transformation of type (generally only raw soils into *gyttja* or eventually *gyttja* into *sapropel*). They are the oldest forms of soil formation, which already may be found in the Cambrium, where besides terrestrial

*) As to the fundaments of the natural system, the establishment of the various categories of the system and their arrangement, see KUBIENA 1948, Entwicklungslehre.

life, also terrestrial soil formations, as well as semi-terrestrial formations were entirely lacking. (Begin with the key of division A-1, page 85.)

The second sub-division of soils consists of *sub-aqueous soils with peat formation*, a type of soil formation which is geologically considerably younger than the above mud soils, whose origin nevertheless, also goes back to palaeozoicum (Upper Devonian, Carboniferous). Formed originally from the remains of pteridophytes, to-day they arise in the first place from the residues of higher plants which root under water but which develop leaf and flower organs above the water surface. The humus formation still takes place completely below the water level. (Begin whith the key of division A-1 *), page 85.)

Division B, Semi-terrestrial Soils or Flooded and Groundwater Soils

Not or only temporarily covered with water, however *generally completely or partially waterlogged, peaty or non-peaty soil formations*, which altogether stand distinctly higher than the previous ones. The main sources of parent material for humus formation are higher plants, a few types already show mull formation. The profile structure starts with simple forms but increases considerably in complexity. Also B horizons may appear in the more mature phases. With increasing maturity the soils become drier, lose gradually the characteristics due to waterlogging and develop into dry terrestrial soils *). The humus formation is more varied, the number of forms distinctly larger and the change of form more pronounced than with the sub-aqueous soils.

They represent the second oldest kind of soil formation appearing as embryonic formation in the Carbon and in full development considerably later. (Begin with the key of division B.)

Division C, Terrestrial or Land Soils.

Soil formations practically never covered with water or waterlogged but at worst in a few transition formations showing stagnant water in particular horizons. In the highest phases of development they show a rich profile division up to seven or more horizons or sub-horizons. The parent material for the humus formation consists primarily of the remains of higher plants. There is an extraordinary variety of humus formations in which mull predominates by far. The soils also show an unusual variety of forms (great number of types) and a strong change of forms (sequences of development with up to seven and more members.

The highest development forms are geologically proportionately young.

*) Individual warp soil types strictly taken already as belonging to terrestrial soils (like the brown warp soil without G horizon, *smonitza*, *ganynyatcha* among others) in order not to break the class warp soils are described in the division of flooded and groundwater soils.

They are not only conditioned by an atmosphere which has become to a high degree perfected as a biosphere but also by the presence of a plant cover which is suitable for the formation of highly developed humus forms. The development of true, deep, mull soils (as the *chernosems, para-chernosems, smonitsa, eutrophic braunerde,* etc.) depends on the presence of a luxuriant grass flora or angiosperm woods, so that the first appearance can be taken at the earliest in the upper Cretaceous and Tertiary. (Begin with the key of division C.)

A. Sub-Aqueous or Underwater Soils (Ramann 1918)

Key for the Determination of the Types and certain particular Sub-types.

1. Soil without peat formation 2
1*. Soil with distinct peat formation 8
2. Soil without macroscopically distinguishable humus horizon 3
2*. Soil with macroscopically distinguishable humus horizons 6
3. Low in chalk, not effervescing with HCl 4
3*. Calcareous to highly calcareous, effervescing with HCl 5
4. Extremely rich in iron, intense rust yellow, rust brown, or rust red coloured.
2. *Dystrophic lake iron protopedon.*
4*. Not extremely rich in iron and otherwise coloured.
1. *Chalk deficient protopedon.*
5. Containing clay to rich in clay.
3. *Lake marl protopedon.*
5*. Low in clay to free from clay, extremely calcareous.
4. *Lake chalk protopedon.*
6. Very acid, consisting almost entirely of brown humus flocks, occurring only in acid brown waters.
II. Dy.
6*. Colour blackish, grey, to grey brown not occurring in brown waters, but in humus free or at most moderately humus containing waters 7
7. Humus layer without or with only slight smell of putrefaction, ric in animal excretions.
III. Gyttja.
7*. With strong to unbearable smell of putrefaction, poor in animal excretions.
IV. Sapropel.
8. Peat composed predominately of the remains of grasses or false grasses. 9

8*. Peat composed predominately of remains of other plants 10

9. Peat predominately composed of the remains of roots, stems, rhizomes and leaves of reeds recognisable by their size, as well as with strong peat decomposition by the visible stalk nodes.

(10). *Phragmites-Fen* (Reed peat moor).

9*. Peat consisting predominately of the remains of sedge species recognisable by their fineness as well as almost always by the presence of lustrous dark seeds of the marsh trefoil.

(11). *Carex-Fen* (Sedge peat moor).

10. Peat thin layered, loose, relatively little decomposed, consisting predominately of the remains of Hynum mosses almost always easily recognisable, besides carex residues 18

(12). *Hypnum-Fen* (Hynum peat moor).

10*. Peat consisting predominately of the leaves, fruits, soft easily cut woody remains of alders and willows.

10. *Wood-Fen.*

Description of Sub-Aqueous soils

AA. Sub-Aqueous Soils not forming Peat.

I. Protopedon

Sub-Aqueous Raw Soil

1. Chalk deficient Protopedon

Chalk deficient sub-aqueous raw soil

Synonyms: Minerogener Seeboden (WASMUND).

General Specification: Embryonic underwater soil formation on chalk deficient clastic sediments with colonization by organisms but without formation of a macroscopically apparent humus horizon.

Characteristics:

Profile: The (A) horizon consists often of an algal layer (Äfja) or a root layer of higher plants. The profile structure is either (A)C, if the subsoil is composed of little weathered sediments, or (A)G, if it is a strongly weathered, more or less coloidal rich and gleyed lake soil layer (sub-aqueous gley soil).

Humus Form: Sub-aqueous raw soil humus with low decomposition and humification and transitions to gyttja.

Dynamic: Underwater weathering increased in acid waters. Gleying. With local increase in oxygen content and by the activity of iron bacteria, oxidation and irreversible precipitation of ferric hydroxide.

Texture *): From the finest clays through loam, silt, pebbles to coarse

*) Used in the sense of particle size distribution.

shingle, which can be expressed also by the name (e. g. lake sand raw soil, lake clay raw soil, in the case of marine formations schlick raw soil, etc.).

Chalk Content: Not effervescing with HCl 1:1. Transitions to chalk sand and marl raw soils can be separated as moderately calcareous s. a. raw soils.

2. *Dystrophic Lake iron Protopedon*
Dystrophic lake iron raw sol

Synonyms: Erzseeboden.

General Specification: S. a. raw soil formation on extremely limonite rich sediments, resulting by flocculation from acid, iron rich waters deficient in electrolytes.

Characteristics:

Profile: Colonized by organisms but no development of humus horizon. The (A) horizon consists mostly of a poor Äfja. The underlying Fe horizon (iron enriched layer) is due entirely to sedimentation and consists predominately of rust brown to rust yellow flocks and concretions of ferric hydroxide, partly also of manganese hydroxide.

Humus Form: S. a. raw soil humus with tendency to dygyttja formation.

Occurrence: Frequent in northern Europe and known particularly from its occurrence in Fennoskandia, namely areas of acid igneous rocks and crystalline schists with predominance of terrestrial soils with raw humus or acid coarse moder formation. From these come the acid substances, to which is due the strong weathering and the strong solution (peptization) of the ferric hydroxides.

3. *Lake marl Protopedon*
Lake marl raw soil

Synonyms: Weisserde, Seeziger (Swiss), subhydrous chalk raw soil, white marl (American), maremud (Dutch); on land utilization: meadow marl, meadow chalk.

General Specification: Lake soil rich in chalk and clay, superficially colonized by plants and animals without macroscopically distinguishable humus horizon. Its chalk is mostly organic in origin. For its differentiation from lake chalk raw soil and alm-raw soil, see page 88.

Characteristics:

Profile: Generally thin (A) horizon which consists of an algal cover (Afja) or root layer of higher plants, above a whitish coloured C horizon.

Humus Form: S. a. raw soil humus with transition to gyttja.

Chalk Content: 20-70 % $CaCo_3$.

Texture: Presupposes a certain clay content. Soils consisting of chalk-sand, chalk-pebbles, or chalk shingles, have to be designated specifically (e. g. chalk sand raw soil).

4. *Lake chalk Protopedon*

Lake chalk raw soil

Occurrence: In all zones with sufficient content of chalk and clay, substances in the feeding waters.

Synonyms: Soblage, Sjöblecke, Wysse (Swiss), Kalkmudde (C. A. WEBER), weisse Leber (Swiss); with higher shell content: Schill (unbroken shells), Schnecklilehm (Swiss), Bruchschill (mechanically and coprogenically comminuted); if formed by chalk precipitating stoneworts = characeae chalk, crai lacustre (French).

General Specification: Extremely calcareous sediments low in clay, superficially colonized by organisms, however showing still no humus horizon formation; the chalk fraction is of organic origin (decomposed shells of mussels and other shell remains, formation by chalk precipitating plants).

In comparison to the *lake marl protopedon* low in clay and to the alm raw soil *) predominence of organogenic chalk. Phytogenic sub-aqueous chalk under the influence of higher plants is easily transformed into gyttjas as the plant litter is decomposed in the autumn.

Characteristics:

Profile: Above the whitish coloured C horizon mostly an (A) horizon in the form of a thin algal cover (Afja) or a characeae sward or of a root horizon of higher plants. Raw soil of phytogenic lake chalks have therefore a particular profile structure, which underneath the (A) horizon shows a layer containing the little decomposed remains of Characeae, Nitellea and chalk encrusted higher plants, which may be designated as (A)/C horizon.

Humus Form: S. a. raw soil humus with transition to gyttja.

Chalk Content: 70-90 % $CaCo_3$.

*) *Alm* (SENDTNER 1854) or spring chalk appears rarely as soil forming sediment in larger areas and is purely inorganogenic, precipitated by supersaturation.

Structure: Dense to powdery, permeated by shell residues and a few plant remains. With characeae chalks occasionally tubular structure.

Plant Cover: Generally algae (with characeae chalk and under water meadows of stoneworts), as well as also pondweeds, Myriophyllae, chickweeds etc.

Occurrence: Typical of smaller lakes and ponds rich in chalk of almost all zones. It reaches a great thickness in the littoral of great lakes. Northern boundary about 55° latitude, highest altitude about 1.100 m.

II. Dy

(Swedish folk name, H. v. Post 1862)

Synonyms: Braunschlamm, Tyrfopel (NAUMANN), Helopel (GAMS); in high moor regions: Torfmudde (C. A. WEBER), limnic peat (FRÜH and SCHRÖTER), liver peat (EISELEN, 1802), peat mud. The last five designations are not always exact synonyms.

General Specification: Muddy acid AC-soils, biologically extraordinarily inert, occurring at the bottom of brown waters which consist to a great extent of an amorphous precipitation of humus gels.

Characteristics:

Profile: The dark liver brown to blackish brown A horizon is not a pure sediment layer, but shows the marks of products of an autochtonous (although sparse) soil life. There is generally no Äfja. C horizons with infiltrated organic matter are designated A/C.

Structure: Amorphous, fragmentary, crumbly, fine-fibred to floccular. Occasionally the mass contains fragments of pure dopplerite (precipitates of pure humus gels) which are translucent as dark glass and show a jelly-like to glassy consistency with conchoidal fracture.

Micromorphology: As well as pure precipitates of humus substances also excrement balls of aquatic animals and thin broken-up fragments of the recognizable remains of organisms, remains of chitin predominate. Plant residues are almost completely absent.

Chemical Characteristics: Low base content, strong acidification and nutrient deficiency.

Dynamic: Strong weathering of the mineral particles, reduction and continual loss of O_2 in the region of humus precipitates. Occasionally translocation of colloidal material into the subsoil.

Biology: Poor in life to inimical to life, therefore deficient in organisms and organism remains. Plant organisms rare, among the aquatic animals molluscs and fishes are generally completely absent.

Explanation of plate III.

1. **Dy** in a pool of a podsol and highmoor zone over granite below spruce forest (Bohemian Forest).
2. **Eutrofic Gyttja** with *Nymphea alba* and an äfja of green algae (Wies, Styria).

Quality of the Water: Colour brownish to brown with low depth of visibility, rich in humus sols, poor in plankton, acid, low in chalk and eletrolytes.

After Drainage: Strong shrinkage (up to 1/10), often break down into hard fragments going into powder by frost action which is difficult to reunite on rewetting. As terrestrial soils, infertile, unsuitable for cultivation.

Occurrence: In the region of podsols and dystrophic rankers with strong raw humus formation, furthermore in highmoor areas. The humus sols originate from the leachings of these soil formations.

III. Gyttja[*]

(Swedish folkname, H. v. Post 1862)

Synonyms: Grauschlamm, Mudde: refers usually only to inactive *gyttja* but also *dy* formations transformed into peat.

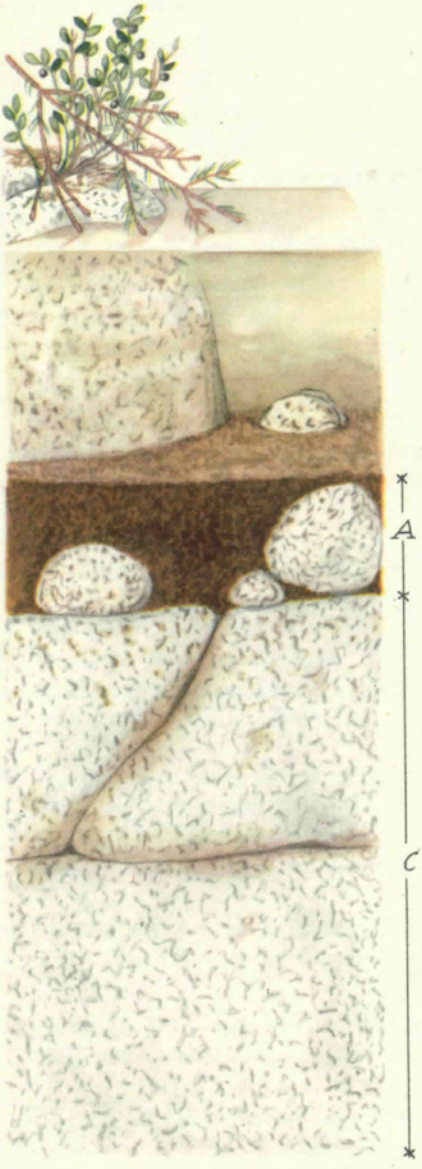
General Specification: Active, muddy, predominately coprogenic, grey, grey brown to blackish coloured AC-soils, rich in organisms occurring in waters sufficiently rich in nutrients and oxygen, containing great quantities of organic food (partly in excess).

Characteristics:

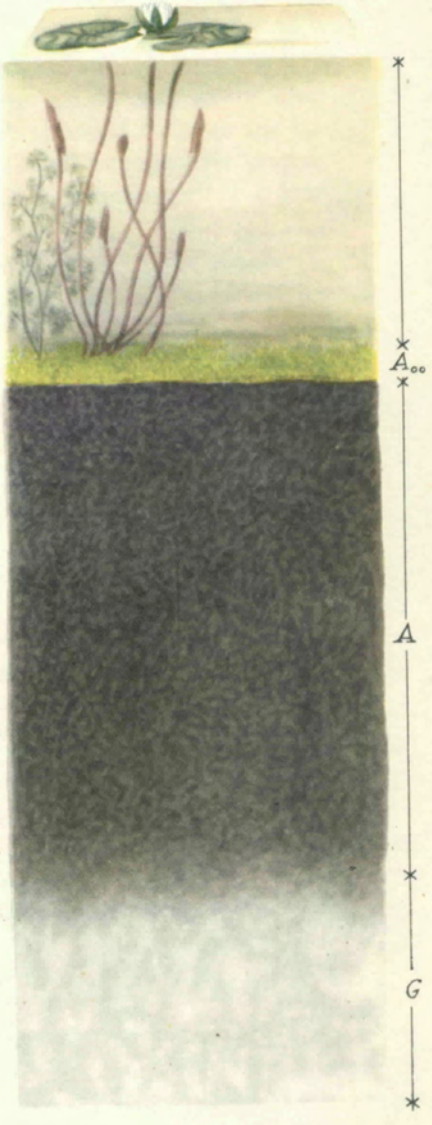
Profile: A horizon of a very variable thickness, from a few centimeters to several meters. Several to numerous A horizons frequently occur, alternating with buried C or G horizons. With very rapid alternation and clay material, micro-horizons of a few millimetres may appear (band clays). The soil surface of *limnic gyttja* generally shows prolific growth (algal layer or sward of higher plants). The algal layer with its scarcely decomposed plant remains is called Äfja, little decomposed litter layer of higher plants derived from shore vegetation is called Förna.

Biology: Generally good decomposition and proportionately good humification of the plant residues which prevail, due predominately to the activity of the soil and water fauna. Coprogenic elements prevail strongly in the product of transformation which consists of a good mixture of the organic

*) Pronounced: yuetya.



1.



2.

and inorganic substances; these are mostly well mixed but do not show the formation of clay humus complexes.

Structure: Loose, running easily through one's hand, very rich in water to semi-solid and elastic. On drying, shrinking strongly.

Colour: The colour changes with humus and mineral content. Mineral rich gyttjas are light grey. With a high humus content especially with eutrophic gyttja, the colour becomes almost black to brownish black.

Smell: Typical gyttja smell, slightly inky. In transition forms to sapropel slight smell of H_2S.

Micromorphology: Loose coprogenic particles, strongly eaten through corroded plant remains, silica shells of diatoms, chitin residues of crustaceae and rotiferi, maxillae of chironomidi larvae, rhizopod skeletons and mineral particles. The organic constituents, under the microscope, have preponderately a grey yellow, brown yellow, yellowish to greenish yellow colour.

Coprogenic Constituents: In general easily broken down, however, often the droppings of insect larvae, small crayfish, worms and molluscs are distinctly recognisable. A gyttja, rich in droppings and excrement residues is stable, less liable to erosion by water.

Occurrence: Outside the region of dystrophic terrestrial soils, in all zones in a level or slightly sloping foundation. If steep easily washed away and raw soil formation preponderate.

Key to the Identification of the Gyttja Sub-types and Varieties.

1. Occurring in inland waters ... ... 2 and 3
1*. Occurring in marine shallows 4
2. Luxuriantly developed humus layers in yellowish, nutrient rich waters with low depth of visibility.
(1) Eutrophic gyttja.
2*. Mostly poorly developed humus layers in nutrient and chalk deficient, very clear blue to grey waters.
(3) Oligotrophic gyttja.
3. Humus layer rich in chalk, effervescing strongly with HCl.
(2) Chalk gyttja.
3*. Humus layers generally brownish, raw, extremely chalk deficient and acid, already containing amorphic humus flocks in brownish waters.
(4) Dygyttja.
4. Generally bare, without äfja (algal growth layer) 5
4*. With Cyanophiceae cover.
(7) Cyanophyceae watt gyttja.
5. Formed of fine sediments in marine shallows.
(5) Schlickwatt gyttja.

5* Formed of coarse sandy sediments in marine shallows.

(6) Sandwatt gyttja.

Note: In addition gyttjas can be sub-divided according to *degree of division:* into **fine detritus gyttja** (mostly formed from algae, consisting primarily of broken down animal excreta and **coarse detritus gyttja** (many coarse tatters mainly of higher plants; brownish colours predominate); *parent material:* in **algae gyttja, diatomaceae gyttja, phanerogamae gyttja, leaf gyttja,**, etc.; *particular constituents:* in **chitin gyttja** (recession of plant material), **pollen gyttja** or **fimmenit** (particularly rich in flower pollen), **shell gyttja** (rich in mollusc remains), etc.

5. *Limnic Gyttja*

(1) Eutrophic Gyttja

General Specification: Generally luxuriantly developed *gyttja* in mature waters, rich in nutrients and plancton with prolific litoral plant production.

Characteristics:

Profile: A horizon generally of considerable thickness and in it well developed vegetation.

Variability of Form: Proportionately great. Besides fine detritus gyttja, owing to richer vegetation in shallow waters many coarse detritus gyttja. Slight tendency to form sapropel, so that there is almost always local sapropelization, especially in deep waters.

Quality of Water: Rich in plancton and nutrients, yellowish to greenish colour with low depth of visibility.

Average Depth of Water: In temperate climates not over 18 m, deeper in warm climates.

Hydroclimate: Formation favoured in temperate and warm hydroclimates.

Chemical Characteristics: Many forms contain varying quantities of iron sulphide, which appear as a powdery black pigment.

(2) Chalk Gyttja

Synonyms: Kalkmudde.

General Specification: *Gyttja* with high chalk content in calcareous waters.

In comparison with other formations the nutrient deficient *chalk gyttja* is well delimitated. The nutrient rich (*eutrophic*) *chalk gyttja* approaches

closely the foregoing *eutrophic gyttja* and generally differs little from it except for the high chalk content. However, it is important to distinguish between the two for pedological and agricultural reasons in regard to their different further development and cultivation in the drained state.

Characteristics:

Profile: Generally an easily recognisable whitish coloured C horizon. Also the chalk content of the A horizon is, in many cases, recognisable to the naked eye by its visible chalk fragments and amorphous chalk precipitates.

Dynamic: Chemical weathering, gleying and movement of material in the soil horizon is impeded by the high chalk content.

Chemical Characteristics: A and C horizons effervescing with dilute HCl.

Quality of Water: High in chalk, with oligotrophic forms, of intense blue to emerald green colour with considerable depth of visibility.

After Drainage: Easily transformed into *calcareous anmoor* and further to extraordinarily fertile chernozem-like warp soils (*Smonitsa*).

(3) Oligotrophic Gyttja

General Specification: Low in nutrients, generally with shallow horizons in acid, immature waters, low in electrolytes.

Characteristics:

Profile: A horizons generally of little thickness, usually with high mineral content.

Chemical Characteristics: Effervescing with HCl, acid reaction.

Biology: Due to plankton deficiency and low plant growth in shallow waters, low supply of plant material, therefore low humus production. Relatively strong oxidation and little reduction in the humus layer. The soil fauna is usually rich in species. Only slight tendency to fetid slime formation, almost never occurring in deep waters.

Variability of Form: Low, uniformity in profile structure and character of the humus formation.

Quality of Water: Chalk and nutrient deficient, of blue to green colour with considerable depth of visibility.

(4) Dygyttja

Synonyms: Dystrophic gyttja.

General Specification: *Gyttja* of low activity, in part containing pre-

cipitated humus gels in acid humic waters, transition formation to dy. (Dy contains predominately precipitates of displaced humus.)

Characteristics:

Profile: A horizons of brownish grey colour, generally of slight thickness, still with a distinct gyttja character.

Biology: Low in life, with low supply of plant parent material and a soil fauna, low in numbers of species. Acid humus soils and gels have a depressing effect on life.

Quality of Water: Very low in electrolytes, slightly brownish coloured due to humus soils.

Hydroclimate: Predominately cold.

6. *Marine Gyttja*

Synonyms: Marine shore gyttja (WESENBERG-LUND 1905); shallows soil, Wattboden; wad (Duch), kvelderboden: in those designations the marine sapropels (see 95) are also included.

(5) Schlickwatt Gyttja

Synonyms: Schlickwatt (WOHLENBERG 1931), Schlickwattboden.

General Specification: Soil formation of gyttja-like character on fine shallows sediment, whose organic fraction consists predominately of remains of droppings of small animals.

Characteristics:

Profile: Generally deep, blackish A horizons becoming light when exposed to air. The äfja is almost completely missing.

Structure: Characteristically tubular upper soil layer with dense, often honeycomb perforation of the surface.

Biology and Dynamic: Very rich in animals. Bare schlick shallows soils are colonized most strongly by small schlick crayfish (*Corophium volutator*), as well as by Annelida (in particular *Nereis diversicolor*). Decomposition of remains of organisms is carried out mainly by small animals. Owing to the numerous living tubes the upper soil layer is richly provided with oxygen at low water. The walls of the tubes are stabilized by oxidation of ferrous sulphides and the encrustation by ferric hydroxide.

Phenology: Characterized by a continuous alternation of draining and flooding with the ebb and flow of the water, which holds for all the following shallows soils.

(6) Sandwatt Gyttja

Synonyms: Sandwatt (WOHLENBERG 1931), Sandwattboden.

General Specification: Soil formation low in humus of gyttja-like character formed on coarse sandy shallows sediments.

Characteristics:

Profile: Generally deep in humus, very loose A horizons with äfja layer almost completely missing.

Biology: Dense colonization by animals, especially *Arenicola marina* which is absent in schlickwatt and whose heaps of worm casts are characteristic for the sandwatt. The walls of the numerous living tubes have a reddish concretion-like oxidation layer of ferric hydroxide several millimeters thick. Humus formation is primarily caused by soil fauna.

(7) Cyanophyceae Watt Gyttja

Cyanophyceae Shallows Gyttja

Synonyms: Blaualgenwatt (WOHLENBERG 1937).

General Specification: Gyttja-like schlickwatt with leathery cyanophyceae skin.

Characteristics:

Profile: Above the A horizon a dense äfja which can be removed like a skin and which is missing in other gyttja-like watts.

Biology: Not low in animals as the diatom watt, but richly colonized, particularly by *Bledius spectabilis* (Staphylinide) further by Enchytraidae (*Enchytraeus albidus*) various Carabidi (*Heterocerus flexuosus, Cillenus lateralis*), etc. The upper soil layer is well supplied with oxygen through the numerous living tubes of the *Bledius*.

IV. Sapropel

(Lauterborn 1901)

Synonyms: Fetid slime.

Key for the Determination of the Sub-types and Varieties.

1. Occurring in inland waters. 7. *Limnic sapropel.*

1*. Occurring in marine shallows 2

2. Mostly thin pasty to fluid. Formed under a dense cover of seaweed or sea-grass.

(8) Muddwatt sapropel.

2*. Not a thin pasty fluid. Formed under a dense, slimy algal skin.

(9) Diatomwatt sapropel.

7. *Limnic sapropel*

Synonyms: Limnic fetid slime.

General Specification: Stinking, strongly reduced soil in completely stagnant water with strong putrefaction due to complete loss of oxygen and copious formation of hydrogen sulphide and other foul gases.

Characteristics:

Profile: Primarily AG soils with generally deep black, seldom browned humus horizon with marked gleying in subsoil. There is no äfja.

Structure: The mass of the humus horizon is loose and flaky, sometimes dense and greasy, occasionally slimy.

Microscopic Characteristics: Usually presence of reddish flocks of sulfur bacteria, no excreta of small animals, presence of residues of a sparse characteristic sapropel fauna.

Chemical Characteristics: Always contains a significant quantity of ferrous sulphide partly in chemically very unstable forms. They form a blue-black pigment in the humus whose colour however is rapidly lost by removal and oxidation of the soil (often bleached completely). The presence of ferrous sulphide is easily shown by heating (stinging smell of SO_2 given) or by wetting a sample with dilute HCl (H_2S smell).

Biology: Primarily plant remains, partly protein rich, are decomposed up to entire destruction of the cell structure under almost complete absence of oxygen with strong action of anaerobic bacteria accompanied by strong development of hydrogen sulfide and other foul gases.

Smell: Foul smell which can become unbearable.

Quality of the Water: Yellowish, rich in nutrients, but containing putrefaction poisons. Usually formation of gas bubbles.

Hydroclimate: Formation strongly favoured in temperate to warm hydroclimate.

After Drainage: As iron sulphide is a heavy plant poison, the plant growth appears strongly impeded in former chalk deficient *sapropels*. In highly calcareous or heavily chalked soils with sufficient aeration (favoured by tillage) oxidation and complete transformation to harmless gypsum occurs.

Its abundant presence in the form of powdery precipitates and small crystals, pinacoids, lenses or grains becomes a diagnostic characteristic. The colour of the former blackish *sapropels* changes mostly into light grey by this transformation. Humus rich, calcareous *sapropels* may be transformed to *calcareous anmoor* with increasing mull formation and afterwards also to chernosem-like warp soils.

8. *Marine Sapropel*

(8) Muddwatt Sapropel

Synonyms: Mudd-Watt (Holstein folk name, WOHLENBERG 1937).

General Specification: Marine, very thin, partly almost fluid *sapropel* formation of great depth and strong evolution of gas with primarily luxuriantly developed seaweed and sea-grass as parent material.

Characteristics:

Profile: AG profile with mostly very deep humus horizons of blackish colour, which may be approached by boat at high water. Depth of humus horizons up to 130 cm. and more.

Structure: The humus has a high water content, being almost fluid even at low water. Animal droppings are rare, putrefaction products common.

Vegetation: Primarily dense seaweed meadows of *Fucus Mytili*, usually united with the sea mussel *Mytilus edulis* and sea grass vegetation of *Zostera angustifolia* and *Zostera stenophylla.*

Phenology: Never completely free of water. Even at low water, it is under a certain depth of water.

Biology and Dynamic: Strong putrefaction, greatly exceeding the formation of humus by animals, almost continuous evolution of gas bubbles if strong formation of H_2S. Strong reduction, precipitation of bluish black iron sulphide and of elementary sulphur in whitish yellow haze.

(9) Diatomwatt Sapropel

Diatom Shallows Sapropel

Synonyms: Diatomeen-Watt (WOHLENBERG 1931).

General Specification: Marine fetid mud formation produced by a complete closing up and covering of former *gyttja* formations by dense diatom skins.

Characteristics:

Profile: Above the blackish A horizon a strongly developed, usually olive brown coloured, extraordinarily slimy and smooth äfja layer *) composed principally of silicate algae. Generally there is a band structure of several diatom layers.

Biology and Dynamic: The algal skins are formed in particular by diatoms of the species *Pleurosigma, Pinnularia* and *Navicula,* living in the slimy mass which they secrete. If the skin is covered by a fresh layer of flood water sediment the algae for the most part, work their way to the surface. Owing to the soil being completely sealed by the slimy äfja, it is very deficient in fauna, and there is strong development of putrefying bacteria. The schlick crayfish disappears almost completely with increasing diaton growth. Due to the high production of H_2S, the iron in the soil solution is precipitated and concentrated as blackish blue amorphous iron sulphide of ferrous sulphide hydrate (hydrotroilite). Strongly reducing.

Occurrence: Greatest concentration on the North Sea coast 5-20 cm. under the average high water line.

Phenology: The strongest development of siliceous algae occurs in late summer to autumn.

AB. Peat-forming Sub-aqueous Soils

V. Fen **)

(Engl. folk name, Sir D. Hall 1903 Whittles 1928)

Synonyms: Sub-aqueous moor, infraaquatic moor, limnic moor, low moor, valley moor, basin moor, hard water moor, veen (Dutch) Fehn (North German) eutrophic moor (Germany): can only have real value in soil science if applied to nutrient rich low moor, while the nutrient deficient low moor to be consistent should be called oligotrophic, and further, the wood peat moor (page 117) and the high moor (page 118) dystrophic; meadow moor: refers only to the series of sub-types with the designation turf peat moor.

General Specification and Delimitation: Biologically inert soils below water with mineral deficient to mineral free humus forms, in which, due

*) This is so slippery that one can slide on it like a skater with bare feet.

**) The name corresponds to the Dutch veen and German Fehn. In England the term has been applied in recent years to calcareous soils high in organic matter and plant nutrients formed under stagnant water. According to the nomenclature of this book, soils which do not show real peat formation, but gyttja, anmoor or other non-peaty humus forms are excluded from peat soils. Therefore many soils with good humification formerly designated as *fens* belong to the *anmoor* type.

to the almost complete lack of oxygen, the generally acid reaction, the excessive production of organic matter and the unfavourable conditions for rapid humification, there is a strong accumulation of little decomposed plant remains.

The objects of study in soil science are primarily the recent «living» moor soils and the humus soils resulting from transformed former moor peats. The buried «dead» peat layers and former moor soils, whose humus formation owing to biological inertness of the environment are well preserved, are either parent material for new soil formations or mere substrata. It is however just as important to have knowledge of them as of any other parent material or substratum.

The most important recent soil formations derived from old moor peat are specially described in the division of semi-terrestrial soils in the appendix on hig moor soils (page 122). The characteristics of the old buried peats will be attached to the corresponding «living» form.

9. Turf Fen

Turf Peat Moor

(10) Phragmites Fen

Reed Peat Moor

Synonyms: Phragmites peat, rush-peat moor, darg = reed peat mostly rich in iron sulphide in the North Sea coast, originating in brackish water, permeated strongly by sand and silt.

Occurs frequently also as a buried peat layer under marsh soils (page 114). Other buried peat layers on coastlines have wrongly been described as darg.

General Specification: Soil formed under fresh or brackish water with peat humus composed mainly of the roots, steams and leaves of the reed cane.

Characteristics:

Profile: The reed peat cover is generally formed over a gyttja layer (page 90) and at first will not stand walking upon, but immediately gives way; it thus floats, so to speak, on the mud. When it is firm enough to bear one it forms the so-called *swing moor* which when trodden distinctly shakes. In the *stable moor* phase the heavier and thicker peat cover has compressed the mud layer up to the greatest possible extent. With buried reed peat or with that which has become land, lense-like water cushions may occur between it and the gyttja layer, and on penetration their contents are often explosively thrown out. The sub-soil is generally an impermeable gley layer, rich in colloidal material, or the gyttja horizon can lie directly on the dense rock (granite, basalt, clay schist). Under the moor, the chemical weathering and clay formation is sharply increased. With a permeable subsoil the stagnant water of the moor combines with the deeper dammed-up ground-water.

Characteristics of Peat Layer: Young reed peat consists of a light, felted, bulky, almost undecomposed mass of the plant remains given above and is easy to recognise by its broad leaves and the wide bands of flattened horizontal roots (rhizomes), further by hairless nodes occurring regularly 5-20 cm. apart. Root stalks and stems are only slightly compressed. Peat samples shrink little on drying and only reabsorb water slowly. The mineral content can occasionally be considerable.

Plant Cover: «Living» reed peat moor is always covered by a dense reed turf (*Phragmites communis*). In it are found numerous other swamp plants, like *Equisetum palustre* and *limosum, Scirpus lacustris, Sparganium ramosum,* etc.

Depth of Water: Its formation begins already at a depth of about 2.50 m., whereby it precedes all pure peat formations which require essentially shallower water.

Thickness: With mature formations, considerable (up to 3 m. and more).

Characteristics of Old Reed Peats: Older reed peat, buried under other moor covers, consists when strongly decomposed of a stramineous mass, but on being exposed to the air rapidly turns black and feels slippery. Morphologically it is composed of still recognisable rhizomes (with striking nodule formation) and remains of broad leaves which are imbedded in a fairly homogeneous, muddy ground mass. The decomposition is gyttja-like (*peat gyttja* No. [1], whereby the characteristics of this old peat approach those of *gyttja*. In this connection appears also the strong shrinkage of peat samples on drying, up to about a quarter of their original volume.

Decomposability: Even the young fibrous reed peats are decomposed easily after draining.

Appearance after Drainage: Reed peat moor is changed fairly quickly into a fertile, loose, blackish cultivated soil. For possible transformation forms see page 122.

Occurrence: Very widespread in Central and Northern Europe, rare in Southern Europe, absent in the sub-arctic.

(11) Carex Fen
Sedge Peat Moor

Synonyms: Carex peat, seggenmoor.

General Specification: Soils formed under stagnant freshwater, with peat humus form, composed primarily of the stalks, leaves, rhizomes and roots of sedges.

Characteristics:

Profile: Peat layer of proportionately slight thickness, which has ge-

nerally been found on a thick reed peat layer. These are followed generally by more or less highly compressed gyttja layers lying on strongly gleyed mineral horizons.

Characteristics of the Peat Layer: Young sedge peat consists of a light yellowish coloured root felt containing, besides stalk and leaf remains, numerous fruits of carex species, and usually the characteristically lens-shaped seeds of marsh trefoil (*Menyanthes trifoliata*).

Depth of Water: Sedge grasses develop only in shallow water and therefore the sedge peat is formed mainly in the margin of the waters made shallow by the growing reed peat. If the pat formation by tall sedges has reached the average height of the water surface, small sedges appear. With their dense root mat the soil is further consolidated.

Biology: Biological relations are considerable improved in the shallow water by the greater air content and nutrient supply, whereby life can develop more intensely.

Decomposability: Generally very easy.

Characteristics of Old Sedge Peats: In freshly cut condition dirty yellow-grey mass which rapidly darkens in the air, containing stalk and root remains of sedges in dark ground mass. With stronger (*gyttja*-like) decomposition (see page) becomes almost black by accumulation of muddy coprogenic elements. Also in strongly decomposed peats, the smooth dark coloured, lens-shaped seeds of marsh trefoil are often a striking constituent.

Appearance after Drainage: Generally almost deep lack coloured, earthy, fertile cultivated soil. With regard to possible transformation forms see page .

Occurrence: Very widely distributed in Central and Northern Europe. Very frequently the highest layer of cultivated low moors in a transformed condition.

(12) Hypnum Fen
Hypnum Peat Moor

Synonyms: Knotted moss peat moor, brown moss peat moor.

General Specification: Soil formed on old low moors under stagnant water with peat humus composed mainly of the remains of various brown mosses.

Characteristics:

Profile: The brown moss peat forms generally only thin layers or sometimes only isolated nests in the sedge and reed peat (see page 100).

Plant Cover: Brown moss meadows (low moor hypneta) i. e. sedge turf with prolific development of *Hypnum* species.

Characteristics of the Peat Layer: Decidedly loose, easily crumbled yellow to red brown peat mass which never becomes as light coloured as the otherwise similar white peat (see page 118). The mosses which besides a few sedge remains form the main mass are well preserved and easy to recognise and by their prolific branching and other form characteristics sharply distinguished from the *Sphagnum.*

Decomposability: Considerably lower than the reed and sedge peats and therefore always easily recognized in old low moor profiles.

Characteristics of Old Hypnum Peat: Loose, very friable peat masses of blackish colour with brown moss remains always recognisable. Peat samples show a low shrinkage and have a far lower absorbing and retaining capacity for water than the Sphagnum peats.

Occurrence: On old low moors in the Alps, in Scandinavia, partly also frequently in Northern Germany, however generally in proportionately smaller formations. They are more important as buried layers in old peat profiles overlain by high moor covers.

10. Wood Fen

Synonyms: Alder swamp, swamp wood peat, low moor wood peat, Auwaldtorfmoor = variation in river valley characterized by the appearance of other woods, specially the pedunculate oak, Rüllenwaldtorf = variation which forms along the run-off channels (Rüllen) of high moor (type XII).

General Specification: Low moor soil formed in stagnant or frequently slowly flowing hard water under alder swamp woods, with peat, rich in leaf cone and wood remains.

Characteristics:

Profile: The swamp wood peat is formed either on old *turf fens* or it can be produced directly on *gyttja* becoming land, or also completely independently on gley horizons. In all cases this peat humus is formed below the water surface i. e. as a low moor formation.

Characteristics of the Peat Layer: When moist, soft and heavy peat of high mud content, when dry, becoming friable, breaking into fragments, shrinking strongly; it is characterized most distincly by its alder cones and brownish red woody remains.

Plant Cover: Principally alder woods (in particular *Alnus glutinosa*) interspersed with willows, with swamp plants, luxuriantly growing, shade and water-loving herbs and ferns below them. Gradually new species of trees appear, spruces, peduncular oaks, shaking aspens, etc. (stable low moor wood).

Thickness of Peat Layer: Low, as the rapidly growing soil soon allows colonization by other species of trees.

Biology: Higher oxygen content, better supply of nutrients (generally slow running water), more rapid warming up of the shallow water permits a better development of life than in other low moor peats. The decomposition of plant remains is gyttja-like and is done exclusively by water organisms.

Decomposability: Very easy.

Quality after Drainage: Well decomposed and humified, generally deep black coloured, earthy, particularly valuable cultivated soils.

Occurrence: Widely distributed in Central and Northern Europe, especially in Northern Germany, where amongst others it appears most frequently as a top layer of cultivated low moors.

Appendix to Peat- forming Underwater Soils

Sub-aqueous Transformation Forms of Peat

[1]. *Peat Gyttja* *)

General Specification and Delimitation: *Gyttja*-like transformation of peat layers of a most diverse kind underwater or with excessive waterlogging, without real addition of parent material for humus formation of fresh higher plants.

For differences from other transformation forms of peat see descriptions page 122.

Characteristics:

Profile: The transformation is generally fully shown within existing moor profiles, in which individual layers become more or less strongly decomposed according to their innate decomposability or biological conditions. This is shown especially strongly by the transformation of thin peat layers buried under mud or gyttja (e. g. darg covered by schlick on the North Sea coast).

Characteristics of the Peat Layer: Decrease of recognisable plant remains, together with growth of a muddy, strongly humified groundmass which consists predominately of the broken-down excreta of aquatic animals.

*) Forms in mature state according to their character are subvarieties of the *limnic gyttja*.

The entire peat mass becomes a darker colour (mostly blackish), feels slippery and shrinks more on drying. Occasionally the formation of methane and hydrogen sulphide is observed together with the precipitation of iron sulphide (generally as a black pigment), primary sulphur, vivianite (blue iron ore, $Fe_3(PO_4)_2$, white precipitates becoming an intense blue en exposure to air), white iron ore (colloidal ferrous carbonate, white cheesy masses rapidly becoming brown on exposure to air), etc.

Biology: The decomposition and humification is produced predominately by the activity of aquatic and mud fauna, bacteria in particular are important, primarily for fetid, mud-like varieties.