Summary of contents.

At the FRESHWATER BIOLOGICAL LABORATORY ON FURESØ investigations have been carried on during the last two years as to the different deposits occurring in the beds of the Danish lakes. Among these 14 of the largest and deepest, varying in size from 5 to 34 □ kilom. and in depth from 8 to 40 m. were selected, to the exclusion of such lakes, where a connection with the sea could be proved to have existed up to a recent date. Furesø, size 9 □ kilom., depth 33 m. was particularly explored.

This paper will give the results of the investigations of the lime deposits, pea-ore (»Bohnerz«) and the bottom mud of the lakes, the latter taken in the limitation given by v. POST and by him termed lake-gytje.

Kap. 1. The lime producing organisms and the calcareous deposits of the lake bottom.

It may be assumed, that the water brought by streams and springs into larger lakes is always subjected to a decalcination mainly arising from three causes: A mechanical dropping down of calcareous particles suspended in the water; a chemical precipitation of lime held in solution by carbonic acid; the agency of organisms, which fix the lime in their tissues and deposit it in the shape of calcareous coatings and skeletons.

Owing to this decalcination the calcareous deposits of the lakes arise. Physical and chemical explorations of our freshwaters being as yet wanting, we shall here principally restrict ourselves to an investigation of lime-deposits, whose origin may be traced to the agency of organisms, hoping that physical-chemical explorations will before long elucidate the former two. In classifying the different kinds of lime-deposits found in freshwater, I have used the following terms: lake-lime, calcareous tufa formed in springs, and moor-lime »Wiesenmergel«. Of these we shall only consider lake-lime in this paper.

One of the main results of the investigations has been to point out the fact, that the lime-producing organisms of our lakes with very few exceptions do not go out beyond the 11 m. curve. The lime-deposits in- and outside this curve in all probability differ somewhat as to their origin. Whilst the deposits inside the curve must be supposed to have arisen mainly from the pulverization of local lime-producing organisms, the lime-deposits outside the curve have either been formed by the dropping down of lime particles held in suspension in the water or by precipitation of lime held in solution by carbonic acid; lime-deposits derived from pulverised lime-skeletons secreted by organisms living in the deeper parts of the lake will here undoubtly only be of minimal importance.

In accordance with these facts I have further classified the lake-lime as follows.

The lime-deposits outside the 11 m. curve, when comparatively pure and unmixed I have termed »lake-blege« (Søblege) and when strongly mixed with clay and organic matter »lime-gytje«. The lime-deposits inside the 11 m. curve, when comparatively pure and unmixed I have termed Characee-lime or Mollusk-lime and when impure lake-marl.

The freshwater lime-deposits may in our lakes accordingly be classified as follows: .

I. Lake-lime.

Lime-deposits outside 11 m. curve.	impure (20—80 $^0/_0$ $CaCo_3$).	*Lake-gytje.*
	pure (more than 80 $^0/_0$ $CaCo_3$).	*Lake-blege.*
Lime-deposits inside 11 m. curve.	impure (20—80 $^0/_0$ $CaCo_3$).	*Lake-marl.*
	pure (more than 80 $^0/_0$ $CaCo_3$)	*Characee-lime.* *Mollusk-lime*

II. Calcareous tufa formed in springs (Kildekalk).

III. Moor-lime (Mosekalk »Wiesenmergel«).

The lime incrustations of aquatic plants.

It is a wellknown fact, that many freshwater plants precipitate calcium carbonate on their leaves and stems; among these *Chara* is the most predominent, the lime not only coating the plant, but being probably deposited in the cellular tissues also. P. 12 the different plants have been mentioned on which incrustations have been found as well as those, where I have looked for them in vain. As to the origin of the incrustations see: PRINGSHEIM, HASSACK and KOHL, who have set forth their separate opinions on this point.

The precipitation of lime effected more especially by *Chara* plays an essential part in the formation of lake-lime. In spring the incrustations are only slight, but in the course of summer they increase in thickness and in autumn the lime drops off in great quantities from the floating islets of *Myriophyllum* and *Ceratophyllum*; on *Potomageton lucens* the coatings last til late in the year and may still be found on *Elodea* in shallow water after the frost has set in. The incrustations on the plants of a given lake are at no time of the year equally heavy; even plants of the same species are not incrusted to the same degree in the different parts of the lake. On *Elodea* and *Fontinalis* at the depth of 8—10 m. (Furesø) no traces of lime-coatings occur throughout the seasons of the year. In shallow water the limecrusts of the latter increase in thickness, according as the plants rise to the level of the lake, so that the leaves near the surface are most heavily covered. When the plant dies, the crusts fall off. No lime incrustations occur on plants that grow in swiftly running water. The degree of incrustation greatly depends on the shape of the organ of assimilation. The precipitated lime does not accumulate to the same extent on vertical and cylindric organs as on horizontal planes; it is most conspicuous on the upper side of the leaves, but if the under side, owing to outward influences (webs of insects) is turned up, this side will become incrusted; on the floating leaves of *Nymphæaceæ*, *Hydrocharis* etc. no crusts appear, probably owing to mechanical conditions; they occur on the submerged leaves of *Nymphæa*.

The lime incrustations (with the exception of the Characees) are not as reported by HASSACK solid, adhesive crusts, which when once formed will continue to cover the stems and leaves; drifting plants of *Elodea* and *P. lucens* present no lime coatings, though the corresponding plants growing c. 70 m. off the beach are heavily overlaid; the stroke of an oar amidst the thick growths of *P. lucens* will make the lime drop off abundantly. Where cornetlike depressions occur in leaves or between leaf and stem, the cornet is seen filled to the rim with lime powder dropping down from the plant into these receptacles. In August the large tops of *P. lucens* and *perfoliata* in Furesø are covered with the delicate web of a Phryganee larva; the lime-particles, as they fall are caught in the net, and the tops of the plant not being able to carry the heavy weight, the stems will bend downward in great curves. Owing to some mechanical action or other, parts of the crusts break off, but are soon replaced by new flakes of a thinner structure than those on the other parts of the leaf, and in this manner a terraced series of layers will form. The thicker flakes may be detached and will show traces of nerves, possibly even of the epidermis-cells of the leaves on their smooth underside. The outerside of the crust is rough with numerous small pointed faucets consisting of lime-particles. — Owing to the above observations I have been led to interpret the process of incrustation somewhat differently to other investigators:

In clear, calm weather the lime accumulates in thick flakes on leaves and stems, but is swept off in stormy weather by the wave action. The precipitation probably goes on unceasingly during the assimilation; the leaves not being able to carry the full weight of the lime continually drop broken particles, which will sink to the bottom at a shorter or greater distance from the plant. The thickness of the limecrusts is depending on the conditions of light; they will be thickest on those plants or parts of plants, that are exposed to the strongest light. In order to show as far at it was practicable, that the precipitation of lime owing to the *Potomogeton* and *Elodea* play a prominent part in the formation of lake-lime, two bottom samples were taken in Furesø, one from a bed of *P. lucens* and *Elodea*, the other from a depht of 33 m., the former containing 72.41 %, the latter 35.30 % of lime, viz. less than one half; yet it must be remembered, that the mollusks of the vegetation-zone will raise the lime amount of the first sample. On separately weighing the dried leaves of *P. lucens* and their coatings it appeared, that a leaf often carried more lime than its own weight; one leaf weighing 0.35 gram carried no less than 4.1 gram of lime; as one plant has often some 30 leaves, their joint amount of lime would be considerable. The deposits underlying the *Characeæ* growths are mainly owing to dead plants and broken remnants, which sink to the bottom and settle there.

Crustforming, stonecovering blue-green algæ.

The stones along the shores of our lakes are often more or less covered with crusts, which in most cases are the work of lime-incrusted algæ of the genus *Schizotrix* and *Rivularia*. The thin, white coatings seen in spring are however often due to the *Diatoms*, others to certain species of green algæ (*Cladophora)*. The crusts are often overlaid by other algæ colonies, *Rivularia rufescens*, *Pleurocladia lacustris* etc. We shall here only consider the incrustations of the blue-green algæ.

The crusts chiefly occur on the stones of shallow water, rarely at the depth of 1 m. below the surface and often 2 m. above the ordinary summer waterline. With us they do not cover the stones to the same extent as on the shores of the Bodensee and Genfersee and play a less predominent part in our lakes. Concerning the hygroscopic property of the calcareous crusts, their chemical compound and the relations they bear to the algæ, see KIRCHNER; here we shall only consider their co-operation in the formation of lake-lime.

As to the question, from what source the calcium carbonate of the algæ-crusts is derived, the algæ have two ways of acquiring the lime: one, as the above mentioned plants by precipitating it from the water, the other, by abstracting it from the substratum on which they grow. Yet observations from nature prove, that the crusts prevail to the same extent, whether the algæ happen to grow on flint, granite or lime; it must then be concluded, that the algæ principally precipitate the lime from the water, and that the substratum at any rate is of secondary importance. On the other hand an examination of the stones prove them to be subjected to a mouldering process of decay. The different authors all agree as to the corroding influence of water upon the surface of stones, but as to the agency of algæ in this respect, two differing opinions obtain. According to FOREL and KIRCHNER the corrosion of the stones is owing to the fauna living in the algæ-crusts; according to these authors the algæ themselves far from exercising any destructive influence rather serve to protect the stones, whereas CHODAT asserts, that the algæ are the main cause of destruction, the agency of the animals being to his opinion of minor importance. Evidently the algæ crusts are exposed to attacks from without, and to such the meandric ridges and holes on their surface must be ascribed; in our comparatively small lakes, where of course the surf action must be less vigorous, than as recorded by KIRCHNER on the shores of Bodensee, the perforated surface of the algæ crusts is mainly due to the work of animals, principally Amphipodes, snails (*Neritina, Limnæa auricularia*) a few herbivorous Phryganees (*Goëra, Molanna*), *Ostracoda* and *Copepoda*. — *Rhyacophila*, *Ephemeridæ*, *Perlidæ* and the larvæ of gnats, to whom the holes are generally ascribed, are all carnivorous animals, that do not subsist on the algæ; they possibly repair their hidingplaces, but can scarcely be supposed to live a burrowing life in the crusts, their mandibles and the structure of their legs are certainly not suggestive of it.

The question then is, whether the above fauna is also conducive to the corrosion of the very stones on which the algæ grow. FOREL and KIRCHNER, who maintain this, are of opinion, that the animals by gnawing the algæ crusts give the water admittance to the surface of the stone, that they afterwards burrow in the corroded parts, and further increase the dissolving properties of the water by saturating it with carbonic accid arising from their respiration; though much may be said in favour of this theory, the two authors in my opinion take a rather onesided view of the case in stating, that the algæ even exercise a protecting influence with regard to the stones. CHODAT distinctly points out, and my own observations in a great measure corroborate his statement, that the algæ are often active agents in the corrosion of the stones; on this point I agree with CHODAT, the more so, as I have observed, that the stones on the shores of lakes, where incrustations occur, are more corroded, than where they are wanting, and in my opinion particularly so on those parts of the shore, where the crusts are most predominent. Moreover it seems improbable that vegetable coatings, otherwise exercising a disintegrating and pulverizing influence upon stones should in this case constitute a protecting covering. However I think that CHODAT has somewhat underrated the signification of the fauna.

The mouldering process depends chiefly on the petrografic qualities of the stone; to the present day only the algæ-coatings on l i m e s t o n e s have been studied. In Denmark it seems that the corrosion of f l i n t takes a slower course, but as to the final result no less destructive. Even on black flint a whitish crust is seen under the algæ, but whether this is owing to the corroding agency of the algæ or is only the white crust common upon flint must as yet remain undecided; yet it is a fact that the lime incrusted flints along the shores of Furesø are being subjected to a corrosion of an intensive description. If it be remembered, that all flint, even black flint, contains calcium carbonate in the shape of calcareous spar, it seems by no means incredible, that the algæ derive some practical gain from the substratum, even if this be flint — as also, that when particles of the calcium spar have been dissolved by the agency of the algæ, the substratum may be said to undergo a corrosive process due to the algæ.

My opinion as to the correlations of the lime-incrusted algæ and the stone surfaces is then as follows:

O n p a r t o f t h e a l g æ a s w e l l a s o f t h e a n i m a l o r g a n i s m s a j o i n t a s s a u l t i s m a d e o n t h e s u r f a c e o f t h e s t o n e s, w h i c h b y t h i s m e a n s a r e p e r f o r a t e d a n d c o r r o d e d; w h e t h e r t h e p l a n t s o r t h e a n i m a l s a r e t h e m o s t a c t i v e a g e n t s c a n s c a r c e l y b e d e t e r m i n e d; a t o n e p e r i o d t h e f o r m e r p r o b a b l y h a v e t h e u p p e r h a n d, a t a n o t h e r t h e l a t t e r; t h e p e t r o g r a p h i c q u a l i t y o f t h e s t o n e i s h e r e u n d o u b t e d l y o f s o m e m o m e n t. T h e f i r s t a t t a c k i s u n q u e s t i o n a b l y d u e t o t h e a l g æ; s u b s e q u e n t l y t h e a n i m a l s b y o p e n i n g a w a y f o r t h e w a t e r t o t h e s u r f a c e o f t h e s t o n e, a n d b y e x c a v a t i n g t h e c o r r o d e d p a r t s, h a v e a g r e a t s h a r e i n t h e f u r t h e r p r o c e s s o f d e c a y.

Lake-lime deposits owing to the agency of lime-incrusted algæ arise partly from the bursting and pulverization of the sun-dried coatings, and partly from the grating of the ice, which scours the crusts off the stones. Lime-deposits of this description do not occur in our relatively small lakes. KIRCHNER records them as occurring on the shores of the Bodensee.

With regard to the stone-covering algæ I have been able to demonstrate, that the incrustations are most copious on the shores of those lakes, where the lime percentage of the bottom soil is high, and wanting where it is low or 0.

Lime-producing animal organisms.

In freshwater the only animal organisms of special importance as lime producing factors are the mollusks. The snails prevailing in our larger lakes belong mainly to the genera: *Unio, Anodonta, Pisidium, Bithynia, Valvata, Neritina;* and of *Limnæa* only: *L. auricularia, ampla, ovata,* — more rarely *L. stagnalis* and some small species of *Planorbis.* Only these forms play an essential part in the formation of lake-lime.

The lime secreted in the shells of mussels does not proceed from exactly the same source as that secreted in the shells of snails, the mussels being able directly to fix in their tissues the lime held in solution or suspension in the water, whereas snails can only utilize the lime already deposited in other organisms. A well known characteristic of snails is their predilection for lime; the immense number of freshwater snails occurring upon Charagrowths and on lime-incrusted higher plants may be instanced in this connection. Though covered with the excrements of snails, the colour of which is about the same as that of the lime crusts, the leaves of the plants are but slightly injured; the snails only seem to relish the lime and deposit it as a protecting skeleton surrounded by organic matter. Though the structure of the mollusk-shells varies greatly, one feature is common to all, viz. that the lime is secreted between membranes of an organic substance, generally termed conchyolin and in close affinity to chitine. As an additional coating the shell is often furnished with a thick cuticle *(Periostracum)* which is particularly the case with freshwater mollusks.

The fundamental difference existing between the above mentioned respectively by plants and by mollusks precipitated lime will be, that the lime produced by plants (partly with the exception of the Characees) not surrounded by organic membranes will quickly be dissolved in the water, whereas lime produced by animal organisms being surrounded by organic matter is only dissolved by slow degrees and after a long space of time.

By what process then is the dissolution and pulverization of the shells brought about, and how do we account for the formation of lake-lime originating from the deposits of shell débris in the bed of the lake?

On examining the empty old shells of mussels it will appear, that they are all more or less in a state of decay; the cuticula is often wanting, and the prismatic layer, which as a granular powder partly covers the exposed parts of the shells, is often more or less falling away (tab. I fig. 9); the further corrosion of the shell takes place intermittantly, the conchyolin lamels preventing the uninterupted course of the process. On the sides of the grooves often found in decaying shells a terraced succession of lime and conchyolin layers may be observed.

On taking such old shells of mussels or snails f. ex. *Valvata piscinalis* and submerging them in Pérényis liquid, the lime will be dissolved in the course of a few minutes and the whole shell literally have disappeared. The shells of living individuals take several hours in dissolving, and in the acid the remaining organic parts will indicate the outline of the shell. The difference between the subfossil and the recent shell consequently is, that in the former the conchyolin and the cuticula are wanting. A considerable number of old shells in the deeper parts of the lake bottom are generally found in a peculiar plastic and pliable state; in such old specimens neither cuticula nor conchyolin layers are observable; this condition probably sets in, when the organic substance has wholly disappeared. The next stage will be the total dissolution and smouldering away of the shell, conclusively resulting in the formation of Mollusk-lime. Probably the course of the process may vary slightly in the different species, our difficient knowledge regarding the structure of mollusk-shells more particularly fresh-water mollusks, prevents our pursueing this subject.

By Conchyologists it is an often observed phenomenon, that the cuticula in still living animals has given way, and that the further corrosion of the shell consequently is in progress. It will be easly understood, that the formation of Mollusk-lime will be greatly accelerated, when the shells already at the death of the animals are in a more ore less fragile condition, being thus more exposed to the corrosive powers of the water as well as to mechanical influences involving the smouldering away of the shell. Hitherto the corrosion of shells of live animals has been studied merely as a conchyological curiosum without any appreciation of the circumstance, that the corroding factors are Natures principal instruments in the pulverization and dissolution of lime precipitated by animal organisms. I have tried to throw light upon the agency of these factors and to point out their signification. As to literature I must refer to page 41—44 and shall here confine myself to my own observations.

In studying the corrosion of shells it becomes evident, that two wholly different agencies must be considered, one causing the rupture of the cuticle, and the other the dissolution of the lime. The former comprises pebbles and gravel, attacks of other snails and algæ, the latter principally the acidity of the water and the acids proceeding from the roots of the plants.

As has often been recorded, snails living in water poor in lime steal it from each other by eating the houses of their neighbours. Large tufts of algæ will cause a depression in the place of growth, but no corrosion will take place, as long as the cuticle remains unimpaired. When it is broken off or severely damaged, the further dissolution of the lime will in most cases be owing to the greater or lesser acidity of the water; many a shell bears witness to the struggle carried on by the animal in preventing the lime from being dissolved as fast as it has been secured. The mussels, on which it will be most easy to follow the process, repair the damage by adding one conchyolin lamel on top of the other over the bare parts of the shell and contrive to secrete lime between them. Mussels are often found in lakes and ponds, where the animals are no longer able to procure the necessary lime for their houses, and where thick chonchyolin lamels form the only means of defence against the surrounding element. On such shells various attempts at repair may be observed. (Tab. I Fig. 7.)

A special kind of corrosion is brought about by certain »lime-boring« algæ. These have already been found in mussels by CHODAT and are also common in this country in shells from 8—10 m. The corrosion seen on *Planorbis corneus* (tab. I fig. 1—6) is probably due to algæ. The shells are covered with a green coating of algæ, from which processes penetrate into the shell. Through the orifices thus produced, the algæ spread radially and circular grooves are formed in the shell substance; while the snail is alive the bottom of the groove remains intact, but when the animal dies it is dissolved, and the shell will be reduced to a network and smoulder away.

The corrosion is most intensive in bogs and ponds and particularly conspicous in early spring and in autumn. In winter, when the humic acids owing to the frost are precipitated in white floccular particles covering the bottom, the additional acidity of the lower layers of the water will probably promote the process of corrosion. The older parts of the shells are most liable to decay. Where the bottom consists of mud, the corroding factors are more predominating, than when it consists of sand. After the death of the animals the further decomposition is essentially promoted by the same factors.

Consequently the corrosion on shells of live animals will in the first place cause the empty shells to be more exposed to the dissolving influence of the water, by whose agency the lime secreted in the shell will be set free and given back to the water, and secondly the already damaged shell will be more apt to smoulder away and be reduced to powder by which the calcareous deposits of the lake bottom will be increased. Outer circumstances (surf, acidity of the water, bottomsoil etc.) cause the destruction of the shells in one of the above mentioned ways. In shell-deposits occurring in deep water the process of decay is very slow; the organic membranes etc. disappear, and the shells will gradually by converted into a pliable substance from which the special sort of lake lime Mollusk-lime arises; in shallow water the shells will be much sooner dissolved and pulverized (see the section treating upon Mollusk-lime).

The lime-deposits.

From the above it will appear, that in our more extensive lakes four special groups of lime-producing organisms may be distinguished: The higher plants, the Characeæ, the blue-green stonecovering algæ and the mollusks; by the agency of these factors lime is secreted and deposited either as an outer coating or between membranes of organic matter within the body of the organisms. The various methods of decomposition having been mentioned, we shall now discuss the different lime-deposits.

The lime producing organisms of our lakes do not range beyond 11 m., and the lime produced in the lakes is formed within this curve. A great quantity of lime will in a pulverized or dissolved state be carried out beyond this curve and be intermixed with the sediments of the deeper parts of the lake or be carried out of the same. Lime-deposits of this origin will be described in the chap. on »lake-gytje«. The lime deposited inside the 11 m. curve becomes intermixed with substances of various kinds: sand, clay, organic matter; so that deposits consisting of different components are formed. Among these peat deposits, lake-marls and shore-gytje, which will be mentioned in the following are the most predominent. As lake-marl I include the impure lime-deposits specially rich in organic matter and occuring in shallow water; they are common in most of our larger lakes at 5—8 m. In an ideal walk across the bottom of the lake the three above mentioned deposits would in due succession be traversed; near the shore the lake-marl gradually changes into peat, further out in the deeper parts of the lake into »shore-gytje«. Local conditions often effect changes, so that one of the three deposits may be substituted by one of the other two, or that all may be represented by some special formation characteristic of the particular locality. Among these two must specially be mentioned: the Characee lime and Mollusk- or shell-lime. Both these deposits owe their origin to the circumstance, that the above organisms have spread and increased at the expence of all others, and that the local circumstances have been such as *to render the sediments relatively pure and unmixed.* The Characee-lime occurs principally at a depth of 4—9 m.; certain conditions are essential to the formation of Characee-deposits. The study of lake-marl in the signification here applied being closely allied to the study of peat, which has not been included in these researches, we shall here only discuss the pure lime-deposits in shallow water: Characee- and Mollusk-lime, passing by the several more complicated lake-marls.

The Characee-lime.

Considerable deposits of Characee-lime occur in a lake 3 *kil. in length and 4—5 m. in depth: Hingesø in central Jütland.* The upper layer of the bottom soil consists of a bed of mud well stocked with mollusks, the lower strata gradually changing into a more solid greyish peat; underlying this is a bluish grey bed of lime-deposit, measuring 2—3 m. in thickness and resting on a solid layer of peat. On placing the fresh lime in a sieve numerous small tubular fragments will remain; these tubules measure c. 1. cm. in length and are of a bluish grey colour, rough on the outside and often ridged by 14—16 longitudinal lines. They occur in two types, one in section showing only a circle the other of a more complicated structure, in section 10—20 smaller circles concentering a larger central tube; the tubules are most conspicuous in the upper part of this layer gradually decreasing in numbers downwards, the lower parts consisting solely of a homogeneous pulverized substance. The tubules are the broken fragments of the Characeestems; the two types must either have belonged to the same plants viz. as thicker or thinner stems or as branches) or to plants belonging to two different sub-families: *Chareæ*, (the stem covered with cortical cells) or *Nitelleæ* (the cortical cells wanting see fig. pag. 60); the *Nitelleæ* have probably played an essential part in the formation of the lime. The excellent preservation of the tubules is owing to the circumstance, that the *Characeæ* not only precipitate the lime on the outer side of the stems and branches, but probably also fix it between the cortical cells and the central cell and between the cortical cells respectively. The lime percentage of the Characee-lime was 88.50 %; according to KOHL the p. c. of lime in the *Characeæ* can amount to 95.96 %. That the lime deposits in Hingesø have been built up by the agency of the *Characeæ* is sufficiently demonstrated by the superabundance of tubules and the homogenity of the material.

The origin of the Characee-lime must be traced to an earlier period in the history of the lake, when the depth was considerably greater and the water colder. The Characeæ-growths of those days have now disappeared and been surplanted by a vegetation consisting of other plants, such as *Potomogeton*, *Myriophyllum* a. o., now producing the mud-deposits overlying the lime. At the present day several of our lakes are at the stage, at which deposits of Characee-lime are still in the course of formation. This will especially occur in the larger bays of lakes, where the depth is from 3—5 m. The bottom soil will here often be seen covered with luxurient Characee-carpets *(Tolypellopsis)* and underneath the broken refuse of the vegetation in the shape of the lime tubules corresponding with the above mentioned fossil tubules. In peat-bogs abounding in *Characeæ* no deposits of this kind occur, the dead plants and broken remnants here passing into a noxious, sluggish mud the solution of the lime being probably due to the humic acids.

Page 62 the præhistory of the Characeæ is briefly mentioned, as well as corresponding finds reported in literature. Mounds of Characee-lime of a similar character as those reported by FOREL occurring in Lac de Joux, are also met with in our lakes. The Characee-lime in Hingesø is dug out of the lake by means of machinery and made use of for agricultural purposes. It may here be worth mentioning, that at the present day the Characeæ growing in the Bodensee are fished out of the lake and spread on the fields as manure. (MIGULA). In our lakes the *Characeæ* do not range beyond c. 8—9 m.; of other plants only *Fontinalis* and *Elodea* occur so far out, but at this depth the Characeæ evidently have the upper hand. The formation of Characee-lime will take place at a somewhat late period in the history of the lake, viz. when the maximal depth does not exceed 10 m. and the lake bottom is a comparatively level plain over which the Characee-growths can spread.

The Mollusk-lime.

The exploration of the Danish lake bottoms have proved, that the mollusk shells do not occur uniformly all over the bottom surface. With the exception of *Pisidium*-shells they are rarely met with outside the 15 m. curve. The great majority of shells accumulate in a belt situated between the 8 and 11 m. curve. I have termed this belt the shell-zone.

Origin of the shell-zone. — The extensive accumulation of shells within the above limits owe their origin to the local deposition of the shells of mollusks living in the shell-zone. Among these *Unio* and *Anodonta* occur in considerable numbers, *Valvata* and *Bithynia*, especially *Neritina*, more rarely; probably neither of these range beyond the outer limits of the Characee-zone. The other mollusks: *Planorbis*, *Paludina*, *Limnæa* and *Neritina* are rarely or never found as live specimens at this depth in Danish lakes, all inhabiting more shallow water.

As in the shell-zone only the shells of the former occur, on the latter at any rate but exceptionally, it will be apparent, that the molluscan fauna of the more shallow waters only in a very slight degree have contributed to the formation of the shell-zone.

The outer limitation of the shell-zone may be accounted for as a natural sequence of the fact, that the mollusks of our lakes do not extend greatly beyond the 11 m. curve; only the *Pisidium* occur at the greatest depths; *Anodonta* I have taken exceptionally at 13 m. Where the molluscan life stops, the deposition of shells must also stop; at this depth no wind or wave action will be strong enough to carry the shells away from their original place of deposit. — The inner limitation of the shell-zone results from the fact, that the majority of shells in the vegetation-zone on account of the more vigorous action of chemical and mechanical agencies (surf, coarser sediment etc.) will be pulverized and dissolved, and but rarely in a recognisable shape be transported out to the deeper parts of the lake bottom.

The mollusk fauna of the vegetation-zone partly comprises the same species as the shell-zone, partly species only *inhabiting the shallow waters of the shore*. Among the former *Unio* and *Anodonta* occur at a depth of c. $^1/_2$ m.; the *Valvata* occur most abundantly outside 2—3 m. The *Bithynia* are spread throughout the zone, greater part however live nearer the coastline than the *Valvata*. Among the latter *Neritina* increase in numbers towards land; in summer at any rate they principally occur within the depth of one m. The most prevailing species in the vegetation-zone however are those of *Limnæa* and *Planorbis*. Among these the larger species of *Planorbis*, *L. palustris* and *truncatula* rarely extend outside the peaty bays. *Limnæa stagnalis* was not met with beyond 5 m. *Limnæa ovata* and *auricularia* rarely outside 6—7 m. p. 74—75 I have compiled what is known at present as to the bathymetrical distribution of the Mollusks of European lakes.

Among other works SURBECK'S explorations of the Vierwaldstädter See should here be specially noted. The results he has arrived at harmonise well with my own.

In the vegetation-zone the mollusk shells deposited outside the 2—3 m. curve are subjected to a strong chemical corrosion, and are often, contrary to those of the shell-zone, worn very thin (recorded by A. C. JOHANSEN); shells deposited nearer the coastline will after being pulverized into a whitish powder in the surf (milky water) be carried out into deeper water. This particularly applies to shells of *Planorbis*, *Limnæa* and *Neritina*, partly to *Bithynia* and in a slight degree to the shells of mussels. The accumulation and pulverization of shells principally takes place in spring. At this season a general dying out of old snails recurs. At a certain stage of putrifaction the softer parts protrude from out the shells and are converted into balls of jelly, which in the month of April may be seen bordering the beach of the Furesø.

As the molluscan life of our lakes the Pisidium excepted does not extend beyond 11 m. and the shells of the vegetation-zone in a great measure are dissolved or pulverized by the intense action of the various erosive agents of this zone, the mollusks of the intermidiate shell-zone represent a strictly local shell depositing factor by whose agency the mollusk banks are formed. In the more tranquil waters out at this depth, beyond the limits of the vegetation-zone and its copious deposits of organic matter an accumulation of shells can take place without being disturbed by the dissolving and grinding factors of the shallow waters. Explorations show, that in two of our lakes, between the 8—11 m. curve, a series of banks occur consisting chiefly of mollusk shells imbedded in a bluish-grey lake-lime. I consider these banks to owe their origin to the agency of the mollusks. As to this point explorations of larger lakes would be desirable. Often the accumulation of shells in this zone is immense; seemingly there is a striking disproportion between the enormous amount of empty shells and the relatively few specimens of live mollusks; yet it must be remembered, that vast accumulations of shells may as well result from a slow process of deposition during a long space of time as from a more active deposition of a shorter period. Where the soil conditions are suitable, the shells gradually pass into the above mentioned soft and pliable substance, from which the special kind of lake-lime I have termed Mollusk-lime originates. In such sections of the shell-zone where organic matter is predominant in the bottom soil, and the colour of the same is black instead of greyish blue, no lime-deposits will occur and no banks be forming. To elucidate this, the lime percentage of bottom samples from different parts of the shell-zone containing immense quantities of shells imbedded in black mud of a nauseous smell, was determined. These samples from two of our larger lakes respectively contained 0.4 % and 0 % $CaCo_3$. The lime, I suppose, has here been dissolved by the acids resulting from organic decay, and the lime-deposits consequently have been precluded.

In the history of the lake the shell-zone will not always be stationary; according as the lake is being silted up, the outer limits of the shell-zone will be extended and removed farther out from the original coast-line. When the maximal depth of the lake has been reduced to 14—11 m. the mollusks will occupy the entire bottom of the lake, and being scattered all over the same, the formation of a shell-zone will be out of the question.

Kap. II. Limonite in the shape of pea-ore (Bohnerz).

In the summer 1897 the author came across considerable quantities of pea-ore (Bohnerz) in Furesø. A close examination of this substance, which has hitherto not been met with in this country, showed, that the pea-ore found in the above lake mainly *originates from a metamorphose of mollusk shells, chiefly Valvata*, see plate II fig. 10—29 and that the phenomenon is only met with in the shell-zone. My above mentioned explorations in the summer 1900 only brought to light small quantities of pea-ore in the lakes under observation, and in none to the same extent as in Furesø. The samples all originally proved to have been mollusk shells, and were not found outside the shell-zone. In Tjustrupsø the limonite chiefly proved to be metamorphosed mussel shells, of which the scraper brought up some specimens in an unimpaired state, some in a state of transition, and *others in which the transformation into limonite* was complete, see tab. I fig. 36—41. A close study of this transition from shell into pea-ore makes it possible to follow the process of transformation step by step: first the iron coatings upon the cuticula will form, next the cuticula itself becomes imbued; in older shells the prismatic layer assumes a brown colour, whilst the structure still remains distinguishable; in very old shells the nacreous layer and all has been converted into limonite, and the metamorphose is complete; that those unshapely lumps of iron have once been mussels, will not readily occur to the observer. — Iron coatings occur even on the shells of living animals. In how far limonite must be traced to the agency of the bacteria, the author must leave an open question; p. 80 the opinions of WINOGRADSKY and MOLISCH on this point have been set forth.

Kap. III. Gytje and nearly assosiated formations.

With regard to our Danish lakes it was to be expected, that considerable clay and lime-deposits might still be in the course of formation in the upper layers of the deep lake bottoms;

this however proves not to be the case. The formation of pure lake-clay and lake-blege, originating from particles of clay and lime dropping down through the water and settling at the bottom, presumably belongs to a bygone time, when the lakes were colder and deeper, the vegetation-zone narrower and the deposition of organic matter inconsiderable.

The erosive power of the streams being at the time immidiately succeeding the glacial period more active than at present, vast quantities of clay and lime would in an unmixed state be deposited upon the bottom of the lake.

At the present time the organic admixture is so copious, that at any rate the upper layer of the bottom soil does not present deposits either of pure clay or pure lime; the term gytje may then be used as a general denomination for this upper layer in our larger lakes. The word gytje is introduced scientifically by v. POST in his admirable work: »Studier öfver Nutidens koprogena Jordbildningar« (Kungl. Svenska Vetenskaps-Akademiens Handl. 1860), which it must be regretted has not attracted deserved attention abroad. By gytje v. POST understands such deposits as arise in clear and limpid water, and principally consist of the excrements of animal organisms.

I opine that gytje is always a surface layer; the bacteria working in deeper strata of the bottom soil than the fauna, extort the remains of organic matter from the excrements of the fauna, and if the process be allowed to proceed undisturbed, only the mineral compounds will be left. Yet in our comparatively shallow lakes the process is liable to interruption before it is carried through. On comparing the colour of the excrements of the fauna with the colour of the upper layer of the lake bottom I observed, that the excrements are of a lighter shade than the bottom; this is probably owing to the fact, that the animals, having exhausted the organic matter, only let the inorganic matter pass through their digestive tubes; the lighter colour of the gytje is consequently due to excremental processes.

By this digestive agency of the fauna and the bacteria I conclude that the lake-clay and lake-blege may still be forming; the main difference between those recent coprogen clay- and lime-layers and the earlier layers of glacial lime and clay will probably prove to be, that the former are more rich in organic matter than the latter; their origin however is altogether different.

The main condition for the formation of gytje appears to be, that no greater quantities of organic matter are precipitated than the bottom fauna and the bacteria jointly are able to digest. If the supply of organic matter becomes more copious, black, fetid mudformations of a different character will arise (deposits in river-deltas, in many ponds, common sewers etc.).

Where the organic matter, owing to the humic acids of the water is preserved, peat will arise. The proper balance between production and consumption is most easily brought about in pure limpid waters, where according to v. POST and G. ANDERSSON the *formation of gytje consequently will take place.*

According to the different local conditions, different types will occur; v. POST mentions: paper-gytje (EHRENBERG'S, Wiesenpapier), spring-gytje, pond-gytje, river-gytje and shore-gytje. In my opinion this is comprising to many subdivisions under the head of gytje; I only apply the term to those particular mudformations of coprogen nature, which occur at the bottom of pure, limpid waters and which commonly contain a considerable amount of clay and lime (20, 30 %), and only a slight amount of indigested material. The above mentioned pond-gytje and probably also paper-gytje must then be excluded.

As to the lakes v. POST distinguishes between two kinds of gytje, lake-gytje from the deeper parts of the lake and shore-gytje; the latter is found in the littoral zone, and mainly results from an accumulation of débris of beach- and shore-vegetation and the excrements of snails. The boundary line between the two types according to v. POST should be drawn at the depth of 3—4 m. *I agree with v. POST, in as much as I am of opinion, that those* two types of gytje must be maintained also with regard to our lakes, only the line should be moved further out, either to the outer limits of the vegetation-zone or to those of the shell-zone as respectively indicating the nearer and the remoter limits of the copious deposits of shore-vegetation, outside of which the deep bottom fauna, *Oligochæta, Pisidium, Ostracoda* and *Chironomus*-larvæ prevail; as v. POST's exploration only extend to the 5 m. curve, the shell-zone was not known to him.

Of deposits rich in inorganic matter inside the 11 m. curve lake-marl, Characee- and Mollusk-lime have already been mentioned. A more minute study of the chiefly organic deposits occurring inside this curve, f. ex. shore-gytje, is so closely connected with the study of the shore-vegetation as not to be pursued separately. Investigations upon this point being in progress by others, I have not studied these formations. Further researches will undoubtedly show, that several of the formations now termed lake-marl will be closely allied to shore-gytje.

Lake-gytje *differs from other gytje deposits as being in* most cases largely composed of the débris of plankton organisms, chiefly a few easily definable plankton Diatoms — *Stefano-*

discus Niagaræ, *Melosira crenulata* and *granulata*, and very often *Asterionella gracillima* — which may be considered as index fossils; in all probability lake-gytje is richer in inorganic matter than most of the other types of gytje.

The gytjes of our lakes often vary considerably as to character; nevertheless the fixing of distinct types becomes difficult on account of the numerous intermediate forms.

I premise, that lake-gytje of course can not be sharply defined from lake-blege and lake-clay. In the Danish paper pag. 93 I have mentioned the lime percentage in the bottom-soil of our larger lakes which is often very high (20—60 %); as I have proposed to use the name lake-blege only for deposits with a lime percentage exceeding 80 % this word will not apply to the former; gytjes copiously charged with lime I have termed lime-gytje (Kalkgytje). We shall here however only discuss the organic components of the gytje.

The origin of the organic matter of the lake-gytje must be traced partly to the plankton, partly to the flora and fauna of the adjacent country and partly to the littoral zone of the lake. Greater part of the material contributed by the above agencies only reaches the bottom in a pulverized state. By plankton investigators this organic »rain« is often termed »dirt«. The amount of it might possibly be determined by means of a plankton pump, which has however not been at my disposal.

In the pursuit of plankton studies[1]), carried on contemporately with the exploration of the above mentioned lake bottoms, I arrived at some results which I think may influence a more minute study of the lake bottoms; I have thence tried to subdivide the lake-gytje into different types, which I think may be maintained, notwithstanding the difficulty of classifying those mudformations.

As to the origin of gytje sufficient attention has hitherto not been paid to plankton; in studying the gytje of a lake it is first of all necessary to ascertain the character of its plankton; this varies considerably in the different lakes and even in the same lake at different periods; in accordance with this fact the chemical composition of the dead plankton precipitated upon the bottom surface varies greatly as well with regard to time as to locality. A closer study of the chemical nature of the plankton is especially necessary in relation to gytje.

As we are only able at present to determine the cellular contents of the plankton organisms as albumen and water, and as we have no knowledge of the manner in which the albumen is dissolved upon the lake bottom, we must chiefly restrict our-

[1]) which will be published in a subsequent paper.

selves to discuss the chemical composition of the skeletons of the plankton organisms and their bearings upon the formation of lake-gytje. As my own plankton observations prove, that in deeper lakes dead plankton is only deposited in the shape of empty skeletons, I consider this limitation warrantable. With FOREL I take it for granted, that while the organisms are sinking down through the water, the soft parts are consumed by the bacteria; I have found this dead plankton consisting of empty skeletons suspended in deep water in several of our larger lakes. In shallow lakes (3—4 m.) the bottom is often covered with a whitish grey, putrified, fetid layer, consisting of plankton organisms, which have not been consumed during their shorter downward passage, so that the process of decay of the cellular contents here is continued after sedimentation.

The skeletons of plankton organisms consist either of silica, chitine, cutine, cellulose or calcium carbonate; the latter is only skeleton forming in the small number of plankton *Rhizopoda;* it has been pointed out in the shells of *Peridinea* (by SHILLING), and will in all probability be found in small quantities in the chitinous skins of plankton Crustacea. The amount of calcium carbonate, which plankton yields to lake-gytje is however insignificant. Plankton deposits corresponding to the Globigerina deposits of the ocean probably never occur in fresh water basins.

The skeletons of Diatoms are composed of silicic acid; the skins of Crustacea and Rotifera of chitine, probably also the coatings of *Codonella lacustris* and *Dinobryum.* The skeletons of Peridinea consist of cellulose, among these especially *Ceratium hirudinella* is an important agent in the formation of plankton. Closer examinations as to the chemical nature of the cell walls of the *Chlorophyceæ* being to my knowledge as yet wanting, we must for the present also class the cellular walls of these as belonging to cellulose; among the numerous *Chlorophyceæ* only *Pediastrum* is of special importance in relation to plankton and gytje. A substance allied to cutine is said to form the cell walls of the Cyanophyceæ, of which several play an essential part in this respect.

My above mentioned plankton investigations show, that in every one of our lakes only a few species of plankton organisms, differing in the various lakes reach the enormous maxima well-known to all plankton investigators; the chemical composition of the gytje of a lake will therefore principally depend on the chemical nature of the skeletons of these particular organisms.

The plankton investigations have further proved, that the chitine-producing organisms form the essential part of the plankton, especially in shallow lakes, and that our deeper and larger lakes almost never afford equally favourable conditions to both of the two principal plankton forming groups the Diatomeæ, producing silicid acid, and the cutine producing Cyanophyceæ.

In accordance with these results gathered from the plankton investigations we are now able to point out three different kinds of lake-gytje.

In lakes with high Diatomee-maxima the lake gytje contains vast quantities of shells of plankton Diatoms and is termed Diatomee-gytje.

In lakes with high maxima of chitine producing organisms a greyish brown faintly malodorous mud is deposited: chitine-gytje.

In lakes with high Cyanophycee-maxima the gytje will consist of a bluish black, fetid, exceedingly fine mud: Cyanophycee-gytje.

A special kind of lake-gytje arising from deposited cellulose does not occur, as this substance is quickly dissolved and disappears in the gytje.

Owing to the fact, that plankton always contains both some silica-, chitine- and cutine-producing organisms, it must however be emphasized that gytjes of a mixed character often, strictly speaking always will arise; even if one of these groups, say the silica producing, be by far the most predominant, the other groups may yet be represented to an extent, that will influence the general character of the gytje.

Many other conditions contributing to modify and transform the gytje, which according to the nature of the plankton should be typical for the lake in question, may further give rise to gytjes of a mixed character. In the first place the proportions of zoo-plankton and phyto-plankton of a lake, do not correspond with the amount of the respective skeleton-débris in the gytje. Zoo-plankton generally stands deeper in the water than phyto-plankton and is less liable to be caught by the waves or carried away by the outlets; part of the latter, especially the *Cyanophyceæ*, is either deposited as mud near the shore or carried away by the outlets, whereas the zoo-plankton is principally deposited in the deeper parts of the lake bottom. Secondly: the process, which the sedimented material is subjected to in the digestive tubes of the bottom fauna, does not affect the skeletons in the same manner and to the same degree; the cellulose is in all probability quickly dissolved; the chitinous skins get pulverized, but the Diatomee shells will, with the exception of the somewhat jagged edges, pass the digestive tubes almost unimpaired; examinations of the excrements of the *Chironomus* larvæ confirm this. Thirdly: streams receiving tributaries from other water basins will carry plankton from the latter into the next lake, and will deposit it along with the perhaps, greatly differing local plankton of this lake. Fourthly: the incongruity of the plankton and the lake-gytje may be due to the fact, that the various skeletons also apart from the consequences of the digestive processes are not preserved for an equal length of time in the lake bottom. Cellulose probably quickly dissolves into marsh-gas (CH_4), and carbonic acid (CO_2). Six months after an enormous maximum of *Ceratium hirudinella* had been noted in one of our lakes, I was not even able to make out their skeletons in the gytje of the lake. Also the cell walls of *Cyanophycea* disappear completly; of the chitinous skeletons the thinnest likewise seem to disappear (*Rotifera* and *Dinobryum*); occasionally I have met with dead Rotifer-plankton, consisting of partly dissolved chitinous skins; skeletons of *Copepoda* also seem to vanish quickly, or at least to become undistinguishable; best preserved are the coats of *Codonella lacustris*, and the skins of the *Daphnidæ*, among which the wellknown antennæ and valvæ of *Bosmina* are conspicuous. The *Diatoms* will keep longer than any of the other organisms and are important agents in the formation of lake-gytje. The Diatomee-shells are principally due to the plankton Diatoms, and only in a very slight degree to the fixed shore Diatoms; the shells of the latter decrease in numbers towards the deeper parts of the lake, and are here due to the Diatomee coatings of submerged aquatic plants, which in autumn are carried outward, and from which the coatings drop off. Examinations prove, that a special Diatomee flora peculiar to the deeper parts of the lake bottom cannot be pointed out. The brown colour of the cromatophors does not prove, that the forms actually belong to and live in the deeper localities, seeing that this colour according to KIRCHNERS and to my own observations will keep for three months. The various Diatoms are preserved differently and for an unequal length of time. I have never found the thin shells of *Atheya* or *Rhizosolenia; Melosira, Cymatopleura elliptica, Stephanodiscus Niagaræ* often occur in enormous quantities; asteriated Diatoms *(Asterionella, Tabellaria)* are deposited as single individuals.

Notwithstanding the above mentioned special conditions, which may cause incongruities between the gytje of a lake and its plankton, and by means of which the gytjes of a mixed nature may arise, the three above mentioned main types for lake-gytje, Diatomee-, Cyanophycee- and Chitine-gytje are often represented in the Danish lakes (see tab. 3 and discription). The fact is that the *Diatomeæ* reach their maxima in deep, cold lakes, the *Cyanophyceæ* in shallow, warm lakes, and as the Danish lakes are only exceptionally deep and cold, we have but few lakes with high Diatomee-maxima and corresponding lake-gytjes, whereas many lakes show high Cyanophycee-maxima and pronounced Cyanophycee-gytjes; on account of the durability of the Diatomee-shells, these will accumalate in vast quantities in lakes, that excel in Diatoms.

The most typical Diatomee-gytje was found in Haldsö (tp. of bottom sample 28th July 1900 $+ 6^1/_2{}^0$ C.). Just taken out of the water it is perfectly black and contains vast quantities of plankton Diatoms, chiefly *Stephonodiscus Niagaræ,* and *Melosira granulata* (tab. 3) deposited in an almost impalpable black mud, probably consisting of cromatofors seceded from deposited shells. Diatomee deposits of this discription from deeper lake bottoms have to my knowledge not been found before; shallow water deposits chiefly made up of shore Diatoms are known from Reusch and Tryboms statements.

According to Forel and Kirchner the Diatoms in the deep lake bottoms of Genfer- and Bodensee (2—300 m.) are only of slight importance, and the few individuals principally reported as bottom Diatoms.

As the works treating on the plankton of those lakes show, that Diatoms play a prominent part in the same, the question arises, why the shells in the Diatomee-plankton of Bodensee and Genfersee are dissolved and disappear, whilst the shells accumulate upon the bottom of Danish lakes. The vast difference in depth between our deepest lakes, 40 m., and that of the Swiss lakes may account for the fact, that the shells on their descent through the 7—8 times deeper body of water are dissolved before reaching the bottom, whereas in our shallow lakes no such solution takes place. Whether in the course of time a slow dissolution of the deposited shells does take place and renders them unconspicuous in the deeper layers, must at present remain undecided.

In exploring the Silkeborg lakes my attention was called to the fact, that the plankton of the latter, at the point where Salten River enters Guden River, all at once changes character. Up to this point the plankton had been chiefly charactarised by *Diatoms;* beyond the conflux of the two streams by *Cyanophyceæ,* principally *Aphanizomenon,* in enormous quantities ushered into Guden River through Salten River. In accordance with the above, Diatomee-gytje and Diatomee-clay was found in the lakes up to the entrance of Salten River, the Cyanophycee-gytje only beyond this point.

Besides the above mentioned three types of lake-gytje, and the compound gytjes arising from intermixture of their components, a more copious addition of inorganic matter, in this country chiefly clay and lime, will give rise to further compound gytjes. Among these *Cyanophycee-clay*, *Diatomee-clay* and *Diatomee-lime* are most prominent. For the bottom proofs of our larger lakes the following terminology may be established.

chiefly organic matter	Cyanophycee-gytje Diatomee-gytje Chitine-gytje
mixture of organic and inorganic matter	Cyanophycee-clay Diatomee-lime Diatomee-clay
chiefly inorganic matter	lake-clay, lake-blege (Søblege).

If sufficiently deepgoing bottom proofs could be obtained, the consecutive order of these formations would in all probability recur in the bottom proofs, so that we should expect to meet with:

Cyanophycee-gytje,	Diatomee-gytje,	Diatomee-gytje,
— clay,	— clay,	— lime,
coprogen lake-clay,	coprogen lake-clay,	coprogen lake-blege,

With regard to the bottom fauna I shall here only observe, that in all essentials it is of the same character as the deep-lake fauna recorded by FOREL and others. To enter more closely upon this subject would be purposeless, until investigations (on other hands) now in process have been published.

As to the bearings of the fauna in relation to the bottom soil they are of a double character: first, as hightening the lake bottom and adding to the elementary constituents of gytje; secondly, as converting those constituents into excrements.

From the various plankton explorations it must be inferred, that plankton skeletons of entirely different character are precipitated at the different seasons of the year: in early summer chiefly silicid acid, originating from Diatoms; in autumn cutine from Cyanophyceæ. Owing to the fact, that maxima of plankton organisms always occur coincidently with certain temperature optima, year by year recurring at the same time, we might expect to find the lake-gytje stratified and exhibiting distinguishable differences in the chemical nature of the respective layers; however neither recent nor subfossil gytjes confirm such a supposition; to my opinion the original stratification is effaced and lost by the rooting and excrementing agency of the bottom fauna.

It has already been mentioned, that the organic matter by the joint action of the fauna and bacteria gradually disappears, so that at a certain depth only an inorganic remainder will be left. Even by means of the dredge three layers may be distinguished, an upper layer of a deep brown colour, as yet but slightly influenced by the bottom fauna, and in character somewhat differing from »*le feutre organique*« reported by FOREL; owing to the soft almost fluid condition of the bottom mud, I have never met with any typical bottom surface, corresponding with »*le feutre organique*« or with BRANDS: »Grundalgenzone« — beneath this top layer is a yellowish fetid layer, inhabited by numerous organisms, chiefly bacteria, and underlying this the bluish grey layer thorougly excremented and rich in inorganic matter; this layer will gradually blend with the subjacent coprogenous lake-clay or lake-blege which probably rests upon the pure glacial deposits of clay or lime.

POSTSCRIPT.

Shortly after delivering a discourse in the geological society of Copenhagen (12 Dec. 1900) on the origin and formation of lake-lime, in which discourse the occurrance of a considerable amount of Characee-lime in one of the Danish lakes was specially brought forward, this substance not having been found in any of our lakes before, my attention was called to the fact, that two essays by C. A. DAVIS had been published in Journal of Geology Vol. VIII Sep.—Oct. 1900 under the heads: A contribution to the natural history of marl (p. 485—497) and: A remarkable marl lake (p. 498—503).

It appeared, that DAVIS had particularly made the Characee-lime his study. In several points our observations seem entirely to concur, and in others in some measure to supplement each other. As I was not able at the time I had read Ds.' interesting essays to make any mention of them in my manuscript, which was just going into the press, I preferred in a postscript to add an abstract of the same, his explorations being so closely allied to my own, and as it appears, carried on contemporaneously. I have thought fit mainly to use his own words.

According to DAVIS the marl deposits, with the exception of the vegetable matter, owe their origin to the clays of glacial deposits and like disintegrated rock-masses. Percolating water containing dissolved carbon dioxide dissolves the calcium; the water with the dissolved matter runs along underground until an outlet is reached and then issues in the form of a spring. This in turn uniting with other springs forms a stream, which runs into a lake, carrying along with it the greater part of its mineral load. If the amount of carbon dioxide contained in the water is considerable, some of it will escape on reaching the surface because of decrease of pressure, and with its escape, if the saturation point for the dissolved mineral matter has been reached, a part of this matter must be dropped in the form of a fine powder, as the water runs along over the surface. From this point of view it might be expected, that the waters of these springs and streams would show more or less milkiness; as this however is not the case, D. concludes, that there is not a large amount of calcium dioxide and no approach to the saturation point for calcium *bicarbonate in the* springs and streams feeding marly lakes. — In this manner then D. is of opinion that *marl does not originate.*

We are, then, according to D. left, among others, the following alternatives, explanatory of marl formation:

1. The marl is not being formed under existing conditions but at some previous time. 2. The marl is formed not in the springs but exclusively in the lakes, and in consequence of slow evaporation and the reduction of the amount of dissolved carbon dioxide in the water, which brings about deposition of the mineral salts. 3. Some other cause, or causes, than the simple *release from the water of the solvent carbon dixoide must then* be sought.

D. of course at once rejects the first of the three explanations and also concludes, that the marl no more originates in the manner mentioned in 2. He rests his opinion partly upon the circumstance, that the water of lakes with swift flowing and extensive outlets, such as most of the marly lakes explored by him have, is changed so rapidly that little if any concentration of a given volume of water would occur while it *was in the lake, partly upon preliminary investigations which* show, that the volume of water flowing out of these lakes is practically the same as that flowing into them. Further D. founds his opinion upon the explorations of Treadwell and Reuter.

In accordance with the Swiss investigators I think, that D. has somewhat underrated the importance of the directly from the water, by the reduction of the amount of dissolved carbon dioxide precipitated calcium carbonate in the formation of lake-lime.

D. then arives at the conclusion, that, the marl originates *from the agency of organisms; among these the mollusks and* the plants are mentioned. In the localities which D. has explored he considers the former as being only of small importance; as regards our country the conclusions I have arrived at in this respect do not concur with those of D. He then comes to the conclusion, that the plants play the most prominent part as precipitating agents for the calcium salts. The precipitation of lime upon the plants is according to D. owing to one of the two following causes: If the calcium and other salts are in excess in the water, and are held in solution by carbon dioxide, the more or less complete abstraction of the gas from the water in direct contact with plants, causes precipitation of the salts upon the parts abstracting the gas, namely, stems and leaves. But in water containing amounts of the salts, especially of the calcium bicarbonate, so small that they would not be precipitated if there were no carbon dioxide present in the water at all, the precipitation may be considered a purely chemical problem, a solution of which may be looked for in the action upon the bicarbonates, of the oxygen set free by the plants.

In accordance with the fact, that not even all species of the same genera, even when growing side by side, will be coated equally, D. further supposes the presence of some selective metabolic processes as yet not understood. He emphazises, that the lime crusts are purely external which as regards the Characeæ will scarcely hold good (Kohl). Among the lime producing plants the higher plants the Characeæ and the blue-green algæ are particularly mentioned. Principally owing to the fact, that in early spring or late fall, all plants of the higher types will not be found, D. concludes, that the agency of these plants is merely a seasonable one, and that such work as these plants are doing, is but a small factor in the total sedimentation of the lake. Herein I agree with D.

Professor D. further concludes, that the Characeæ play an important part in the formation of the marl; several of the recorded observations coincide with my own. The Characee material has been analysed by D.; upon this point I refer to his own paper. D. points out a fact which did not come under my observation, that marl beds of several, and even as much as twenty or more feet in thickness will »run out« abruptly into beds of »muck«, or pure vegetable débris, of equal thickness. In this connexion D. remarks, that this distribution may show, that up to a certain time conditions unfavorable to the growth of Chara are favorable to other plants obtained, until a depth of water was reached at which Chara was able to occupy the bed of muck. From the time when the Chara began its occupation of the muck the amount of organic matter left would decrease, and the amount of calcareous deposits would increase, until the latter predominated.

The stone covering blue-green algæ seem to be unknown to D.; but he mentions certain not precisely determinated blue-green lime incrusted algæ which grow in colonies, and precipitate the calcium carbonate; these algæ at first are affixed to mussels etc. but subsequently detatch themselves forming pebbles of greater or lesser size. These algal calcareous pebbles show both radial and concentric structure and might well be taken for concretions formed by rolling some sticky substance over and over in the wet marl, on which they occur. Included within the structure of the pebbles are great numbers of plants, besides the calcareous blue-green algæ among the considerable numbers of Diatoms. It is possible to recognise the pebbles, as lumps of coarser matter, even in very old marl; they are found in four typical marl lakes, and have been reported from a number of others by marl hunters. From these facts D. concludes, that they are constant if not important contributors to marl beds. To my knowledge corresponding formations have not as yet been found in Europe.

In the second paper: »A remarkable marl lake« Professor D. has mentioned the deposits of marl in Littlefield lake, Isabella County, Michigan one and one half miles long, by three fourths of a mile broad; in the widest part it was said to be eighty feet deep; in the lake there are three small islands; the entire shore of the lake is formed by beautifully white marl, the exposures varying in width from a few feet to three or four rods in width, so that as one overlooks the lake from one of the surrounding hills, it seems to lie in a basin of white marble. The bottom of the lake and its deposits have not been explored; the marl deposits on the beach are frequently thirty feet deep; the color is yellowish or creamy, or, it is almost purely white. At the surface the marl is coarser, slightly yellowish and more compact. On the parts of the shores where apparently the wave action is chiefly exerted, there are small rounded calcareous pebbles, mixed with molluscan shells, drift material, and considerable quantities of stems, branches, and more or less broken fragments of Characee stems, all parts of which are heavily incrusted with calcareous matter. This Chara material was often piled up in windrows of considerable extent at the high-water mark. From this wind and wave accumulated material the marl deposits arise. Corresponding shore-deposits of partly pulverised Characeæ may also, but in a very inferior degree be observed along the shores of Danish lakes. The above mentioned three islands likewise consist of marl from twenty five to thirty feet deep; they evidently correspond with the islands mentioned by Forel and the submerged banks found in the Furesø.

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