The Third Danish Scientific Expedition to Patagonia and Tierra del Fuego, 1982-83.

Peter Frederiksen

Frederiksen, Peter: The Third Danish Scientific Expedition to Patagonia and Tierra del Fuego, 1982,83. Geografisk Tidsskrift 84: 1-5. Copenhagen January 1984.

Soil and landscape mapping of Tierra del Fuego and Patagonia austral was executed based on LANDSAT false colour composite images, and ground control (augerings and profile studies). A clear relation between 1) the images patterns and land units was established. Further a basis for comparison between northern and southern hemispheric soil development in regions influenced by Pleistocene glaciations was established.

Peter Frederiksen, M.Sc., Graduate in soil science. Geographical Institute, Haraldsgade 68, DK-2100 Copenhagen Ø.

Keywords: *Tierra del Fuego, Patagonia austral, regional pedology, quaternary landscape development.*

The expedition continued soil and landscape investigations undertaken during The First Danish Scientific Expedition to Patagonia and Tierra del Fuego, 1978-79 (Madsen et al, 1980). The work is part of the departments studies in regional pedology of areas influenced by Quaternary glaciations – Scandinavia, Greenland and Tierra del Fuego. The latter is the only region in the southern hemisphere which is not dominantly volcanic, and which has been extensively glaciated, excluding Antarctica.

The specific purpose was to map soils and landscapes of Tierra del Fuego and Patagonia Austral.

THE STUDY AREA

Location

The area is the southernmost part of South America and lies from latitudes 52°S-56°S and longitudes 65°W-72°W, thus covering all of Tierra del Fuego and part of Patagonia Austral (see fig. 1).

Tierra del Fuego is an archipelag made up of a main island and numerous smaller ones – among others Cape Horn, the southernmost tip of South America. The Atlantic and Pacific oceans, the Strait of Magellan and the Drake Passage surrounds the archipelag.

Patagonia Austral is the southernmost part of continental South America separated from Tierra del Fuego by the Strait of Magellan.

State factors of soil formation

Jenny's formula, that soil is a function of topography, parent material, climate, flora, fauna and time, may be taken as a useful working hypothesis in works of pedogenesis and regional pedology. It is therefore of importance to know the dynamics and distribution of these factors before starting and extensive soil and landscape survey.

Topography

The region may be divided into a mountaineous southern and a more undulating northern part (see fig. 2). The former can be subdivided into to coastal, central, *Brunswick* pre- and *Fuegian* pre-Cordillera, and the latter into the Quaternary *Rio Grande Basin, Filaret lowlands, Manantiales lowlands, Oazy Harbour lowlands, Boquerón highlands, Cullen high plain* and *Ciaike high plain* and furthermore the Tertiary *Flamenco hills.* Underlined names are new terms in a region lacking a consistent natural physiographical division in some areas.

Geology

Present day regional geology is mainly a combination of orogenesis, marine sedimentation and glaciations.

In plate-tectonic terms it consists of a fossil stable continent, marginal basin and island arc (Dalziel et al, 1974). The stable continent was during the Mesozoic exposed to cycles of marine transgressions and regressions. Conglomerates, lutites, arenites and other marine sediments deposited in what is called the Magallanes sedimentary basin north of the present Cordillera.

The Mesozoic batholith along the Pacific continental margin probably represents the root of an andesitic volcanic chain initiated on South American continental crust by the late Jurassic. Later intrusions of basaltic magma into the continental crust created a marginal basin between the continents crust and a volcanic island arc, later infilled by andesitic detritus from the active arc during

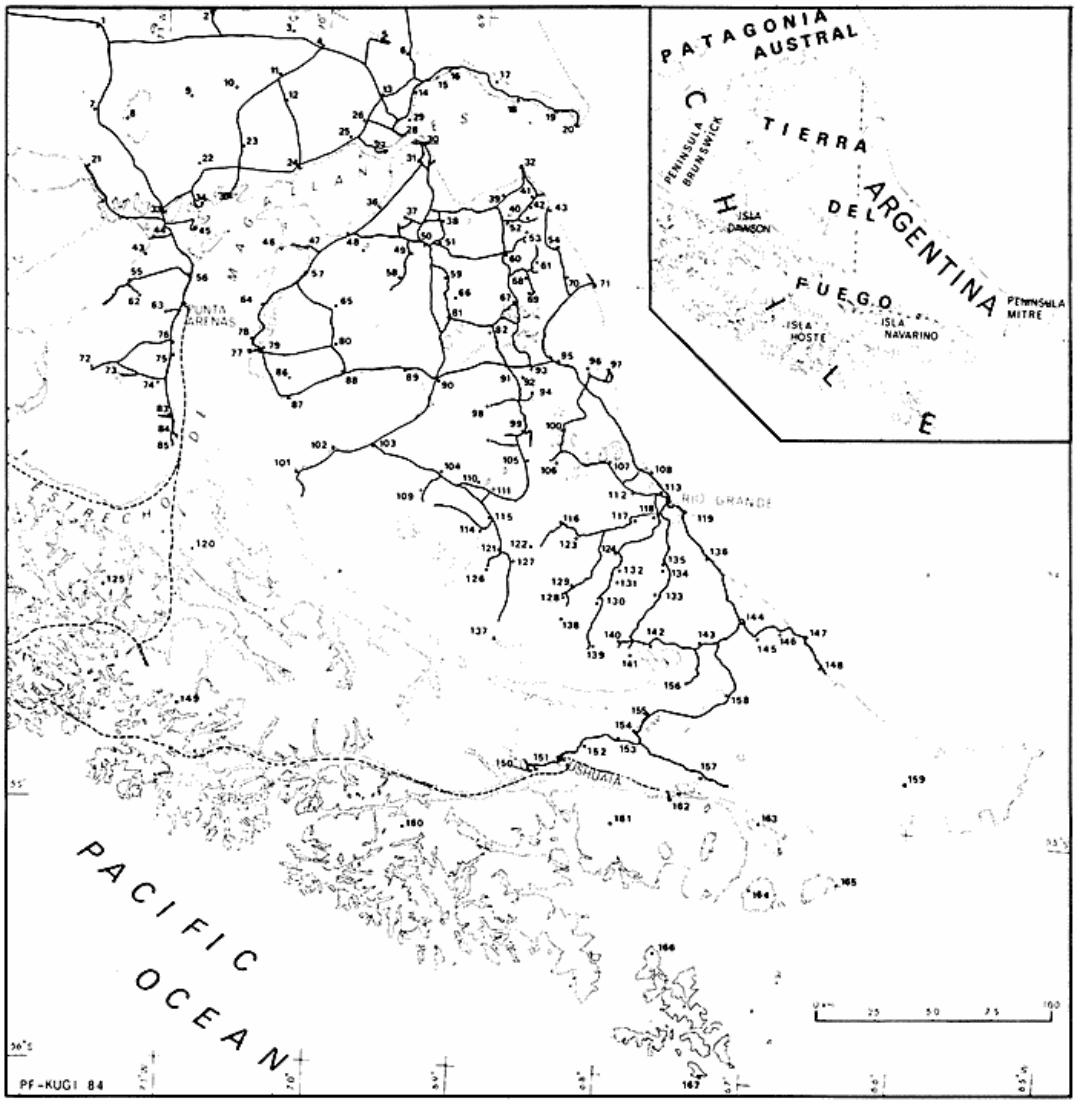

Fig. 1. The study area with expedition route

Fig. 1. Undersøgelsesområdet med ekspeditionsruten

early Cretaceous. During middle Cretaceous the basins rocks deformed when the volcanic arc collided with the continent, metamorphism, igneous activity and uplift followed ceasing in Tertiary.

At the end of Tertiary climate cooled, and during Pleistocene various glaciations resulted in the deposition of glacial and glaciofluvial sediments over most of the study area followed in Holocene by slight volcanic activity (Caldenius, 1932).

Remnants of the andesitic Mesozoic batholith constitute a major part of the archipelag south of the main island of Tierra del Fuego, remnants of the marginal basin and Paleozoic stable continent the central Cordillera, the sediments of marine transgressions the marginal Cordillera north of the central Cordillera, which underlie the present day lowlands of the study area covered by sediments of the Pleistocene.

Climate

The area is situated in the zone of the Southern Westerlies and the Circumantarctic Current.

The westerlies consists of an eastward latitudinal flow of maritime polar airmasses, moving at very high velocities. They originate in a circumhemisperic band between the Subtropical Convergence zone (average latitude at 41°S) and the Antarctic pack ice. The airmasses move nearly exclusively over oceans (the Pacific, Atlantic and Indian Oceans) except where they cross southern South

America and New Zealand's South Island, thus being much more maritime and regular in nature than their northern hemisphere counterparts (van Loon et al, 1975). They give the region a maritime climate with strong westerly winds.

The Circumantarctic Current is driven by the westerlies and also shows a near-strict eastward latitudinal flow pattern. Upon reaching the south Chilean coast, it upwells and diverges with one branch moving through the Strait of Magellan, channels of the archipelag and the Drake Passage. Its temperature is low, 5-10°C, thus maintaining the maritime polar airmasses much colder than those of the northern hemisphere at an equivalent latitude, where the warmer Golf Current produce higher air temperatures.

That part of the maritime polar airmasses which pass over the Andes, loose a major part of their moisture content, as they are forced to ascend over the mountain barrier, thus reaching Patagonian and Fueguian lowlands as a much drier system. Furthermore the circumhemispheric band of maximum frontogenesis frequency run through the region. Thus precipitation may reach 10000 mm/year on the Pacific side and in the central Cordillera (Marangunic, personal communication), decreasing hyperbolically towards the Atlantic side down below 250 mm/year.

Vegetation

Four major plant communities with many subdivisions may be distinguished: steppe, forest, wet heathlands and bogs. They reflect the following ecological features: precipitation, physical impact of wind, temperature, drainage, moisture retention, soil salinity, soil acidity and soil depth (Pisano, 1977).

The steppe occupy the dry lowlands north of the Cordillera and are dominated by Festuca species, with numerous variations. At the borders of saltpans and in salt marshes Salicornia is found, Lepidophyllum in sandysilty sediments with a certain salt content, and Hordeum and meadows in soils with an intermediate salt content. Empetrum rubrum, eventually Bolax gummifera on acid soils of older glacial sediments (dry heathlands) and Chiliothricium diffusum on soils with a certain moisture content. In the forest region Festuca intrudes in glaciofluvial valleys with gravelly and stony sediments.

The deciduous forest cover a band between the steppe and the central Cordilla (approximately corresponding to the pre-Cordillera), furthermore the Carmen Sylva range – probably due to higher relative humidity, finer textures of soil and deeper soils than in surrounding steppe areas, and lastly in a narrow band along the eastern coasts of the Beagle Channel, which separate the main island from the rest of Tierra del Fuego. Its main constituent are Nothofagus species – N.antarctica on poorly drained and coarse-textured localities, and in the foreststeppe transition; N. pumilio closer to the central Cordillera, and along the coasts of the Beagle Channel where they are mixed with N.betuloides. The timberline is at approximately 600 m.a.s. Fine-grained, moderately well or better drained, non-exposed, slightly acid sites with more than approximately 350-400 mm precipitation/year are favorable localities for forest growth.

Wet heathlands develop under exposed conditions, and are dominated by Empetrum rubrum growing on peat or rocky soils. They cover mainly the archipelag south of the Beagle Channel, the Peninsula Mitre and the western part of the main island. The Empetrum rubrum dry heathland communities of the steppe are not part of the wet heathlands. Dwarf-shrub heathland of Empetrum rubrum is generally developed over peat of 10-50 cm depth where water run-off is possible (Moore, 1979). With increasing altitude and exposure it grades into feldmark, with reduced drainage into grass heathland, with increased exposure and reduced drainage into Magallanic moorland of dwarf-shrub communities, with increasing shelter into small tree communities reflecting a stage towards bush or forest.

Bogs are found in the wet heathlands and forest in extremely poorly drained sites.

THE EXPEDITION

An ample analytical material was available as the expedition set out on its southern endeavour. The following analysis had been carried out on most or all of the 170 samples from 36 profiles collected during the first expedition (Madsen et al, 1980): granulometry, pH (H_2O), pH ($CaCl_2$), pH (NaF), moisture retention, C, N, Fe and Al pyrophosphate and dithionite, CEC, exchangeable bases, X-ray of silt and clay fractions, heavy and light mineral countings, micromorphology, total chemical analysis and $CaCO_3$-content. Furthermore 4 complete LANDSAT tapes were processed in an IDIMS-computer and false colour composite (FCC) images of most of the area were produced as paper prints.

Members were the author and wife, Constanza Gumucio. A Volkswagen van equipped as a moderate camper served as field-station. The chilean and argentine oilcompanies, ENAP and YPF, supplied extensive cartographic and bibliographic material, and Instituto de la Patagonia valuable scientific information and access to a complete aerial photograph collection of chilean Tierra del Fuego and Patagonia Austral.

The expedition travelled approximately 9000 km in the study area, and the following localities numbered on Fig. 1 were visited:

The roadnet was drawn in a scale equivalent to that of the FCC-images on a plastic overlay superposed upon the satellite-images. This eased a correct localization on the images and in the landscape.

Various patterns were recognized on the images, and two working hypotheses were formulated. One that the

patterns reflected geomorphological and vegetation states of the area, and a second that a systematic relation between soil, geomorphology and vegetation existed. A verification of these hypothesis would facilitate a much more systematic, precise and efficient soil and landscape mapping based on the use of satellite images and ground control. Both hypotheses thus required field check.

Hypothesis no. 1 was controlled by studies of forms, sediment types and biotopes, which were localized on the image. As the field stay proceded the geomorphological and botanical significance of the patterns was established. By a combination of image analysis and ground control it was possible to obtain a logical and consistent impression of Quaternary geomorphology and vegetation distribution, which will supply in itself much new information on the subjects.

Geomorphologically, the following units could be identified on the images: outwash plains and valleys; drumlin fields; kame-terrace systems; ground-, lateral- and terminal moraines; periglacial thermokarst?, dry lake bottoms; dune systems; marine foreland; marsh; wadden; postglacial lavafields and volcanoes; U- and V-valleys and Tertiary cuesta landscapes.

Botanically, the following biotopes were identified on the images: grass tussock steppe of Festuca; grass tussock/bush steppe of Festuca and Chiliothricium diffusum; grass steppe/bush steppe/dwarf shrub dry heathland of Festuca, Chiliothricium diffusum, Empetrum rubrum and Bolax gummifera in different quantitative combinations; forest; Salicornia salt flats; Salicornia marsh; Hordeum flats; Lepidophyllum cupressiforme flats; wet heathlands; Sphagnum bogs; lowlying bogs; meadows and algae on rocky tidal flats. In some biotopes varying degrees of vitality could be identified based on intensity and type of red on the image, which reflect chlorophyll content.

Hypothesis no. 2 was controlled by augerings and profile studies. Soil variation was examined in the geomorphological and botanical units, and specific soil associations were found in most of the units. An approximate knowledge of distribution of histic, mollic, umbric, ochric, cambic, argillic, spodic, petrocalcic and gypsic diagnostic horizons (Soil Survey Staff, 1975), of soils with hydromorphic properties, and of soils showing characteristics of pedogenetic processes not sufficiently expressed in order to classify as one of the above mentioned diagnostic horizons or properties, was established. No detailed account of state factor – soil type relationships will be given here, as a thesis is on its way.

Both working hypotheses were thus verified and given a content. The base for a systematical soil and landscape mapping was laid. It was now possible to extrapolate to non-accessible areas with a high degree of accuracy. In order to maintain a constant control of the working hypotheses, it was – based on the satellite images – predicted which kind of soil types and landscape units would be present in the area to be studied the following day. Upon arrival in the new area, the veritative value of the prediction was controlled, which enabled a constant revision of the hypotheses and a more precise conception of landscape genesis, landscape forms and related soil associations.

Conclusion

The major results were as follows:

1) acquisition of a precise, regional knowledge of soil landscape distribution and Quaternary landscape development.
2) extensive knowledge of state factor – soil type relationships with approximate knowledge of distribution of histic, mollic, umbric, ochric, cambic, argillic, spodic, petrocalcic and gypsic horizons; of hydromorphic properties; and of soils showing characteristics of pedogenetic processes not sufficiently developed in ordor to classify as one of the above mentioned diagnostic horizons or properties.
3) mapping of icewedge distribution, thermokarst and cryoturbation.
4) correlation of soils developed in glacial meltwater deposits and till from various glaciations and in different, separated areas of the region.
5) 1-4 give together a well-established and extensive soil geographical material as basis for comparison between soil development and distribution in Scandinavia and Tierra del Fuego/Patagonia Austral.

ACKNOWLEDGMENTS

The following are gratefully thanked: Sten Folving, Ph.D., for excellent advice and altruistic support during satellite image processing; The Danish Natural Science Research Council for financing the expedition and Landsat images; Knud Højgaards Fond for financing Landsat-images; Juan Calderon S. of ENAP, Magallanes for excellent hospitability and helpfulness; Rector Mateo Martinić and staff of Instituto de la Patagonia for extensive scientific support; YPF of Argentina for bibliography; the peoples of Tierra del Fuego and Patagonia for warmhearted advice and help, and John Jønsson and Vagn Jacobsen for graphic assistance.

Resumé:

Jordbunds- og geomorfologisk kortlægning af Ildlandet og det sydligste Patagonien udførtes på grundlag af digitalt behandlede Landsatscener og feltstudier (boringer og profilstudier). En klar sammenhæng mellem mønstrene og farverne på Landsatscenerne samt geomorfologi og plantesamfund fastlagdes. Specifikke jordbundsassociationer fandtes i de forskellige landskabsenheder, sidstnævnte defineret som en kombination af geomorfologi, botanik og topografi. Et regionalt kendskab til udbredelsen af jordbundstyperne og til den kvartære landskabsudvikling opnåedes, hvor førstnævnte endvidere danner grundlag for en sammenligning med jordbundsudviklingen i Skandinavien.

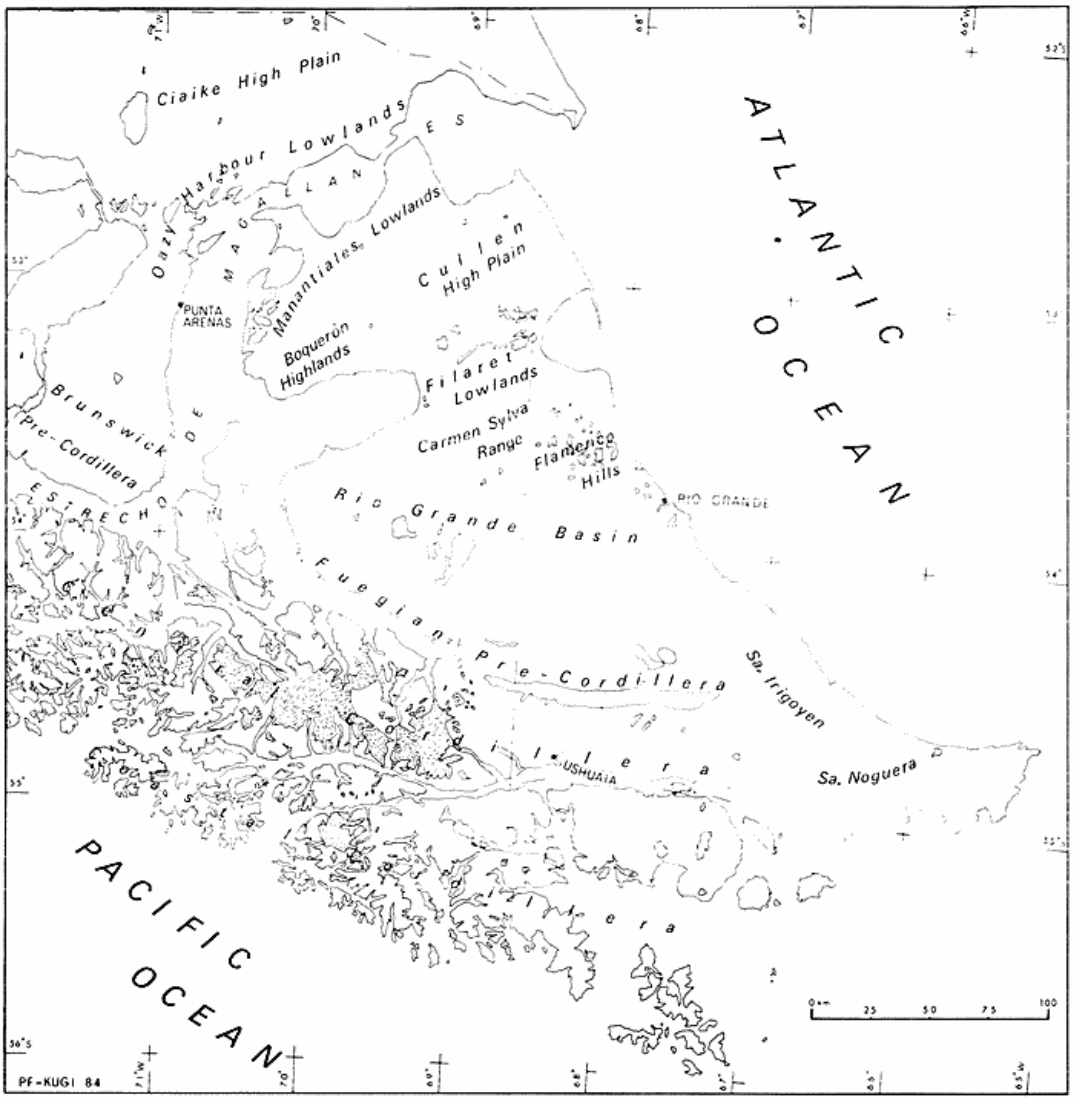

Fig. 2. Physiographic division of the study area

Fig. 2. Undersøgelsesområdets fysiografiske regioner

References

Caldenius, C. C. (1932): Las glaciaciones cuaternárias en la Patagonia y Tierra del Fuego. Geografiska Annaler, 14, 1-164.

Dalziel, I. W. D.; de Wit, M. J.; Palmer, K. F. (1974): Fossil marginal basin in the southern Andes. Nature, 250, 291-294.

van Loon, H.; Taljaard, J. J.; Sasamori, T.; London, J.; Hoyt, D. V.; Labitzke, K.; Newton, C. W. (1972): Meteorology of the southern hemisphere. Meteorological Monographs, 13, no. 35, 87-213.

Madsen, H. B.; Nielsen, E. S.; Ødum, S. (1980): The Danish Scientific Expedition to Patagonia and Tierra del Fuego, 1978-79. Geografisk Tidsskrift, 80, 1-28.

Moore, D. M. (1979): Southern oceanic wet-heathlands (including Magallanic moorland); in Specht, R. L. (editor): Heathlands and Related Shrublands of the World, A. Descriptive Studies. 489-497. Elsevier Scientific Publishing Company.

Pisano V., E. (1977): Fitogeografiá de Fuego-Patagonia chilena. I. Comunidades vegetales entre las latitudes 52 y 56°S. Ans. Inst. Pat., Punta Arenas (Chile), 8, 121-250.

Soil Survey Staff (1975): Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Agriculture Handbook No. 436. Soil Conservation Service. U. S. Department of Agriculture.

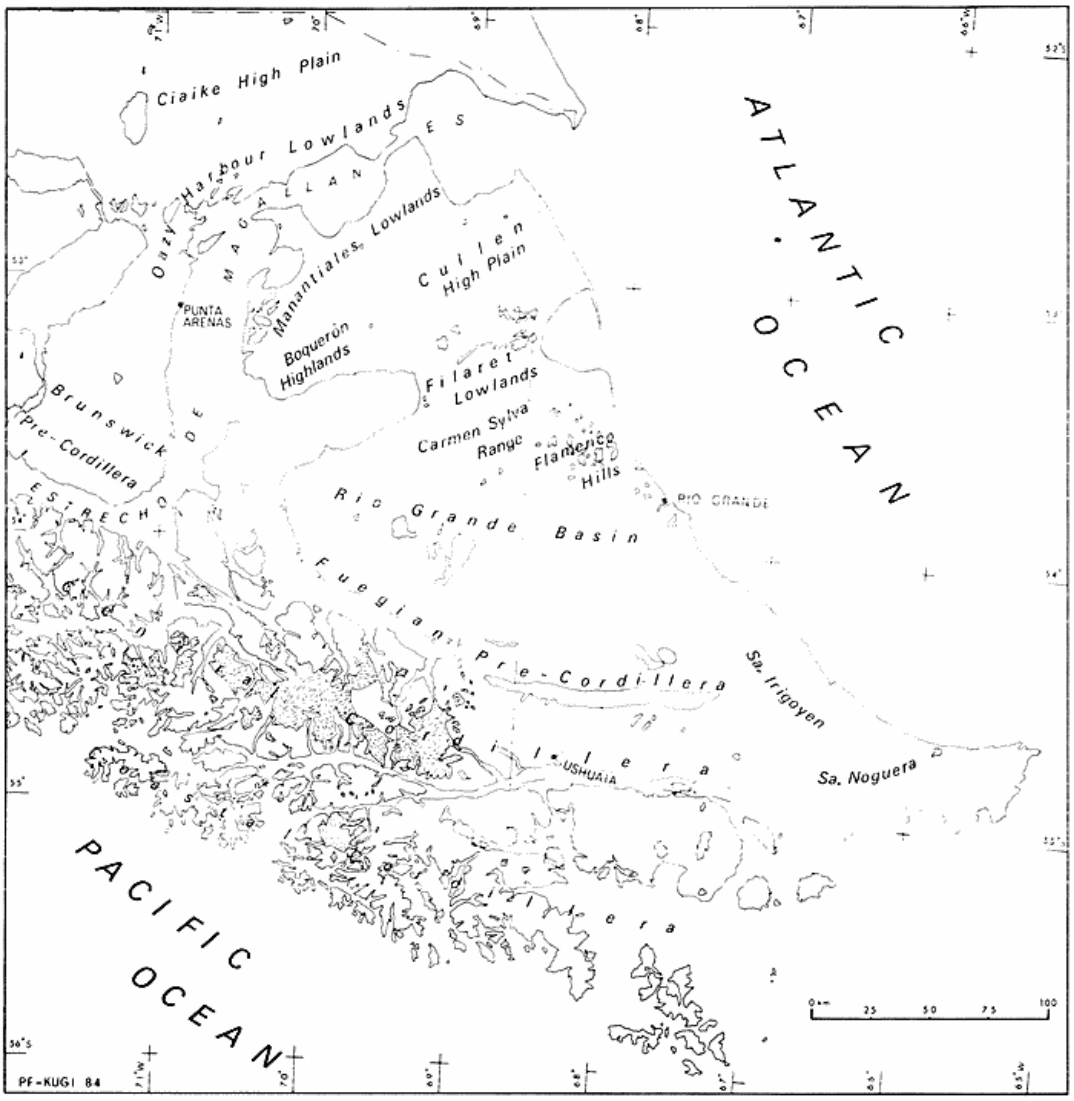

Fig. 2. Physiographic division of the study area

Fig. 2. Undersøgelsesområdets fysiografiske regioner

References

Caldenius, C. C. (1932): Las glaciaciones cuaternárias en la Patagonia y Tierra del Fuego. Geografiska Annaler, 14, 1-164.

Dalziel, I. W. D.; de Wit, M. J.; Palmer, K. F. (1974): Fossil marginal basin in the southern Andes. Nature, 250, 291-294.

van Loon, H.; Taljaard, J. J.; Sasamori, T.; London, J.; Hoyt, D. V.; Labitzke, K.; Newton, C. W. (1972): Meteorology of the southern hemisphere. Meteorological Monographs, 13, no. 35, 87-213.

Madsen, H. B.; Nielsen, E. S.; Ødum, S. (1980): The Danish Scientific Expedition to Patagonia and Tierra del Fuego, 1978-79. Geografisk Tidsskrift, 80, 1-28.

Moore, D. M. (1979): Southern oceanic wet-heathlands (including Magallanic moorland); in Specht, R. L. (editor): Heathlands and Related Shrublands of the World, A. Descriptive Studies. 489-497. Elsevier Scientific Publishing Company.

Pisano V., E. (1977): Fitogeografiá de Fuego-Patagonia chilena. I. Comunidades vegetales entre las latitudes 52 y 56°S. Ans. Inst. Pat., Punta Arenas (Chile), 8, 121-250.

Soil Survey Staff (1975): Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Agriculture Handbook No. 436. Soil Conservation Service. U. S. Department of Agriculture.

patterns reflected geomorphological and vegetation states of the area, and a second that a systematic relation between soil, geomorphology and vegetation existed. A verification of these hypothesis would facilitate a much more systematic, precise and efficient soil and landscape mapping based on the use of satellite images and ground control. Both hypotheses thus required field check.

Hypothesis no. 1 was controlled by studies of forms, sediment types and biotopes, which were localized on the image. As the field stay proceded the geomorphological and botanical significance of the patterns was established. By a combination of image analysis and ground control it was possible to obtain a logical and consistent impression of Quaternary geomorphology and vegetation distribution, which will supply in itself much new information on the subjects.

Geomorphologically, the following units could be identified on the images: outwash plains and valleys; drumlin fields; kame-terrace systems; ground-, lateral- and terminal moraines; periglacial thermokarst?, dry lake bottoms; dune systems; marine foreland; marsh; wadden; postglacial lavafields and volcanoes; U- and V-valleys and Tertiary cuesta landscapes.

Botanically, the following biotopes were identified on the images: grass tussock steppe of Festuca; grass tussock/bush steppe of Festuca and Chiliothricium diffusum; grass steppe/bush steppe/dwarf shrub dry heathland of Festuca, Chiliothricium diffusum, Empetrum rubrum and Bolax gummifera in different quantitative combinations; forest; Salicornia salt flats; Salicornia marsh; Hordeum flats; Lepidophyllum cupressiforme flats; wet heathlands; Sphagnum bogs; lowlying bogs; meadows and algae on rocky tidal flats. In some biotopes varying degrees of vitality could be identified based on intensity and type of red on the image, which reflect chlorophyll content.

Hypothesis no. 2 was controlled by augerings and profile studies. Soil variation was examined in the geomorphological and botanical units, and specific soil associations were found in most of the units. An approximate knowledge of distribution of histic, mollic, umbric, ochric, cambic, argillic, spodic, petrocalcic and gypsic diagnostic horizons (Soil Survey Staff, 1975), of soils with hydromorphic properties, and of soils showing characteristics of pedogenetic processes not sufficiently expressed in order to classify as one of the above mentioned diagnostic horizons or properties, was established. No detailed account of state factor – soil type relationships will be given here, as a thesis is on its way.

Both working hypotheses were thus verified and given a content. The base for a systematical soil and landscape mapping was laid. It was now possible to extrapolate to non-accessible areas with a high degree of accuracy. In order to maintain a constant control of the working hypotheses, it was – based on the satellite images – predicted which kind of soil types and landscape units would be present in the area to be studied the following day. Upon arrival in the new area, the veritative value of the prediction was controlled, which enabled a constant revision of the hypotheses and a more precise conception of landscape genesis, landscape forms and related soil associations.

Conclusion

The major results were as follows:

1) acquisition of a precise, regional knowledge of soil landscape distribution and Quaternary landscape development.
2) extensive knowledge of state factor – soil type relationships with approximate knowledge of distribution of histic, mollic, umbric, ochric, cambic, argillic, spodic, petrocalcic and gypsic horizons; of hydromorphic properties; and of soils showing characteristics of pedogenetic processes not sufficiently developed in ordor to classify as one of the above mentioned diagnostic horizons or properties.
3) mapping of icewedge distribution, thermokarst and cryoturbation.
4) correlation of soils developed in glacial meltwater deposits and till from various glaciations and in different, separated areas of the region.
5) 1-4 give together a well-established and extensive soil geographical material as basis for comparison between soil development and distribution in Scandinavia and Tierra del Fuego/Patagonia Austral.

ACKNOWLEDGMENTS

The following are gratefully thanked: Sten Folving, Ph.D., for excellent advice and altruistic support during satellite image processing; The Danish Natural Science Research Council for financing the expedition and Landsat images; Knud Højgaards Fond for financing Landsat-images; Juan Calderon S. of ENAP, Magallanes for excellent hospitability and helpfulness; Rector Mateo Martinić and staff of Instituto de la Patagonia for extensive scientific support; YPF of Argentina for bibliography; the peoples of Tierra del Fuego and Patagonia for warmhearted advice and help, and John Jønsson and Vagn Jacobsen for graphic assistance.

Resumé:

Jordbunds- og geomorfologisk kortlægning af Ildlandet og det sydligste Patagonien udførtes på grundlag af digitalt behandlede Landsatscener og feltstudier (boringer og profilstudier). En klar sammenhæng mellem mønstrene og farverne på Landsatscenerne samt geomorfologi og plantesamfund fastlagdes. Specifikke jordbundsassociationer fandtes i de forskellige landskabsenheder, sidstnævnte defineret som en kombination af geomorfologi, botanik og topografi. Et regionalt kendskab til udbredelsen af jordbundstyperne og til den kvartære landskabsudvikling opnåedes, hvor førstnævnte endvidere danner grundlag for en sammenligning med jordbundsudviklingen i Skandinavien.