Landsat, aerial photography and state factors in soil survey of arid and humid Patagonia, Argentina

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Frederiksen, Peter: LANDSAT, aerial photography and state factors in soil survey of arid and humid Patagonia, Argentina. Geografisk Tidsskrift 81: 39-48. Copenhagen, June, 1981.

The applicability of LANDSAT, aerial photography, and topographical maps was tested in relation to soil survey of humid and arid Patagonia, Argentina. Fieldwork was carried out as toposequence-studies in five vegetation zones and observations of roadcuts. These data were compared with LANDSAT and aerial photography. Only observations on state factors of soil formation were obtained. These showed as a first rough approximation a consistent relationship between observed state factors as expressed in land systems and stage of soil development.

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INTRODUCTION

Remote sensing techniques are very useful in identifying land systems. Common to most sensors is, that they register surface-features only. Therefore no direct information on stage of pedological development, heterogeneity of parent material in the profile etc. can be obtained with these sensors. But state factors of soil formation such as geomorphology, geology, vegetation, topography and hydrology are observable, and can be used as indicators of type and distribution of land systems and thereby as indicators of soil distribution.

During The Danish Scientific Expedition to Patagonia and Tierra del Fuego, 1978-79, soil studies were carried out in various places along the Andes, and later the applicability of remote sensing techniques to mapping of land systems and stage of soil development was tested.

DESCRIPTION OF THE AREA

Location

The area (approximately 40.000 km²) is located around lat. 41°S between long. 69°W and 72°W in northwestern Patagonia, Argentina, (see fig. 1).

Physiography

The physiography is complicated due to a combination of orogenic activity, the Pleistocene glaciations and an intrinsic lithology. To the west it is dominated by the Andes with numerous glacial valleys of the Pleistocene, now icefree except for the highest summits. Slope processes are active where the vegetation cover is insufficient, i.e. at higher altitudes. Volcanic material dominate where vegetation density is high enough to prevent the onset of slope processes.

The eastern part of the area has a complicated geology and physiography, which consequently influences soil distribution. Major land systems are valley bottoms, plains, pediments, undulating hills and playas.

Climate

The climate differs markedly from west to east due to a strong precipitation gradient produced by the Andes, which acts as a barrier. The cyclones coming from the Pacific Ocean shed most of their water content as orographic precipitation upon crossing the Andes, and thus reaches the eastern part as a drier system. On the Chilean side precipitation reaches 5000 mm/year, in the transition zone 60 km further east 800 mm/year and it falls below 200 mm/year in the extreme east, 250 km away. Potential evapotranspiration has an opposite trend due to higher cloudiness to the west. In the orogeny westfacing slopes tend to receive more precipitation than eastfacing, and northern slopes have a higher potential evapotranspiration due to astronomical reasons; less pronounced in the rainforest because of cloudiness. Many slopes show differences of up to 1000 metres between top and bottom and the temperature difference produce a notable vegetation distribution – see »Vegetation« below.

To the east climate is much more homogeneous because of the moderate topography and the mixing effect of strong westerly winds – an effect not encountered close to and in the Andes because of its sheltering effect.

Vegetation

The vegetation zonation is closely related to climate and has a vertical and a horizontal component. From west to east evergreen, temperate rain forest (Nothofagus dombeyi, Saxegothea conspicua, Fitzroya cupressoides, Chusquea culeou) pass into deciduous, leafshedding southern beech forest (Nothofagus pumilio) which grade into coniferous forest (Austrocedrus chilensis), then to grass-steppe (Stipa and Mulinum spinosum) and finally bushsteppe. A vertical zonation is found most clearly in the rainforest which upwards pass into Nothofagus pumilio (trees, later shrub-like), alpine vegetation and lastly a vegetation-free zone.

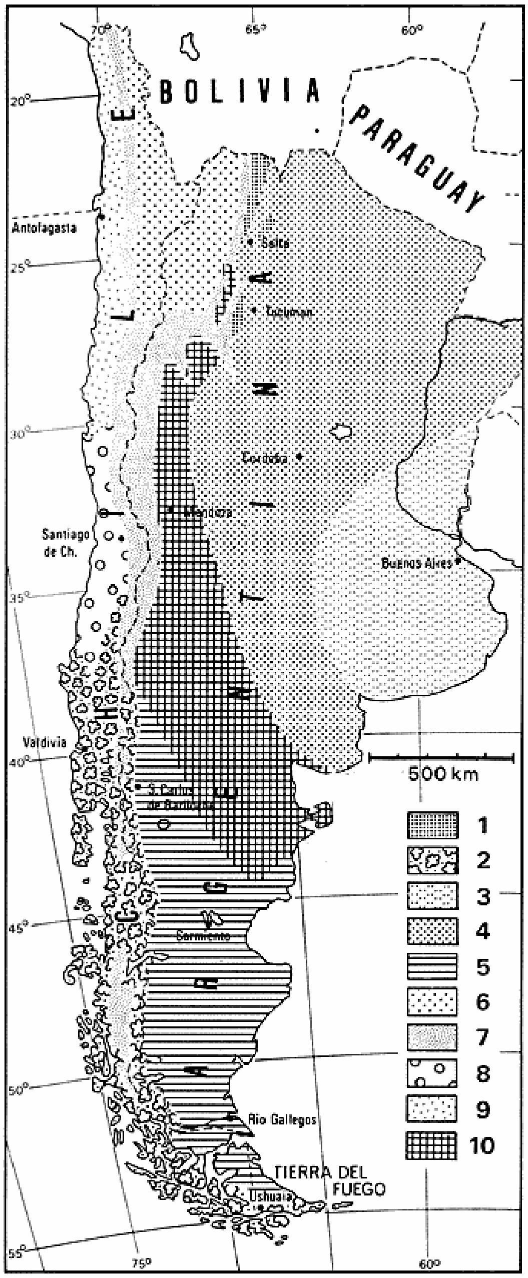


Fig. 1. The study area (around San Carlos de Bariloche), 1: Subtropical forest, 2: Southern beech forest (Nothofagus), 3: Pampas, 4: Xerophytic woodland and scrub, 5: Patagonian steppe, 6: Puna, 7: High andean vegetation and ice, 8: Xerophytic scrub (mediterranean type), 9: Semidesert and desert, 10: Monte and prepuna. Vegetation zones 2, 5 and 7 are found in the study area.

Fig. 1. Studieområdet (omkring San Carlos de Bariloche), 1: Subtropisk skov, 2: Skov af sydbøg (Nothofagus), 3: Pampas, 4: Chaco, 5: Patagonisk steppe, 6: Puna, 7: Højandin vegetaion og is, 8: Maki (mediterran type), 9: Halvørken og ørken, 10: Monte og præpuna. Zonerne 2, 5 og 7 findes i studieområdet.

MATERIAL AND METHODS

Material

LANDSAT, MSS 5 from 2nd and 3rd of March, 1973 (late summer)
Aerial photography, scale 1:71,500, B & W, summer
Topographical maps (1:100,000)
Soil map, 1:200,000 (INTA, Bariloche).

Methods

Fieldwork comprises reconaissance on soil development, vegetation and physiography by car, toposequence-studies in selected places of the above-mentioned vegetation zones and much contact with local inhabitants.

Laboratory work was carried out with an interpretoscope and the drawing of boundaries between land systems were based on texture, tone, pattern, form, position of object in landscape and field experience.

DISCUSSION AND RESULTS

As the eastern two thirds of the area has a very sparse vegetation with easy observable physiography and the western third very dense vegetation, and as the vegetation zones roughly coincide with the major physiographical and climatic division, it was decided to subdivide into land systems of considerable vegetation (forest), areas of transition (forest/steppe) and areas of sparse vegetation (grass- and bush-steppe).

The zones are bound from within, and any lines drawn on these maps are only an attempt to show that differences exist between the various areas – a line does not indicate any immediate and drastic change.

Aerial photographs, the forest

The following land systems based on vegetation type and %-cover are distinguished on the image (see table 1 and figure 2).

a. Evergreen rainforest (Valdivian), dominated by Nothofagus dombeyi, is identified by having a round, cloudy crownrim of coarse texture explained by the vertical heterogeneity of the rainforest quite similar to that of tropical rainforests. According to Weinberger (1973) it belongs to a more oceanic and less xerothermic climate, but resisting considerable atmospheric and physiological saturation deficits for short periods in an otherwise oceanic climate. McQueen (1977) gives the upper limit on eastern and western slopes in Argentina at lat. 40°S to 1000 metres. This coincides very well with field experience, best observed in autumn where Nothofagus pumilio of zone b has yellow/red leaves.
b. Defoliating forest dominated by Nothofagus pumilio grading from tree to bush-like with increasing altitude of fine (even) texture on the image due to a more even crown-topography than Nothofagus dombeyi, dominates this zone between 1000-1200 metres on western slopes and 1000-1400 metres on eastern slopes. In

Table 1.

AERIAL PHOTOGRAPHS			
Forest			
>70% vegetation			
Pumilio		Probably higher C/N than dombeyi	Medium, grey
Very steep (>60°)		AC/OAC	} Separated on the basis
Less - (<60°)	+	A(B)C	of stereovision
>Dombeyi	+	Thicker A than Pumilio zone	Coarse, grey, cloudy crown rim
Slope			
Very steep (>60°)		AC/OAC	} Separated on the basis
Less - (<60°)		A(B)C	of stereovision
Valleybottom		A(B)C/AC/AOC/O	
<70% vegetation			Medium to fine, grey and fine, very light grey, rock pattern, high/steep
0-10%		0-10% AC	} Separated on the basis
10-30%		10-30% AC	of dominance of one of the
30-70%		30-70% AC	two types (rock/veg.)
Steppe			
Organic	+	OAC	Fine, black
Mineral			
Consolidated rock			
Basement w.cover	+0	(A)C to no soil	Very coarse, dark grey, random outcrop pattern, rounded outcrops
Few outcrops			} Separated on the basis
Many outcrops			of number of outcrops
Sedimentary	0	(A)C to no soil	I ll- defined, dark to light grey, stratified, folded
Unconsolidated			
Glacial		AC/(A)C	
Moraine	+		Coarse, light grey to grey, random pattern, moraine arcs
Outwash plain	+		Fine, light grey, cone-shaped
Lacustrine plain	+		Fine, light grey, plane (3-D)
Others			
Pediment		(A)C	Fine, grey, parallel river pattern
Alluvial			
Without veg.		No soil	Very coarse, very light to very dark grey, meander and braided
Some -		(A)C *)	Coarse, light grey, braided
Abundant -			Coarse, river pattern
Humid		AC	, dark grey
Dry		(A)C	, grey
LANDSAT			
Forest			
70% vegetation		A(B)C/AC/OAC/O	Fine, dark grey
10-70% vegetation		AC	Coarse, grey and dark grey
<10% vegetation		No soil	White to light grey
Steppe, see text			
Transition, see text			

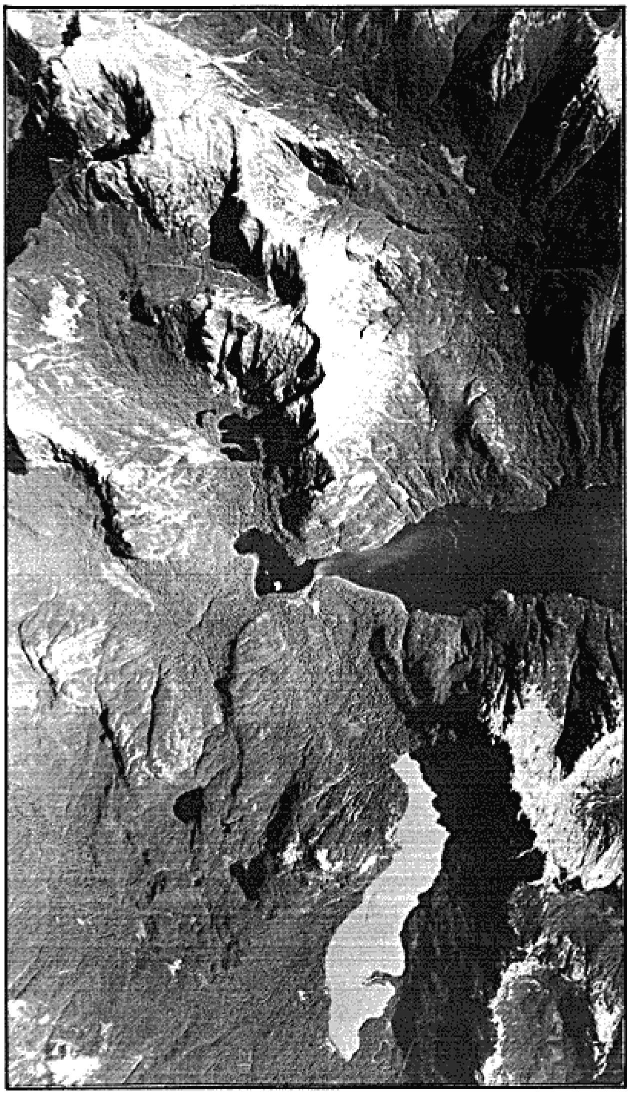
\+ Fieldwork essential   0 With help of INTA-map   *) Under vegetation only

Table 1. Classification key of forest (aerial and LANDSAT) and steppe (aerial) including a list of observed features, necessity of field identification, related soils and characteristics of the image used to define them.

Tabel 1. Klassifikationsnøgle for skov (flyfoto og LANDSAT) og steppe (flyfoto), der inkluderer en liste over observerede landskabstræk, de nødvendige observationer i felten, de relaterede jordbundsprofiler og de karakteristika ved billedet, der er benyttet for at definere dem.

autumn zone b is recognized by the absence of leaves or yellow/red leaves and forms the timberline in most places. Nothofagus pumilio is seldom found in well-drained valley-bottoms as these are in the altitude range of Nothofagus dombeyi. There is a gradual transition from zone a to b and from zone b to c.

c
and
d. Scattered vegetation (10-70% covered by vegetation) of Nothofagus pumilio/Nothofagus antarctica (resist lower temperatures and higher daily temperature variation than Nothofagus pumilio). It is recognized as a mosaic of zone b texture and very light grey to grey (on low sun-angle sites) rock structure on the image – that



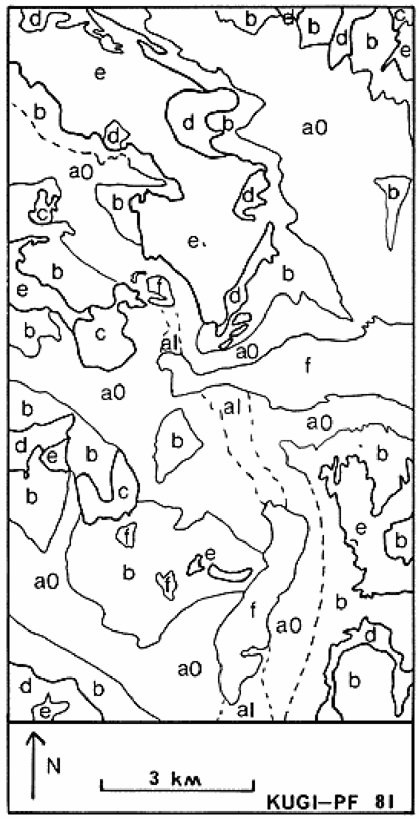


Fig. 3. Aerial photography, the steppe. a: organic soils, b: basement c: sedimentary rocks, d: moraine, e: outwash plain, f: recent alluvial, g: pediment, h: lacustrine, m: lake. For further explanation, see text.

Fig. 3. Flyfoto, steppen, a: organisk jord, b: nøgen klippe, c. sedimentbjergarter, d: morœne, e: hedeslette, f: recente alluviale dannelser, g: pediment, h: lacustrine dannelser, m: sø. For yderligere forklaring, se teksten.

Fig. 2. Aerial photography, the forest. a: Nothofagus dombeyi (a 0: slopes, a 1: valleys), b: Nothofagus pumilio, c: 30-70% vegetation, d: 10-30% vegetation, e: <10% vegetation, f: lake. For further explanation, see text.

Fig. 2. Flyfoto, skoven. a: Nothofagus dombeyi (a 0: skrænter, a 1: dale), b: Nothofagus pumilio, c: 30-70% vegetation, d: 10-30% vegetation, e: <10% vegetation, f: sø. For yderligere forklaring, se teksten.

is, a zone where vegetation in some places is too weak to resist the action of slope processes, snow cover and low temperatures.

e. Vegetationfree zone of bare rock is identified as having a very light grey tone with rock structure. This is the zone of active slope processes noted especially by various traces of avalanches into underlying zones. The lack of vegetation is due to the low temperature and long snowcovered period in most places, because the gradient of the slope is constant from top to bottom and the slope is covered by vegetation in its lower parts. In other cases it is because of too steep a gradient with subsequent erosion on these slopes. Of couse, combinations occur. It is characterized by soils of coarse textured, gravelly, stony and bouldery material arranged in lines or avalanches and the absence of volcanic ash, which has been eroded and deposited at lower slope-sites.

f. Lakes – no comments.

How is this zonation of land systems correlated to soil distribution? Generally, zone c, d and e are without soil development (eventually weakly developed AC soils with high C/N in the A in zone c and d) and mainly of so coarse texture that it has no meaning to talk of soil at all. Zone a and b normally have a soil developed. These can definitely not be separated exactly on the image, but Lithosols are mainly found on the steepest slopes, the Histosols and Fluvisols in valleybottoms. Valley-bottoms are easy to observe on the image, but the two soil-orders are impossible to separate on the image because of the dense vegetation. Andosols A(B)C soils are found on positions intermediate between valley bottoms and steeper slopes (al), that is, in well-drained areas of moderate inclination and absent slope processes. Andosols might also be found in valley-bottoms where volcanic ash overlies other sediments.

Summarizing, only general conclusions can be drawn on the basis of observable state factors (topography, physiogra-

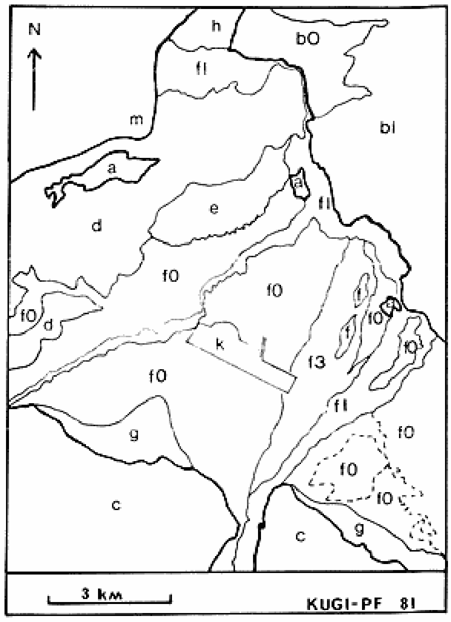


Fig. 3. Aerial photography, the steppe. a: organic soils, b: basement c: sedimentary rocks, d: moraine, e: outwash plain, f: recent alluvial, g: pediment, h: lacustrine, m: lake. For further explanation, see text.

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phy, vegetation) in relation to pedology – fieldwork is absolutely necessary in this case, not only in order to improve borders, but also to localize the major soil orders of zone a and b. On the other hand, zones a and b-soils differ greatly from zone c, d and e-soils and a line can easily be drawn between these on the image.

Aerial photographs, the steppe

Based on geomorphology the area is divided into land systems of organic and mineral materials with further subdivisions of the latter into consolidated rocks of pre-Quaternary origin (sedimentary and magmatites), unconsolidated sediments of Pleistocene age (moraines, lacustrine deposits and outwash plains) and Holocene sediments (recent alluvial deposits) (see table 1 and figure 3).

Especially the Pleistocene sediments are covered by volcanic ash mixed with other aeolian material.

a. Associated either with backswamps or spring water, soils with organic material are identified by their black tone of even texture. They grade into the humid mineral soils.

b. Basement (INTA-map), identified by the very coarse texture, dark grey and a random outcrop pattern with rounded outcrops on the image is dominated by Lithosols on the top and Regosols on the corresponding pediment, separated on the basis of areal coverage of outcrops (bl many outcrops, b0 few outcrops).

c. Folded or faulted sedimentary rocks of marine, Tertiary origin and identified by strata and a close drainage net. Most of the soils are coarse-textured and shallow to nonexistent.

d. The moraine (probably terminal) is recognized on the basis of form (characteristic arcs) and the uneven texture on the image. They consist of coarse-textured material with AC-soils developed in the fine-textured volcanic ash.

e. The glaciofluvial outwash plain is grey and of fine texture on the image, and reaches out as a cone of coarse-textured material from the moraine. It has been eroded in its sides by later rivers perpendicular to the outwash plain. The soils are probably mainly AC-soils. Field-identification essential.

f. Holocene alluvial deposits are easilly recognized by the braided river system, easily seen on the image. The regime of these rivers is niveal, dominated by a high discharge during snowmelt, at times resulting in inundations, and very low to nearly zero discharge in late summer. This is seen on the images as zones of varying vegetation intensity with the zones of most frequent inundations being the present river course (fresh material) and its immediate surroundings. Here no pedogenesis have taken place (fl.) Outside periods of very high discharge the river is diverted southwards instead of continuing straight out upon leaving the mountains. The river follows the straight course only in periods of very high discharge, where its inertia inhibits diversion. This area is dominated by (A)C-soils with the (A) found mainly below plants (f3). The highest vegetation cover is found where only exceptionally high discharges produce inundations (f0), (suffix a means sparse vegetation, suffix b moist soil). It seems, however, that the whole river system might oscillate, thus changing this vegetation and soil pattern.

g. The corresponding pediment of zone c is identified by its topographical position and parallel running rivers with AC-soils developed.

h. Lacustrine plain only observable in the field (AC-soils) developed in the volcanic ash overlying the sediment of lacustrine origin.

Hydrological subdivisions
Most of the soils have a very high permeability and low water retention, and as rain mainly falls in winter, water is scarce in the growing season. For that reason some of the areas have been subdivided on the basis of water content. High water content areas are easily noted on the image by its darker colour, but not as dark as the organic soils. The division on the image is a rough approximate.

Summarizing, soils of pre-Quaternary rocks are very shallow to absent, soils on Pleistocene sediments with volcanic ash cover are of AC-character, recent sediments have (A)C to nonexistent soils.

LANDSAT
Not every land system could be field-identified because of low car-accessibility, but in some of the cases it is greatly aided by maps of INTA (Bariloche) that have classified part of the area according to the Australian land system. The following land systems are distinguished on the image (see table 1 and figure 4).

LANDSAT, the Forest
On the image snow-covered areas coincide with the areas lying above the timberline and encircling these (areas without number) separate the zone of soil development (No. 1 and 2) from the zone without soil development. In some cases bare rock is observed at lower elevations. This area is enclosed in the area without soil development. Images from summertime will not have snow, but anyway the tone of rock is much lighter than that of Nothofagus dombeyi and pumilio vegetation (zone 1) and can then still be separated. These last two zones (No. 1) are difficult to separate visually, observing the LANDSAT-image only, but can eventually be done approximately by using topographical maps (1:100,000), ecological data and the LANDSAT-image. Another possibility not implemented here would be to produce a false colour composite of the scene from a date when all Nothofagus pumilio down to the transition to Nothofagus dombeyi have changed its leaf-colour to red/yellow or eventually defoliated contrary to the evergreen Nothofagus dombeyi. Even better would be a tape. As the tree-limit is of some importance, it is necessary either to have an image after the leaves have changed colour, but before much snow has fallen, which may be difficult, because of cloudy weather in this season, or using an image from spring, when early leaves of Nothofagus pumilio have a light-green colour and Nothofagus dombeyi maintains its darker green leaves.

Major valley-bottoms (No. 2) are easilly observed, but only differentiation with respect to large, open or forest-covered areas is possible.

LANDSAT, the Forest/Steppe Transition
The forest/steppe transition lies in the area topographically influenced by the Andes orogeny mainly covered by Austrocedrus chilensis and Nothofagus antarctica with a relief intermediate between that of the forest and steppe zones. Vegetation is often found in the valley-bottoms, where water concentrates.

X. Strong relief with many dissected valleys, coarse texture (Lithosols).

Y. A more undulating relief, probably glacially eroded of medium texture and grey colour (Regosols dominate).

LANDSAT, the Steppe
The eastern area is diffentiated on the basis of physiography and parent material, as these are the most variable state factors. The different physiographical/geological division has been made on the basis of tone, texture, drainage pattern, position in the landscape and topography. Soils are generally shallow and coarse-textured, irrespective of parent material with AC and (A)C soils dominating (Lithosols, Regosols, Yermosols and Xerosols).

A. *The basalt areas* (A 1-3) are recognized mainly on the

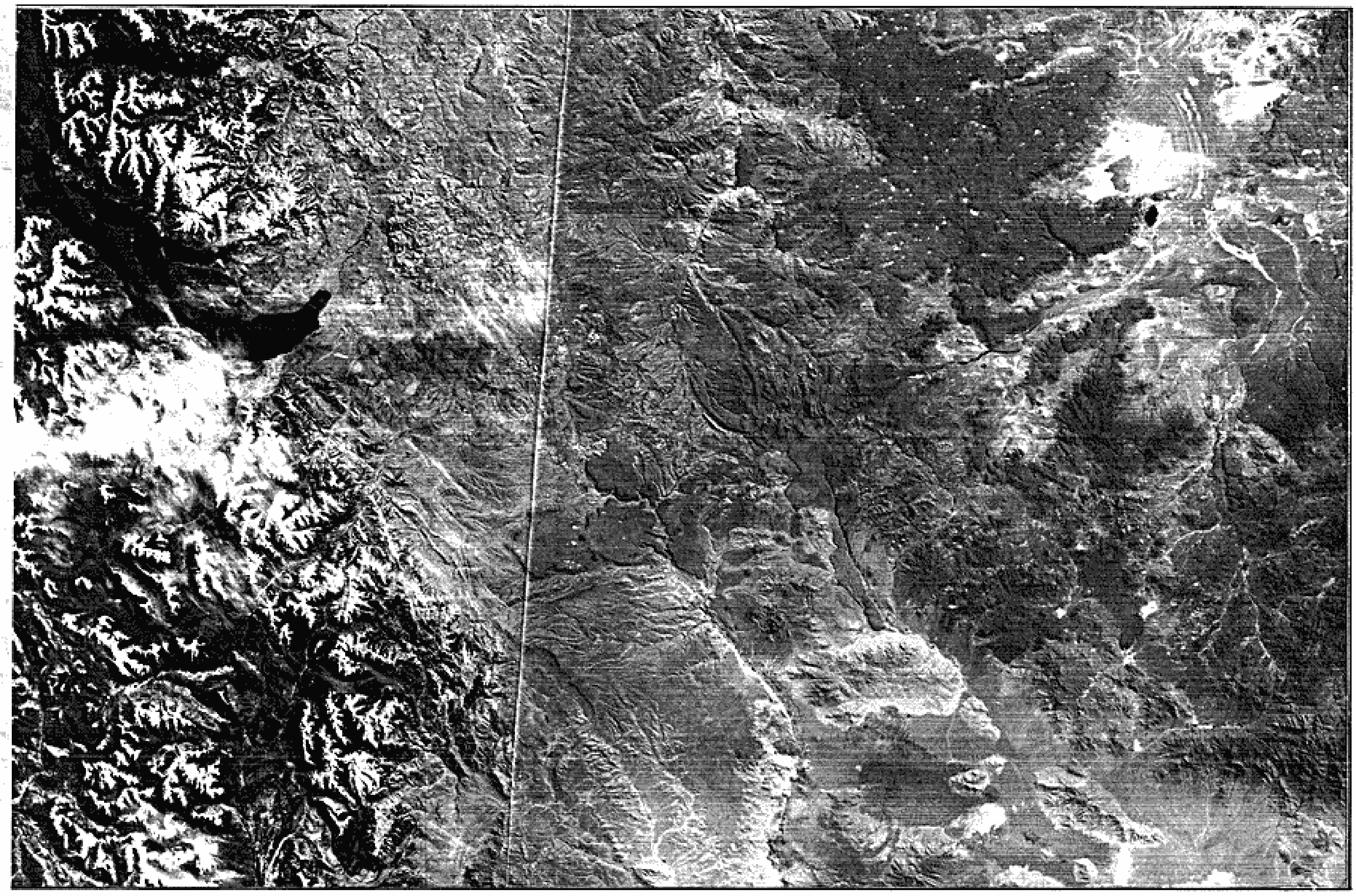

Fig. 4. LANDSAT: Forest. 1: >70% vegetation, 2: 10-70% vegetation (mostly valleys), 3: clouds, 4: lakes, 5: glacier, without number: <10% vegetation. Forest/steppe transition. x: hilly, y: undulating. Steppe. A: basalt, B: basement with meso-siliceous effusive rock, C: hills, weak relative relief, D: hills, medium relative relief, E: pediments, F: major valleys, G: dissected hills, H: sedimentary rocks, I: salt-lakes, J: arcs (morainic ?), K: plains and dissected plains, L: outwash plains, M: mesosiliceous effusive rock, N: cretaceous sediments, O: dissected plains, P: clouds. For further explanation, see text.

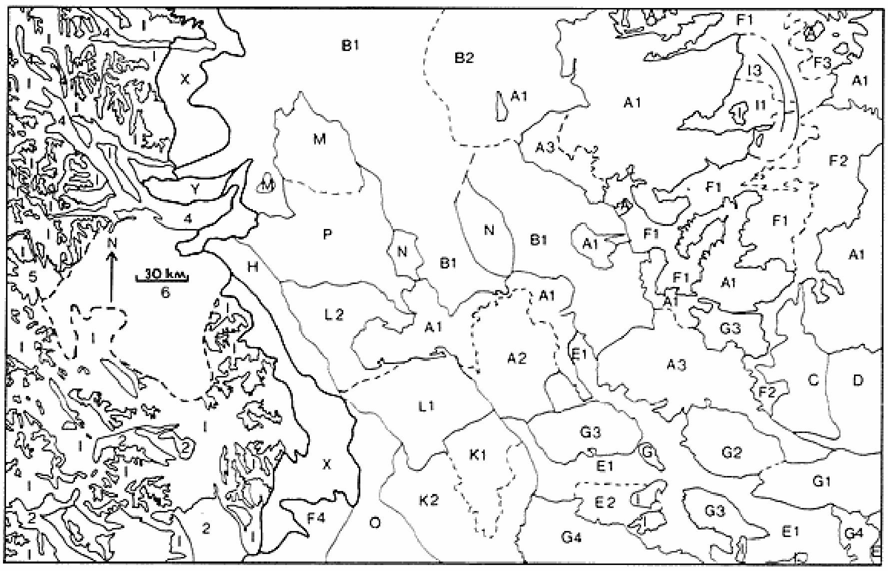

Fig. 4. LANDSAT: Skov 1: >70% vegetation, 2: 10-70% vegetation (hovedsageligt dale), 3: skyer, 4: søer, 5: gletschere, uden talangivelse: <10% vegetation. Skov/steppe overgang x: bakket terræn, y: bølget terræn. Steppe. A: basalt, B: bar klippe med effusiv-bjergarter af mesosilikater, C: bakker med svagt relativt relief, D: bakker med medium relativt relief, E: pedimenter, F: større dalsystemer, G: opdelte bakker, H: sedimentære klipper, I: saltsøer, J: buer (morœner?), K: sletter og opdelte sletter, L: hedesletter, M: effusiv-bjergarter af mesosilikater, N: kridttids sedimenter, O: opdelte sletter, P: skyer. For yderligere forklaring, se teksten.

basis of their dark colour, and are subdivided on the basis of surface topography and pattern. A 1 are the basalt mesetas characterized by a very fine texture and a drainage pattern only well-developed at its borders. Associated with these are soils with a high salt content in small, mostly circular depressions of the meseta. Whether the salt is an aeolian accumulation phenomenon deposited during one of the current duststorms of Patagonia and thus allochtonous, or a dissolution phenomenon of the basalt with following local higher concentrations in depressions is not clear as both types occur in Patagonia (zones F 3 and I 1). A 2 is a very heterogenous area of coarse texture, dark grey and grey tones (image-characteristica) and a more rugged surface topography than the mesetas. A 3 is a coarse-textured heterogenous area with many slopes, probably produced by degradation of a former plane surface, but as the pattern on the image is very complicated in this part and no fieldwork has been carried out in A 3, its classification as A, belonging to the basalt, is tentative. According to INTA all soils are shallow.

N. Cretaceous sediments (INTA) have a dark tone, fine texture and a plane surface dissected by near-parallel rivercourses resembling some of the basalt areas. Soils are coarse and shallow.

L. Outwash plains from the Pleistocene deglaciation are recognized by their braided drainage pattern and a fine texture in between the major drainage channels. L 1 consists almost entirely of this plain whereas L 2 probably is a complex of outwash plain and other landforms (INTA).

O. Dissected plains at different levels and some hills of coarse and a grey tone.

K. An area consisting of a plain (K 1) (fine texture, grey) surrounded by dissected parts, probably of that plain (K 2) (light grey, coarse texture).

H. Sedimentary rocks (INTA) in parallel rows of coarse texture and variable tone. According to fieldwork soils are very shallow to non-existent.

B. *Basement* with meso-siliceous efusive rock (according to INTA) (zones B 1-2) is a heterogenous grey area of varying texture, topography and drainage density (mostly dense) delimited and identified with the help of the INTA-map. It is subdivided on the basis of topography into B 1 which has a less pronounced relative relief than B 2 because of faulting in the latter.

C. Hilly area of weak relative relief and a low drainage density.

M. Meso-siliceous efusive rock (INTA) raised above the surrounding landscape is characterized by its coarse texture, raised position and relative deeply dissected valleys.

D. Hilly area (D), dark grey, medium relative relief and a high drainage density.

G. Dissected hills of stronger relief than C and D surrounding the pediments (E) or plunging up through them.

E. *Pediments* of larger extensions are recognized by their topographical position and many blind often converging river courses and a fine texture. They consist of coarse-textured material with only shallow soils and are found in the southern part of the area where they enter into the sequence rock-talus-pediment-playa. A subdivision into grey (E 1) and dark grey (E 2) areas may imply botanical/hydrological/geological differences.

F. *Major valleys* are recognized mainly on the basis of form and topographical position low in the landscape, subdivided into saltfree valleys (F 4) (fine texture, grey and without white salt patches), partially salt-covered valleys (which with their patchy pattern produced mostly by blowing of salt are subdivided into grey valleys (F 1) and dark grey valleys (F 2)), and lastly valley-bottoms covered by salt (F 3) distinguished from saltlakes by their topographical position in an inclined valley system. They are found only east of saltlakes from which the strong westerly winds transport salt, silt and sand during duststorms up into the valley where it is halted, deposited and thus forms a thin cover on top of the alluvial coarse-textured sediments.

I. *Saltlakes* and playas are identified mainly by their light grey to white colour, fine texture and low position in the landscape. They receive input of fine-textured material and many dissolved salts during rainfall with subsequent evaporation in dry periods producing a hard crust difficult to penetrate with auger. They are takyrs (II) (Russian nomenclature), in some cases with lakes of water in their central part (I 2). In a takyr a pH ($CaCl_2$) of 8,6 decreasing to 7,3 deeper in the profile indicate a dominant upward percolation, whereas a soil outside the takyr had a pH ($CaCl_2$) of 7,1 in the surface increasing with depth to 7,7 indicating some downward percolation.

J. A system of arcs, perhaps terminal moraines.

P. Clouds, shadows and geologically complicated areas without subdivision.

CONCLUSIONS

Vegetation and physiopgraphy were the state factors most easily observed on the images. Vegetation was most directly related to climatic zonation and therefore used at highest level in the classification dividing the area into forest, forest/steppe and steppe.

In the forest vegetation type (apply to climate) and %-cover (apply to erosion resistance and climate) was used in subdivisions. Physiography was used at the lowest level because its role is subordinate to that of vegetation.

In the forest/steppe trees are scattered with shrubs in between. Resistance to erosion is therefore more dependent on physiography for which reason this is used at highest level attempting to divide into soil/non soil.

In the steppe vegetation is sparse and monotonous and

physiography and parent material was used at highest level because differences in these factors separated soils of differing physical and mineralogical composition. Different keys were used for LANDSAT and aerial photography as LANDSAT covers a much larger area and with less detail.

LANDSAT is excellent for small-scale regionalization of major land systems of arid lands and of vegetation distribution in humid areas giving an overall view and a general introduction to the study area. It could be used in the forest as a first rough approximation for differentiation of vegetationless (no soils) and vegetationcovered (A(B)C/AC soils) slopes with further subdivision of vegetation into evergreen and defoliating forest possible. As slope is difficult to observe the differentiation into steep and less steep areas in the vegetation-covered zone is very difficult. Valley-bottoms (mainly Fluvisols and Histosols) observable. In the steppe major landforms such as meseta, playa, pediment, plains, valleys and hilly areas, all with weakly developed AC or (A)C soils could be identified, but except from observation of strongly saline soils and their separation from less saline soils by division of the area into saltcovered and other areas no direct extrapolations could be done without fieldwork. The areas of the steppe identified on the aerial photograph could only be roughly identified on the LANDSAT, and only when aerial photographs were observed before the LANDSAT. This underlines the difference in scale and the sequence in which the different images are viewed.

Aerial photographs

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Topographical maps (1:100.000).

Computer Assisted Cartography for Multitemporal Observations

OLE HEBIN

Hebin, Ole: Computer Assisted Cartography for Multitemporal Observations. Geografisk Tidsskrift 81: 48-54. Copenhagen, sept. 15, 1981.

This paper describes the construction and use of an automated system for drawing maps in multitemporal surveyed areas. In the system are included many options for plotting and the analysis procedures. The system is called COMA (Computer Assisted Mapping).

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INTRODUCTION

The scope of this paper is to show how computer assisted cartography can facilitate the geographers task in analysing multitemporal observations carried out in the same physical or abstract area.

As stated in the title we are concerned with a system that handles many maps of the same area surveyed at different time-points. The goals set out for the system are:

1. It must be easy to use for persons not familiar with computer technic.
2. It must answer the questions raised by the research worker.
3. The turn-around time from surveying to the produced map must be short.
4. It should be an inspiration for applying new technical tools that have not previously been used because of their requirements of work.
5. The graphical output should be nice and clean, although it is not intended to produce maps of the high quality that are made by skilled cartographers.

Of course there are a series of subsidiary goals specified concerning: reliability, speed, storage use, input and updating procedures and, last but not least, cost.

THE COMPUTER CARTOGRAPHY SYSTEM

The system is split into two main parts which are the database and the manipulating procedures, but as the two are closely integrated in the soft-ware and their applications interwoven this paper will not stress this feature - instead the users line of work will be considered the structuring principle.

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