POSSIBILITIES AND LIMITATIONS OF BLACK-AND-WHITE AERIAL PHOTOGRAPHS IN SOIL SURVEYING

HENRIK BREUNING MADSEN

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The paper describes advantages and disadvantages by using panchromatic black-and-white photographs for soil surveying. Two areas different as to drainage conditions, texture, and pedological development were investigated. It was found that the aerial photographs were useful for drawing soil boundaries when combined with field studies (drilling and profile description).

Henrik Breuning Madsen, Mag.scient. Geographical Institute, University of Copenhagen, Haraldsgade 68, DK-2100 Copenhagen Ø.

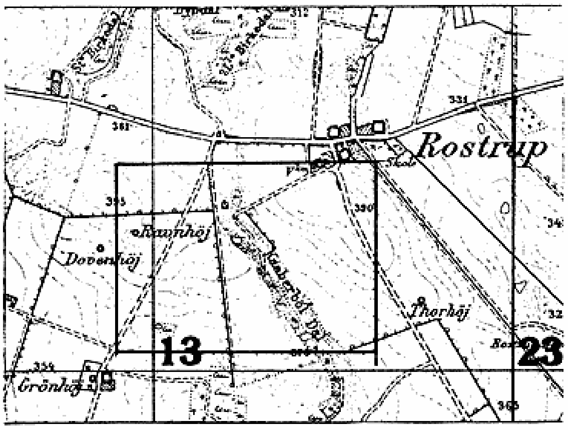

Fig. 1. Topographic map showing the investigated area at Rostrup. Scale 1:20.000, contour line 5 feet.
Kort: Geodætisk Institut.

INTRODUCTION

It has long been known that aerial photographs reveal differences in soil conditions and therefore offer a useful tool for soil surveying. The most used film types for this purpose are panchromatic black-and-white and colour films, infrared black-and-white and colour films. On aerial photopraphs taken near Copenhagen, Fobian (1976) has investigated the applicability of the different film types for soil surveying. He found that panchromatic black-and-white pictures at 1:10,000 were especially well-suited for soil surveying in spring when the fields are without vegetation. Lundén (1974) found in an investigation near Malingbo that it was possible to evaluate the texture and geological origin of the surface on the basis of aerial photographs and that for this purpose IR- and colour films were slightly better than the ordinary black/white pictures. In selected areas near Gadbjerg, about 20 km W of Vejle in E-Jutland, the possibilities and limitations of panchromatic black-and-white aerial photographs for soil surveying have been investigated.

SOIL FACTORS INFLUENCING THE GREYTONE PATTERN

The most important soil factors influencing the variations of greytones on aerial photographs are: texture, structure, organic matter, content of free ironoxides, pedological development and actual moisture content (drainage).

Laboratory tests have shown that the reflection decreases with increasing grain size which means that clay will have a higher degree of reflection than sand. In field studies, however, it is seldom the reflection from the surface texture, but rather that from the soil structure which is of importance, because the topsoil in ploughed fields will mostly have some kind of aggregate formation. The largest and most stable aggregates are found in clayey soils which will therefore generally appear in darker greytones than the sandy soils (Myers 1975).

The content of organic matter in the surface layer and the chemical composition of the humus are of great importance for the reflection from the surface, because humus is one of the most colouring soil components and the colour of the top soil is mainly determined by the humus. When organic matter has been removed from the uppermost top soil, however, the content of free iron-oxides will greatly influence the greytones of an aerial photograph. This is for example seen during the winter in sandy, vegetationless areas where precipitation is able to wash off the humus from the uppermost sand grains and uncover mineral particles, which are often coated with ironoxides. The pedology is of importance when it is influencing the appearance of the top layer. Podzols may for example have a black or greyish topsoil while luvisols and cambisols have more brownish topsoil due to the

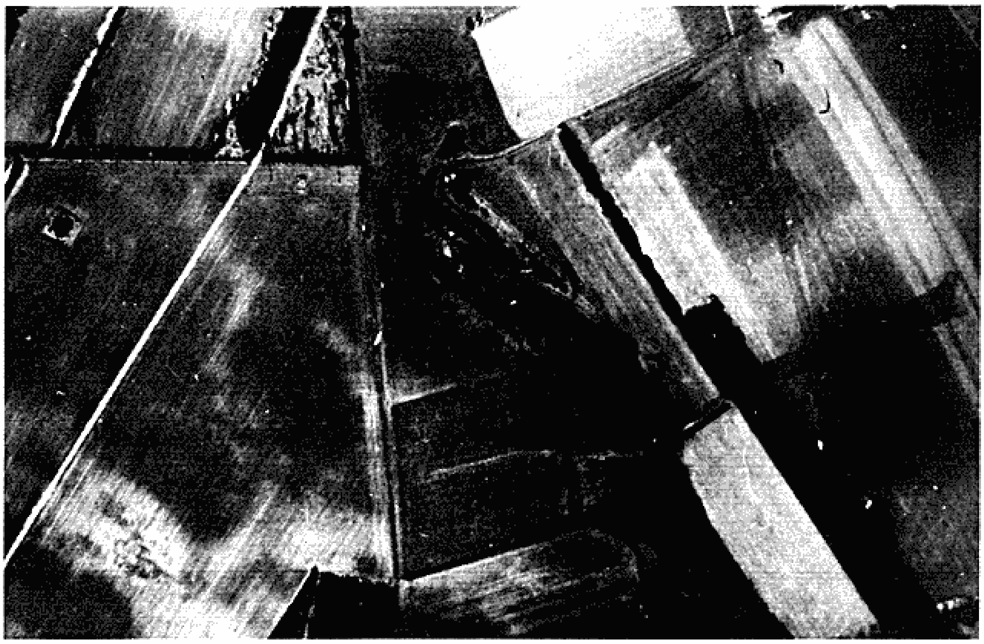

Fig. 2. Panchromatic aerial photograph showing the western part of Rostrup. Scale 1:4.500 (Danish Air Force, April 18th, 1977).

Fig. 2. Pankromatisk luftfoto i 1:4.500 over den vestlige del af Rostrup (Det Danske Flyvevåben, 18. april 1977).

pedological development which gives a different chemical composition of the organic matter. Vegetationless areas with podzols will often have a very special appearance on aerial photographs due to the migration of ironoxides from the upper part of the soil which leaves the sand grains whitish without coating and creates a spodic B-horizon down into the profile. In winter, precipitation will cause a migration of humus from the uppermost sand grains and the fields will get at whitish appearance except where the ploughing in autumn has turned op the spodic B-horizon to the surface where the iron-coated sand grains will give the soil a reddish-brown or yellowish-brown appearance.

Also the moisture content and the drainage of the soil will influence the reflection greatly so that wetter parts will appear in darker greytones than the drier ones.

COLLECTING OF DATA

The investigation fell into two parts, namely the aerial photographing and the soil surveying.

The aerial photographing: The pictures were taken by the Danish Air Force on April 18th, 1977. The height was about 3,000 feet, and an ordinary black-and-white film was used. The aerial photographs show the ground surface in a scale of about 1:4,500.

Soil investigation: The soil investigation was performed in two stages: a preliminary investigation during the summer of 1976, followed by the surveying itself which led to elaboration of maps during the autumn of 1977. The survey was made with a cylindrical auger with diameter 2 cm. and 100 cm. long. The auger was pressed or hammered down until the depth of one metre was reached. Texture, pedology and drainage conditions were evaluated for this uppermost metre of the soil profile. The places for drilling were chosen on the basis of the greytones on the aerial photographs, terrain and drainage features (catena) and vegetation. In some places a special investigation was necessary where vegetation was dense and the greytone therefore blotted out. The drilling was described after the nomenclature below and dotted on the aerial photograph which served as basis map.

NOMENCLATURE

Texture and pedology

A: well-sorted medium sand (125 μ-500 μ), normally dune or meltwater sand, pedologically cambisols, arenosols or very weakly developed podzols.

B: stony or gravelly medium sand or coarser matrix, normally sandy morainic material. Pedologically arenosols.

C: finesand (125 μ-20 μ) or silt (2-20 μ) normally ice-lake sediments.

D: clayey sand — about 5% to 8% clay, sandy morainic material, pedologically cambisols or luvisols.

Æ: sandy clay — about 8% to 13% clay, morainic material, pedologically mainly luvisols.

E: clay — more than 13% clay, morainic material, pedological mainly luvisols.

F: peat — more than 30% organic matter.

T: weakly developed podzols with a bleached horizon and a reddish-brown spodic horizon, but without a black spodic horizon. Texture like A.

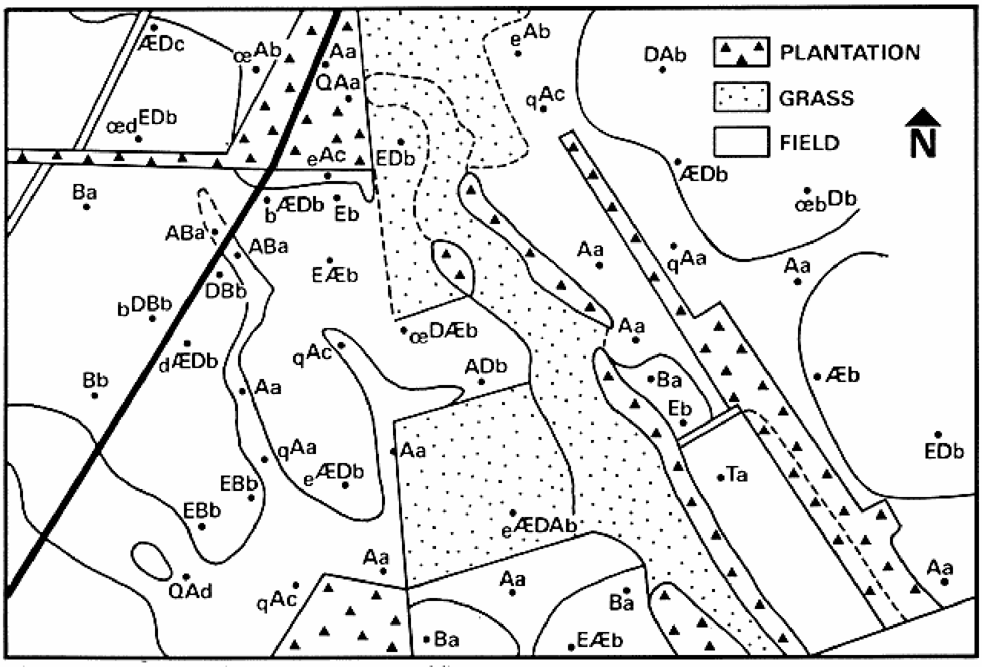

Fig. 3. Soil boundaries drawn on the basis of the greytone pattern of fig. 2. Furthermore, drilling sites, profile description and land-use are indicated.

Fig. 3. Jordbundsgrænser udtegnet på basis af gråtonevariationerne i fig. 2. Endvidere er boresteder, profilbeskrivelser samt land-use angivet.

S: strongly developed podzols with a bleached horizon and a black and reddish-brown spodic horizon. Texture like A.
W: strongly developed podzols as A, but without a bleached horizon.
X: weakly developed podzols as T, but without a bleached horizon.
Z: undeveloped, sandy soil, normally meadow soils.

DRAINAGE

a: excessive drainage	no sign of groundwater in the profile
b: well-drained	
c: moderate drainage	gley below the depth of 40 cm.
f: imperfect drainage	gley in the upper 40 cm. or groundwater below 50 cm.
g: very bad drainage	groundwater in the upper 50 cm. of the profile.

ORGANIC MATTER

If the soil has an organic rich topsoil, one of the following numbers will be added after drainage class in the profile description:

3: under 15 cm. thick
6: between 15 cm. and 45 cm. thick
9: more than 45 cm. thick

To describe a profile, the topsoil's grain size is designated by a capital letter followed by drainage class in small letter. Where texture variates within the upper 50 cm., a preceding capital letter is used to designate the next type; if found in the lower 50 cm. of the drilling, the preceding letter will be a small one. Thus, eDb means a well-drained clayey sand with clay below a depth of 50 cm.

RESULTS

On the basis of the aerial photographs two localities were selected for a detailed investigation.

Rostrup

This area lies in the W-part of Rostrup, mainly on the watershed between the three rivers Vejle Å, Omme Å, and Grindsted Å, but so that the section shown below is mainly drained towards the S. Fig 1 shows a topographic map of the area.

The highest points are found in the N-part of the area while the lowest points, apart from the bottom of the large valley, are located in the S-part of the map. The most conspicuous feature in this landscape is the almost N-S running, steep-sided valley named Kaaberbøldal. This is most likely a late-glacial meltwater valley draining through Vejle Å towards the Kattegat.

The area E of Kaaberbøldal is gently sloping towards the valley, whereas the W-area falls into three parts: uppermost, it is slooping towards the N, the large intermediate part is sloping gently parallel to the great valley, and the lowermost part is nearly flat with two small hills.

Fig. 2 shows the aerial photograph of the area, and fig. 3 reproduces the most pronounced greytones from fig. 2 and indicates the profile descriptions from the survey and the different types of land use.

By comparing figs. 1, 2 and 3 it is seen that where without vegetation the relatively low areas are generally light-coloured, whereas the more elevated parts are dark.

When looking at the area W of the valley, it appears that some of the light areas form a drainage system leading toward the SW-plantation. The light area consists of well-sorted, well-drained medium sand which in a depth of 50 to 100 cm. often changes into finesand or silty material. Pedologically the profiles are difficult to classify as they contain podzollic topsoils without iron-oxides and with a dark-greyish colour, but the profiles have no well-developed spodic horizon; sometimes the sand just under the topsoil is even yellowish.

In the relatively more elevated locations there is in the W-part gravelly and stony sand in the whole profile, whereas the N- and W-part often contains a clayey subsoil. A division into soil with/without a clayey subsoil seems impossible on the basis of the available aerial photographic material. It should further be noticed that the two small hills on the plateau between Kaaberbøldal and the SW-plantation appear in dark greytones. The borderline between the light sandy soil in the NW and the darker, clayey soils is difficult to follow as it disappears into a plantation and a grassfield. For grass-covered fields it is difficult to make any soil boundaries by studying aerial photographs; this is clearly shown for the grassfield just NE of the SW-plantation. In principle the E-part of the picture shows the same as the W-part, namely the dark hills and the light valleys, which is quite natural as the material is alike except for the S-part near Kaaberbøldal where the soils are more well-developed podzols with a reddish-brown spodic horizon.

It may seem odd that the low-lying parts appear in pale colours, and the hills in dark greytones, but this is due to the content of white sand and humus in the topsoil of the low-lying sandy fields. When these have been without vegetation for some time, the humus is washed away from the sand grains in the upper millimetres which gives the surface a whitish appearance. After the ploughing, the soil resumes its normal greybrown colour. The hills do not get whitish because the clay content — although low — is binding the humus and because the sand grains are coated with free ironoxides which gives a brownish appearance.

Birkebæk

The second area lies about 1 km S of the village Skolding at the confluence of the rivulets Birkebæk and Omme Å. Geologically, the area consists of a clayey moraine over-lain by a cover of shifting sand, in most places more than one metre thick. On fig. 4 it is seen that the general topography of the area is level, but gently sloping towards Omme Å; the survey revealed, however, a well-developed microrelief with small valleys winding between small plateaus, often down to the Omme Å. This microrelief does not appear on the topographical map, because the

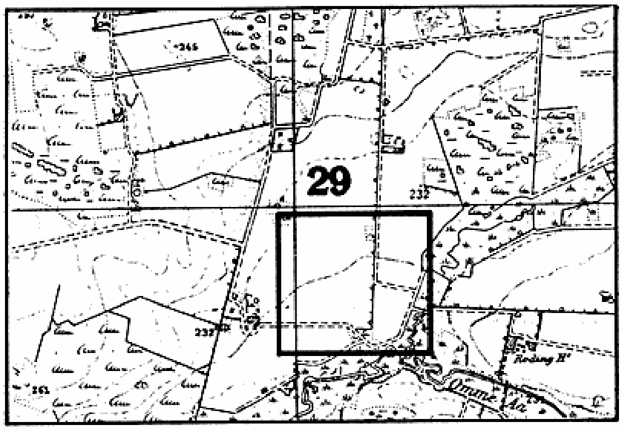

Fig. 4. Topographic map showing the investigated area at Birkebæk. Scale 1:20.000, contour-line 5 feet.
Kort: Geodætisk Institut.

difference in level between valleys and plateau is about half a metre only.

Fig. 5 shows the aerial photograph of the investigated area. The river in the E-part of the picture is Birkebæk just before its confluence with Omme Å to which the meadow in the S belongs. The area E of Birkebæk is somewhat dark because of clouds which also dimmed the W-part. Fig. 6 shows a soil map made on the basis of the greytone variations on fig. 5 and the profile description based on drillings. Furthermore the map shows the land use pattern in this area.

The most detailed investigation has been made near Birkebæk and the results were thereafter extrapolated to the rest of the area by means of the aerial photographs and a few drillings. A comparison between the greytone variations on the aerial photograph and the microrelief revealed that the dark parts in fig. 5 lie in the shallow areas of the microrelief and the lighter parts on the plateaus which were elevated about half a metre above the dark areas.

Still looking at the field nearest Birkebæk, the dark area in the middle of the field shows a pattern much resembling a meandering river. Most likely, this is a former natural drainage system. From the drillings it appears that the W-branch has a much more organic top layer than the easternmost one and has persumably been the main course. Farthest to the E, parts of the river valley have been cultivated and two depressions are visible as black spots. In the NW-corner of the field the beginning of an elongated black area is seen which is continuing into the next two fields. This black part has formerly been a moor, but has now been ploughed into the rest of the fields and only a small depression is left, with topsoil rich in organic matter and a high-standing groundwater level.

In the SW-part of the picture some elongated dark parts are seen which represents a second drainage system

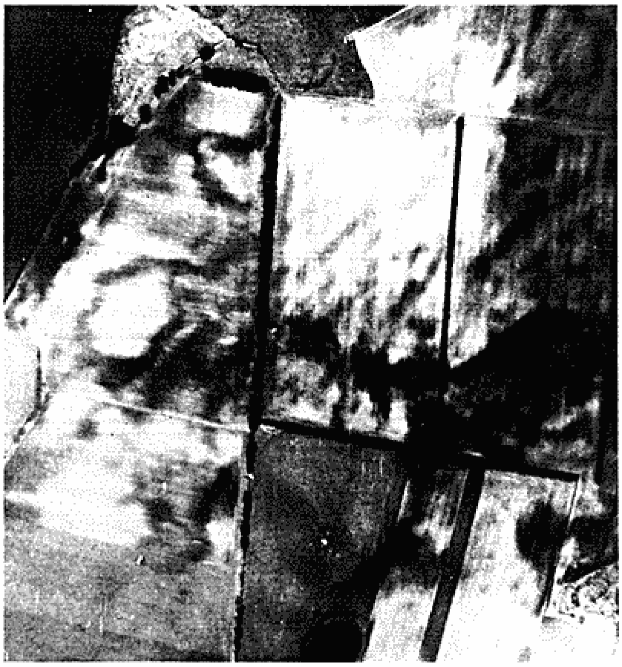

Fig. 5. Panchromatic aerial photograph showing the western part of Birkebæk. Scale 1:4.500 (Danish Air Force, April 18th, 1977).
Fig. 5. Pankromatisk luftfoto i 1:4.500 over den vestlige del af Birkebæk (Det Danske Flyvevåben, 18. april 1977).

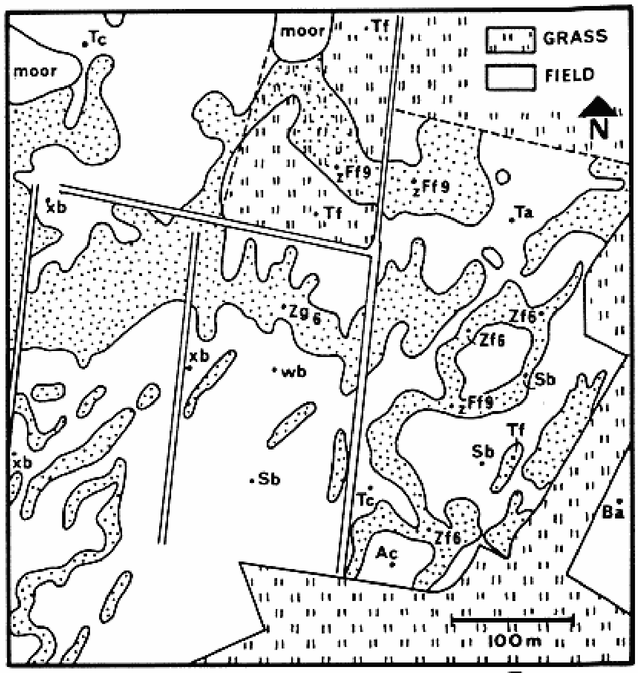

Fig. 6. Soil boundaries drawn on the basis of the greytone pattern of fig. 5 and with indication of drilling sites, profile description and land-use.
Fig. 6. Jordbundsgrænser udtegnet på basis af gråtonevariationerne i fig. 5 og med angivelse af boresteder, profilbeskrivelser og land-use.

towards the Omme Å. In northern fields there are also dark, elongated spots — even in the grassfields different greytones can be distinguished in a pattern radiating from a small peaty depression in the northernmost part of the picture.

The drillings show that the dark sections contain soil types with a topsoil rich in organic matter, sometimes even peaty horizons occur e.g. where the two branches interwine in the meandering drainage system in the field nearest Birkebæk. A profile description was made in this place as follows:

O_a (0–40): black, sand-mixed peat, well decomposed
L_{co} (40–85): olive-brown gyttje
G (85 →): well-sorted grey sand with groundwater at a depth of 95 cm.

The pedological development is weak in these soils, and there is often groundwater in the uppermost metres of the profiles. These soil types can be classified as histosols and gleysols. On the higher-lying plateaus there are comparatively well-drained podzols at different stages of development. Only in few of the podzols groundwater occurs in the uppermost metre. In good accordance with the aerial photograph of Rostrup, these soils have a light appearance on the picture.

CONCLUSION

When comparing the two areas Rostrup and Birkebæk it is seen that they differ essentially in appearance on the aerial photograph. The Rostrup area is well-drained and its valleys appear in light greytones, whereas the hills have darker greytones. The opposite is the case for the Birkebæk area of which large parts have a poor drainage and the small, often elongated depressions appear in dark greytones, whereas the relatively high-lying plateaus appear in lighter greytones. It was possible to distinguish podzols from well-drained cambisols and luvisols due to the migration of sesquioxides from the topsoil. In winter, when the fields are without vegetation, precipitation will cause a migration of humus from the uppermost sand grains and where podzols develop, the fields will get a whitish appearance. It can be concluded that without field investigations, aerial photographs are not well suited for soil surveying, because greytones are the result of an interplay between many factors which cannot be interpreted without investigations in the field. On the other hand, the aerial photographs proved of great value in combination with field studies where they were a very useful tool for drawing the soil boundaries. Reasonably applied, aerial photographs can reduce the number of drillings necessary for making a good map in a soil surveying. It must be emphasized, however, that only the condition of the topsoil will be known and that possible variations in subsoil texture — which may be of great importance for the fertility — will not be recognized.

RESUME

Denne artikel omhandler en undersøgelse af pankromatisk sort/hvide flyfotos egnethed ved jordbundskartering. Undersøgelsen blev foretaget i to områder, Rostrup og Birkebæk, nær Gadbjerg ca. 20 km vest for Vejle. Flybillederne (målestok 1:4500) blev taget i april 1977, hvor hovedparten af markerne var vegetationsløse. En jordbundsundersøgelse ud fra gråtonevariationerne på flyfotoerne og terrænformerne blev foretaget ved opboring af prøver fra den øverste meter af jorden. Tekstur, humus, pedologi og dræningstilstand blev vurderet.

Man fandt, at Rostrup var et veldrænet område af varierende tekstur, og hvor dalene på flyfotoet fremstod i lysere nuancer end bakkerne. Det lyse skær over dalene skyldes den svage podsolering af sandet, samt at humusen i de øverste millimeter af pløjelaget gennem vinteren er slået fra sandkornene. På bakkerne fandtes der ingen tegn på podsolering, og de jernoxiddækkede sandkorn giver selv fri for humus et brunligt skær. I Birkebæk, hvor der er udviklet et markant mikrorelief, fremstår de lave områder i mørke nuancer, medens de ca. en halv meter højere plateauer fremstår i lysere nuancer. Dette skyldes, at podsoller dominerer på plateauerne, hvorimod dårligt drænede, ofte tørvede jorder findes i de relativt lave områder. Disse kan sommetider have udformning som et dræningssystem.

Man kan generelt konkludere, at flybilleder kan være velegnede til grænsedragning mellem forskellige jordbundstyper, såfremt disse giver sig udslag i pløjelagets fremtoning (brunjorde/podsoller), medens teksturskift i underjorden ofte er umulige at erkende. Man kan endvidere konkludere, at flyfoto uden feltobservationer af jordbunden ikke er særlig velegnet, da gråtonerne dannes ved et samspil af mange faktorer såsom tekstur, struktur, pedologi, humus, sesquioxider og dræningstilstand, dvs. at en gråtone ikke entydigt kan relateres til en bestemt jordbundstype.

LITTERATUR

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DIE POSTSEDIMENTÄRE VERTEILUNG DER ADSORBIERTEN KATIONEN IM MARSCHBÖDEN

ARNE SKJOLDAGER

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DAS DÄNISCHE WATTENMEER.

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Die Watten werden zwei mal täglich und die Hochsänder werden nur bei extraordinärem hohen Hochwasser überschwemmt. Die Marschbildung findet teils auf der Ostseite der Barriereinseln und teils auf der Westseite der Küste Jütlands statt. Mit der Zeit hat eine Meeresspiegelsteigung in Kombination mit einer positiven Materialbilanz, teils wegen einer natürlichen Vegetation und teils wegen einer Landgewinnung eine Marschbildung statt gefunden.

Die großen Flüsse: Varde Å, Ribe Å, Brede Å und Viså, fuhren ihr Wasser in das Wattenmeer hinaus. Da diese Flüsse Material mitführten, entstand an einigen Stellen eine Binnengewässermarsch, wo die Küste zu dem betreffenden Zeitpunkt meist exponiert war, findet sich heute eine marine Vorlandsmarsch. (Vadehavet, Bygd 1976).

DER ZWECK DER UNTERSUCHUNG.

Das Ziel unserer Untersuchung war, ob die Verteilung der adsorbierten Kationen im Boden, von dem heutigen oder dem damaligen Milieu, zum Zeitpunkt der Entstehung der betreffenden Bänder, bestimmt wurde. Um zu einer vergleichenden Analyse kommen zu können, ist es notwendig abzuklären ob die Vergleichsgrundlage in Ordnung ist, d.h. in Bezug auf unsere Untersuchung, daß bevor eigentliche Vergleichungen angestellt werden können, müssen die Umstände und Zeitpunkte der betreffenden Marschbildungen festliegen.

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Denne artikel omhandler en undersøgelse af pankromatisk sort/hvide flyfotos egnethed ved jordbundskartering. Undersøgelsen blev foretaget i to områder, Rostrup og Birkebæk, nær Gadbjerg ca. 20 km vest for Vejle. Flybillederne (målestok 1:4500) blev taget i april 1977, hvor hovedparten af markerne var vegetationsløse. En jordbundsundersøgelse ud fra gråtonevariationerne på flyfotoerne og terrænformerne blev foretaget ved opboring af prøver fra den øverste meter af jorden. Tekstur, humus, pedologi og dræningstilstand blev vurderet.

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