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APPLICATION OF LANDSAT IMAGES TO THE STUDY OF LEVEL SOILS FOR RECOGNIZING DRAINAGE AREAS

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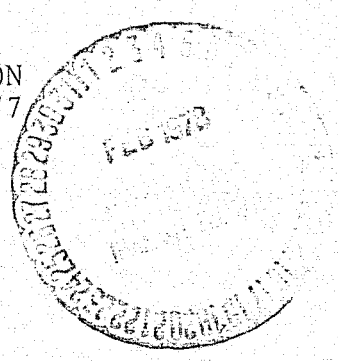

ACKNOWLEDGEMENTS

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To the Director and technicians of the Earth Resources Technological Satellite ERTS-Bolivian program, for the orientation, help and support they provided during the execution of this task.

By the same token, to the members of the Advisory Committee of the "Martín Cárdenas H." School of Agricultural Sciences, for their valuable suggestions.

My extensive appreciation also to all those friends and other people who in one way or another contributed to the elaboration of this work.

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COCHABAMBA
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ORURO
SUCRE
POTOSI
TARIJA

I INTRODUCTION

The Earth Resources Technological Satellite Program (LANDSAT) is the first major step in the joint exploitation of space technology and remote detection within a system for the research and development /1* of the country's natural resources.

The purpose of this study is to qualify and quantify the resource soil, under a system of LANDSAT-1 image interpretation and field work adjusted to a soil inventory at survey level. It corresponds to an area covered by the so-called Desaguadero image. We thus show the advantages of information obtained via multispectral satellite images in various bands and combinations; this study has been restricted, so far as possible, to photointerpretation techniques, adjusted to the particular characteristics of the images.

This survey-type inventory displayed the favorable peculiarity of showing clearly marked physiographic contrasts; the availability, in addition, of significant complementary information was most helpful. Without it, this study may have remained one of an exploratory level.

Instead, the study provides basic information for future soil studies at a more detailed level, of areas with a higher agricultural and livestock potential.

Studies based on LANDSAT images are important to the country, and /2 for this reason the Bolivian government has actively participated in the use of this information via the ERTS Program. Ambitious plans exist to use this system to perform "integrated studies", especially of Eastern Bolivia.

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*Numbers in margin represent foreign pagination

OBJECTIVES

The objectives of this study are:

1. To demonstrate the applicability of photographic images from the LANDSAT-1 satellite to soil studies.

2. To submit a soil study at survey level of the area covered by the Desaguadero image, showing the various units on a map, classified according to soil taxonomy.

II LITERATURE SEARCH

II1. DEFINITION OF REMOTE DETECTION

The basic material for this study is provided by the LANDSAT images, /3
one of the products resulting from the information gathered by the multispectral scanner (MSS) related to the covering of the earth' surface, due to the satellite's trajectory (Figure 1). Hence the multispectral scanner is the sensor capturing the electromagnetic energy reflected by the earth surface. This process constitutes the REMOTE DETECTION defined as "the obtention of measurements or information regarding some properties of remote objects, without being in physical contact with them."

R. Tessier and A. Alouges define remote detection as "any qualitative or quantitative process, in which the measuring instrument, or, more properly, this instrument's sensor, is not in direct contact with the object under investigation."

More specifically in this field of remote sensors, Dr. Hoffer defines it as "the discipline dedicated to the acquisition of data on the earth surface, or an environment of the earth surface, by means of the use of various sensor systems generally transported by an air or spacecraft, and the transformation of these data into information useful for the understanding and/or manipulation of the environment in which human activity develops."

According to the above definitions, in order to obtain remote detection of the earth's surface cover, it is necessary that it irradiate some energy, in this case, electromagnetic energy.

It is necessary to point out that bodies irradiate various types of /5
energy that can be detected by sensors designed for this purpose;

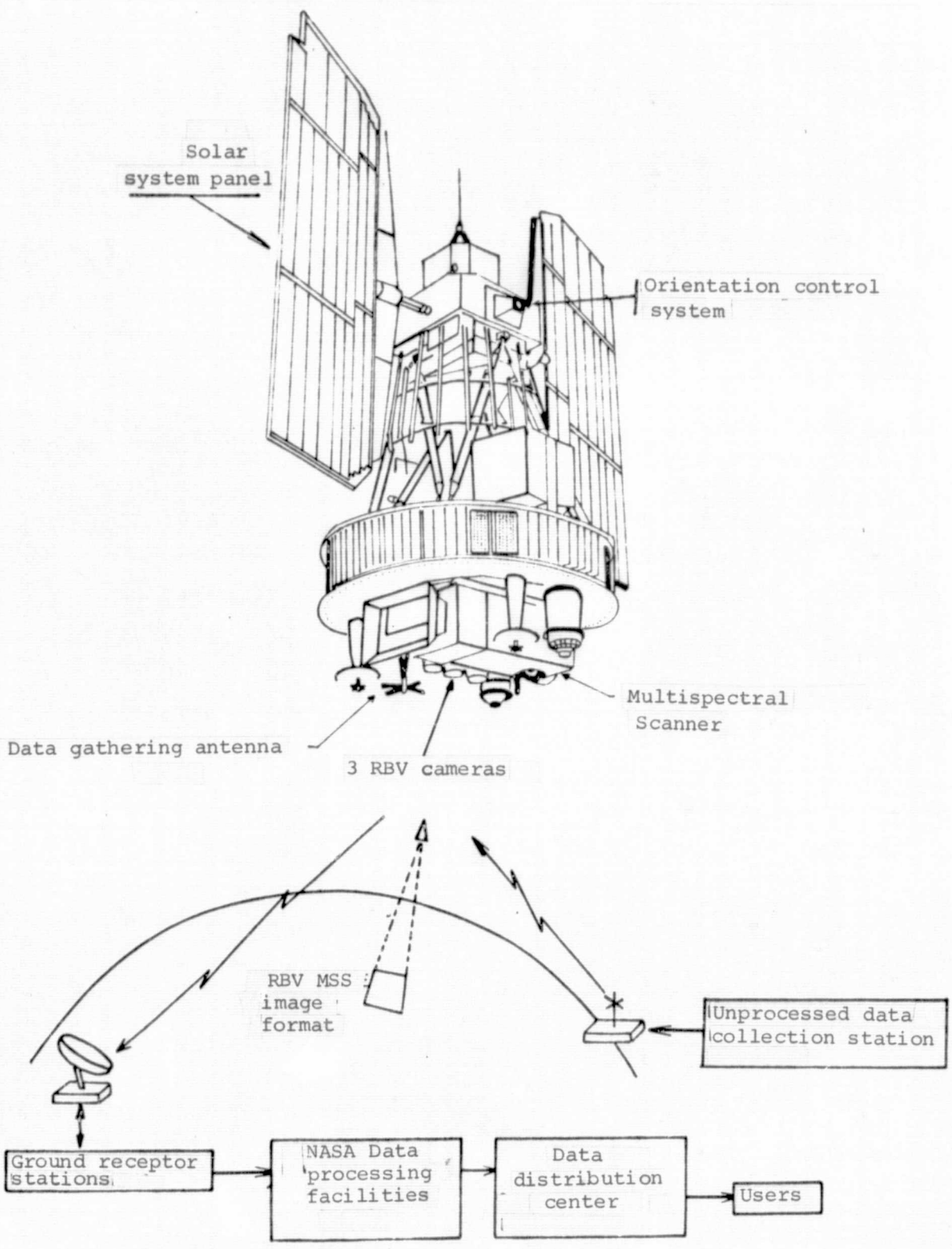


FIGURE 1. LANDSAT-1 DATA GATHERING SYSTEM

thus, energy can be transmitted by acoustic, thermal, electromagnetic or other waves.

In this study we shall consider only the energy reflected by the earth's surface and which produces variations in the electromagnetic forces.

II2. PHYSICAL BASES OF THE REMOTE SENSORS

For a better understanding it becomes necessary to point out that there exist three important types of variations in the electromagnetic field.

- Spectral variations, which are changes in the intensity of the radiation at given wavelengths, i.e., color differences.
- Spatial variations, which are changes in the radiation at different locations, i.e., differences in form and position.
- Temporal variations, which are changes in the radiation as a function of time, i.e., differences between eras, or differences throughout time (14).

To obtain information on these fields of variation, one must:

First, measure these variations and second, compare these measurements with known averages for natural or man-made objects. These principles can be illustrated by means of an example. If a map for a given area is needed that shows strongly salty areas - as manifested by strong salt efflorescence -these areas of the earth's /6 surface can not be apprehended directly at flight altitude; however, signs of such areas can be detected at such an altitude as electromagnetic radiation, which can be measured and analyzed to determine which areas are or are not soils of this degree of salinity. We can repeat the same reasoning for bodies of water or any other material.

Figure 2 shows the information gathering system, in which all the solar energy reaching the earth's surface is reflected, scattered or absorbed by bodies or objects as electromagnetic radiation, accordingto their physical and chemical properties.

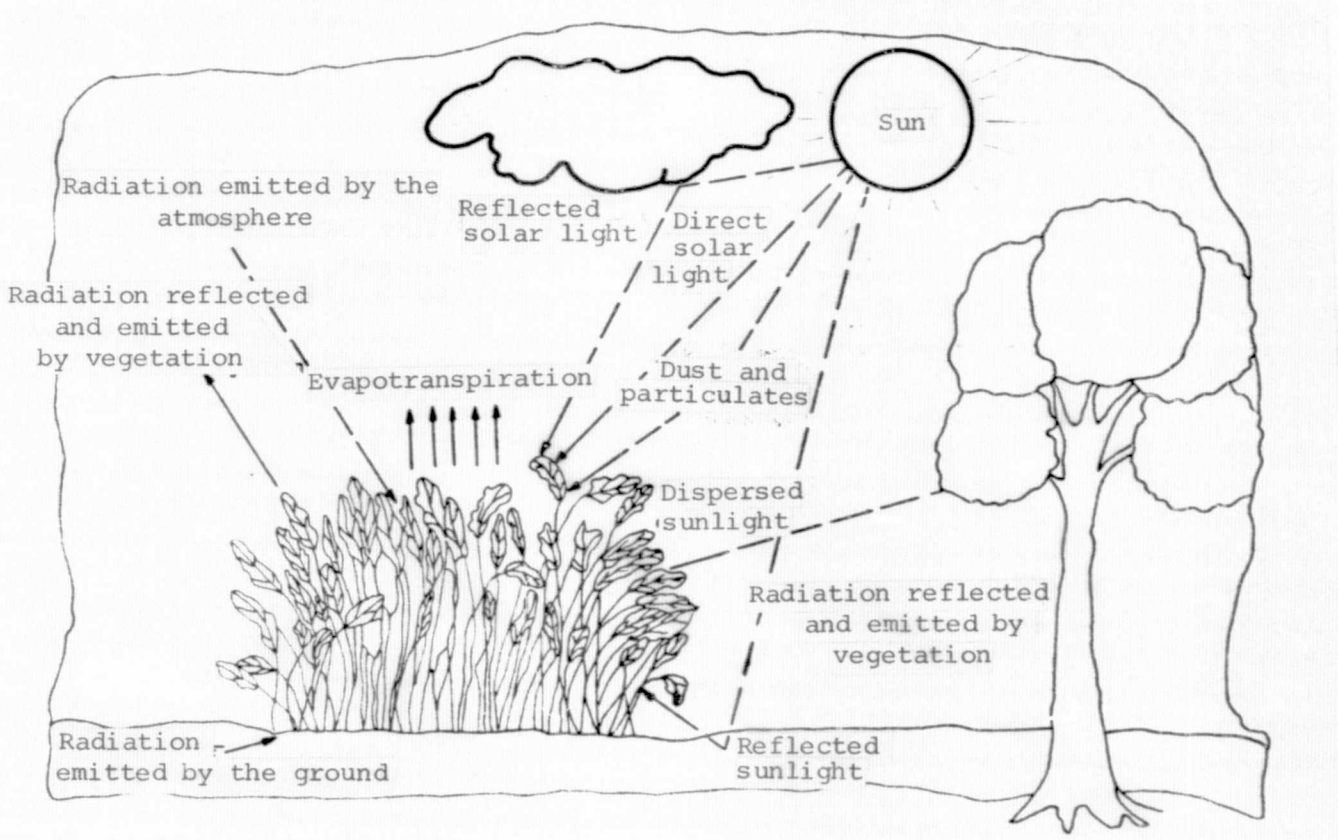


FIGURE 2. REFLEXION OF SOLAR RADIATION

II3. ELECTROMAGNETIC SPECTRUM CHARACTERISTICS

Some basic information regarding the electromagnetic spectrum is necessary for a better understanding of the use and functions of spectral variations in a remotely acquired electromagnetic spectrum. (Figures 3 and 4).

The portion of the electromagnetic spectrum between 0.3 and 15.0 microns is known as "optical wavelengths"; it is the range used by the mechanisms in the remote sensors, which depend on the sun as a primary source of energy as this sensor's system is passive.

The portion of the electromagnetic spectrum visible to the human eye lies between 0.4 and 0.7 microns. Wavelengths shorter than 0.4 microns are in the ultraviolet; the range above the visible spectrum /10 is the infrared. The region between 0.7 and 3.0 microns in wavelength is known as the reflective infrared and the region from 3.0 to 15.0 microns is known as the thermal infrared. In this latter case, energy is emitted by an object because of its temperature: basically all bodies at a temperature above 0° absolute emit electromagnetic energy due to atomic and molecular motion (5).

Electromagnetic radiation emitted and reflected by the earth surface may be measured by a given system during information gathering in the study of the earth's cover. In LANDSAT satellites, there is some data processing capability on board for the sensors, including data related to the calibration of the sensor and the direction in which it was positioned. These data are then transmitted to the ground by telemetry, for analysis and further processing, or are returned as direct packages as in the case of SKYLAB.

During the data gathering process, there usually is a need for some data processing, followed by one or more data analysis steps (Figure 5.)

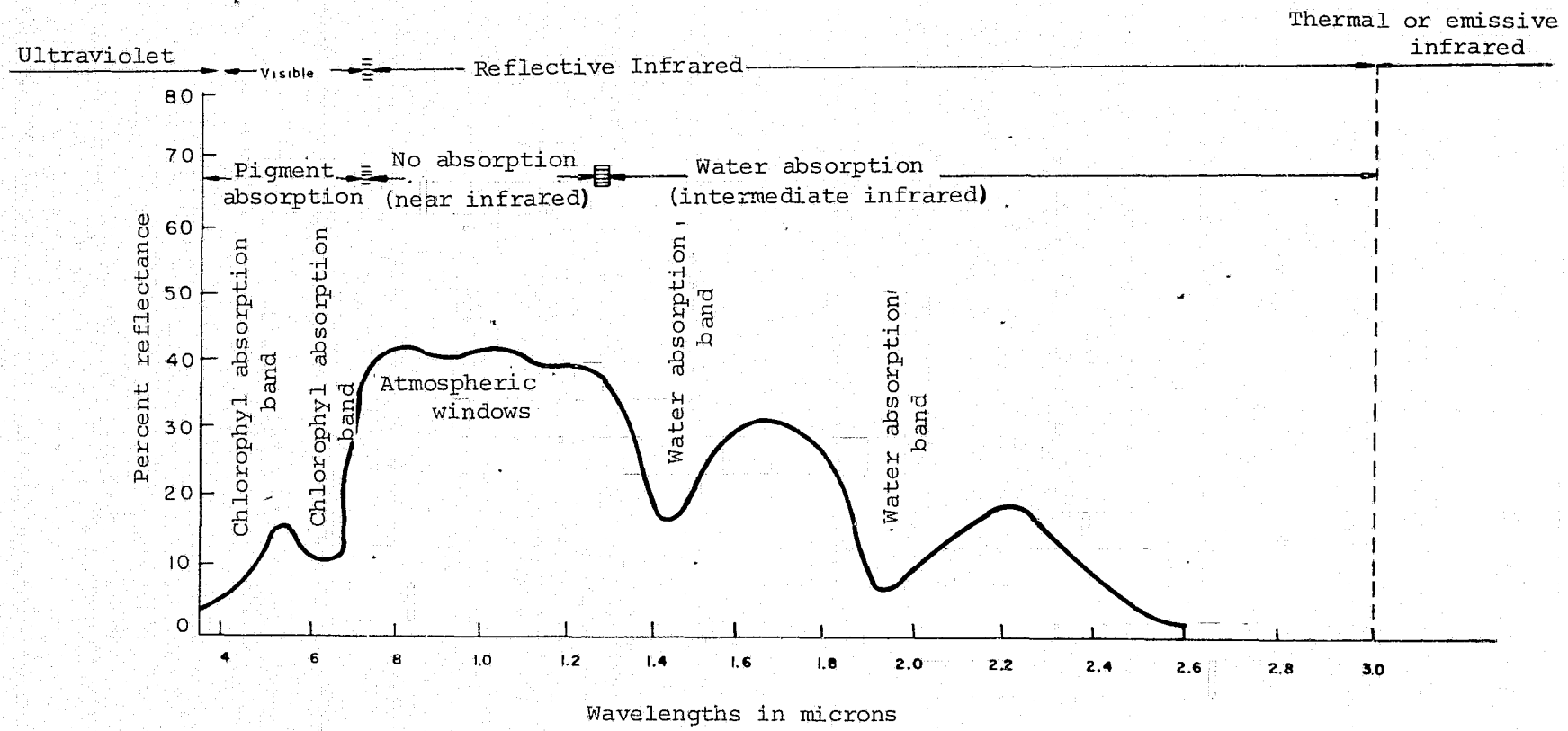


FIGURE 3. THREE PRIMARY RESPONSE REGIONS IN RELATION TO LEAF REFLECTANCE

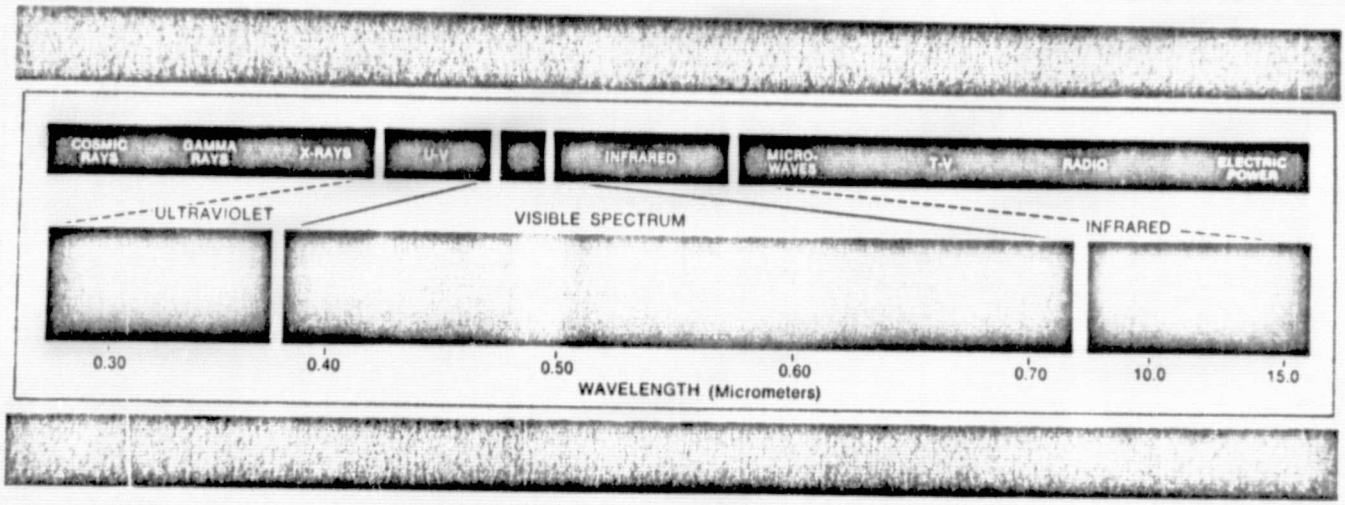


FIGURE 4. ELECTROMAGNETIC SPECTRUM

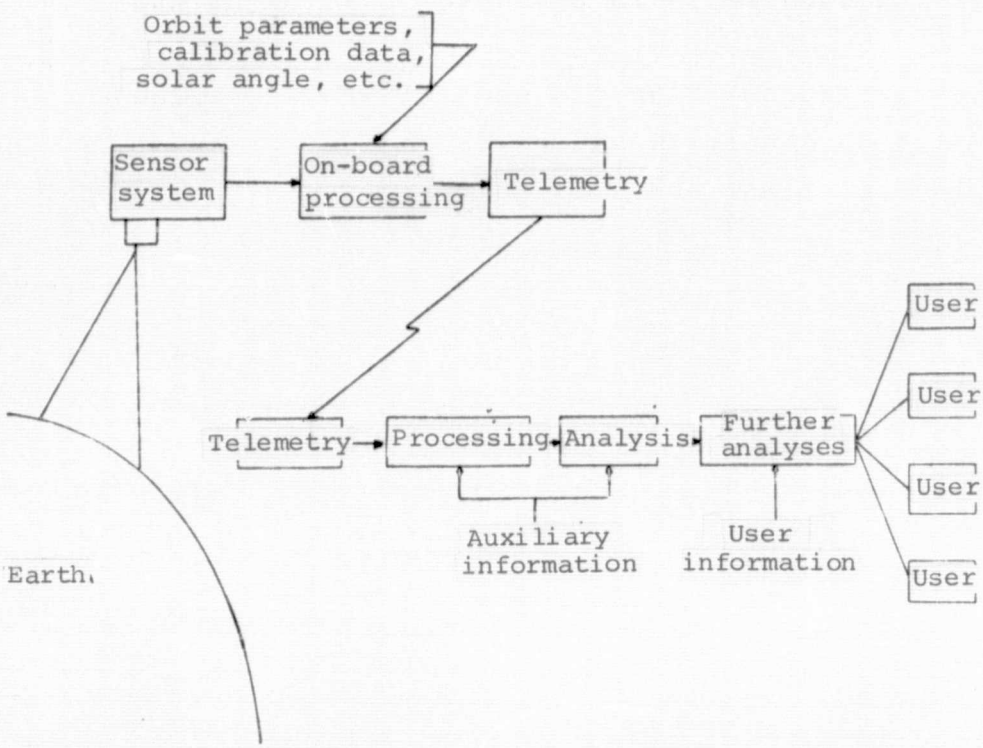


FIGURE 5. ORGNNIZATION OF AN EARTH RESOURCES SURVEY SYSTEM

Summing up, we may state that it is possible to gather information and knowledge regarding the earth surface and its resources, by means of measurements of spatial and temperal spectral variations. To render this information more useful, it is necessary to have an adequate understanding of the types of materials responsible for such data and information.

II4. MISSION OF LANDSAT-1

LANDSAT-1 was placed in orbit on 23 July 72 by the National Aeronautics and Space Administration (NASA). In order to achieve its objectives, LANDSAT was built to obtain high-resolution, multispectral data on the earth surface. It is multitemporal in that it provides /11 global information on a periodic basis.

The Multispectral Scanner System is a linear instrument that uses an oscillating mirror which continuously scans perpendicularly to the satellite's velocity (Figure 6.)

During each mirror pass, six lines in the four spectral bands are simulateneously investigated (19). The space vehicle's motion provides the progression of the lines investigated; during data processing, the images, stored in continuous bands, are transformed into square images with a 10% superposition between adjacent images.

The satellite's orbit is at 915 Km and it circumnavegates the earth every 103 minutes, completing 14 polar orbits daily. Thus, the earth surface is completely covered every 18 days, for a total of 152 orbits in each cycle (Figure 7).

However, due to restrictive factors both within and without the LANDSAT system, not all regions can be explored continuously. These restrictive factors are:

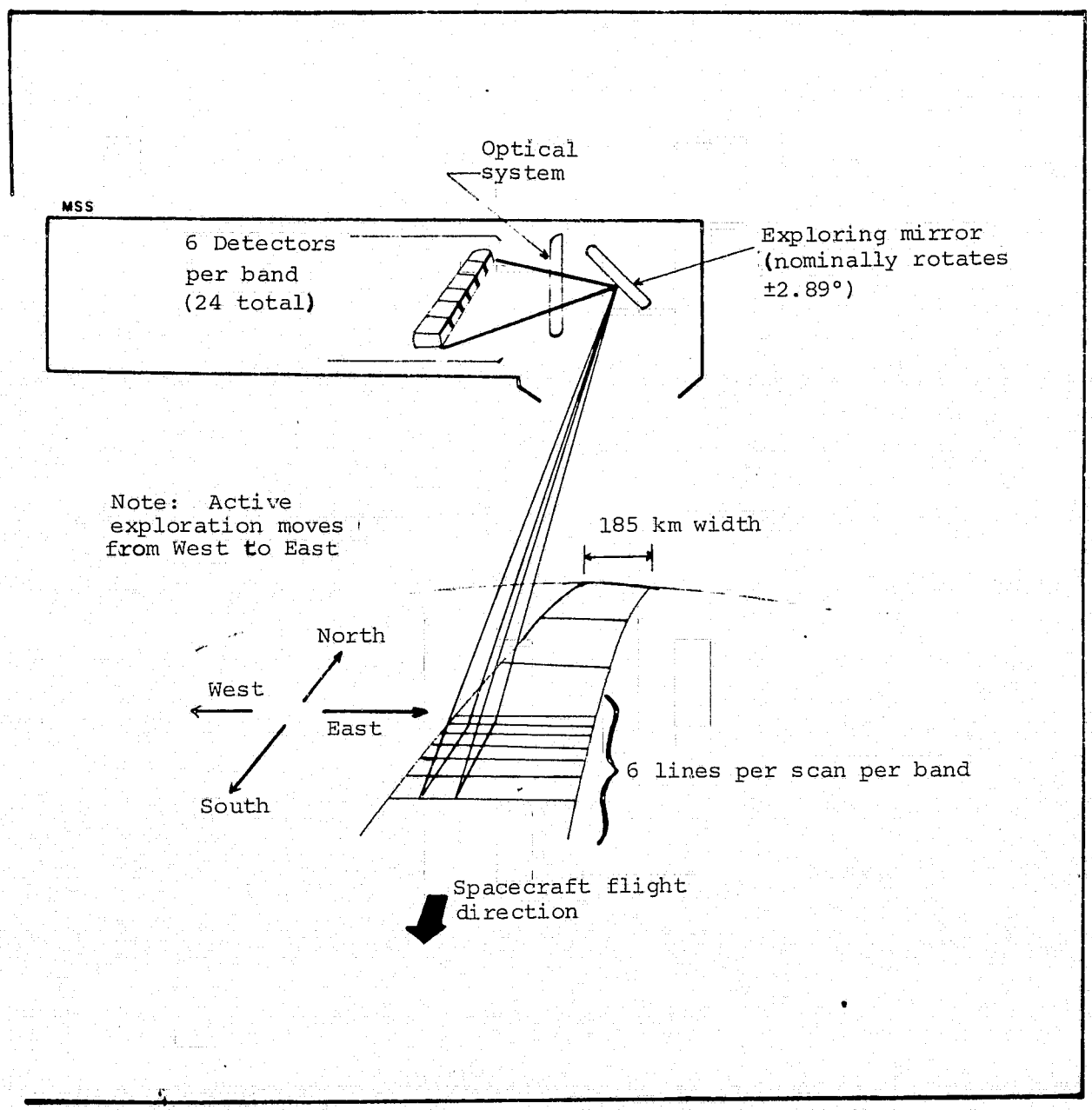


FIGURE 6. MULTISPECTRAL SCANNER (MSS) SCHEMATIC

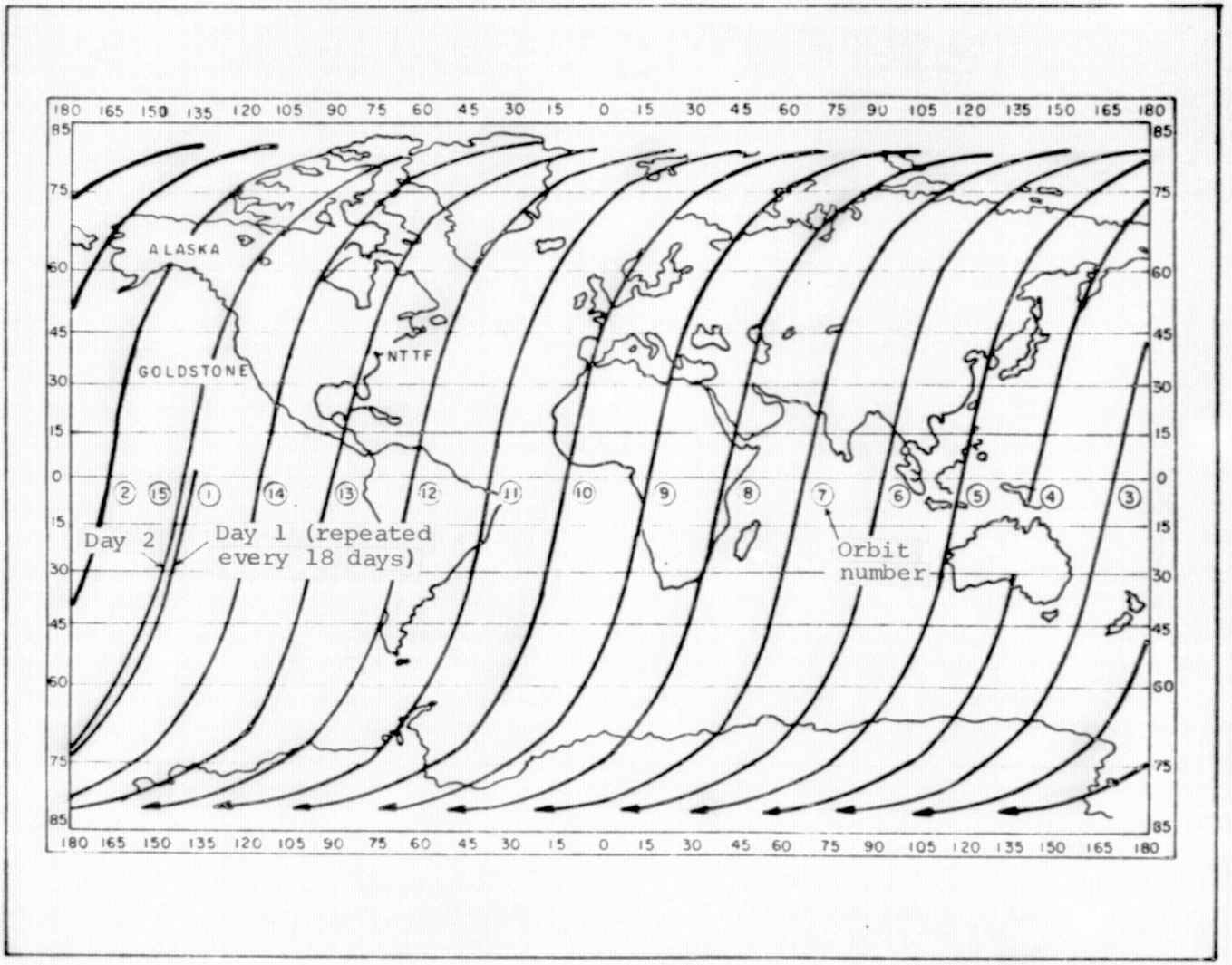


FIGURE 7. TRACING A TYPICAL DAILY LANDSAT-1 TERRESTRIAL PASS

- Maximum operating time of on-board recorders (30 minutes)
- Operating capability of the memory controlling the turning on and off of on-board sensors.
- Transmissions to ground stations and duration of contact.
- Lighting conditions on earth surface being scanned.
- Cloud cover.
- The electric energy required to operate the various systems is generated by means of two directional solar antennae with battery storage for periods of eclipse and space launches (19). /14

II5. MULTISPECTRAL CHARACTERISTICS

The multispectral scanner characteristically acquires data in four spectral ranges called channels or bands. In a simplified explanation, the scanner receives radiation reflected by and emitted from the ground, in resolution increment units (pixel = 0.5 Has). This radiation is separated by means of a dichroic filter or grating which reflects the visible wavelengths and transmits by dispersion the entire infrared portion of the spectrum. The visible wavelengths are reflected by a mirror and pass through a prism which differentially reflects the wavelengths in the various portions of the visible spectrum (Figure 8).

The radiation intensity at different wavelengths is then measured by detectors that generate electric signals, which are either stored on magnetic tape or transmitted directly to ground by telemetry; in this manner band 4 contains information in the range 0.5 - 0.6 microns; band 5, from 0.6 - 0.7 microns; band 6 from 0.7 - 0.8 microns and band 7, finally, corresponds to wavelengths between 0.8 and 1.1 microns.

Thus, any cover or object on the earth surface will appear, in the photographic image, in different shades, depending on the spectral band. A typical example is shown in Figure 9, where we see that the

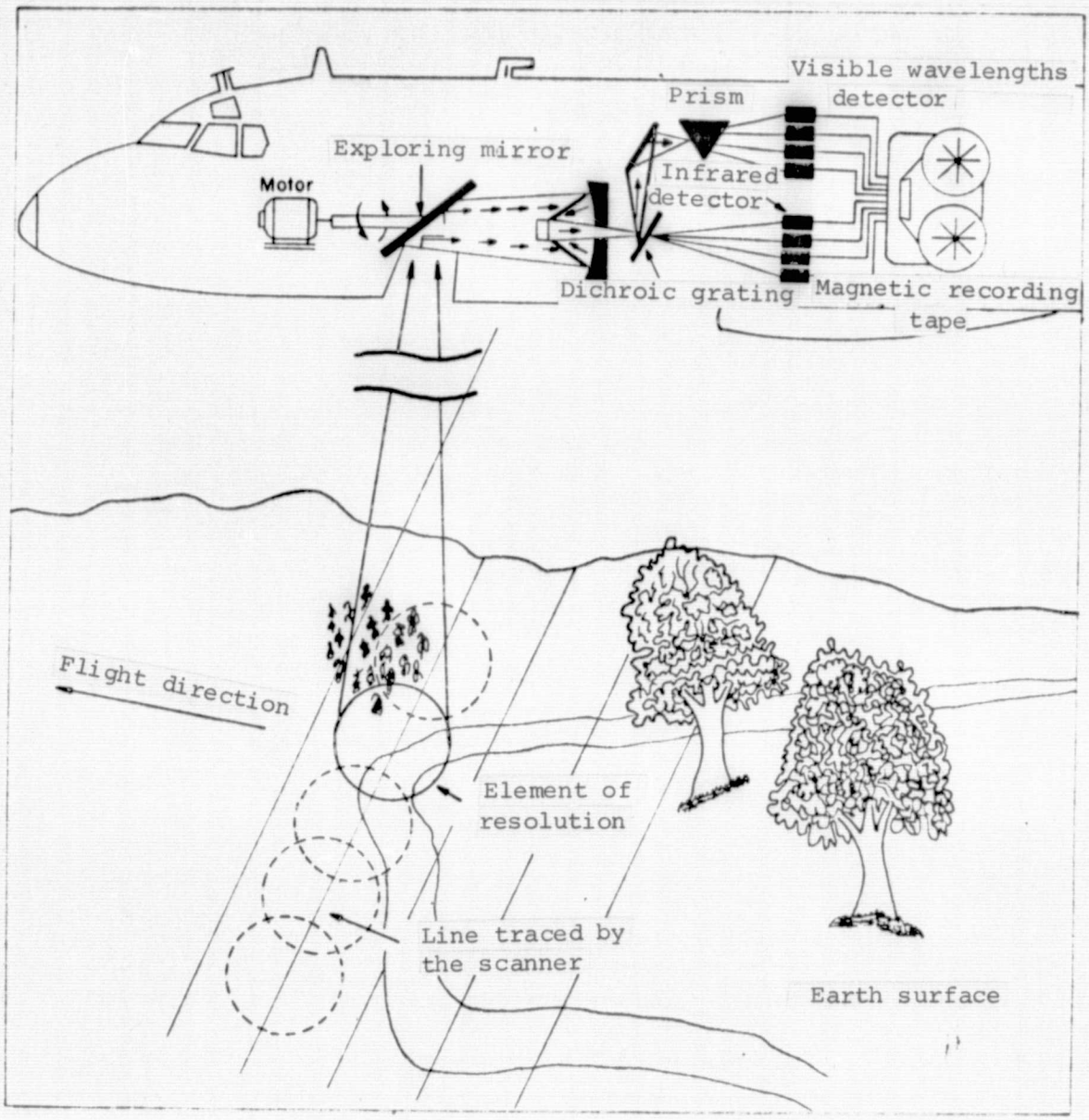
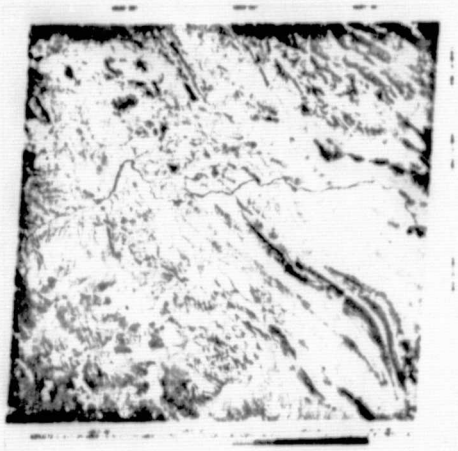
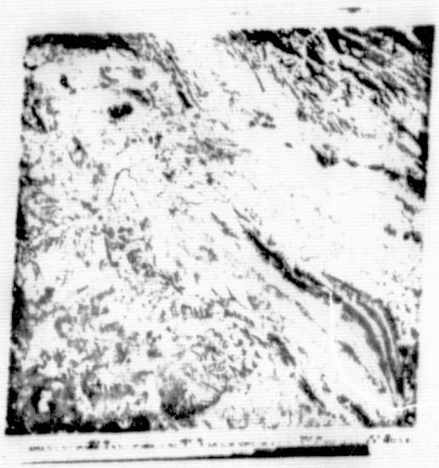


FIGURE 8. MULTISPECTRAL SCANNER DETECTION SYSTEM

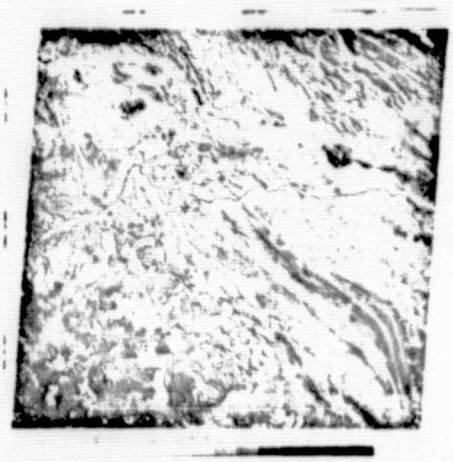
BAND 4



BAND 7

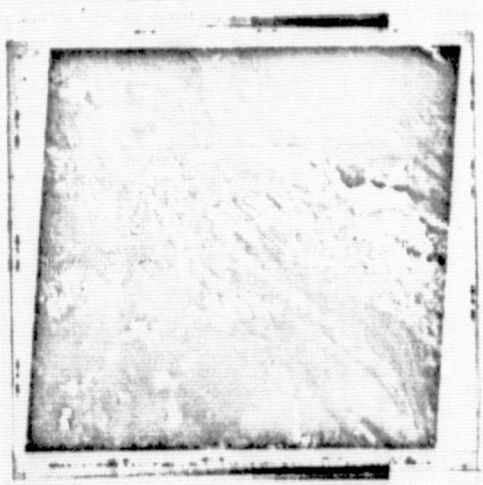


BAND 5



BAND 6

FIGURE 9. THE FOUR BANDS OF LANDSAT-1 IMAGES, 4, 5, 6 and 7, AT THE ORIGINAL 1:3,300,000 SCALE



DIAZO COMPOSITE OF THE THREE BANDS 4, 5 AND 7, AT 1:3,300,000 SCALE

Deasguadero river, for instance, appears as a very dark gray and almost black color in band 7, while in band 4 the same water appears as light gray. /16

Thus, for each object there exists a unique spectral combination of the gray shades considered in the four bands (black and white images); this characteristic is called the SPECTRAL SIGNATURE, and is very important in interpretative analysis and especially so during computer analysis (Figures 10 and 11).

II6. IMPORTANCE OF LANDSAT DATA RESEARCH CENTERS

NASA considers the agencies and investigators who use LANDSAT data a very important and essential part within this program of evaluation of results.

The research and analyses performed on these data have shown their importance and their usefulness in the study of earth resources. The ERTS/BOLIVIA program is one of the pioneers in this research; it studies and evaluates our natural resources.

The ERTS Program is currently performing research in various fields: geology, geomorphology, mining, hydrology and especially in the agricultural sciences, such as forestry, current soil usage and soil studies. The latter is being studied by two methods: the first being based on LANDSAT image interpretation, covering extended areas with a regional focus - as is the case in this study - and the second based on the analysis of multispectral data by means of a computation system that starts with information stored on magnetic tape.

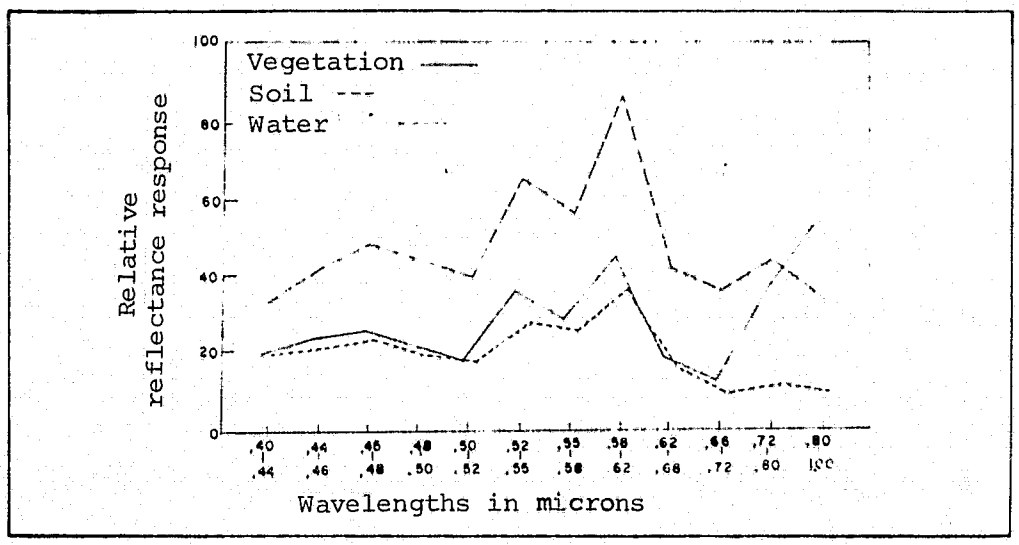


FIGURE 10. MULTISPECTRAL SIGNATURES

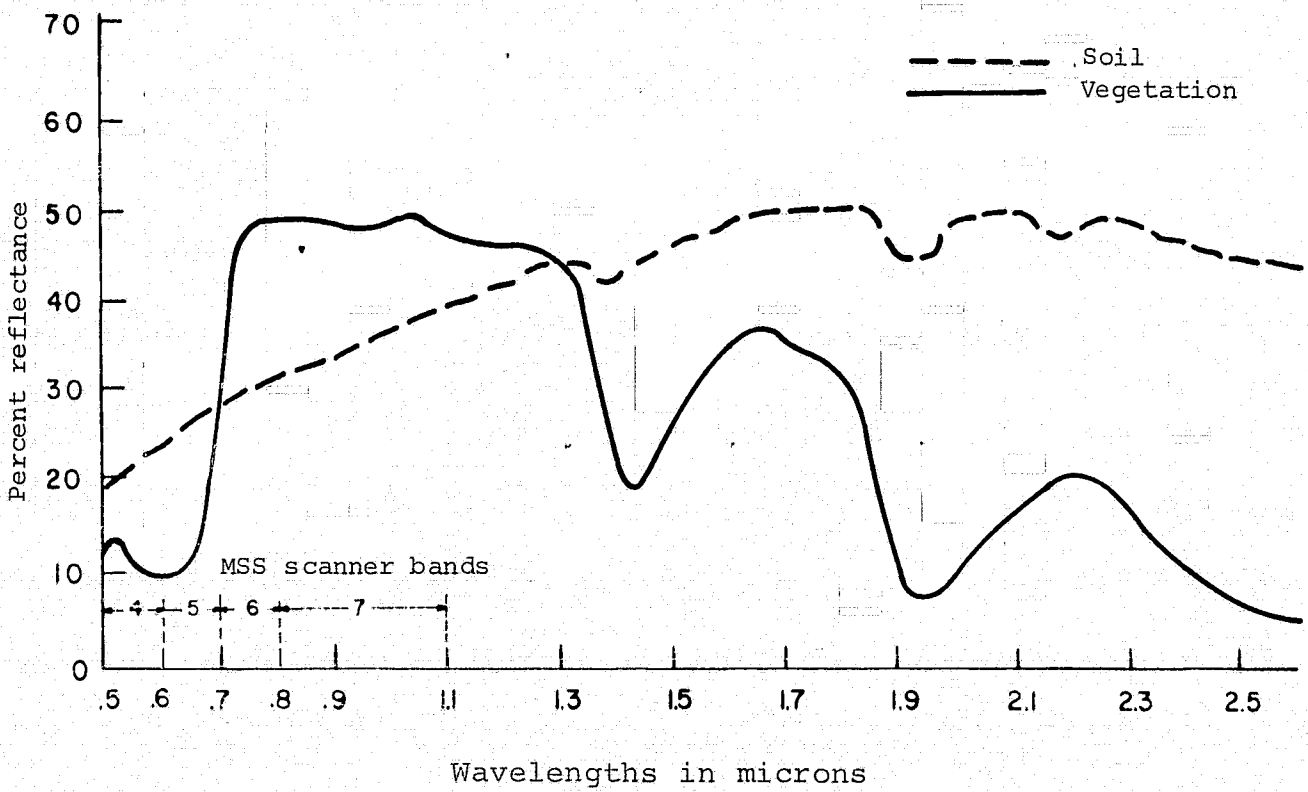


FIGURE 11

II7. PREVIOUS AGRICULTURAL AND LIVESTOCK STUDIES PERFORMED IN THIS AREA

Several surveys have been performed in the area under study here; /19
the agricultural and livestock potential in certain sectors has been evaluated, while in others soil quality has been determined for irrigation purposes. Among the more important we point out the exploratory agricultural study of the Patacamaya-Umala sector (16). This study covers an area of approximately 71,150 Has, mapped in 15 different soil units.

Another publication on the agricultural and livestock potential of the area under investigation was performed by (2); its information is of a very generalized nature.

The Department of Agriculture's Soil Department has also performed a soil survey, towards the irrigation of a large portion of the high plateau plains; this area will be affected by the Ulloma dam, the construction of which is planned. This particular study was performed at survey level, with a minor area in semidetail.

II8. SOME CONSIDERATIONS ON SOIL STUDY LEVELS

Soil studies can be performed at various levels or survey orders, depending on the greater or lesser detail with which the results are presented.

According to the Soil Surevey Manual (15) there are six study levels:

- Detailed soil maps.
- Survey maps.
- Detailed and survey maps.
- Generalized edaphic maps.
- Schematic soil maps, and
- Exploratory soil maps.

Smith, as quoted in (7), distinguishes the following orders or classes of edaphological surveys, depending on the levels of intensity or detail.

- Detailed edaphological surveys of low, medium or high intensity.
- Survey-level edaphological surveys, and
- Exploratory level edaphological surveys.

The nomenclature used by different edaphologists for different classes or levels of surveying has given rise to such a confusion that communication problems occur: often no one can tell with certainty what the meaning is of a survey-level survey, or of a semi-detailed survey, for instance.

In an effort to resolve these difficulties, the Interamerican Center for Photointerpretation (CIAF = Centro Interamericano de Fotointerpretación) has been working for the last 5 years on the development of a methodology, nomenclature and specifications of various levels of edaphological surveys, adaptable to different ecological and working conditions, as found in developing nations (7).

Noting the multitude of environments to be found, it was concluded /21 that the conventional types of survey (detailed, semi-detailed and survey-level) were not sufficient to accomodate the various situations. Hence, six survey orders or levels were designed; they are shown in a general specifications table for soil surveys (Table on page 20).

Wherever possible, these specifications were followed in this study, adjusting them to LANDSAT images; in soil mapping, we used soil groupings ("consociations"), associations and soil complexes. They were also used in the descriptive portions of the mapping units.

It can be seen in the Table mentioned above that starting with the 3rd order (Semi-detailed) and up to the 6th (Exploratory) we see SAMPLING AREAS that correspond to certain areas representative of

GENERAL SCHEMATIC OF EDAPHOLOGICAL SURVEY SPECIFICATIONS

Survey order, name	Survey use	Area characteristics	Taxonomic generalization level
1st order, very detailed	INTENSIVE USE: for instance, feasibility; operation and management of irrigation projects, horticultural drainage, experimental field stations	Very developed and completely accessible	Series phase, by surface horizon texture (< 25 cm; old soil types)
2nd order detailed	INTENSIVE AGRICULTURE: for instance, planning of individual farms, official appraisals, presumptive income, project feasibility	Developed and accessible	Series and series phases
3rd order, semi-detailed (SD)	PREDECESSOR OF 1ST AND 2ND ORDER SURVEYS: used for project prefeasibility planning, general project planning, land use, general recommendations for use and management	For the most part somewhat developed, with good agricultural and livestock potential, without major problems	Aggregates within subgroups named for the landscape
3rd order, sampling zone (SZ)			Same as 3rd order
4th order, general (G)	INVENTORY: also for recommendations for extensive agricultural and livestock management, and official purposes in general	Developed areas with limited agricultural potential, with some access	Aggregates of great groups, by landscapes

(Table continued on following page)

SURVEY SPECIFICATIONS (continued)

Survey order, name	Survey use	Area characteristics	Taxonomic generalization level
4th order, sampling zone (SZ)			Same as 4th order
5th order, survey (S)	GENERAL INVENTORY: to indicate zones deserving further study; very general appraisal of the agricultural and livestock potential	Inaccessible and/or large. In the case of broken topography (a); in case of unbroken topography, level of taxonomic generalization (b)	a) aggregates of suborders by landscapes b) aggregates of great groups by landscapes
5th order, sampling zone (SZ)			Same as 5th order
6th order, exploratory (E)	VERY GENERAL INVENTORY: to indicate zones deserving more detailed study	Very large and/or very inaccessible zones; in cases of broken topography, tax. gen. level (a). Cases of unbroken topography, tax. gen. level (b)	a) aggregates of suborders by great landscape b) aggregates of suborders by landscapes
6th order, sampling zone (SZ)			Same as 6th order

(Table continued on following page)

SURVEY SPECIFICATION (continued)

Survey order, name	Mapping units (outside of undifferentiated groups, complexes and misc. soil types)	Mapping method	Physiographic legend subdivisions to:
1st	Groupings	FREE MAPPING. Close photointerpretation (daily alternating photointerpretation and field work	Subdivisions of landscape elements
2nd	Groupings (groupings are often associations of phases)	Same as 1st order	Same as 1st order
3rd, (SD)	Associations and groupings	Same as 1st order	Subdivisions up to landscape elements
3rd, (SZ)	Groupings (often associations of phases)	Same as 1st order	Subdivisions of landscape elements
4th, (G)	Associations and groupings	FREE MAPPING. Pedological characterization of physiographic units	Subdivisions up to sublandscapes

(Table continued on following page)

SURVEY SPECIFICATIONS (continued)

Survey order, name	Mapping units (outside of undifferentiated groups, complexes and misc. soil types)	Mapping method	Physiographic legend subdivisions to:
4th, (SZ)	Associations and groupings	FREE MAPPING. Close photointerpretation (daily alternation of photointerpretation and field work)	Subdivisions up to landscape elements
5th, (S)	Associations and groupings	FREE MAPPING. Close photointerpretation (daily alternation of photointerpretation and field work in transects)	Subdivisions up to landscapes
5th, (SZ)	Associations and groupings	Same as 5th order	Subdivisions up to sublandscapes
6th, (E)	Associations and groupings	Same as 5th order	Divisions up to great landscapes or landscapes
6th, (SZ)	Associations and groupings	Same as 5th order	Subdivisions up to sublandscapes

(Table continued on following page)

SURVEY SPECIFICATIONS (continued)

Survey order, name	Observation avg. density: Detailed	Observation avg. density: Identification	Photograph or image scale	Publication scale	Minimum mapping area 0.25 cm^2	Special conditions	Estimated minimum yield*	Soil characterization	Area of mapping zone
1^{st}	15/km^2. Maximum distance 300 m	85/km^2	$\geq$1:20,000 Enlargements	1:5,000	0.0625 has.	A 3^{rd} order survey must exist	2,000 has.	Range of characteristics by horizons. Form A	
2^{nd}	2/km^2. Max. dis. 1000 m	8/km^2	$\geq$1:30,000	1:25,000	1.56 has.	Same as 1^{st} order	10,000 has.	Same as 1^{st} order	
3^{rd}, (SD)	1/km^2. Max. dis. 1500 m	4/km^2	$\geq$1:40,000 $\leq$1:20,000	1:50,000	6.25 has.		25,000 has.	Range of characteristics by horizon groups. Form B	
3^{rd}, (SZ)	2/km^2. Max. dis. 1000 m	8/km^2	$\geq$1:20,000 1:40,000 Enlargemts.	1:25,000	1.56 has.				10% of total
4^{th}, (G)	1/3 /km^2	2/3 /km^2	$\geq$1:70,000 $<$1:40,000	1:100,000	25 has.		100,000 has.	Range of characteristics by profiles. Form C	

(Table concluded on following page)

SURVEY SPECIFICATIONS (concluded)

Survey order, name	Observation avg. density		Photograph or image scale	Publication scale	Minimum mapping area	Special conditions	Estimated minimum yield*	Soil characterization	Area of mapping zone
	Detailed	Identification			0.25 cm^2				
4^{th}, (SZ)	3/km^2	6/km^2	1:40,000	1:50,000	6.25 has.				5% of total
5^{th} (S)	1/5 /km^2		≦1:70,000 Mosaics 1:100,000 Satellite or radar images	1:250,000	156 has.		400,000 has.	Same as 4^{th} order	
5^{th}, (SZ)	2/2 km^2		1:70,000	1:100,000	25 has.				2% of total
6^{th}, (E)	1/25 /km^2		1:250,000 Satellite or radar images	1:500,000	625 has.		1,200,000	Same as 4^{th} order	
6^{th}, (SZ)	1/10 /km^2		1:70,000	1:100,000	25 has.	In some cases, start from 3rd-order-survey areas			1% of total (0.1% based on 3rd ord. survey)

*Per edaphologist per year.

of the landscapes and soil types mapped during interpretation. These areas were studied in greater detail, in order to later extrapolate this information to areas similar in both physiography and other characteristics of interpretation.

II9. DESCRIPTION OF SOME OF THE TERMS USED IN THIS STUDY

- Soil grouping ("Consociation"). A unit of soil mapping in which at least 70% of the pedons (soil units) have the same taxonomy at the level defined for the survey (it is synonimous with soil series and used to avoid confusion with series taxonomy.)

- Soil association. A group of named and defined taxonomic units usually geographically or physiographically associated in a defined, proportional distribution and limited to one mapping unit.

- Soil complex. A cartographic or mapping unit in soil surveys, /23 consisting of two or more recognizable taxonomic units; these may or not be similar, but are found together more or less regularly and are intimately associated either geographically or physiographically and can not be outlined separately at the scale used (15).

- Detailed observations. Observations that allow an estimate of the minimum external and internal characteristics of a soil and thus permitting a tentative taxonomic classification, and the identification of the taxonomic unit to which they belong. These observations are carried out on a small open hole (approximately half profile), of perhaps 50 cm in diameter and sufficiently deep to study the B horizon (if it exists); this is followed by drilling to study the deeper portions of the soil.

- Identification observations. Observations performed by drilling, or direct observations on a natural cut, which allows identification of the txonomic unit and the mapping unit, already well known, and on which information exists from previous detailed observations.

- Modal profile. A profile with characteristics common to most of those examined in the area (mapping unit); it serves to represent the taxonomic unit of which it is a part (it is not an average, theoretical profile of the range of characteristics.)

- Soil mapping unit. A group of natural, limited soil bodies, within which polipedons may or not be of a contrasting classification (7). /24

III MATERIALS AND METHODS

III1. LOCATION AND GENERAL DESCRIPTION OF THE AREA UNDER STUDY

A. GEOGRAPHIC LOCATION

The study area of the Desaguadero image identified by the number /25
1010-14033, taken on 2 August 72, was the basic material for this study (Figure 12). It lies between the following coordenates:

S. 16° 40' 26"	S. 16° 55' 29"
W. 68° 53' 37"	W. 67° 13' 31"
S. 18° 11' 29"	S. 18° 26' 44"
W. 69° 19' 53"	W. 67° 38' 58"

Politically it comprises the Southern portion of the Department of La Paz, including the provinces of Ingavi, Aroma, Pacajes, G. Villarroel, Loayza and Inquisive, and the Northern portion of the Department of Oruro, including the provinces of Sajama, Carangas, Saucari, Cercado and Litoral (Figure 12a). It covers a surface area of 32,395 Km^2.

It may prove of interest to mention some of the more important cities located within the study area: Jesús de Machaca, Patacamaya and Luribay in the Northern sector; Chacarilla, Huayllamarca and Eucaliptus in the central part; Curahuara de Carangas Turco y Corque in the Southern sector. These cities have been important centers during the development of field work.

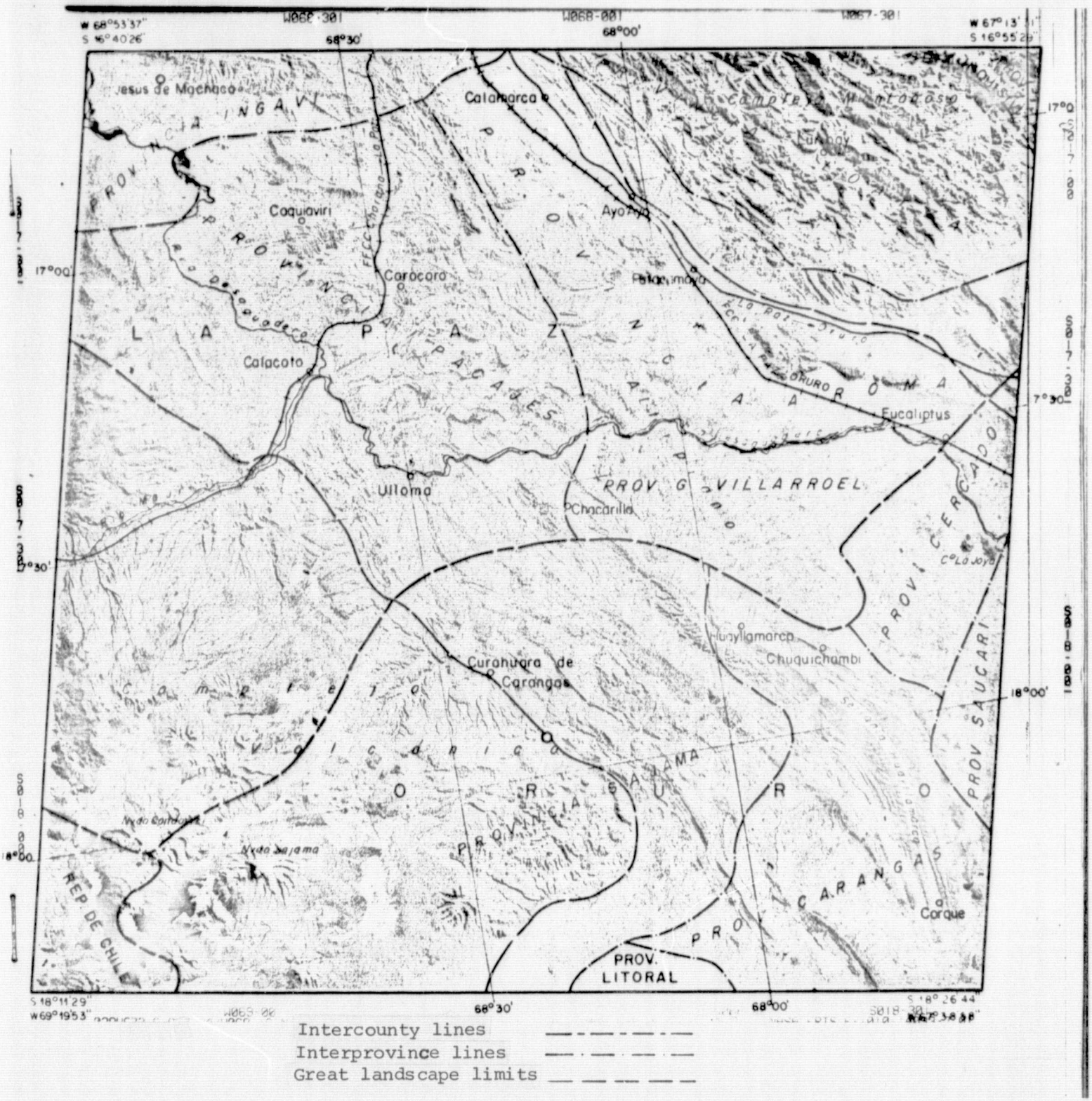


FIGURE 12. PHOTOGRAPHIC IMAGE OF THE DESAGUADERO IN BAND 7. SCALE 1:1,000,000

B. GENERAL DESCRIPTION OF THE AREA UNDER STUDY

a. Climate.

The climatologic information available for this area is a synthesis of six meteorological stations, and based on averages for approximately 15 years. These stations are located in the cities of Ayo-Ayo, Patacamaya, Sica-Sica, Chuquiña, Calacoto and Charaña. They are within or very close to the study area and are the only stations with information relevant to the area. Regarding this climatological information, we may also point out that the narrow valleys mapped offer a microclimate considered temperate and benign. However, a factor that must be considered negative is the existence of frecuent severe hailstorms that destroy the vegetation (in these regions there are no meteorological observatories). /27

Temperature.

The mean annual temperature is 9.88°C. The existence of marked seasonal differences is well established; the warmest months correspond to the summer season or rather, the months of November to March, with a mean of 19.47°C; the cold months are from April to October, with a mean of 2.68°C. Nevertheless, extreme minimal temperatures are found in Charaña during the month of July, with a mean of -18.2°C, corresponding to the coldest part of winter.

Precipitation.

The mean annual precipitation is of 340.7 mm, the main portion of which falls between the months of November and March, with 83.34% of the total annual rainfall. The highest precipitation, however, occurs during the months of January and February, while the lowest are found during June and July. /28

Studies performed with climatological data on the Patacamaya zone (16) regarding edaphic humidity requirements, show a clear water deficiency in soil for vegetation development; the potential evapotranspiration calculated for cultures that are important in the region reaches 1135 mm; hence the climate was classified as

relatively cold, arid to semiarid continental.

It should also be borne in mind that these regions suffer considerable showfalls with a certain frecuency, which damage crops and cause the death of animals.

b. Vegetation.

The dominating vegetation in the various physiographic landscapes is typical of the Bolivian high plateau and is distributted according to each zone's ecological conditions. These may appear as /29 poor grasses, some bushes and very few species of trees.

The surviving native botanical species that have been identified are:

Paja brava	Festuca ortophylla
Tola	Lepidophyllum quadrangulare
Yareta	Azorella glabra
Khota or yaretilla	Azorella Spp.
White Chiji (Chiji blanco)	Distichlis humilis
Mouse Tail (Cola de ratón)	Hordeum andícola
Keñhua	Polylepis incana

The agricultural activity in the area is of the subsistence type and beginning development; it takes place primarily in the areas identified as terraces, ondulated plains, at the foot of hills and on low hills; there are few foothills.

The most important traditional crops growing on small holdings are:

Potato	Solanum tuberosum
Quinoa	Cheropodim quínoa
Barley	Hordeum vulgare
Beans	Vicia faba
Oca	Oxalis tuberosa

It should be added that the narrow valleys, because they /30 constitute a very special ecological medium, permit the growth of crops such as maize (Zea mayz), alphalpha (Medicago sativa), and exotic tree species such as molle (Schimus molle), eucalyptus (Eucaliptus lanceolata), and variety of fruit trees such as:

Peach trees	Prunus pérsica
Plum trees	Prunus domestica
Apple trees	Pirus malus
Pear trees	Pirus communis
Vine	Vitis vinifera

c. Livestock

Cattle raising is limited by the scarce food that can be grown in the arid and salty soils of the high plateau. The most significant livestock species raised are sheep, "auquénido" (translation unknown, but presumably refers to llamas, vicuñas and such) and very little beef; they are distributed mainly on the high plateu plains, the terraces and at the foot of mountain ranges and hills. Development of livestock in the Eastern range is very limited, as it is in the high sierras; it is even rarer in the Western mountain range.

The alpaca has found its optimum ecological niche in the hydromorphic soils, sheep develop best on the terraces and the plains, and the llama at the foot of mountain ranges and low hill country.

It should be pointed out that overgrazing by sheep is causing soil depletion and leaving some areas in practically desert /31 condition.

d. Accessibility.

In regard to means of communication, the area has an extensive network of 2nd and 3rd order roads, including trunk roads such as the La Paz-Oruro highway. There are also two important railroad branch lines crossing the area: one from La Paz to Oruro and the other between La Paz-Corocoro-Charaña.

In the Western sector, however, the road network is very poor and in bad condition.

This road infrastructure played an important role during field work, since it made access to more remote areas possible.

e. Geology and geomorphology.

The study area contains a series of geological formations constituting the mountain ranges, hill country and plains; their ages range from the paleozoic to the quaternary, which forms the parent material of the soils.

The geomorphological and physiographic characteristics of the landscapes are a result of the meteorization and ulterior denudation of the rock material during past geological ages, giving rise to soil formation.

Geomorphological analyses made possible an evaluation of the process of relief formation, studied from the genetical point /32 of view to reconstruct the history of the earth's surface with reference to its external forms, and to establish their diverse relationships.

For this study, the area was divided into three great landscapes or main geomorphical units:

Volcanic Complex or Western Range.

This great landscape occupies the Southwestern portion of the study area, from the town of Achiri in the North, going South via Curahuara de Carangas. Within this unit magmatic effusions stand out; the most important is the ignimbrite meseta between the Mauri river and the Curahuara de Carangas hill country.

The lithological constitution of the stratovolcanoes is provided by dacitic and andesitic lavas associated with prioclastic rocks.

High Plateau

This unit occupies the largest portion of the study area and is located in the image's center; its position corresponds to the deep and internal part of two large continental masses: the volcanic complex or Western mountain range in the West and the Eastern mountain range in the East.

This great landscape is composed of material originating in the continental masses mentioned, formed by denudation of the high parts; the effect of running water and eolic processes were the /33 transporting agents.

Among sedimentary materials in the Northern high plateau we could mention conglomerates, sandstones and lutites, interspersed in many places with gypsum layers and, sporadically with tobaceous strata. For the most part, however, this sector of the high plateau contains quaternary sediments, which constitute the most important portion of this region.

Among the main geological formations to be found in this portion of the high plateau we have:

- Totora formation (tertiary)
- Chacarilla formation (tertiary)
- Huayllamarca formation (tertiary)
- Ballivián formation (tertiary)
- Pando formation (tertiary)

Cañaviri formation (tertiary)

- Tiahuanacu formation (tertiary)
- Umala formation (quaternary)

It is important to mention the diapyric gypsum present in the high plateau region; they do not have a definite stratigraphic position and are formed by gypsum deposits which have contributed to the presence of calcium carbonates in most soils on the high plateu plains.

Mountain Complex of the Eastern Range (Paleozoic block) /34
Characterized by its strong folding and fracturization, it is formed by numerous dislocations caused by tangential and vertical forces that have been active in the area. These processes resulted in the formation of the Eastern Range. It owes its current profile and altitude to techtonic forces and the instruction of igneous bodies, that culminated in the development of the Range.

The effects of glaciation have also influenced the development of the current landscape, whose eternal snow fields cover vast areas, such as the snow-capped Tres Cruces.

The geology of this complex includes ordovicic, siluric and devonic systems, whose predominant lithologic materials are lutites, siltites, quarcites, schists and sandstones.

III2. MATERIALS USED

A. LANDSAT IMAGES

LANDSAT images have been the basic product used in the elaboration of this study; we shall briefly refer below to their different classes and scales. /35

a. Original negative image in black and white. This was the first product NASA sent the ERTS/BOLIVIA Program, in a scale of 1:3,300,000. They are similar to ordinary film negatives. They correspond to a computerized processing of the information gathered by the Multispectral Scanner along the satellite's trajectory.

There are four negatives, corresponding to the four channels or bands taken of the same scene, and covering an area of approximately 185 x 185 Km.

NASA also sends slides at scales of 1:3,300,000 and 1:1,000,000 for interpretive analyses, using the instruments outlines under III3 (A) and (B).

b. Photographic images in black and white at a scale of 1:250,000 of bands 4, 5, 6 and 7. These are images obtained from the original negative; this stage in processing is carried out in the photographic laboratories of the ERTS Program, with equipment mounted especially for this purpose.

This products provides excellent material and is the basis for interpretation tasks in the different application disciplines.

The images obtained from each of the bands have their own /36 peculiar characteristics; the image in band 7 is the most propitious for soil studies (Figure 12).

c. Composite photographic image in false color on a geometrically corrected scale of 1:250,000. Another product processed by a computerized system, based on the information in bands 4, 5 and 7; it is furthermore geometrically corrected such that the original data are adjusted so that the columns correspond to the North-South direction while the rows are perpendicular to it.

These images offer specific features the interpretation of which is very important, contributing effectively to the determination of soil units (Figure 14).

d. Diazo or composite images in false color at a scale of 1:1,000,000 These products are processed from a slide by a contact system. It is usually formed of three superimposed, transparent images, each corresponding to one of the bands; bands 4, 5 and 7 are most frecuently used for this purpose. Each band is obtained /38 in colors such as magenta (violet red), sepia (coffee), cyam (sky blue), yellow, blue, green, red and black.

B. COMMONLY USED MATERIALS

a. Multispectral aerial photographs. These are pictures taken by a multispectral camera at a 1:24,000 scale, corresponding to five folios within the area of the Desaguadero image. Whenever possible, the most significant physiographic changes are traversed (Figure 15).

These photographs are taken within wavelength close to those of the channels or bands of the Multispectral Scanner. Hence the resulting photographic products in these four channels are very similar to corresponding images in each of these bands. These photographs are also useful in the interpretation of details in certain areas of interest.

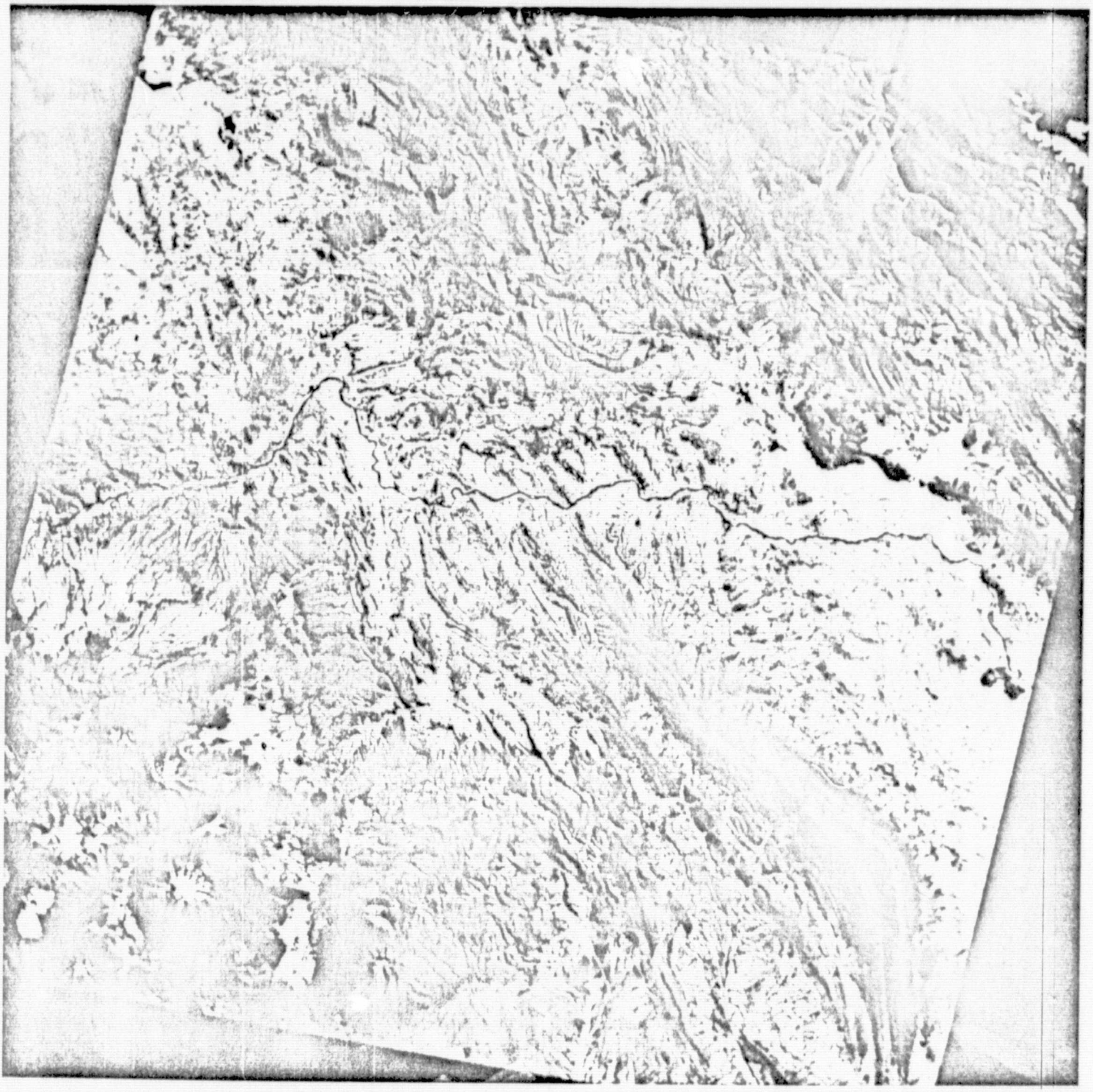


FIGURE 14. COMPOSITE PHOTOGRAPHIC IMAGE IN FALSE COLOR. BANDS 4, 5 AND 7. SCALE 1:1,000,000, GEOMETRICALLY CORRECTED

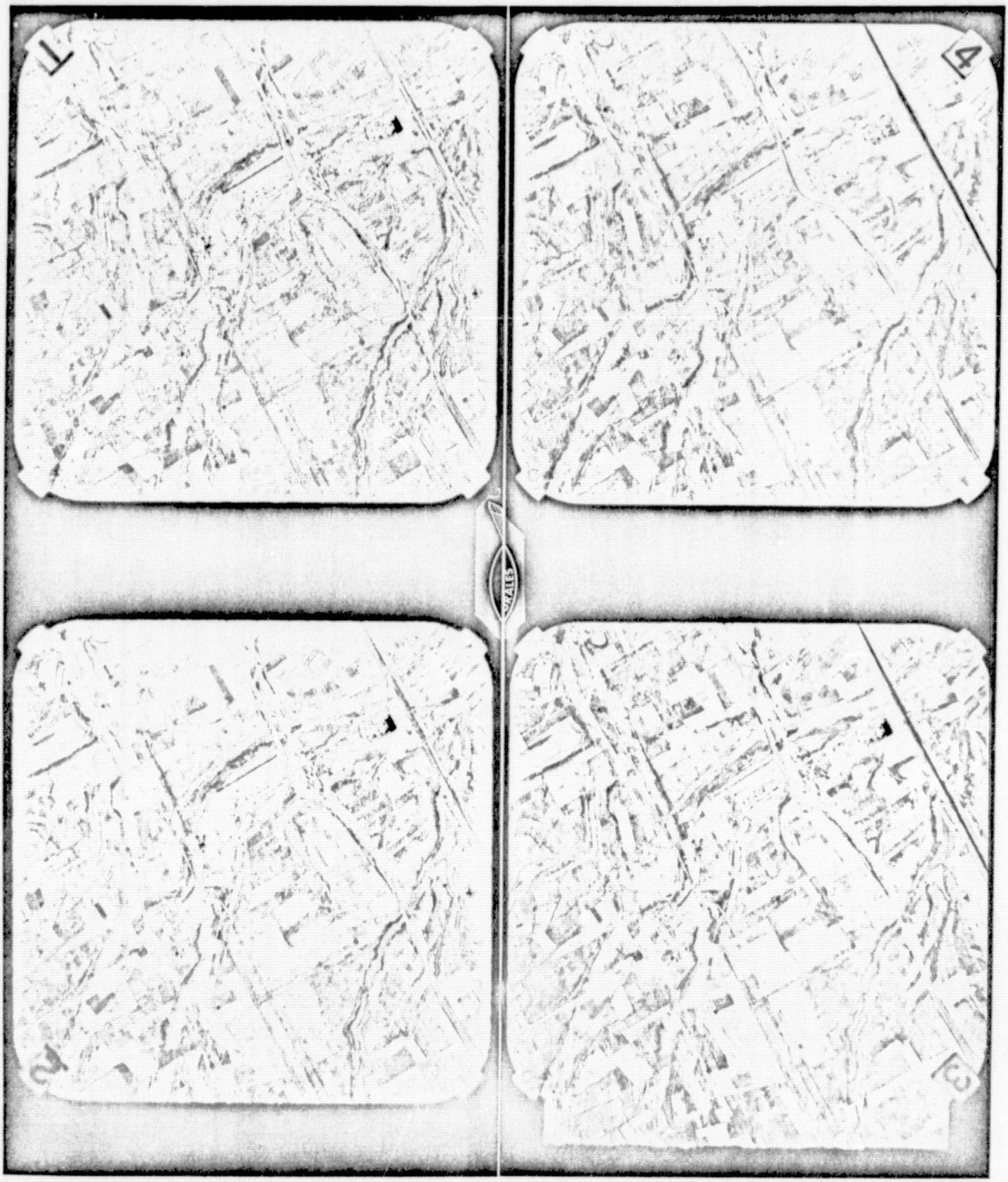


FIGURE 15. MULTISPECTRAL AERIAL PHOTOGRAPH.
SCALE 1:24,000

b. Topographic maps. They are prepared by the Military Geographic Institute on a scale of 1:250,000 and are used as important references in the location of towns, roads, rivers, etc. They They are also used in the comparison of scales, between these and photographic images on the same scale. It should be pointed out that these topographic maps were not used as basic maps, but rather the image itself, properly annotated as to toponomy.

The national topographic charts on a scale of 1:50,000 served the same purpose in the preparation of soil maps and the field work in the plains, referred to in chapter III4 (F). /40

Other important materials used in this study were: Soil profile descriptive guide (FAO), Soil Taxonomy, Munsell color chart, Kodatrace paper, etc.

III3. INSTRUMENTS USED

Among the most significant instruments used during this study we /41 shall mention the following:

A. Additive Color Viewer. A compact, optical projection instrument with four channels. It projects the four images corresponding to the four LANDSAT spectral bands onto a screen (with a superimposed Kodatrace paper), on a 1:1,000,000 scale, starting from original black and white slides on a 1:3,300,000 scale.

Each band can be projected independently, or all bands together and at the same time, or simply some of the bands, depending on the interpreter's requirements or needs.

Among other features, this system has the peculiarity of being able to project each band in any desired color: green, red, violet, or in black and white; in this manner a series of appropriate combinations are possible, using filters that will print those colors. At the same time, the light intensity can be regulated independently for each band.

This interpretative process is often used to achieve the necessary detail in the results of investigations on possibly new features, of difficult interpretation on a photographic image.

B. VP-8 Image Analyzer. This is another instrument on which LANDSAT images are analyzed and interpreted.

The image is projected onto two screens similar to those of a /42 television system; the projection starts with a black and white slide on any scale, although 1:1,000,000 and 1:3,300,000 are the scales most commonly used.

One of the screens shows the image projected in different colors and tone intensities, each of which corresponds to a specific class of soil cover. This cover is responsible for the differences in the slide image.

In reality the variations in color are due to different densities in the shades of gray recorded on the image, measured by the instrument and projected onto the screen according to the needs and purposes of the interpreting analyst.

On the other screen are projected, simultaneously, other image features such as tonal density curves of the image, in a normal scale or amplified 5 times, in addition to other characteristics of interest.

These two instruments are mounted in the ERTS Program laboratories; their handling requires special calibration and interpretation techniques.

Other important instruments are the following: 3X and 8x magnifying glasses; light table; eclimeter, altimeter and compass (Brunton); pH-meter (La Motte-Morgan); planimeter, etc.

III4. METHODOLOGY ADOPTED FOR THIS STUDY

A. FIRST RESEARCH PHASE, CORRESPONDING TO PRELIMINARY INTERPRETATION

This phase consisted of a series of consecutive preliminary interpretation stages on photographic images, by means of composite /43 slides in false color or diazos; finally, detailed interpretations based on the analysis of slide images on the Additive Color Viewer and the VP-8 Image Analyzer.

During this work, we followed, for the most part, the known methodology for the interpretation of conventional aerial photographs, since there is much similarity between them; this method of interpretation is detailed below. However, the steps followed during interpretation had their own characteristics, adjusted to the monoscopic view of the image and the larger scale analysis made possible by the ample, regional scene, combinations of images taken in different bands or wavelength ranges, etc.

This phase of interpretation started with the main drainage network, on Kodatrace paper superimposed on the image in black and white of band 7, at a scale of 1:250,000. This first information was used later as the basic element in the ulterior interpretation of soil units.

Next the three great landscapes were outlined. They constitute the study area and are: The Western or Volcanic Range (v), the High Plateau (A) and the Eastern Range (O). This outline was adjusted on the basis of existing geological and geomorphological information, whose study was also based on LANDSAT images.

Next we proceeded with the interpretation and identification of landscapes and physiographic units, associating them with soil /44 units, since they are intimately related. Care was also taken during this interpretative stage, to perform an exhaustive analysis to relate standards and interpretative elments in soil - such as

photographic tonality, drainage, features due to erosion, shapes of slopes, hydric influences, etc., which characterize each of the identified soil classes.

It should be pointed out that during this phase the diazos were an important source for providing the detail necessary to establish the limits of the mapping units. The resulting map was later completed by bringing out new features in detail by means of the Additive Color Viewer and the VP-8 Image Analizer referred to in the previous section (III3.)

Finally, a tentative soil legend was prepared, based on the physiographic names to which each of the mapped units correspond; at the same time the field work was planned, considering the existing road infrastructure in the most important areas for observation.

B. FIRST FIELD WORK PHASE FOR SURVEY AND EVALUATIVE ANALYSIS OF THE PRELIMINARY INTERPRETATION MAP.

During this survey, the identification of the mapped soil units showed that the preliminary interpretation map retained a correct separation of the units, with a few exceptions in which a correction to soil limits became necessary. At the same time the physiographic nomenclature used was verified and, in some cases, modified.

During this phase the information relative to geology and geomorphology was also briefly examined, with the aid of two geologists, a geomorphologist and a hydrologist. /45

It should be pointed out that during this field work phase, soil profiles in outcroppings were not described; observations were limited to soil surveys in natural cuts, and drillings only in the most important areas.

C. SECOND RESEARCH PHASE

Following the first field work phase, soil limits were adjusted, while the legend was also slightly corrected.

Based on the road infrastructure and existing accessability, plans were drawn up for the second field work phase; 15 properly distributed camp sites were set up during the work.

During this phase, sampling areas were selected, whenever possible on accessible roads; possible outcrops to be described were sought in the same areas.

The field work had to be performed by cutting across in transects (identification of soil classes by moving perpendicularly to the soil limits, generally manifested by changes in physiographic features), over soil limits established by interpretation. The units identified within the sampling area had to show the most representative characteritics of that soil class.

It was also planned thatfield information from this phase was to used for computer processing, to obtain detailed alphanumeric maps (printouts) as a function of these data. To this end it also became necessary to measure the reflectance of the surface covering, to relate to reflectance information gathered by the Multispectral Scanner during image taking.

D. SECOND FIELD WORK PHASE

Observations during field work were taken on outcroppings or soil profiles; detailed and identification observations (7) were later expressed by modal profiles following the specifications in the Table (page 20).

The objective of this second field work phase was to perform more detailed field checks than during the previous one: /47 verifying, correcting and adjusting the interpreted soil lines by means of field runs performed normally in transects, and filling in any necessary areas by means of free checks.

One of the fundamental purposes was to locate and select the typical or modal profiles in the field, such that they showed the most representative characteristics of each of the units mapped, to consider them as such.

Location of the sampling areas followed one basic purpose: to establish a standard for each unit, against which other units could be compared; in some cases, the effects of processes such as deposition, erosion and periodic flooding could be observed. Modal profiles have been described on typical or representative portions of the unit, considering external features or physiographic position; the same applies to the vegetation cover, associating internal or edaphic characteristics diagnosed by detailed and identifying observations.

Once the location of of the modal profiles was determined, these were opened up for description according to the FAO guide (20), followed by a tentative taxonomic classification based on the characteristics identified during profile description. This was later either corrected or confirmed, depending on the analytical laboratory results; these were performed at the Santa Cruz laboratories.

E. THIRD RESEARCH PHASE

On the basis of the information from the field, an analysis of the information stored on magnetic tape was performed by means of a computer system. The analysis was performed at Purdue University, in the United States. As a result, digitalized maps (PRINTOUTS) were obtained, on a 1:250,000 scale, of the entire area covered by the image under investigation.

Following the final classification of the digitalized maps, they were printed, by computer, as photographs, in which each soil class is identified by a specific color (Figure 16).

This computer processing is extensive and complex; it is detailed in the report prepared for publication under the title "Digital processing of LANDSAT-1 data to be used in the inventory of natural resources in Bolivia's Desaguadero area."

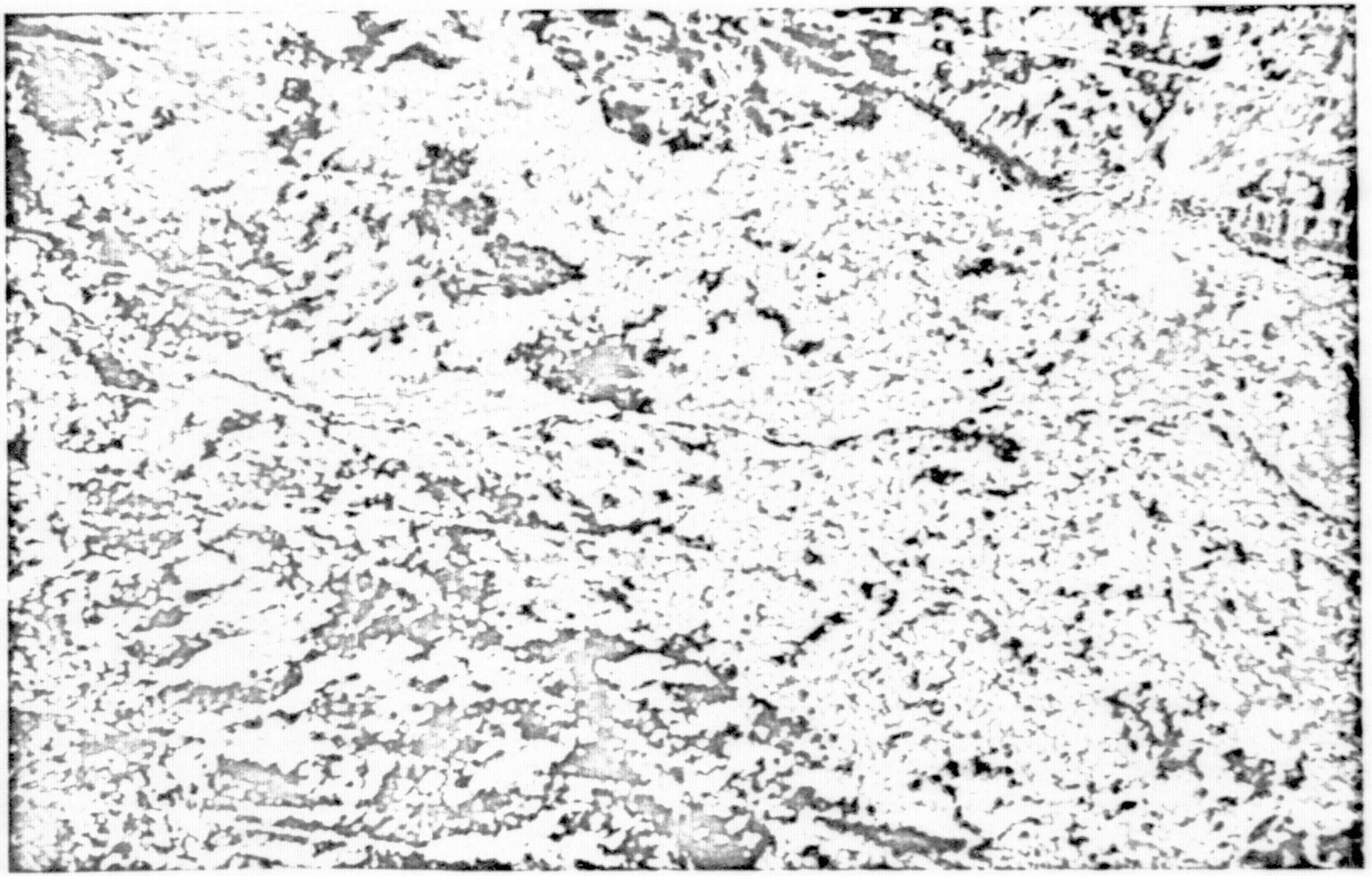


FIGURE 16. PHOTOGRAPH RESULTING FROM THE FINAL COMPUTER CLASSIFICATION (PRINTOUTS), SHOWING ONE CLASS OF SOIL PER COLOR. APPROXIMATE SCALE 1:250,000

F. THIRD FIELD WORK PHASE

There were two purposes for this field work phase. The first /48
one, to verify the accuracy of the soil limits on the preliminary maps resulting from computer processing; and the second one, to round out the field work in order to finish the map obtained from the interpretation of photographic images. At this stage the working mode was similar to that of the second field work phase, with the difference that several points had been located within the study zone, corresponding to natural features represented on topographic and soil maps. These were taken as arbitrary control points and made possible a perfect orientation of the soil maps on a 1:50,000 scale resulting /50
from the printouts and the corresponding topographic maps. The superpositioning of the soil maps on the topographic ones was the basic criterion for orientation and location during field work.

G. FINAL REINTERPRETATION AND COMPLEMENTATION BASED ON THE GEOMETRICALLY CORRECTED DESAGUADERO IMAGE COMPOSED IN FALSE COLOR

Once the field work was concluded, all the information obtained was ordered and classified, and preliminary soil classification based on soil taxonomy (23) was confirmed and corrected as a result of laboratory data.

At the same time cartographic generalization was continued, taking as mapping units groupings ("consociations"), associations and soil complexes; these last two are formed by soil combinations described in the chapter on results.

Lastly, final reinterpretation took place, first on the black

white image, and then on a false color image composed of /51
three bands and geometrically corrected (Figure 14). The latter photographic image offers individual interpretation characteristics that aided significantly in the identification of soils, especially in regard to areas subject to periodic flooding, salty areas, moist soils under the vegetation cover, dunes, and others. This material was very valuable for interpretation. The photographic image in black and white, on the other hand, was an excellent product in the identification of physiographic units, one of the basic portions of this study.

H. METHODS ADOPTED DURING THE INTERPRETATION OF PHOTOGRAPHIC IMAGES

The methodology adopted for the photographic interpretation of LANDSAT images is similar, in many respects, to that used in the interpretation of conventional aerial photographs. Both products have a number of common characteristics from the point of view of interpretative features.

LANDSAT images offer a large panoramic view, in which the interpreter sees the image not as a figure, but as the expression of an enormous variety of natural phenomena; from /52
this complex relationship the required information is derived: if differences are found in the image, it is because differences in the terrain are responsible for the differences seen.

While this is not the time to describe and discuss each of the methods in a detailed manner, it is, however, necessary to indicate that in the interpreting procedure three well known methods of photointerpretation are used:

1. Standard analyses. They are based on the identification

of major landscape units and their division into smaller units characterized by so-called "local standard elements."

The starting assumption is that each standard element is related to certain soil conditions. These standard elements are: land profile, drainage, erosion features, vegetation, photographic shade and cultural features, although some of these are identified only with difficulty (8).

According to Frost, these elements are indicative of surface and subsurface conditions; obviously, this relationship was found during field work. This line of reasoning is applied, for instance, to the identification and delimitation of volcanic cones, which normal have radial, centrifugal drainage; when these are associated, in many cases, to the light or white shades of snow (band 7) found on the top of the cones, then the possibility becomes certainty. The disadvantage of this method is that very few interpretation /53 standards for LANDSAT images are known. Publication, however, is slowly endeavoring to satisfy this need.

2. Analyses of Elements. In this method developed by Buringh, each of the elements is analyzed systematically. It is based on the fact that most of the characteristics of the earth's surface are related, in one way or another, with soil conditions.

   For some elements, the connection is immediate, as is the case with relief; for others, such as soil use, the connection is less immediate. All elements considered are assumed related to soil formation factors. (Climate, organisms, nature of the material, relief, time and human activity.)

The study of the elements in the image starts with the elimination of all those elements that have little or no relation to

the soil (land use); in this manner, interest can be focused on the more important, related elements. The elements can be divided into two groups:

a. Elements that are systematically and closely related to soil units, such as relief.

b. Elements that indicate only a change in the soil covering, /54 and do not always coincide with soil units, such as vegetation, which can be changed so much by human activity.

Among the most important elements used in image interpretation for soil surveys, we may mention: soil or landscape type, relief, shapes of slopes, drainage conditions, constructive or depositional drainage system, destructive drainage system or formation of "cárcavas" (translation unknown), natural vegetation, parental material associated to color, etc.

3. Physiographic analysis. Physiographic analysis was very well developed by Vink and Goosen in studies based on conventional aerial photographies. It can also be readily applied to the analysis of LANDSAT photographic images, since physiographic relationships correlate well with soil classes, because the earth's surface is classified according to physiographic units each of which has a unique association of soils (8).

   Image analysis is based on a complete knowledge of the relationship between physiography and soils, and on the knowledge of the dynamic processes rather than statistical elements. The elements considered above are just as important as those in the analysis of elements, but are used differently. Many of them are analyzed first to draw in limits, to be used later as basic elements in understanding the landscape's physiographic relationships. Since that relationship exists primarily because of interaction between physiographic processes, we can

define physiographic analysis as an "analysis of processes rather than one of phenomena." Hence observed phenomena are translated in terms of the processes that gave them and are giving them origin.

The most important step in physiographic analysis was to recognize and identify the basic processes that came into play in specific cases.

The applications and uses of the three methods we briefly described is somewhat artificial. In actual practice, a mixture of all three methods is used; this resulted as a consecuence of acquired experience, as well as of the way in which this study was proposed.

IV RESULTS

The information on image interpretation, in addition to field and laboratory data made it possible to prepare the final soil map on /57 a scale of 1:250,000. On it are identified 24 units, of which 17 correspond to agriculture and livestock soil properly. They are represented by modal or typical profiles, classified according to soil taxonomy.

The map shows a physiographic soil legend (Table on page), in which the three great landscapes in the region have been subdivided into landscapes down to the physiographic unit. Each physiographic unit corresponds to one mapping unit, composed of soil groupings ("consociations"), associations and complexes. The naming of the mapping units is based on some outstanding characteristic, or on a significant local name. The area covered by each mapped soil unit was also quantified. Thus, all the characteristics of a soil survey at survey level have been compiled.

DESCRIPTION OF MAPPING UNITS AND THEIR TAXONOMIC CLASSIFICATION

V. WESTERN OR VOLCANIC RANGE REGION

V11 Volcanic Cones

As indicated by the name, they have the conical shape resulting from prior volcanic activity; the surface area is 128,358 Has and they are located along the Western Range, in the image's Southwestern /58 sector.

These volcanic cones exhibit extremely steep slopes - of over 60% - are made of volcanic rock and are of no agricultural or livestock

PHYSIOGRAPHIC SOIL LEGEND

GREAT LANDSCAPE	LANDSCAPE	PHYSIOGRAPHIC UNIT	MAPPING UNIT	TAXONOMIC CLASSIFICATION (Modal Profiles)	SURFACE (Hectares)	SYMBOL ON MAP
(WESTERN OR VOLCANIC RANGE) V	VOLCANOES V1	Volcanic cones V11	Volcanic cones		128 358	V_{11}
		Footing of volcanic cones V12	Footing of volcanic cones	Psamments	137.156	V_{12}
	VOLCANIC LAVA MESETA V2	Little dissected V21	Volcanic lavas		47 782	V_{21}
		Strongly dissected V22	Eroded lavatic meseta		402.524	V_{22}
	PLAINS V3	Hilly V31	Grouping Ojsani	Spodic Cryopsamments	53.710	V_{31}
		Well drained plains V32	Grouping Cosapa	Spodic Cryopsamments	47510	V_{32}
		Hydromorphic soils V33	Grouping Bofedal	Aquic Cryopsamments	12.866	V_{33}
		Salt pans V34	Grouping Depresión	Spodic Psammaquents	35.358	V_{34}
	HILLY COUNTRY A1	Hilly country A11	Grouping Huayllamarca	Lithic Ustochrepts	365.466	A_{11}
		Hills A12	Complex Toponoco, Techos, Los Lomas	Lithic Ustipsamments, Andic Ustochrepts, Aridic Haplustalfs	595 536	A_{12}
		Hill footing and hills A13	Complex Chuquichambi, Pichuco, Romero, Comanche	Typic Ustipsamments, Lithic Ustipsamments, Aridic Haplustalfs, Aridic Ustochrepts	232 836	A_{13}

Table continued on following page

TABLE (continued)

ALTIPLANO **A**	PLAINS A2	Hilly country A21	Grouping Sullama	Entic Durorthids	207.275	A_{21}
		Bad lands, A22	Grouping Erodados	Typic Ustipsamments	27.790	A_{22}
		Dunes A23	Las Dunas		14.475	A_{23}
		Plana A24	Complex La Oveja Chijini Tolar A Tolar B El Rio	Duric Camborthids Vertic Camborthids Ustertic Camborthids Fluventic Ustochrepts Lithic Ustorthents	316.410	A_{24}
		Periodically flooded A25	Grouping Conchillas Hornillos	Typic Natrargids Vertic Camborthids	39.905	A_{25}
		Salt pans; A26	Association Cap.Castrillo C de Carangas Kolla La Cantera	Typic Psammaquents Aquic Salorthids Typic Salorthids Typic Natrargids	94.235	A_{26}
		Recent A27	Grouping Patacamaya	Typic Cryopsamments	3.870	A_{27}
		Terraces A28	Grouping Corocoro Sud	Lithic Ustorthents	65.515	A_{28}
EASTERN RANGE **O**	High hill country 01		High hill country		268.950	O_1
	LOW HILL COUNTRY 02	Hills 021	Hilly		73.740	O_{21}
		Hill footing and hills 022	Grouping Belén	Lithic Ustipsamments	25.720	O_{22}
	Rohling terraces 03		Grouping Toloma	Vertic Ustorthents	28.565	O_3
	Narrow valleys 04		Grouping Luribay	Mollic Ustifluvents	6.570	O_4

value. They are little meteorized. Because of their high altitude, many of these volcanic cones are covered by permanent snow fields and constitute an inexhaustible supply for the generation of thaw water.

Although these units have been identified on the map, they are formed by non-edaphisized rock material. No soil profiles were described in this case, since these units are considered of no importance from the agricultural point of view.

V12 Footing of Volcanic Cones

These soils cover an area of approximately 137,156 Has and are located near the bottom of the volcanic cones. Their slopes are also steep (30-60%) and they suffer intense erosion; hence what little soil is formed is continuously eroded towards lower lands, forming the plain.

Soil profiles were not described for this unit, since it is considered of little agricultural importance. Detailed observations were however performed, making it possible to classify these units within the order of the entisols, suborder Psamments.

V21 Volcanic Lavas

This soil class is found on the volcanic lava mesetas, covering an area of 47,782 Has. Their main identifying characteristic is little landscape dissecting. These soils are mostly rocky, with significant /59 rock outcrops of ignimbrites. Small areas of highly eroded soils have been found, however, that are unsuitable for agriculture. They result from colluvial depositions or the insitu development of badlands; these areas were not mapped, because they are small enough to remain below the minimum mapping unit.

No soil profiles were described for this unit, and only detailed observations were performed, since the areas are unsuitable for agricultural development.

V22 Eroded Lavatic Meseta

It is also located on the great volcanic lava meseta, covering an area of 402,524 Has. Its main characteristic is strong dissecting, caused by erosion processes on very deep "carcavas". The area shows, in general, a very craggy, hilly relief; its sparse soil is eroded towards lower and more concave portions of the region, forming light soils.

These areas are considered unsuitable, of desert-like characteristics and lacking agricultural value. Soil profiles were not described for this unit and only detailed observations were performed.

V31 Ojsani Grouping("Consociation")

This grouping ("consociation") covers an area of 53,710 Has and /60 corresponds to the hilly part of the plain, located near the Western Range. The characteristic of the soil in this area is its very light texture, in many cases with salty efflorescences and poor in nutrients.

From the agricultural and livestock point of view they are of relatively low value; the soil is covered primarily by "paja brava", used for animal feed. No agricultural activity was observed. The typical or modal profile of these soils was classified as Spodic Cryopsammantes, identified with the following profile:

MODAL PROFILE 12

A. INFORMATION ON THE SAMPLING SITE

Profile number: 12
Soil name: "Ojsani" grouping ("consociation")
Taxonomic classification: Spodic Cryopsamments
Date of observation: September 14, 1975
Author: Moisés Ureña Espinoza
Location: 1.5 Km NE of the locality of Ojsani; 2.5 Km S of Challa Krollu, Sajama Province in the Oruro County
Elevation in meters: 3,960 above sea level
Form of the terrain:
a) Physiographic position of the site: hilly plain
b) Form of surrounding land: Nearby ignimbrite rock outcrops can be observed
Slope at profile location: plain
Vegetation or land use: Soil covered by "paja brava" and other native grasses used for pasture of sheeps, llamas and related species.

B. GENERAL SOIL INFORMATION /61

Starting material: soils composed of alluvial sediments derived from volcanic material.
Drainage: Excessively drained
Humidity of the profile: humid
Depth of phreatic layer: 80 cm
Presence of rocks and rocky outcrops on the surface: None
Evidence of erosion: Natural, laminar and to slight extent
Presence of salts and alkali: Slightly salty
Human influence: Areas used exclusively for grazing of sheep and llamas and related species.

C. BRIEF PROFILE DESCRIPTION

Profile corresponds to consecutive accumulation of very light material of volcanic origin; the soil does not show development of horizons and is formed by slightly differentiated sand layers; the phreatic layer is close to the surface.

D. PROFILE DESCRIPTION

Au1 0-25 cm. Presents no diagnostic epipedon.
Gary (5Y 5/1) when humid; sandy texture, without structure, loose grained; non-adherent, non-plastic, loose whether humid or dry; presence of a few gravel fragment, angular shapes; very few fine roots; diffuse and plain horizon limit. /62

Au2 25-85 cm. Presents no diagnostic horizon.
Dark gray coffee (10YR 3/2) when humid; coarse sandy texture with much gravel; lacks agglomerate structure; non-adherent, non-plastic; loose whether humid or dry; abundant unaltered gravel; presence of abundant large, hard, irregular nodules of volcanic material; very few very fine roots (no samples taken).

V32 Cosapa Grouping ("Consociation")

This unit includes the well dained, flat alluvial plain and covers an area of 47,510 Has. It is located adjacent to the Western Range.

It corresponds to very light, poor and slightly salty soil under adverse climatic influence. These are extreme conditions for the development of vegetation. Profile 21 shows the typical characteristics of this unit, classified as Spodic Cryopsamments.

LABORATORY ANALYSIS

PROFILE NO. 12

Depth in cm		0-25	25-65				
Texture		A	A				
pH		7.3					
Electric conductivity, mmohs cm		143					
Free carbonates		A					
Soluble cations in me./100 gr.	Ca^{++}	-					
	Mg^{++}	-					
	Na^{+}	-					
	K^{+}	-					
Cation exchange data in me. /100 gr.	Ca^{++}	5.6					
	Mg^{++}	1.4					
	Na^{+}	1.17					
	K^{+}	1.22					
T. B. I.		9.59					
C. I. C.		9.79					
% Base Saturation		98					
Phosphorus (Olsen)		5.0					
Acids me /100 gr.		0.2					

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

MODAL PROFILE 21

A. INFORMATION ON SAMPLING SITE

/64

Profile number: 21

Soil name: "Cosapa" grouping ("consociation")

Taxonomic classification: Spodic Cryopsamments

Observation date: October 12, 1975

Author: Moisés Ureña Espinoza

Location: 1 Km S of the town of Cosapa, 100 m E of the Cosapa-Turco road, 10 Km E of the Sajama volcanic cone, Sajama Province in Oruro County

Elevation in meters: 3,880 above sea level

Form of the terrain:

a) Physiographic position of the site: flat plain

b) Form of surrounding land: well drained flat plain

Slope at profile location: plain /65

Vegetation or land use: Development of very poor grazing, primarily paja brava; there is no agricultural activity, and only pasturing of sheep, llamas and related species.

B. GENERAL SOIL INFORMATION

Starting material: soils composed of alluvial sediments derived exclusively from volcanic material.

Drainage: Excessively drained

Humidity of the profile: humid

Depth of phreatic layer: very deep

Presence of rocks and rocky outcrops on the surface: None

Evidence of erosion: Natural, laminar, of moderate intensity

Presence of salts and alkali: Soils slightly affected by salinity

C. BRIEF PROFILE DESCRIPTION

Deep profile, of very light texture, formed by gray sand in the first horizon, and coffee to dark coffee at greater depth.

D. PROFILE DESCRIPTION

Au1 0-35 cm. Presents no diagnostic epipedon.
Gray (10YR 5/1) when humid; coarse, sandy texture with little gravel; without loose-grain structure; non-adherent and non-plastic when wet; loose whether humid or dry; low content of rounded gravel; little biological activity; diffuse and plain horizon limit.

Au2 35-80 cm. Presents no diagnostic horizon. /66
Dark coffee (7.5YR 3/2) when humid; coarse sandy texture with much gravel, without loose grain structure; non-adherent and non-plastic when wet, loose whether humid or dry; high content in volcanic material gravel, strongly meteorized; little biological activity; plain, diffuse limit (no samples were taken).

C 80-150 cm. Coffee (7.5YR 5/4) when humid; coarse sandy texture with abundant gravel; lacks agglomerate structure; non-adherent and non-plastic when wet, loose whether humid or dry; (no samples taken).

V33. Bofedal Grouping ("Consociation") /68

Located in depressed locations or next to river beds, mostly between the lava meseta or near the foot of volcanic cones close to the Western Range. Area covered: 12,866 Has.

These soild are characterized by keeping very humid and almost flooded; the phreatic level is close to the surface and sometimes reaches the surface during the rainy period. The presence of gleyzed horizons is

LABORATORY ANALYSIS

PROFILE NO. 21

Depth in cm		0-3	35-60	60-130			
Texture		A	A	A			
pH		7.2					
Electric conductivity, mmohs cm		38					
Free carbonates		A					
Soluble cations in me./100 gr.	Ca^{++}	-					
	Mg^{++}	-					
	Na^{+}	-					
	K^{+}	-					
Cation exchange data in me. /100 gr.	Ca^{++}	3.					
	Mg^{++}	1.					
	Na^{+}	0.38					
	K^{+}	0.90					
T. B. I.		6.08					
C. I. C.		6.28					
% Base Saturation		97					
Phosphorus (Olsen)		3.2					
Acids me /100 gr.		0.2					

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

the most outstanding characteristic of these soils. Because of these conditions, no agricultural activity has developed; they offer, however, a good grassland cover, used for livestock grazing.

The modal profile described for these soils has been classified as Aquic Cryopsamments.

MODAL PROFILE 13

A. INFORMATION ON SAMPLING SITE

Profile number: 13
Soil name: "Bofedal" grouping ("consociation")
Taxonomic classification: Aquic Cryopsamments
Observation date: September 14, 1975
Author: Moisés Ureña Espinoza
Location: At 20 Km W of Curahuara de Carangas, 2 Km W of the town of Kellkhata, 100 m W of the Kellkhata river, Sajama province of Oruro County
Elevation in meters: 3,840 above sea level /69
Form of the terrain:
a) Physiographic position of the site: Depression
b) Form of surrounding land: Ignimbrite lava mesetas
Slope at profile location: Plain
Vegetation or land use: Development of paja brava, white chiji and other grasses typical of humid areas; used as feed for sheep and especially for llamas and related species.

B. GENERAL SOIL INFORMATION

Starting material: soils composed of alluvial sediments derived from ignimbrite materials
Drainage: deficiently drained soils
Humidity of the profile: humid
Depth of phreatic layer: at 1.5 m; when the Kellkhata river rises, however, the phreatic level rises to 0.30 m.

Presence of rocks and rocky outcrops on the surface: None
Evidence of erosion: The soil was observed to be built by consecutive alluvial depositions.
Human influence: The area is covered by natural grass used for grazing sheep and llamas and related species.

C. BRIEF PROFILE DESCRIPTION

Soils limited in depth because of the shallow and fluctuating phreatic layer. Very uniform sandy texture.

D. PROFILE DESCRIPTION

Au 0-40 cm. Ocrico epipedon.
Light reddish coffee (5YR 6/4) when humid, coarse /70 sandy texture with little gravel; lacks agglomerate structure; non-adherent and non-plastic when wet, loose whether humid or dry; frequent medium pores, little worm activity; few fine roots; gradual and ondulating horizon limit.

Bs 40-150 cm. Cambic horizon.
Dark green gray (gleyzed) (5Y 3/2) when wet, with frequent, medium sized spots, defined and clear, brown in color; coarse sandy texture with little gravel; lacks agglomerate structure; non-adherent and non-plastic when wet, loose whether humid or dry; few pores, moderate biological activity; very few very fine roots (no samples taken).

V34 Depression Grouping ("Consociation")

Covers an area of 35,358 Has located near the Western Range; physiographically in includes depressed areas, or plane-concave areas of /72 the plains showing strong salty efflorescences. As was the case with the Bofedales (hydromorphic soils), these soils too have their phreatic

LABORATORY ANALYSIS

PROFILE NO. 13

Depth in cm		0-40	40-150				
Texture		A	A				
pH		7.5					
Electric conductivity, mmohs cm		170					
Free carbonates		P					
Soluble cations in me./100 gr.	Ca^{++}	-					
	Mg^{++}	-					
	Na^{+}	-					
	K^{+}	-					
Cation exchange data in me. /100 gr.	Ca^{++}	9.3					
	Mg^{++}	1.0					
	Na^{+}	0.48					
	K^{+}	0.44					
T. B. I.		11.22					
C. I. C.		11.22					
% Base Saturation		100					
Phosphorus (Olsen)		21.0					
Acids me /100 gr.		-					

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

layer close to the surface, or are under the influence of thaws. The high salt content has allowed the development of only poor grasses, used for grazing of cattle. A modal profile classified as Spodic Psammaquents has been described in this unit.

MODAL PROFILE 11

A. INFORMATION ON SAMPLING SITE

Profile number: 11
Soil name: "Depression" grouping ("consociation")
Taxonomic classification: Spodic Psammaquents
Observation date: September 14, 1975
Author: Moisés Ureña Espinoza
Location: 5 Km SW of Huyullani station, 3 Km NE of the town of Tomarapi, 10 Km N of the volcanic cone Sajam; in Sajama province, Oruro County.
Elevation in meters: 4,020 above sea level
Form of the terrain:
a) Physiographic position of the site: plane-concave plain
b) Form of surrounding land: plain surrounded by foothills of the Western Range /73
Slope at profile location: inclined
Vegetation or land use: covered with very poor grasses in arid and salty regions, used for grazing of sheep and llamas and related species.

B. GENERAL SOIL INFORMATION

Starting material: soils formed by colluvio-alluvial processes, derived from volcanic lavas.
Drainage: imperfectly drained
Humidity of the profile: very humid
Depth of phreatic layer: 60 cm
Presence of rocks on the surface: rocky
Presence of rocky outcrops: moderately rocky

Evidence of erosion: Moderate laminar erosion can be observed
Presence of salts and alkali: Strongly affected by salts
Human influence: Areas used for the grazing of sheep and llamas and related species.

C. BRIEF PROFILE DESCRIPTION

Profile with well differentiated horizons; corresponds no soils of little depth, limited by the closeness to the surface of the phreatic layer; with strong salt influence.

D. PROFILE DESCRIPTION

Au1 0-10 cm. Ocric epipedon. /74
Yellowish coffee (10YR 5/4) when wet, many large, outstanding spots, diffuse and of yellowish color; fine sandy texture; lacks agglomerate structure; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry; few medium pores; presence of large quantitites (5%) of rock fragments of volcanic material; few fine roots; plane and gradual limit.

Au2 10-35 cm. Dark gray coffee (10YR 4/2) when humid; open, fine sandy texture; structure in medium-sized sub-angular blocks; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry; few medium pores; strongly calcareous; very few, very fine roots; plane and diffuse limits.

Bu1 35-50 cm. Gray (10YR 6/2) when humid; limey-clayey texture; structure in medium-sized, sub-angualr blocks; slightly adherent and slightly plastic when wet; friable when humid, slightly hard when dry; numerous fragments of volcanic lava are found, soft, irregular and of whitish coclored volcanic material; strong carbonate reaction; plane and gradual horizon limits.

LABORATORY ANALYSIS

PROFILE NO. 11

Depth in cm		0-10	10-35	35-50	50-70		
Texture		A	FA	YL	FY		
pH		8.1	7.9	8.1	7.6		
Electric conductivity, mmohs cm		800	580	380	560		
Free carbonates		PP	PP	PP	A		
Soluble cations in me./100 gr.	Ca^{++}	2.2	1.9	-	0.5		
	Mg^{++}	0.8	0.6	-	0.3		
	Na^{+}	1.22	1.66	-	1.85		
	K^{+}	0.87	0.54	-	0.39		
Cation exchange data in me. /100 gr.	Ca^{++}	17.0	15.5	15.2	15.8		
	Mg^{++}	7.2	5.2	4.0	6.7		
	Na^{+}	4.10	0.54	2.00	0.59		
	K^{+}	2.13	0.46	1.00	7.71		
T. B. I.		30.43	21.70	22.20	30.80		
C. I. C.		30.43	21.70	22.20	30.80		
% Base Saturation		100	100	100	100		
Phosphorus (Olsen)		24.0	19.5	8.0	28.0		
Acids me /100 gr.		-	-	-	-		

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

Bu2 50-70 cm. Black (10YR 2.5/1) when humid; open, clayey texture; weak structure, in medium-sized, sub-angualr blocks; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry.

A. HIGH PLATEAU REGION

A11 Huayllamarca Grouping ("Consociation")

Corresponds to the high hill country located on the Bolivian high plateau. These hills have a strongly rolling relief, with rocky outcrops present. There are, however, relatively moderately rolling reliefs in the area, were shallow soils have formed. These are used for dryland agricultural and livestock activities. /76

The surface area covered by this unit is of 365,466 Has. These soils have a very restricted use, the topography is highly accidented, and the presence of rocky outcrops are the main reasons for only incipient agricultural and livestock activity. The modal profile described has been classified as Lithic Ustochrepts, and is located in the most representative rolling part of the unit.

MODAL PROFILE 1

A. INFORMATION ON SAMPLING SITE

Profile number: 1
Soil name: "Huayllamarca" grouping ("consociation")
Taxonomic classification: Lithic Ustochrepts
Observation date: September 6, 1975
Author: Moisés Ureña Espinoza
Location: 7 Km SE of the town of Huayllamarca, 10 Km NW of Chuquichambi, 16 Km SW of Papel Pampa and 37 Km S of the Desaguadero river; in Carangas province, Oruro County. /77
Elevation in meters: 3,860 above sea level.

Form of the terrain:

a) Physiographic position of the site: Huayllamarca foothills

b) Form of surrounding land: hill country associated with low lands with strongly rolling physiography.

Slope at profile location: Lightly inclined

Vegetation or land use: Natural vegetation cover consists of very small and very sparse natural grasses; very small areas are used to grow potatoes and barley

B. GENERAL SOIL INFORMATION

Starting material: Formed by colluvial processes or under in situ conditions, derived from reddish sandstones with inclusions of tabaceous shoals.

Drainage: well drained

Humidity of the profile: Dry

Presence of rocks on the surface: few rocks

Presence of rocky outcrops: there are few rocky outcrops

Evidence of erosion: Strong, natural erosion can be observed, of laminar form, in furrows and "cárcavas".

Human influence: Grazing of sheep and llamas and related species; development of subsistence agriculture

C. BRIEF PROFILE DESCRIPTION

A lithic contact was observed at a depth of 60 cm; the profile /78 shows very little color variation throughout; nonetheless, illuviation characteristics of fine materials towards the second horizon can be observed.

D. PROFILE DESCRIPTION

Ap 0-20 cm. Ocric epipedon.

Brownish red (10R3/3) when humid; fine, open sandy texture; weak structure in fine, sub-angualr blocks; non-adherent and non-plastic when wet, very friable when humid, soft when dry; many pores; common quantities of roots of fine size; plane, gradual limit.

LABORATORY ANALYSIS

PROFILE NO. 1

Depth in cm		0-20	20-60				
Texture		AF.	FY.				
pH		6.4	7.0				
Electric conductivity mmoHs cm		43	100				
Free carbonates		A	P				
Soluble cations in me /100 gr.	Ca^{++}	-	-				
	Mg^{++}	-	-				
	Na^{+}	-	-				
	K^{+}	-	-				
Cation exchange data in me. /100 gr.	Ca^{++}	7.4	15.6				
	Mg^{++}	0.9	1.0				
	Na^{+}	0.12	0.21				
	K^{+}	0.39	0.35				
T. B. I.		8.81	17.36				
C. I. C.		9.01	17.36				
% Base Saturation		98	100				
Phosphorus (Olsen)		0.5	11.5				
Acids me /100 gr.		0.2	-				

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

Bt 20-60 cm. Cambic horizon.
Brownish red (10R3/2) when wet; retains the color of the parent material;open, clayish; moderate structure in sub-angular blocks; adherent and plastic when wet, friable when humid, hard when dry; few, fine pores; no biological activity; few roots, very fine.

C 60+ The lithic contact is found at this depth. /80

A12. Complex: Topohoco (Lithic Ustipsamments)
Techos (Andic Ustipsamments)
Las Lomas (Aridic Haplustalfs)

This soil complex covers 595,536 Has., corresponding to a hill country landscape; the relief varies from modferate to strongly undulating.

This complex is formed of three soil aggregates covering a hill-country landscape of rounded outlines, with slopes as high as 40%; soil depths vary from shallow to very deep; rocky outcrops abound; parts of the area are dedicated to dryland agriculture and livestock activities.

Each of the three soil aggregates contributing to the complex are described by means of a typical profile. These are:

MODAL PROFILE 17

A. INFORMATION ON SAMPLING SITE

Profile number: 17 (corresponds to a natural cut)
Soil name: "Topohoco" aggregate
Taxonomic classification: Lithic Ustipsamments
Observation date: September 18, 1975
Author: Moisés Ureña Espinoza
Location: 5 Km SW of the town of Topohoco, 2 Km S of the community of Phusuta, 100 m N of the Corocoro-Topohoco road; Pacajes province, La Paz County
Elevation in meters: 4,100 above sea level /81
Form of the terrain:
a) Physiographic position of the site: convex slope
b) Form of surrounding land: strongly rolling hill country
Slope at profile location: craggy, with 30% slopes
Vegetation or land use: The predominant vegetation is paja brava, associated with the tola characteristic of this environment; potatoes and barley are incipiently grown as the only crops.

B. GENERAL SOIL INFORMATION

Starting material: Soils constituted by colluvio-alluvial deposi-tions, and developed from sandstones
Drainage: Excessively drained

Humidity of the profile: dry
Depth of phreatic layer: very deep
Presence of rocks on the surface: exceedingly stoney
Presence of rocky outcrops: Rocky
Evidence of erosion: Natural, to a strong degree, both laminar and in furrows and "cárcavas"
Presence of salts and alkali: No salt problems
Human influence: These soils are under development for poor grasses, used as sheep feed; areas with agricultural activity are very rare.

C. BRIEF PROFILE DESCRIPTION /82

A profile of surface soils, they have only the first horizon as edafisized soil; from there on and throughout its depth, gravel and stones are found, but little sand.

D. PROFILE DESCRIPTION

Au 0-35 cm. Little developed Ochric epipedon.
Dark gray (5Yr 5/1) when humid; sandy texture, with gravel and stones; weak structure in sub-angular blocks; slightly adherent and slightly plastic when wet, very friable when humid and soft when dry; many medium-sized, intersticial pores; abundant gravel and stones in angular, round and flat shape; their nature is quarcitic sandstone, little altered; very few very fine roots, and an ondulating, gradual limit.

C 35-130 cm. Horizon, or layer of accumulated material (there is no visible sub-surface diagnostic horizon) consisting of gravel, stones and rocks of angular, rounded or flat forms and quarcitic nature (no sample taken).

LABORATORY ANALYSIS

PROFILE NO. 17

Depth in cm		0-35	35-130				
Texture		A	Grava y Piedra				
pH		6.0					
Electric conductivity, mmohs cm		20					
Free carbonates		A					
Soluble cations in me./100 gr.	Ca^{++}	-					
	Mg^{++}	-					
	Na^{+}	-					
	K^{+}	-					
Cation exchange data in me. /100 gr.	Ca^{++}	9.6					
	Mg^{++}	1.4					
	Na^{+}	0.18					
	K^{+}	0.80					
T. B. I.		11.98					
C. E. C.		12.08					
% Base Saturation		99					
Phosphorus (Olsen)		5.5					
Acids me /100 gr.		0.1					

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

MODAL PROFILE 6

A. INFORMATION ON SAMPLING SITE /84

Profile number: 6

Soil name: "Techos" agglomerate

Taxonomic classification: Andic Ustochrepts

Observation date: September 10, 1975

Author: Moisés Ureña Espinoza

Location: 1 Km S of the Desaguadero river, 100 m W of the San Pedro de Curahuara-Chilahuala road, 12 Km S of Umala, 34 Km SW of Sica Sica; G. Villarroel province, La Paz County

Elevation in meters: 3,760 above sea level

Form of the terrain:

a) Physiographic position of the site: convex slope

b) Form of surrounding land: rolling hills

Slope at profile location: inclined, with 8% slopes

Vegetation or land use: Development of very poor grazing, as associations of paja brava and tola; there is incipient cultivation of potatoes, barley and oca (translation unknown)

B. GENERAL SOIL INFORMATION

Starting material: Soils of colluvio-alluvial formation, derived from reddish sandstones

Drainage: insufficiently drained

Humidity of the profile: dry

Depth of phreatic layer: does not affect vegetation development

Presence of rocks and rocky outcrops on the surface: none

Presence of salts or alkali: moderately affected by salts /85

Evidence of erosion: Natural, to a moderate degree, in furrows and "cárcavas".

Human development: Areas used for routine agricultural and livestock activity.

C. BRIEF PROFILE DESCRIPTION

Profile of deep soils, of very poor fertility, affected by alkaline salts and especially carbonates.

D. PROFILE DESCRIPTION

Au 0-8 cm. Ochric epipedon
Yellowish red (5YR 4/6) when humid;open-sandy, with gravel; weak structure in sub-angular blocks; slightly adherent and non-plastic when wet, loose when humid and soft when dry; few, medium-sized pores; presence of a few rounded gravel fragments; few fine roots, flat and gradual horizon limit.

Bt 8-47 cm. Cambic horizon.
Dark red coffee (5YR 3/4) when humid; limey-clayish texture with little gravel; strong structure in angular blocks; adherent and plastic when wet, very friable when humid and slightly hard when dry; presence of continuous and thin "cutanes" (translation unknown) /86 surrounding peds; few gross, continuous, random pores; very few very fine roots; flat and gradual limit.

C1 47-105 cm. Reddish coffee (5YR 4/6) when humid; fine sand texture; weak structure in sub-angular blocks; slightly adherent and slightly plastic when wet, friable when humid, slightly hard when dry; presence of calcium carbonates.

C2 105-150 cm. Reddish coffee (5YR 4/6) when humid; very fine, sandy texture with little gravel; cery weak structure in sub-angular blocks; slightly adherent and slightly plastic when wet, friable when humid, slightly hard when dry; calcium carbonates are present.

LABORATORY ANALYSIS

PROFILE NO. 6

Depth in cm		0-8	8-47	47-105	105-150		
Texture		AF	VL	A	A		
pH		7.9	7.2	7.9	8.5		
Electric conductivity, mmhos cm		170	190	600	180		
Free carbonates		P	P	P	P		
Soluble cations in me /100 gr.	Ca^{++}	-	-	1.0	-		
	Mg^{++}	-	-	0.2	-		
	Na^{+}	-	-	1.94	-		
	K^{+}	-	-	0.25	-		
Cation exchange capacity in me /100 gr.	Ca^{++}	13.8	15.2	4.6	8.2		
	Mg^{++}	1.4	3.6	2.6	1.9		
	Na^{+}	0.38	1.71	0.23	1.00		
	K^{+}	1.33	0.40	0.15	0.35		
E. S. P.		15.91	20.91	7.58	11,45		
C. E. C.		15.91	20.91	7.58	11,45		
Base saturation		100	100	100	100		
Phosphorus (Olsen)		0.5	0.3	0.5	1.0		
Nitrogen me /100 gr.		-	-	-	-		

Remarks: Texture = T = Clay, L = Loam, A = Sand

MODAL PROFILE 38

A. INFORMATION ON SAMPLING SITE /88

Profile number: 38
Soil name: "Las Lomas" agglomerate
Taxonomic classification: Aridic Haplustalfs
Observation date: July 20, 1976
Author: Moisés Ureña Espinoza
Location: 1 Km S of the Crusani farm, 100 m E of the San Pedro de Curahuara road, 12 Km E of Pedro Domingo Murillo; G. Villarroel province, La Paz County.
Elevation in meters: 3,800 above sea level
Form of the terrain:
a) Physiographic position of the site: hills
b) Form of surrounding land: undulating, maximum slopes 2-15%
Slope at profile location: moderately craggy
Vegetation or land use: Development of tola, paja brava, native grasses, in addition to some subssistence crops.

B. GENERAL SOIL INFORMATION

Starting material: Soils formed by colluvio-alluvial processes, derived from reddish, clayish sandstones
Drainage: Imperfectly drained
Humidity of the profile: dry
Depth of phreatic layer: not observable
Presence of rocks and rocky outcrops: none /89
Evidence of erosion: slight, natural, laminar, hydric and eolic.
Human influence: none

C. BRIEF PROFILE DESCRIPTION

Profile on deep soils; little color change throughout, with color remaining similar to that of parent material; shows well formed structures in the second and third horizons.

D. PROFILE DESCRIPTION

Ap 0-20 cm. Ochric epipedon.
Reddish (2.5YR 4/6) when humid; coarsely sandy; no agglomerate structure; non-adherent and non-palstic when wet; very friable when humid, soft when dry; few, fine and medium-sized pores; little biological activity; few fine roots; horizon limit diffuse and flat.

Bt 20-50 cm. Cambic horizon.
Dark red (2.5YR 3/2) when humid; open, clayish texture; strong structure, medium and coarse prismatic; adherent and slightly plastic when wet, firm when humid and hard when dry; there are conyinuous, clayish "cutanes" surrounding the peds (argilanes); weakly cemented; few, fine pores; few, fine roots; horizon limit neat and flat.

BC1 50-90 cm. Dark reddish coffee (5YR 2.5/2) when humid; open, clayish-sandy texture; strong structure, medium and coarse prismatic; slightly adherent, non-plastic when wet, firm when humid, very hard when dry; one observes white covering of volcanic material, with strong reaction to HCl; few, fine pores; few, very fine roots; horizon limit neat and flat.

BC2 90-150 cm. Dark reddish coffee (5YR 3/3) when humid; open, clayish-sandy texture; structure in fine and medium-sized angualr blocks; slightly adherent and slightly plastic when wet, firm when humid and very hard when dry; One observes white covering of volcanic material, with strong reaction to HCl; there are no roots.

A13 Complex: Chuquichambi (Typic Ustipsamments)
Pichuco (Lithic Ustipsamments) /92
Romero (Aridic Haplustalfs)
Comanche (Aridic Ustochrepts)

LABORATORY ANALYSIS

PROFILE NO. 38

Depth in cm		0-20	20-50	50-90	90-150		
Texture		A.	F.y.	F.Y.A.	F.Y.A.		
pH		7.2	7.5	8.4	7.5		
Electric conductivity, mmohs cm		47	66	220	950		
Free carbonates		A	A	P	P		
Soluble cations in me./100 gr.	Ca^{++}	-	-	-	2.8		
	Mg^{++}	-	-	-	0.6		
	Na^{+}	-	-	-	1.45		
	K^{+}	-	-	-	0.39		
Cation exchange data in me. /100 gr.	Ca^{++}	7.4	18.0	11.2	13.5		
	Mg^{++}	0.8	3.4	2.4	2.4		
	Na^{+}	0.22	1.00	1.60	0.85		
	K^{+}	0.21	0.54	0.41	0.25		
T. B. I.		8.63	22.94	15.61	17.00		
C. I. C.		8.73	22.94	15.61	17.00		
% Base Saturation		99	100	100	100		
Phosphorus (Olsen)		1.0	0.3	1.0	6.0		
Acids me /100 gr.		0.1	-	-	-		

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

This unit comprises a soil complex formed by four taxonomically classified aggregates; they are located at the foot of hills in the high plateau region and presents a relief of gentle slopes, varying approximately from 3 to 10%.

The soils are deep and their textures generally vary from light to slightly heavy; they are light near the hills and become heavier as the distance to the hills increases.

These soils are relatively important for their agricultural and livestock activity: we find the preponderance of dryland agriculture in these areas. A more representative profile has been described for each of the aggregates in this complex, as indicated below.

MODAL PROFILE 2

A. INFORMATION ON SAMPLING SITE

Profile number: 2
Soil name: "Chuquichambi" aggregate
Taxonomic classification: Typic Ustipsamments
Observation date: September 6, 1975 /93
Author: Moisés Ureña Espinoza
Location: 2.8 Km N of Chuquichambi, next to the Huayllamarca-Chuquichambi road, 36 Km S of the Desaguadero river; Carangas province, Oruro County
Elevation in meters: 3,740 above sea level
Form of the terrain:
a) Physiographic position of the site: foot of the Huayllamarca hill country
b) Form of surrounding land: slightly sloped
Vegetation or land use: Covered approximately to 90% by paja brava, tola and other native species; some small areas used to grow potatoes, barley, quinua, etc.

B. GENERAL SOIL INFORMATION

Starting material: Soils composed of colluvio-alluvial sediments derived from reddish sandstones

Drainage: Somewhat excessively drained

Humidity of the profile: dry

Depth of phreatic layer: does not affect vegetative development

Presence of rocks and rocky outcrops: none

Evidence of erosion: Natural, laminar and eolic

Presence of salts and alkali: Slightly affected by salts

Human influence: Development of incipient agriculture, but most of the area is used for pasture of sheep and llamas and related species.

C. BRIEF PROFILE DESCRIPTION /94

Deep soils with little variation in texture or color; they are sandy, and brownish red.

D. PROFILE DESCRIPTION

Au 0-35 cm. No diagnostic epipedon
Brownish red (10R3/4) when humid; sandy texture with little gravel; without agglomerate structure; non-adherent, non-plastic when wet, loose when humid, loose when dry; very few, very fine roots; limit diffuse and flat.

AB 35-110 cm. No diagnostic horizon.
Brownish red (10R3/3) when humid; very fine sandy texture; weak structure in sub-angular blocks; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry; many medium-sized pores; very few, very fine roots; horizon limit diffuse and flat.

LABORATORY ANALYSIS

PROFILE NO. 2

Depth in cm		0-35	35-110	110-170			
Texture		A	A	F.L.			
pH		8.1	8.2	8.1			
Electric conductivity, mmhos cm		100	87	120			
Free carbonates		P	PP	PP			
Soluble cations in m.e./100 gr.	Ca^{++}	-	-	-			
	Mg^{++}	-	-	-			
	Na^{+}	-	-	-			
	K^{+}	-	-	-			
Cation exchange data in m.e./100 gr.	Ca^{++}	8.2	9.6	9.6			
	Mg^{++}	0.3	0.8	1.1			
	Na^{+}	0.11	0.09	0.20			
	K^{+}	0.31	0.22	0.17			
C. E. C.		8.92	10.71	11.07			
C. E. C.		8.92	10.71	11.07			
Base Saturation		100	100	100			
Phosphorus (Olsen)		1.0	0.5	1.0			
Boron m.e./100 gr.		-	-	-			

Remarks: Prairie = P; V = Clay; L = Silt; F = Fine

Bu 110-170 cm. Brownish red (10R3/3) when humid; open, limey texture; weak structure in fine, sub-angular blocks; slightly adherent and slightly plastic when wet, very friable when humid, slightly hard when dry; horizon limit not determined.

MODAL PROFILE 20 /96

A. INFORMATION ON SAMPLING SITE

Profile number: 20 (profile in a natural cut)
Soil name: "Pichuco" aggregate
Taxonomic classification: Lithic Ustipsamments
Observation date: October 9, 1975
Author: Moisés Ureña Espinoza
Location: 1 Km NE of the town of Caquiaviri, 100 M N of the Corocoro-Caquiaviri road; Pacajes province, La Paz County
Elevation in meters: 3,890 above sea level
Form of the terrain:
a) Physiographic position of the site: foot of hill country
b) Form of surrounding land: undulating relief
Slope at profile location: slightly sloped
Vegetation or land use: Soils used for development of poor grazing, predominantly paja brava; incipient agriculture with potato, barley and quinoa crops.

B. GENERAL SOIL INFORMATION

Starting material: Soils are of colluvio-alluvial formation, derived from sandstones
Drainage: Somewhat excessively drained
/97
Humidity of the profile: dry
Presence of rocky outcrops: none
Evidence of erosion: Natural, moderately laminar.

Presence of salts or alkali: Without effect on vegetation
Human influence: Grazing of llamas and related species and especially sheep; little agricultural activity.

C. BRIEF PROFILE DESCRIPTION

Profile of sandy and gravelly soils; they are deep; color remains pretty uniform throughout the profile: dark red coffee.

D. PROFILE DESCRIPTION

Ap 0-25 cm. No diagnostic epipedon
Dark red coffee color (5YR 3/3) when humid; coarse sandy texture with little gravel; no agglomerate structure; non-adherent and non-plastic when wet, loose when humid or dry; gravel of rounded form; very few, fine roots; limit neat and flat.

C 25-200 cm. No sub-surface diagnostic horizon
Dark red coffee color (5YR 3/3) when humid; horizon formed by sand with much gravel and stones of angular and rounded forms; of quarcitic nature with moderate weathering (no sample taken).

LABORATORY ANALYSIS

PROFILE NO. 20

Depth in cm		0-25	25-200				
Texture		A	Arena Grava y Piedra				
pH		5.8					
Electric conductivity, mmhos cm		23					
Free carbonates		A					
Soluble cations in me./100 gr.	Ca^{++}	-					
	Mg^{++}	-					
	Na^{+}	-					
	K^{+}	-					
Cation exchangeable in me./100 gr.	Ca^{++}	2.6					
	Mg^{++}	0.8					
	Na^{+}	0.13					
	K^{+}	0.48					
T. E. B.		4.02					
C. E. C.		4.21					
% Base Saturation		95					
Phosphorus (Olsen)		2.5					
Acidez me./100 gr.		0.2					

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MODAL PROFILE 8

A. INFORMATION ON SAMPLING SITE /99

Profile number: 8

Soil name: "Romero" aggregate

Taxonomic classification: Aridic Haplustalfs

Observation date: September 11, 1975

Author: Moisés Ureña Espinoza

Location: 7 Km N of the Chacarilla mine, 1 Km S of the Desaguadero river, 4 Km SW of Puerto Aroma, 35 Km E of the town of Ulloma; province of G. Villarroel, La Paz County.

Elevation in meters: 3,750 above sea level

Form of the terrain:

a) Physiographic position of the site: foot of undulating hills

b) Form of surrounding land: hill country

Slope at profile location: slightly inclines, slopes less than 5%

Vegetation or land use: Soils used for grazing of sheep and llamas and related species; the most important vegetation species are tola and paja brava.

B. GENERAL SOIL INFORMATION

Starting material: Soils of colluvio-ahluvial formation, derived from the reddish sandstones of the Chacarilla formation.

Drainage: Moderately well drained

Humidity of the profile: almost dry /100

Depth of phreatic layer: Very deep

Presence of rocks and rocky outcrops on the surface: none

Evidence of erosion: Natural laminar erosion to moderate degree and also hydric deposition

Presence of salts and alkali: Moderate; however, at depth greater than 50 cm, there is a strong salt influence.

Human influence: Soil use for subssistence agricultural and livestock activity.

C. BRIEF PROFILE DESCRIPTION

Corresponds to soils on slopes of undulating relief, with little color variation between horizons; clayish texture throughout its depth; the third horizon shows pressure surfaces.

D. PROFILE DESCRIPTION

Au 0-26 cm. Ochric epipedon.
Yellowish red (5YR 4/6) when humid; open, clayish texture; moderate structure in sub-angular blocks; adherent and plastic when wet, friable when humid hard when dry; few, fine pores; little worm activity; few, medium-sized roots; flat, diffuse horizon limit.

Bt1 26-50 cm. Argillic horizon.
Reddish coffee (5YR 4/4) when humid; clayish texture in sub-angular blocks; strong structure; very /101
adherent and very plastic when wet, very friable when humid, slightly hard when dry; few, fine pores; little worm activity; very few, fine roots; flat, diffuse horizon limit.

Bt2 50-95 cm. Reddish coffee (5YR 4/4) when humid; clayish texture, moderate structure in medium sized, sub-angular blocks; very adherent and very plastic when wet, friable when humid, hard when dry; few, fine pores; flat and gradual limit.

BC 95-150 cm. Dark red coffee (5YR 3/2) when humid; few, small spots, indistinct and diffuse, yellowish red in color; clayish texture, strong structure in angular blocks; very adherent and very plastic when wet, firm when humid, very hard when dry; discontinuous, thin cutanes around peds; weakly cemented; few, fine pores; carbonate nodules can be observed; limit not determined.

LABORATORY ANALYSIS

PROFILE NO. 8

Depth in cm		0-26	26-50	50-95	95-150		
Texture		FY	Y	Y	Y		
pH		6.2	6.5	8.1	8.3		
Electric conductivity, mmohs cm		63	53	140	600		
Free carbonates		A	A	A	A		
Soluble cations in me /100 gr.	Ca^{++}	-	-	-	2.8		
	Mg^{++}	-	-	-	0.5		
	Na^{+}	-	-	-	3.70		
	K^{+}	-	-	-	0.60		
Cation exchange data in me. /100 gr.	Ca^{++}	22.4	17.4	19.2	11.0		
	Mg^{++}	1.4	1.2	2.0	2.6		
	Na^{+}	0.28	0.30	1.45	2.90		
	K^{+}	1.12	0.82	0.75	0.15		
T. B. I.		25.20	19.72	23.40	16.65		
C. I. C.		25.50	19.82	23.60	16.65		
% Base Saturation		99	99	99	100		
Phosphorus (Olsen)		2.5	4.0	4.0	12.0		
Acids me /100 gr.		0.3	0.1	0.2	-		

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

MODAL PROFILE 18

A. INFORMATION ON SAMPLING SITE

Profile number: 18

Soil name: "Comanche" aggregate

Taxonomic classification: Aridic Ustochrepts

Observation date: October 7, 1975

Author: Moisés Ureña Espinoza

Location: 2 Km SE of the town of Comanche, 20 Km N of the town of Corocoro, 1 Km E of the Corocoro-Viacha road; Pacajes province, La Paz County.

Elevation in meters: 3,920 above sea level

Form of the terrain:

a) Physiographic position of the site: Foot of hill country

b) Form of surrounding land: hill country

Slope at profile location: Slightly inclined

Vegetation or land use: Used exclusively to develop poor grazing, used as feed for sheep and llamas and related species; paja brava is the most important species of vegetation

B. GENERAL SOIL INFORMATION

Starting material: Colluvio-alluvial soils derived from reddish, clayish sandstones

Drainage: Moderately well drained

Humidity of the profile: Dry

Depth of phreatic layer: Very deep

Presence of rocks and rochy outcrops on the surface: none

Evidence of erosion: Natural, laminar and in "cárcavas" of hydric nature

Presence of salts or alkali: Witout influence on agriculture

Human influence: Soils covered by natural grasses used as feed for sheep and llamas and related species

C. BRIEF PROFILE DESCRIPTION /104

Profile of deep soils with little color and texture variation; however, at depth greater than 2 m, there is coarse sand, as observed at a nearby natural cut.

D. PROFILE DESCRIPTION

Au 0-7 cm. Ochric epipedon
Reddish coffe 5YR 4/3) when humid; open limey texture; weak, crumbly , fine structure; slightly adherent and slightly plastic when wet, very friable when humid and soft when dry; many fine pores and random coarse ones; moderate biological activity; few, fine roots; flat, gradual limit.

Bt1 7-25 cm. Cambic horizon.
Reddish coffe (5YR 4/3) when humid; open, limey-clayish texture; moderate structure in medium-sized, sub-angular blocks; adherent and plastic when wet, very friable when humid, slightly hard when dry; many pores, medium sized or coarse, continuous and random; moderate biological activity; very few, very fine roots; flat, diffuse horizon limit.

Bt2 25-60 cm. Dark red coffee (5YR 3/3) when humid; open, limey-clayish texture; moderate structure in medium-sized, sub-angular vlocks; adeherent and plastic when wet, very friable when humid, slightly hard when dry; many pores, medium sized and coarse; very few, very fine roots; undulating, gradual horizon limit.

/105

C 60-130 cm. Dark red coffee (5YR 3/3) when humid; fine, sandy texture; no agglomerate structure; non-adherent and non-plastic when wet, loose when humid or dry; limit not determined.

LABORATORY ANALYSIS

PROFILE NO. 18

Depth in cm		0-7	7-25	25-60	60-130		
Texture		FL	FYL	FYL	A		
pH		5.5	5.4	6.0	6.4		
Electric conductivity, mmohs cm		54	32	28	38		
Free carbonates		A	A	A	A		
Soluble cations in me./100 gr.	Ca^{++}	-	-	-	-		
	Mg^{++}	-	-	-	-		
	Na^{+}	-	-	-	-		
	K^{+}	-	-	-	-		
Cation exchange data in me. /100 gr.	Ca^{++}	8.2	8.2	7.6	7.1		
	Mg^{++}	1.1	0.9	0.9	0.7		
	Na^{+}	0.12	0.12	0.12	0.14		
	K^{+}	0.81	0.73	0.39	0.28		
T. B. I.		10.23	9.95	9.01	8.24		
C. I. C.		10.43	10.15	9.11	8.34		
% Base Saturation		98	98	99	99		
Phosphorus (Olsen)		6.0	2.0	4.5	6.0		
Acids me %/100 gr.		0.2	0.2	0.1	0.1		

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

A21 Sulloma Grouping ("Consociation") /107

These soils are located on the high plateau plain, near hills; they cover an area of 207,275 Has. The relief is undulating, with slopes ranging from 2 to 8%; the area has been strongly influenced by volcanic sinters, considered as the possible cementing factor, together with calcium carbonates observed in certain soil horizons. A typical profile is described for these soils, classified Entic Durorthids.

MODAL PROFILE 9

A. INFORMATION ON SAMPLING SITE

Profile number: 9
Soil name: "Sulloma" grouping ("consociation")
Taxonomic classification: Entic Durorthids
Observation date: September 13, 1975
Author: Moisés Ureña Espinoza
Location: The profile is located 500 m from the Jachipe-Rio Sulloma road, 20 Km N of Curahuara de Carangas, 25 Km NW of the town of Totora; Pacajes province, La Paz County
Elevation in meters: 3,870 above sea level
Form of the terrain:
a) Physiographic position of the site: Undulatingplain
b) Form of surrounding land: Hill country
Slope at profile location: Flat /108
Vegetation or land use: Covered by white chiji, paja brava and tola; the first two used for grazing of sheep and llamas and related species.

B. GENERAL SOIL INFORMATION

Starting material: Soils composed of alluvial sediments derived from clayish sandstones with inclusions of sinter material
Drainage: Imperfectly drained
Humidity of the profile: dry
Depth of phreatic layer: very deep
Presence of rocks and rocky outcrops on the surface: none
Evidence of erosion: natuarl, light laminar
Presence of salts or alkali: little salt influence
Human influence: Grazin of sheep and llamas and related species

C. BRIEF PROFILE DESCRIPTION

Profile of soils with little color variation; second horizon is compact and shows strong hardening, possibly because of its content in calcium compounds and volcanic sinter; this constitutes a limiting factor for root development of vegetation species.

D PROFILE DESCRIPTION

Au 0-25 cm. Ochric epipedon.
Yellowish red (5YR 4/6) when dry, frequent, medium-sized spots, indistinct, diffuse and brown in color; limey-clayish texture; moderate structure, in sub-angualr blocks of medium size; adherent and plastic when wet, friable when humid, slightly hard when dry; frequent fine pores, random, interstitial; little biological activity; few, very fine roots; flat, diffuse limit.

Bca 25-50 cm. Calcic horizon /109
Reddish coffee (5YR 5/3) when dry; clayish sandy texture with little gravel; strong structure in coarse angular blocks; slightly adherent and slightly plastic when wet, firm when humid, extremely hard when dry; strongly cemented; strong carbonate reaction; little, round gravel; very few, very fine roots; flat, gradual horizon limit.

LABORATORY ANALYSIS

PROFILE NO. 9

Depth in cm		0-25	25-50	50-75	75-120		
Texture		VL	VA	A	VA		
pH		5.9	6.2		7.8		
Electric conductivity, mmohs cm		39	22		110		
Free carbonates		A	PP		P		
Soluble cations in me./100 gr.	Ca^{++}	-	-		-		
	Mg^{++}	-	-		-		
	Na^{+}	-	-		-		
	K^{+}	-	-		-		
Cation exchange data in me. /100 gr.	Ca^{++}	15.2	15.6		16.3		
	Mg^{++}	2.9	0.9		3.4		
	Na^{+}	0.25	0.13		0.25		
	K^{+}	1.24	0.59		0.80		
T. B. I.		19.59	17.22		20.75		
C. I. C.		19.79	17.32		20.75		
% Base Saturation		99	99		100		
Phosphorus (Olsen)		8.0	12.5		1.0		
Acids me %100 gr.		0.2	0.1		-		

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

C1 50-75 cm. Reddish coffee (5YR 4/3) when humid; many medium-sized spots, neatly defined, dark red coffee in color; sandy texture, with gravel; no agglomerate structure; non-adherent, non-plastic when wet, very friable when humid, soft when dry; frequent, medium-sized pores; abundant, rounded gravel fragments; neat and flat horizon limit (no sample taken).

C2 75-120 cm. Dark red coffee (5YR 3/3) when humid; sandy clay texture with little gravel; no agglomerate structure; non-adherent, non plastic, very friable when humid, hard when dry; weakly cemented; few fragments of gravel, rounded, unaltered.

A22. Eroded Groupings ("Consociations") /111

They cover an extension of 27,790 Has located near the Desaguadero river, or between hill countries in the high plateau area; the relief is slightly undulated. These soils are under very intensive erosion, exhibiting deep "cárcavas", where soil material loss is greater than formation. They are considered Bad Lands. They are areas of desert characteristics, almost completely denuded of vegetation; they are formed of generally light soils without visible agriculture and livestock activity. The typical or modal profile described for this unit has been classified as Typic Ustipsamments.

MODAL PROFILE 19

A. INFORMATION ON SAMPLING SITE

Profile number: 19
Soil name: "Erodadas" Grouping ("Consociation")
Taxonomic classification: Typic Ustipsamments
Observation date: October 8, 1975

Author: Moisés Ureña Espinoza

Location: 3 Km NE of the town of Callapa, 2.5 Km N of the Desaguadero river, 20 m E of the road to Callapa; Pacajes province, La Paz County.

Elevation in meters: 3,800 above sea level /112

Form of the terrain:

a) Physiographic position of the site: Badlands on an undulating plain

b) Form of surrounding land: undulating and craggy

Slope at profile location: slightly inclined

Vegetation or land use: Soils extremely eroded in "cárcavas" and furrows with very little growth of paja brava and tola; there is no human influence in this area considered desertic.

B. GENERAL SOIL INFORMATION

Starting material: old alluvial sediments derived from reddish sandstone

Drainage: moderately well drained

Humidity of the profile: dry

Depth of phreatic layer: very deep

Presence of rocks and rocky outcrops on the surface: none

Evidence of erosion: Natural, in furrows and carcavas, in addition to very intense eolic erosion

Presence of salts or alkali: Moderately affected by soluble salts, especially of calcium

Human influence: No human activity or influence is observed

C. BRIEF PROFILE DESCRIPTION

Deep, very eroded profile of uniform coloration; the texture is sandy in the first two horizons and limey-clayish in the third; all are derived from sandstones.

D. PROFILE DESCRIPTION /113

Au 0-40 cm. Little developed ochric epipedon

Dark red (2.5YR 3/6) when humid; open, coa.se sandy

texture; very weak structure in medium-sized, sub-angular blocks; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry; few, fine pores; flat and diffuse horizon limit

AB 40-75 cm. No diagnostic subhorizon
Reddish coffee (5YR 5/4) when humid; fine, sandy texture; no agglomerate structure; non-adherent and non-plastic when wet, very friable when humid, soft when dry; slightly calcareous; neat and flat horizon limit.

Bt 75-130 cm. Reddish coffee (5YR 4/4) when humid; few small, diffuse, brown spots; limey-clayish texture; moderate structure in medium-sized, sub-angular blocks; adherent and plastic when wet, firm when humid, hard when dry; presence of soluble salts.

A23. Las Dunas

This unit covers an area of 14,475 Has and is located on the high plateau plain; it corresponds to depositions of loose sand, /115 accumulated by eolic processes and considered as continental dunes. These dunes were very clearly identified on the LANDSAT images, next to the rivers providing the sand.

As they are merely accumulations of loose sand, their agricultural and livestock importance is practically nil. No soil profiles were described.

A24. Complex: La Oveja (Duric Camborthids)
Chijini (Vertic Camborthids)
Tolar A (Ustertic Camborthids)
Tolar B (Fluventic Ustochrepts)
El Rio (Lithic Ustorthents)

LABORATORY ANALYSIS

PROFILE NO. 19

Depth in cm		0-40	40-75	75-130			
Texture		AF	A	VL			
pH		7.9	7.8	7.6			
Electric conductivity, mmohs cm		100	240	390			
Free carbonates		P	P	P			
Soluble cations in me./100 gr.	Ca^{++}	-	-	-			
	Mg^{++}	-	-	-			
	Na^{+}	-	-	-			
	K^{+}	-	-	-			
Cation exchange data in me./100 gr.	Ca^{++}	8.2	7.6	8.2			
	Mg^{++}	1.7	1.4	1.4			
	Na^{+}	0.18	0.70	0.70			
	K^{+}	0.17	0.23	0.21			
T. B. I.		10.25	9.93	10.51			
C. I. C.		10.25	9.93	10.51			
% Base Saturation		100	100	100			
Phosphorus (Olsen)		2.5	2.0	15.0			
Acids me./100 gr.		-	-	-			

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

This unit consists of a soil complex covering 316,410 Has, distributed on the flat plain. It corresponds to deep soils with moderate salt influence; its textures vary from moderately heavy to light, with a sandy subhorizon in some cases and in others slightly cemented, similar to a fragipan (translation unknown), impeding the radicular development of vegetation.

This complex consists of five soil aggregates that are identified and taxonomically classified; a modal profile has been described for each aggregate.

MODAL PROFILE 33 /116

A. INFORMATION ON SAMPLING SITE

Profile number: 33
Soil name: "La Oveja" aggregate
Taxonomic classification: Duric Camborthids
Observation date: July 14, 1975
Author: Moisés Ureña Espinoza
Location: 3 Km S of the Huincu Tataya quarry, 8.5 Km N of the Desaguadero river, 15 Km SE of the town of Sica Sica; Aroma province, La Paz County
Elevation in meters: 3,730 above sea level
Form of the terrain:
a) Physiographic position of the site: plains
b) Form of surrounding land: flat or nearly flat, with slopes not exceeding 2%
Slope at profile location: flat
Vegetation or soil use: presence of natural species, with yaretilla or Khota dominant; vegetation in the area is used as feed for sheep and llamas and related species.

B. GENERAL SOIL INFORMATION

Starting material: lacustrine sediments with ulterior deposition of alluvial material derived from reddish sandstones.
Drainage: imperfectly drained.
Humidity of the profile: dry except for the 6th horizon, which is slightly humid.
Depth of phreatic layer: very deep /117
Presence of rocks and rocky outcrops on the surface: none
Evidence of erosion: Slight laminar and eolic erosion
Presence of salts or alkali: Moderately affected by salts
Human influence: Only for grazing of sheep and llamas and related species.

C. BRIEF PROFILE DESCRIPTION

Deep soil profile; the horizons are fairly unchanged from reddish coffee; strong structure from the 2nd to the 4th horizon, the latter being slightly cemented.

D. PROFILE DESCRIPTION

Au 0-10 cm. Ochric epipedon
Reddish coffee (5YR 4/3) when humid; open, fine, sandy texture; no agglomerate structure; non-adherent, non-plastic; very friable and soft when dry; frequent, medium-sized pores; abundant, very fine roots; no biological traces; neat and flat horizon limit,

Bs1 10-22 cm. Cambic horizon.
Light reddish coffee (5YR 6/4) when humid; presence of many medium-sized, defined and reddish coffee colored spots (5YR 5/4); limey-clayisg texture; strong structure in medium-sized, sub-angular blocks; adherent and plastic when wet, hard when dry; few, fine and medium-sized pores, normal amount of fine roots; no biological traces; flat and sudden horizon limit. /118

LABORATORY ANALYSIS

PROFILE NO. 33

Depth in cm		0-10	10-22	22-50	50-66	66-85	85-115
Texture		F.A.	Y.L.	Y.L.	Y.L.	A	FYL
pH		5.6	6.4	7.0	8.6	9.0	8.3
Electric conductivity, mmohs cm		320	76	250	750	620	2900
Free carbonates		-	-	-	P P	P	PP
Soluble cations in me /100 gr.	Ca^{++}	-	-	-	0.6	0.5	1.2
	Mg^{++}	-	-	-	0.1	0.1	0.5
	Na^{+}	-	-	-	4.40	3.38	13.68
	K^{+}	-	-	-	0.65	0.47	1.34
Cation exchange data in me. /100 gr.	Ca^{++}	7.1	6.6	8.2	6.3	2.3	6.4
	Mg^{++}	1.8	2.0	3.2	1.2	0.7	2.3
	Na^{+}	1.94	1.50	3.72	0.10	0.76	4.82
	K^{+}	1.74	1.56	2.52	1.09	0.53	1.27
T. B. I.		12.58	11.66	17.64	8.69	4.29	14.79
C. I. C.		12.88	11.76	17.84	8.69	4.29	14.79
% Base Saturation		98	99	99	100	100	100
Phosphorus (Olsen)		33.0	9.0	2.0	3.0	0.5	2.0
Acids me /100 gr.		0.3	0.1	0.2	-	-	-

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

Bs2 22-50 cm. Reddish coffee (5YR 4/4) when humid; limey-clayish texture; strong structure, in medium-sized angular blocks; very adherent and very plastic when wet, very hard when dry; very few, very fine roots; neat and flat horizon limit.

Bs3 50-66 cm. Yellowish red (5YR 5/6) when humid; limey-clayish; string structure in fine, sub-angualr blocks; adherent and plastic when wet, firm when humid and hard when dry; (weakly cemented); strong carbonate reaction; flat and sudden horizon limit.

Cu 66-85 cm. Reddish coff-e (5YR 5/4) when humid; fine sand.

Cca 85-115 cm. Yellowish red (5YR 4/6) when humid; open, limey-clayish texture; weak structure, medium laminar type; slightly adherent and slightly plastic when wet, friable when humid and slightly hard when dry; strong carbonate reaction.

MODAL PROFILE 3 /120

A. INFORMATION ON SAMPLING SITE

Profile number: 3
Soil name: "Chijini" aggregate
Taxonomic classification: Vertic Camborthids
Observation date: September 6, 1975
Author: Moisés Ureña Espinoza
Location: 200 m E of the town of Papel Pampa, 30 Km S of the Deasaguadero river; province G. Villarroel, La Paz County.
Elevation in meters: 3,730 above sea level
Form of terrain:
a) Physiographic position of the site: plains

b) Form of surroinding land: Flat or nearly flat, with slopes not exceeding 2%

Slope at profile location: flat

Vegetation or land use: Soil covered with native grasses, resistant to strong salinity; used for grazing of sheep and llamas and related species; crops very limited due to high salt content.

B. GENERAL SOIL INFORMATION

Starting material: Lacustrine sediments with ulterior deposition of alluvial material derived from reddish sandstones.

Drainage: moderately well drained

Humidity of the profile: dry down to 80 cm, moist at greater depths.

Depth of phreatic layer: 2 m. (Observed at a nearby well).

Presence of rocks and rocky outcrops on the surface: none

Evidence of erosion: natural, moderately laminar.

Presence of salts or alkali: Strongly affected by salts /121

Human influence: Grazing of sheep and llamas and related species

C. BRIEF PROFILE DESCRIPTION

Deep soils with well defined horizons; heavy, especially the very salty first horizons; phreatic layer fluctuating between 1 and 2 m.

D. PROFILE DESCRIPTION

Au 0-10 cm. Ochric epipedon.
Reddish coffee (5YR 4/4) when humid; fine, sandy, open; weak structure in sub-angular blocks; slightly adherent, non-plastic when wet, very friable when humid, soft when dry; frequent, medium-sized pores; few, fine roots; neat and flat horizon limit.

Bt 10-40 cm. Cambic horizon.
Dark red coffee (2.5 YR 3/4) when humid; clayish; strong structure in angular blocks; adherent and plastic when wet, little friable when humid, very hard when dry; few, very fine pores; few, fine roots; neat and flat horizon limit.

LABORATORY ANALYSIS

PROFILE NO. 3

Depth in cm		0-10	10-40	40-70	70-130	130-200	
Texture		AF	Y	FYL	A	FL	
pH		5.8	6.8	7.6		7.6	
Electric conductivity, mmohs cm		51	124	400		540	
Free carbonates		A	P	PP		PP	
Soluble cations in me./100 gr.	Ce^{++}	-	-	-		3.4	
	Mg^{++}	-	-	-		0.3	
	Na^{+}	-	-	-		0.51	
	K^{+}	-	-	-		0.42	
Cation exchange data in me. /100 gr.	Ca^{++}	3.6	7.4	11.2		7.8	
	Mg^{++}	1.7	2.0	0.8		0.7	
	Na^{+}	1.22	0.90	0.68		0.11	
	K^{+}	1.28	0.73	0.51		0.33	
T. B. I.		7.80	11.03	13.19		8.94	
C. I. C.		8.00	11.03	13.19		8.94	
% Base Saturation		97	100	100		100	
Phosphorus (Olsen)		38.0	2.0	5.5		0.3	
Acids me /100 gr.		0.2	-	-		-	

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

Bs 40-70 cm. Dark red (2.5 YR 3/6) when humid; open, limey-clayish; weak structure in fine, sub-angular blocks; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry; few, very fine pores; saline efflorescences; neat and flat horizon limit.

C1 70-130 cm. Red (2.5YR 5/2) when humid; coarse sand, without agglomerate structure; non-adherent and non-plastic when wet, loose when humid or dry; neat and flat horizon limit (no sample taken).

C2 130-200 cm. Reddish coffee (2.5YR 4/4) when humid; open, limey texture; weak structure in sub-angular blocks; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry; limit not determined.

MODAL PROFILE 36 /124

A. INFORMATION ON SAMPLING SITE

Profile number: 36
Soil name: "Tolar A" aggregate
Taxonomic classification: Ustertic Camborthids
Observation date: July 18, 1976
Author: Moisés Ureña Espinoza
Location: 3 Km S of the Kheto river, 8.5 Km N of the Desaguadero river, 7 Km E of the town of Turini, 34 Km W of the town of Eucaliptus; Aroma province, La Paz county.
Elevation in meters: 3,735 above sea level
Form of the terrain:
a) Physiographic position of the site: plains
b) Form of surrounding land: Flat or nearly flat, with slopes not exceeding 2%
Slope at profile location: flat

Vegetation or soil use: Tola, used for wood, and low, natural grasses used as feed for sheep.

B. GENERAL SOIL INFORMATION

Starting material: Alluvial, derived from reddish sandstones.
Drainage: imperfectly drained
Humidity of the profile: Dry
Depth of phreatic layer: Very deep
Presence of rocks and rocky outcrops on the surface: none
Evidence of erosion: Natural, eolic of laminar type
Presence of salts or alkali: No salty characteristics
Human influence: Soils covered by tola, used as fuel

C. BRIEF PROFILE DESCRIPTION /125

Deep profile, corresponding to soils less affetcted by salinity, located a little higher than other, nearby soils; coloration very uniform throughout the profile.

D. PROFILE DESCRIPTION

Au 0-20 cm. Ochric epipedon.
Coffee (7.5YR 4/4) when humid; open, fine sandy texture, without agglomerate structure; non-adherent and non-plastic when wet, loose when humid or dry; little biological activity; abundant, fine roots; neat and flat limit.

Bt1 20-52 cm. Cambic horizon.
Dark coffee (10R 4/3) when humid; open, clayish; strong structure in medium-sized and large angular blocks; slightly adherent and slightly plastic when wet, friable when humid and hard when dry; many, medium-sized pores; flat and sudden horizon limit.

LABORATORY ANALYSIS

PROFILE NO. 36

Depth in cm		0-20	20-52	52-67	67-150 A	67-150 B	
Texture		FA	FYA	Y	FA	FA	
pH		6.2	6.3	6.8	6.8	7.2	
Electric conductivity, mmohs cm		47	41	43	37	138	
Free carbonates		-	-	-	-	A	
Soluble cations in me./100 gr.	Ca^{++}	-	-	-	-	-	
	Mg^{++}	-	-	-	-	-	
	Na^{+}	-	-	-	-	-	
	K^{+}	-	-	-	-	-	
Cation exchange data in me. /100 gr.	Ca^{++}	3.8	6.9	14.2	6.9	9.3	
	Mg^{++}	1.2	2.0	6.0	6.2	3.9	
	Na^{+}	0.14	0.22	0.40	0.28	1.48	
	K^{+}	1.86	1.56	2.19	1.58	2.01	
T. B. I.		7.00	10.68	22.79	14.96	16.69	
C. I. C.		7.20	10.78	22.89	15.06	16.89	
% Base Saturation		97	99	99	99	99	
Phosphorus (Olsen)		27.0	20.0	6.0	3.0	2.0	
Acids me /100 gr.		0.2	0.1	0.1	0.1	0.2	

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

Bt2 52-67 cm. Dark reddish coffee (5YR 3/3) when humid; clayish; moderate structure in angular blocks; very adherent and very plastic when wet, firm when humid and hard when dry; neat, flat horizon limit.

C 67-150 cm. Dark reddish coffee (5YR 3/4) when humid; open, sandy; weak structure in medium-sized, sub-angular blocks; slightly adherent and slightly plastic when wet, friable when humid and hard when dry; limit not determined.

MODAL PROFILE 37 /128

A. INFORMATION ON SAMPLING SITE

Profile number: 37
Soil name: "Toalr B" aggregate
Taxonomic classification: Fluventic Ustochrepts
Observation date: July 19, 1976
Author: Moisés Ureña Espinoza
Location: 4.5 Km SW of the town of Maximiliano Paredes, 5 Km NE of Pedro Domingo Murillo, on the road between the two above towns; G. Villarroel province, La Paz County.
Form of the terrain:
a) Physiographic position of the site: plains
b) Form of surrounding land: Flat or nearly flat, with slopes not exceeding 2%
Slope at profile location: flat
Vegetation or land use: Tola is the dominant vegetation; potato, barley and quinoa crops are also observed in the area.

B. GENERAL SOIL INFORMATION

Starting material: Lacustrine sediments with ulterior deposition of alluvial material derived from reddish sandstones.

Drainage: Well drained
Humidity of the profile: Dry
Depth of phreatic layer: Very deep /129
Presence of rocks and rocky outcrops on the surface: none
Evidence of erosion: light, natural, laminar and eolic.
Presence of salts or alkali: Strongly affected by salinity.
Human influence: Development of subsistence crops and grazing for cattle.

C. BRIEF PROFILE DESCRIPTION

Deep soils, consisting of open sandy texture down to 82 cm, reddish coffe in color throughout the profile, except for the second horizon. Strong influence of salinity.

D. PROFILE DESCRIPTION

Au 0-20 cm. Ochric epipedon.
Reddish coffee (5YR 5/4) when humid; open, fine, sandy texture, without agglomerate structure; non-adherent and non-plastic when wet, loose when humid or dry; moderate biological activity; abundant, fine roots; flat and diffuse horizon limit.

Bt 20-68 cm. Little developed cambic horizon.
Yellowish red (5YR 4/6) when humid; open, clayish-sandy; weak structure in fine, sub-angular blocks; non-adherent and non-plastic when wet, very friable when humid and soft when dry; frequent pores; moderate biological activity; normal amount of very fine and fine roots; horizon limit gradual and undulated (no sample taken).

Bs1 68-82 cm. Reddish coffee (5YR 5/3) when humid; fine, open, sandy; moderate, laminar, medium sized structure; alightly adherent and slightly plastic when wet, very friable humid, soft when dry; few, fine pores; few, fine roots; horizon limit diffuse and flat.

Bs2 82-125 cm. Reddish coffee (5YR 4/4) when humid; clayish-limey; moderate structure in fine and medium-sized sub-anglar blocks; adherent and plastic when wet, firm when humid, hard when dry; few, very fine pores; horizon limit neat and flat.

C1 125-145 cm. Dark coffee (7.5YR 5/4) when humid; fine, sandy texture.

C2 145 + cm. Dark coffee (5YR 5/4) when humid; open, moderate structure in medium-sized sub-angular blocks; slightly adherent and slightly plastic when wet, friable when humid and slightly hard when dry; limit not determined.

LABORATORY ANALYSIS

PROFILE NO. 37

Depth in cm		0-20	20-68	68-82	82-125	125-145	145 +
Texture		FA	FVA	FA	VL	A	F
pH		6.8		7.9	8.0	8.0	7.7
Electric conductivity, mmohs cm		1.000		1.600	2.400	830	3.300
Free carbonates		A		PP	P	P	P
Soluble cations in me./100 gr.	Ca^{++}	2.2		1.9	4.1	0.9	9.3
	Mg^{++}	0.5		0.5	1.0	0.2	1.7
	Na^{+}	1.45		5.52	6.84	2.60	10.15
	K^{+}	0.39		0.54	0.85	0.32	0.75
Cation exchange data in me. /100 gr.	Ca^{++}	11.1		11.40	15.1	3.2	21.1
	Mg^{++}	1.1		2.10	3.0	0.9	2.9
	Na^{+}	0.44		1.00	3.80	2.23	1.37
	K^{+}	0.65		0.40	0.61	0.38	0.25
T. B. I.		13.29		14.90	22.51	6.71	25.62
C. I. C.		13.29		14.90	22.51	6.71	25.62
% Base Saturation		100		100	100	100	100
Phosphorus (Olsen)		4.0		2.0	4.5	2.0	2.0
Acids me /100 gr.		-		-	-	-	-

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

MODAL PROFILE 31

A. INFORMATION ON SAMPLING SITE /132

Profile number: 31

Soil name: "El Rio" aggregate

Taxonomic classification: Lithic Ustorthents

Observation date: October 17, 1975

Author: Moisés Ureña Espinoza

Location: 15 Km NW of the town of Ayo-Ayo, 12 Km W of the Oruro-La Paz road; Aroma province, La Paz County.

Elevation in meters: 3,900 above sea level

Form of the terrain:

a) Physiographic position of the site: plain. or the most remote part of a fan.

b) Form of surrounding land: Coalescing fans

Slope at profile location: almost flat

Vegetation or land use: Development of grazing, especially paja brava, white chiji and some tola; used for grazing of sheep and llamas and related species.

B. GENERAL SOIL INFORMATION

Starting material: Soils derived from reddish sandstones and formed by alluvial sediments

Drainage: somewhat excessively drained.

Humidity of the profile: dry

Depth of phreatic layer: 1 m. /133

Presence of rocks and rocky outcrops on the surface: none

Evidence of erosion: Natural, moderate, laminar.

Presence of salts or alkali: Without influence on vegetation development.

Human influence: Most of these soils are used for grazing, but there are small areas growing crops.

C. BRIEF PROFILE DESCRIPTION

Profile of moderately light texture; the first horizon is formed of coarse sand, the second is open clayish with abundant biological activity and the third horizon is composed of gravel and stones.

D. PROFILE DESCRIPTION

Au 0-12 cm. Little developed Ochric epipedon.
Dark coffee (7.5YR 4/2) when humid; coarse sandy texture with little gravel, with no agglomerate structure; non-adherent and non-plastic when wet, loose when humid or dry; very little biological activity; very few, very fine roots; horizon limit neat and flat (no sample taken).

Bt 12-55 cm. Cambic horizon.
Dark coffee (7.5 YR 3/2) when humid; open, clayish texture with little gravel; weak structure in fine, sub-angular blocks; adherent, plastic when wet, very friable when humid, soft when dry; frequent fine and medium-sized pores; much worm activity is observed; very few, very fine roots; horizon limit neat and flat.

C 55-100 cm. Coarse material without textural classification, formed of gravel and stones composed of quarcitic sandstones (no sample taken). /134

A25. Grouping ("Consociation"): Conchillas (Typic Natrargids)
Hornillos (Vertic Camborthids)

This grouping ("consociation") corresponds to soils located on the temporarily flooded plain of the high plateau; its relief is flat or slightly concave; it covers 39,905 Has.

LABORATORY ANALYSIS

PROFILE NO. 31

Depth in cm		0-12	12-55	55-100			
Texture		A	FY	GRAVA Y PIEDRA			
pH			6.6				
Electric conductivity, mmohs cm			44				
Free carbonates			A				
Soluble cations in me./100 gr.	Ca^{++}		-				
	Mg^{++}		-				
	Na^{+}		-				
	K^{+}		-				
Cation exchange data in me. /100 gr.	Ca^{++}		13.3				
	Mg^{++}		3.2				
	Na^{+}		0.38				
	K^{+}		0.75				
T. B. I.			17.63				
C. I. C.			17.73				
% Base Saturation			99				
Phosphorus (Olsen)			8.0				
Acids me /100 gr.			0.1				

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

The soils are deep, and clayish affected strongly by salinity; they are generally covered by a thin sheet of water during the rainy season, thus forming flooded areas. Because of these characteristics, there was no development of agricultural activity; it sustains only poor grazing land for cattle.

Two profiles were described within this unit, representing the grouping ("consociation"). /136

MODAL PROFILE 28

A. INFORMATION ON SAMPLING SITE

Profile number: 28
Soil name: "Conchillas" grouping ("consociation")
Taxonomic classification: Typic Natrargids
Observation date: October 17, 1975
Author: Moisés Ureña Espinosa
Location: 8 Km SE of the town of Iñacamaya, 10 Km S of the town of Chijmuni, 15 Km E of the town of Umala; Aroma province, La Paz county.
Elevation in meters: 3,750 above sea level
Form of the terrain: /137
a) Physiographic position of the site: flat plain
b) Form of surrounding land: Alluvial plain
Slope at profile location: flat
Vegetation or land use: Areas covered by very sparse grass, used as cattle feed; the most important species in the area is the "Mouse tail" (Cola de ratón) grass; there is no agricultural activity in these areas.

B. GENERAL SOIL INFORMATION

Starting material: Soils formed by alluvial sediments deposited over older, lacustrine sediments.
Drainage: imperfectly drained

Humidity of the profile: Dry
Depth of phreatic layer: 2.00 m at the time of observation
Presence of rocks and rocky outcrops on the surface: none
Evidence of erosion: none visible
Presence of salts or alkali: Strongly affected by salts
Human influence: areas used for grazing

C. BRIEF PROFILE DESCRIPTION

Deep profile with little variation throughout in either color or its clayish texture; below 2.00 m there is a whitish horizon with a high content of mollusc shells ("conchilla") under decomposition.

D. PROFILE DESCRIPTION /138

Au 0-30 cm. Ochric epipedon.
Yellowish coffee (10YR 5/4) when humid; open, clayish texture; moderate structure in medium-sized, sub-angular blocks; adherent and plastic when wet, friable when humid, hard when dry; few, fine pores; very little biological activity; few, fine roots; limit diffuse and flat.

Bt 30-200 cm. Natric horizon with argillic charcateristics.
Dark gray coffee (10YR 4/2) when humid; frequent spots, medium-sized, indistinct, diffuse and reddish coffee in color (5YR 5/4); clayish texture; strong structure in medium-sized, angular blocks; very adherent and very plastic when wet, firm when humid, very hard when dry; presence of continuous cutanes, thin and of argillic characteristics covering peds; slightly calcareous horizon; very few, very fine roots; neat horizon limit.

LABORATORY ANALYSIS

PROFILE NO. 28

Depth in cm		0-30	30-200				
Texture		FY	Y				
pH		8.2	8.8				
Electric conductivity, mmohs cm		235	1.100				
Free carbonates		A	P				
Soluble cations in me./100 gr.	Ca^{++}	-	6.1				
	Mg^{++}	-	1.6				
	Na^{+}	-	3.78				
	K^{+}	-	1.22				
Cation exchange data in me. /100 gr.	Ca^{++}	44.8	11.3				
	Mg^{++}	5.4	2.4				
	Na^{+}	2.90	11.16				
	K^{+}	1.28	5.62				
T. B. I.		54.38	30.48				
C. I. C.		54.38	30.48				
% Base Saturation		100	100				
Phosphorus (Olsen)		37.0	27.0				
Acids me /100 gr.		-	-				

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

MODAL PROFILE 41

A. INFORMATION ON SAMPLING SITE /140

Profile number: 41

Soil name: "Hornillos" grouping ("consociation")

Taxonomic classification: Vertic Camborthids

Observation date: July 2, 1976

Author: Moisés Ureña Espinoza

Location: 5 Km NE of the town of Llanquera, 1.5 Km N of the town of Rosas Pampa, 18 Km W of Chuquichambi; Carangas province, Oruro County.

Elevation in meters: 3,700 above sea level

Form of the terrain:

a) Physiographic position of the site: plains

b) Form of surrounding land: Flat or nearly flat, with slopes not exceeding 2%

Slope at profile location: flat

Vegetation or land use: They develop grazing known as "Mouse tail", used as cattle feed

B. GENERAL SOIL INFORMATION

Starting material: Soils, formed by alluvial sediments, were deposited over older lacustrine sediments.

Drainage: imperfectly drained.

Humidity of the profile: humid. /141

Depth of the phreatic layer: 2.5 m (observed in a nearby well).

Presence of rocks and rocky outcrops on the surface: none

Evidence of erosion: light, natural erosion.

Presence of salts or alkali: Moderately affected by salts

Human influence: The few native grasses in the area are exploited for grazing of sheep and llamas and related species.

C. BRIEF PROFILE DESCRIPTION

Deep profile, of very uniform coloration; the third horizon is heaviliy influenced by carbonate accumulations; poor soils, they are recent depositions from floodings. Marked and deep fissures.

D. PROFILE DESCRIPTION

Au 0-19 cm. Ochric epipedon.
Reddish coffe (5YR 4/4) when humid; open, limey-clayish; weak structure in fine and medium-sized sub-angular blocks; slightly adherent, slightly plastic when wet, friable when humid, soft when dry; frecuent, fine pores; normal quantities of fine and medium-sized roots; horizon limit diffuse and flat (no analytical data).

Bs 19-54 cm. Little developed cambic horizon
Dark reddish coffee (5YR 3/4) when humid; open, limey; moderate structure in fine and medium-sized sub- /142
angular blocks; slightly adherent, non-plastic when wet, friable when humid and soft when dry; light carbonate reaction; few, fine pores; moderate biological activity; few, very fine roots; horizon limit sudden and flat.

Bca 54-130 cm. Dark red coffee (5YR 3/3) when humid; whitish spots, due to carbonate accumulation; clayish texture; strong structure of angular type, medium-sized and large; very adherent and very plastic when wet, very firm when humid, very hard when dry; strong carbonate reaction; limit not determined.

A26. Association: Cap. Castrillo (Typic Pssamaquents) /144
C. de Carangas (Aquic Salorthids)
Kolla (Typic Salorthids)
La Cantera (Typic Natrargids)

LABORATORY ANALYSIS

PROFILE NO. 41

Depth in cm		0-19	19-54	54-130 A	54-130 B		
Texture		FYL	FL	Y	Y		
pH			7.2	8.9	8.2		
Electric conductivity, mmohs cm			106	630	2000		
Free carbonates			P	PP	P		
Soluble cations in me./100 gr.	Ca^{++}		-	9.6	56.8		
	Mg^{++}		-	2.4	2.4		
	Na^{+}		-	4.50	9.48		
	K^{+}		-	1.08	1.16		
Cation exchange data in me. /100 gr.	Ca^{++}		9.3	0.3	56.8		
	Mg^{++}		0.7	0.4	0.6		
	Na^{+}		0.40	2.75	0.42		
	K^{+}		0.42	0.20	0.54		
T. B. I.			10.82	3.65	58.36		
C. I. C.			10.82	3.65	58.36		
% Base Saturation			100	100	100		
Phosphorus (Olsen)			2.5	5.5	1.0		
Acids me /100 gr.			-	-	-		

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

This association of soils covers an area of 94,235 Has located on the high plateau plain; it offers a flat relief, accasionally subjected to flooding.

Soils are characterized by their depth and strong salt influence; the phreatic layer is very close to the surface in certain parts. The strong salt content in these soils prevented the development of any agricultural activity; only very poor vegetation exists, mostly grasses.

This unit is formed by four soil aggregates each, identified by means of modal profiles.

MODAL PROFILE 5

A. INFORMATION ON SAMPLING SITE

Profile number: 5
Soil name: "Cap. Castrillo" aggregate
Taxonomic classification: Typic Psammaquents
Observation date: September 7, 1975
Author: Moisés Ureña Espinoza /145
Location: 200 m S of the Desaguadero river and 100 m N of the town of Capitán Castrillo; G. Villarroel province, La Paz County.
Elevation in meters: 3,750 above sea level
Form of the terrain:
a) Physiographic position of the site: plains
b) Form of surrounding land: Flat or nearly flat, with slopes not exceeding 2%
Slope at profile location: flat
Vegetation or land use: soils covered by tola and native grasses

B. GENERAL SOIL INFORMATION

Starting material: soils formed by alluvial sediments deposited by the Desaguadero river.
Drainage: imperfectly drained
Humidity of the profile: very humid
Depth of phreatic layer: 80 cm at the time of observation
Presence of rocks and rocky outcrops on the surface: none
Evidence of erosion: none visible
Presence of salts or alkali: strongly affected by salts
Human influence: grazing of sheep and llamas and related species

C. BRIEF PROFILE DESCRIPTION /146

Soils limited in their depth by the continuous fluctuations of the phreatic level; very light in texture and of uniform coloration throughout their depth.

D. PROFILE DESCRIPTION

Au 0-35 cm. No diagnostic epipedon.
Dark red (10YR 3/6) when humid; sandy; without agglomerate structure; non-adherent and non-plastic when wet, very friable when humid, loose when dry; few, very fine roots; horizon limit gradual and flat.

Csa 35-80 cm. Salic horizon.
Dark red (10YR 3/6) when humid; fine sand; no agglomerate structure; non-adherent, non-plastic when wet, very friable when humid, loose when dry; few, fine pores, random; very few, very fine roots.

The phreatic layer is found at this depth.

LABORATORY ANALYSIS

PROFILE NO. 5

Depth in cm		0-35	35-80				
Texture		A	A				
pH		8.6	8.2				
Electric conductivity, mmohs cm		400	280				
Free carbonates		P	P				
Soluble cations in me /100 gr.	Ca^{++}	-	-				
	Mg^{++}	-	-				
	Na^{+}	-	-				
	K^{+}	-	-				
Cation exchange data in me. /100 gr.	Ca^{++}	2.8	5.6				
	Mg^{++}	0.9	1.2				
	Na^{+}	8.70	1.12				
	K^{+}	1.56	0.62				
T. B. I.		13.96	8.54				
C. I. C.		13.96	8.54				
% Base Saturation		100	100				
Phosphorus (Olsen)		1.0	1.0				
Acids me /100 gr.		-	-				

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

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MODAL PROFILE 10

A. INFORMATION ON SAMPLING SITE

Profile number: 10

Soil name: "Curahuara de Carangas" aggregate

Taxonomic classification: Aquic Salorthids

Observation date: September 13, 1975

Author: Moisés Ureña Espinoza

Ubicación: 8 Km al NE of Curahuara de Carengas, 12 Km SW of the Sulloma river, 100 m W of the road between Curahuara de Carangas and the Jankho Khota farm; Sajama province, Oruro County.

Elevation in meters: 3,750 above sea level

Form of the terrain:

a) Physiographic position of the site: flat plain

b) Form of surrounding land: there is hill country nearby

Slope at profile location: flat

Vegetation or land use: Area of grazing development, with grass, paja brava, tola; area is uncultivable because of high salinity.

B. GENERAL SOIL INFORMATION

Starting material: Alluvial soils derived from reddish sandstones.

Drainage: Moderately well drained

Humidity of the profile: Very humid

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Depth of phreatic layer: 0.85 m

Presence of rocks and rocky outcrops: none

Evidence of erosion: natural, laminar and light, or else alluvial depositions.

Presence of salts or alkali: strong salt efflorescences observable

Human influence: Soils used to develop poor grasses, used as feed for sheep and llamas and related species

C. BRIEF PROFILE DESCRIPTION

Profile corresponds to soils with moderately light textures and reddish coffee color throughout its depth. Strongly salty soils with salt efflorescences and a very shallow phreatic layer.

LABORATORY ANALYSIS

PROFILE NO. 10

Depth in cm		0-25	25-85				
Texture		YL	FYA				
pH		8.1	8.3				
Electric conductivity, mmohs cm		430	260				
Free carbonates		PP	P				
Soluble cations in me./100 gr.	Ca^{++}	1.3	-				
	Mg^{++}	0.3	-				
	Na^{+}	1.56	-				
	K^{+}	0.24	-				
Cation exchange data in me./100 gr.	Ca^{++}	12.9	9.3				
	Mg^{++}	1.1	1.4				
	Na^{+}	0.44	1.50				
	K^{+}	0.37	0.56				
T. B. I.		14.81	12.76				
C. I. C.		14.81	12.76				
% Base Saturation		100	100				
Phosphorus (Olsen)		5.0	2.5				
Acids me /100 gr.		-	-				

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

D. PROFILE DESCRIPTION

Au 0-25 cm. Ochric epipedon.
Reddish coffee (5YR 4/4) when humid; limey-clayish texture; weak structure of the crumby type; adherent and plastic when wet, very friable when humid, slightly hard when dry; few, medium-sized pores; very few, fine roots; moderate carbonate reaction; horizon limit diffuse and flat.

Asa 25-85 cm. Salic horizon.
Reddish coffee (5YR 4/3) when humid; open, clayish-sandy texture; weak structure of sub-angular type; slightly adherent and plastic when wet, very friable when humid, soft when dry; frequent, fine and medium-sized pores; light calcareous influence; very few, very fine roots; the phreatic layer is below this horizon.

MODAL PROFILE 7 /151

A. INFORMATION ON SAMPLING SITE

Profile number: 7
Soil name: "Kolla" aggregate
Taxonomic classification: Typic Salorthids
Observation date: September 10, 1975
Author: Moisés Ureña Espinoza
Location: 3 Km W of the town of Manquiri, 3 Km S of the Desaguadero river, 38 Km W of the town of Eucaliptus; G. Villarroel province, La Paz County.
Elevation, in meters: 3,790 above sea level
Form of the terrain:
a) Physiographic position of the site: flat alluvial plain
b) Form of surrounding land: Flat or nearly flat, with slopes not exceeding 2%

Slope at profile location: flat

Vegetation or land use: soils covered by native botanical species, used for grazing of sheep and llamas and related species; the main species of vegetation are tola, paja brava and others; there is no agricultural activity.

B. GENERAL SOIL INFORMATION

Starting material: Soils of alluvial formation, derived mostly from reddish sandstones.

Drainage: Moderately well drained

Humidity of the profile: Dry

Depth of phreatic layer: Very deep

Presence of rocks and rocky outcrops: none /152

Evidence of erosion: Natural, slight, laminar and eolic.

Presence of salts or alkali: Strongly affected by salts.

Human influence: Areas used for grazing of sheep, beef and llamas and related species.

C. BRIEF PROFILE DESCRIPTION

Deep soils, reddish coffee in color, clayish structure to the second horizon, with strong salt influence.

D. PROFILE DESCRIPTION

Au 0-12 cm. Ochric epipedon.
Reddish coffee (5YR 5/4) when humid; open, clayish texture; moderate structure in sub-angular blocks; very adherent and very plastic when wet, very friable when humid, soft when dry; many, medium-sized pores; carbonates present; very few, very fine roots; flat and gradual limit.

Bsa 12-45 cm. Salic horizon.
Reddish coffee (5YR 5/4) when humid; clayish texture; moderate structure in sub-angular blocks; very adherent and plastic when wet, firm when humid, hard

Depth in cm		0-12	12-45	45-85	85-150		
Texture		FY	Y	A	A		
pH		7.8	7.5	7.3	7.7		
Electric conductivity, micro mhos cm		120	110	83	193		
% Free carbonates		P	A	A	P		
Soluble cations in me./100 gr.	Ca^{++}	-	-	-	-		
	Mg^{++}	-	-	-	-		
	Na^{+}	-	-	-	-		
	K^{+}	-	-	-	-		
Cation exchange data in me./100 gr.	Ca^{++}	22.4	27.6	16.3	6.1		
	Mg^{++}	3.1	4.0	2.2	1.2		
	Na^{+}	0.25	0.38	0.32	0.18		
	K^{+}	0.47	1.42	1.14	0.40		
T. B. I.		26.22	33.40	19.96	7.78		
C. I. C.		26.22	33.60	20.16	7.78		
% Base Saturation		100	99	99	100		
Phosphorus (Olsen)		6.0	5.5	5.0	7.5		
% in me./100 gr.		-	0.2	0.2	-		

Texture: Franco = F; Y = Clay; C = Lime and A = Sand

when dry; carbonates present; frequent, fine, random pores; very few, very fine roots; diffuse and flat limit.

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C1 45-85 cm. Dark red coffee (5YR 3/4) when humid; coarse sandy texture, without agglomerate structure; non-adherent and non-plastic when wet, loose when humid, soft when hard; very few, very fine roots; horizon limit gradual and flat.

C2 85-150 cm. Dark red coffee (5YR 3/4) when humid; coarse sandy texture, with gravel; no agglomerate structure; non-adherent and non-plastic when wet, loose when humid or dry; limit not determined.

MODAL PROFILE 34

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A. INFORMATION ON SAMPLING SITE

Profile number: 34
Soil name: "La Cantera" aggregate
Taxonomic classification: Typic Natrargids
Observation date: July 15, 1976
Author: Moisés Ureña Espinoza
Location: 2.5 Km NW of the Huinco Tataya quarry, 0.5 Km W of the Kheto river, 12 Km SW of the town of Chijmuni, Aroma province, La Paz County.
Elevation in meters: 3,730 above sea level
Form of the terrain:

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a) Physiographic position of the site: flat to slightly concave
b) Form of surrounding land: flat or nearly flat, with slopes not to exceed 2%

Slope at profile location: flat
Vegetation or land use: Presence of sparse natural vegetation, consisting of yareta and Khota or Yaretilla.

B. GENERAL SOIL INFORMATION

Starting material: Deposition of alluvial sediments over older material of lacustrine origin.
Drainage: Imperfectly drained
Humidity of the profile: Humid throughout its depth
Depth of phreatic layer: very deep
Presence of rocks and rocky outcrops on the surface: none
Evidence of erosion: Moderate, natural, laminar and eolic; also some hydric deposition.
Presence of salts or alkali: Strongly affected by alkaline salts
Human influence: none

C. BRIEF PROFILE DESCRIPTION

Humid profile throughout, of clayish characteristics; sand can be observed at depths greater than 1.2 m.

With the exception of the first horizon, there are salt pockets throughout the profile, especially in the fourth horizon; this profile corresponds to a very salty area with very sparse vegetation cover.

D. PROFILE DESCRIPTION

Au 0-10 cm. Ochric epipedon.
Light reddish coffee (5YR 6/4) when humid; limey-clayish; moderate structure in fine and medium-sized sub-angular blocks; adherent and plastic when wet, friable when humid and slightly hard when dry; frequent, medium-sized pores; due to the high salinity, there are no roots or vegetation; horizon limit flat and gradual.

Bt 10-20 cm. Natric horizon.
Reddish coffe (5YR 4/4) when humid; clayish; strong structure in medium-sized angular blocks; very adherent and very plastic when wet, firm when dry; noticeable

LABORATORY ANALYSIS

PROFILE NO. 34

Depth in cm		0-10	10-20	20-40	40-120 A	40-120 B	120+
Texture		Y.L.	Y	F.L.	Y	Y	A
pH		8.5	8.6	8.4	8.6	8.6	7.9
Electric conductivity, mmohs cm		8.000	6.000	5.600	7.000	6.000	2.700
Free carbonates		P	P	P	P	P	P
Soluble cations in mΘ/100 gr.	Ca^{++}	1.0	7.6	13.8	56.8	24.4	0.5
	Mg^{++}	0.6	0.8	1.2	1.7	1.2	0.1
	Na^{+}	41.08	31.12	27.93	32.30	31.92	9.78
	K^{+}	1.94	1.92	1.74	3.56	3.20	0.77
Cation exchange data in mΘ/100 gr.	Ca^{++}	7.7	47.6	4.8	53.6	32.4	1.2
	Mg^{++}	2.7	1.8	0.4	0.3	0.5	0.7
	Na^{+}	13.45	7.80	4.63	9.70	2.88	7.60
	K^{+}	2.68	2.03	0.42	0.79	1.05	1.15
T. B. I.		26.53	59.23	10.25	64.39	36.83	10.65
C. I. C.		26.53	59.23	10.25	64.39	36.83	10.65
% Base Saturation		100	100	100	100	100	100
Phosphorus (Olsen)		21.0	6.0	0.3	0.3	0.3	1.0
Acids mΘ/100 gr.		-	-	-	-	-	-

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

pressure surfaces; few, very fine pores; no roots; horizon limit neat and flat.

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Bs1 20-40 cm. Light reddish coffee (5YR 6/4) when humid; open, limey; weak structure in subangular blocks; slightly adherent, slightlyplastic when wet, friable when humid and soft when dry; few fine, medium and coarse pores; horizon limit flat and sharp.

Bs2 40-120 cm. Dark reddish coffee (5YR 3/4) when humid; clayish; strong structure in medium-sized and large angular blocks; very adherent and very plastic when wet, firm when humid and very hard when dry; few, very fine pores.

C 120+ cm. Pale yellow (2.5Y 7/4) when humid; fine sand; limit not determined.

A27. Patacamaya Grouping ("Consociation")

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This unit has been identified on the high plateau plains, with deep soils, light texture, resulting from recent depositions; they are generally well drained and without salt problems. Most of the area is used for intensive agriculture, with irrigation potential throughout most of the year. It covers an area of 3,870 Has, with a typical profile classified as Typic Cryopsamments.

MODAL PROFILE 30

A. INFORMATION ON SAMPLING SITE

Profile number: 30
Soil name: "Patacamaya" grouping ("consociation")
Taxonomic classification: Typic Cryopsamments
Observation date: October 18, 1975

Author: Moisés Ureña Espinoza

Location: 1 Km S of the town of Patacamaya, 1 Km W of the state railroad; Roma province, La Paz County

Elevation in meters: 3,790 above sea level

Form of the terrain:

a) Physiographic position of the site: flat plain

b) Form of surrounding land: plains, with slope not exceeding 2%

Slope at profile location: flat /160

Vegetation or land use: Soil in intensive agricultural exploitation: potatoes, barley, beans; there is also very little paja brava; adequate for mechanized agriculture.

B. GENERAL SOIL INFORMATION

Starting material: Alluvial soils, recently derived from sandstones and lutites

Drainage: well drained

Humidity of the profile: humid

Depth of phreatic layer: very deep

Presence of rocks and rocky outcrops on the surface: none

Presence of salts or alkali: no salt influence

Human influence: Development of intensive agriculture

C. BRIEF PROFILE DESCRIPTION

Profile of light soils formed by open, sandy and coarse sand textures predominantly, with little color variation among horizons

D. PROFILE DESCRIPTION

Ap 0-25 cm. No diagnostic epipedon

Dark brown (5YR 4/2) when humid; open, sandy texture; weak structure of crumbly type; adherent and plastic when wet, very friable when humid, soft when dry; frequent fine and medium-sized pores; little biologic activity; few, fine roots; horizon limit diffuse and flat.

Au1 25-50 cm. Shows no diagnostic horizon. /161
Very dark gray coffee (10YR 3/2) when humid; open, sandy texture; weak structure in sub-angular blocks; slightly adherent and slightly plastic when wet, loose when humid, soft when dry; frequent fine and medium-sized pores; moderate biological activity; very few, very fine roots; limit neat and flat.

Au2 50-65 cm. Grayish coffee (10YR 5/2) when humid; coarse sandy texture with an abundance of rounded gravel; sharp flat limit (no sample taken).

Bu 65-95 cm. Dark gray coffee (10YR 4/2) when humid; open, limey texture; weak structure in sub-angular blocks; slightly adherent and slightly plastic when wet, loose when humid and soft when dry; frequent fine and medium-sized pores; little biological activity; neat and flat limit.

C 95-120 cm. Dark gray coffee (10YR 4/2) when humid; coarse sandy texture with an abundance of gravel of rounded shapes (no sample taken).

A28. Corocoro Sud Grouping ("Consociation") /163

This grouping corresponds to old terraced soils providing a flat to gently rolling relief, with an extension of 65,515 Has, located generally between hills.

Soils are limited in their depth by the high rock content; there are no salt content problems; used for dryland agricultural and livestock activities. The typical profile described for this unit has been classified Lithic Ustorthents.

LABORATORY ANALYSIS

PROFILE NO. 30

Depth in cm		0-25	25-50	50-65	65-95	95-120	
Texture		AF	AF	A	FL	A	
pH		7.1	7.2		7.5		
Electric conductivity, mmohs cm		97	78		115		
Free carbonates		A	A		A		
Soluble cations in me /100 gr.	Ca^{++}	-	-		-		
	Mg^{++}	-	-		-		
	Na^{+}	-	-		-		
	K^{+}	-	-		-		
Cation exchange data in me. /100 gr.	Ca^{++}	8.7	6.9		14.7		
	Mg^{++}	3.2	2.9		5.8		
	Na^{+}	0.48	0.54		1.30		
	K^{+}	0.73	0.42		0.35		
T. B. I.		13.11	10.76		22.15		
C. I. C.		13.31	10.96		22.15		
% Base Saturation		98	98		100		
Phosphorus (Olsen)		0.5	1.0		7.5		
Acids me /100 gr.		0.2	0.2		-		

Texture: Franco = F Y = Clay; L = Lime and A = Sand

MODAL PROFILE 15

A. INFORMATION ON SAMPLING SITE

Profile number: 15
Soil name: "Corocoro Sud" Grouping ("Consociation")
Taxonomic classification: Lithic Ustorthents
Observation date: September 16, 1975
Author: Moisés Ureña Espinoza
Location: 5 Km NW of the town of Caquingora, 3 Km S of the state railroad; Pacajes province, La Paz County
Elevation in meters: 3,780 above sea level
Form of the terrain:
a) Physiographic position of the site: terrace
b) Form of surrounding land: old, flat terraces
Slope at profile location: flat
Vegetation or land use: Approximately 90% of the area is used to develop native grasses; the remainder is used to grow potato, barley and quinoa crops

B. GENERAL SOIL INFORMATION

Starting material: old alluvial soils forming a terrace
Drainage: somewhat excessively drained
Humidity of the profile: dry
Depth of phreatic layer: very deep
Presence of rocks and rocky outcrops on the surface: none
Evidence of erosion: natural, laminar, moderate
Presence of salts or alkali: no salt influence
Human influence: soils used for routine agriculture and the development of poor grazing

C. BRIEF PROFILE DESCRIPTION

Profile of shallow soils, forming a terrace, with abundant gravel and rocks, especially in the lower horizons.

D. PROFILE DESCRIPTION

Ap 0-20 cm. Ochric epipedon.
Light red coffee (5YR 6/4) when humid; sandy texture with little gravel; weak structure in fine, sub-angular blocks; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry; many medium-sized and large pores; there is some gravel, rounded, not altered; little biological activity; few, fine roots; horizon limit neat and flat.

Au 20-40 cm. Presents no diagnostic horizon. Dark, brownish red (5YR 4/2) when humid; coarse sandy texture with abundant gravel and stones; without loose grain structure; non-adherent, non-plastic when wet, loose when humid or dry; many large pores; rounded gravel predominates; very few, very fine roots; horizon limit gradual and flat (no sample taken). /165

Bt 40-100 cm. Yellowish when humid (5YR 4/6); clayish texture with abundant gravel; strong structure in medium-sized angular blocks; very adherent and very plastic when wet, firm when humid, very hard when dry; frequent gravel fragments and rounded stones; very few, very fine roots.

LABORATORY ANALYSIS

PROFILE NO. 15

Depth in cm		0-20	20-40	40-100			
Texture		A	A	Y			
pH		6.0		6.9			
Electric conductivity, mmohs cm		20		44			
Free carbonates		A		A			
Soluble cations in me./100 gr.	Ca^{++}	-		-			
	Mg^{++}	-		-			
	Na^{+}	-		-			
	K^{+}	-		-			
Cation exchange data in me. /100 gr.	Ca^{++}	4.1		22.4			
	Mg^{++}	0.9		6.8			
	Na^{+}	0.14		1.45			
	K^{+}	0.75		1.08			
T. B. I.		5.89		31.73			
C. I. C.		6.09		31.93			
% Base Saturation		97		99			
Phosphorus (Olsen)		5.0		1.0			
Acids me /100 gr.		0.2		0.2			

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

0. EASTERN RANGE REGION

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01. High Sierras

They correspond to a portion of the Eastern Range located in the Northeastern part of the image studied; it is formed by a relief appropriate to the high sierra, very broken, with a preponderance of rocky outcrops, or very superficial soils with an almost non-existent vegetation cover. In its higher parts there are very significant bodies of permanent snow, the thaw of which can be exploited.

Because of the characteristics indicated, these areas are of very low agricultural and livestock value; they cover an area of 268,950 Has; no soil profiles were described.

0.21 Foothill sierras

They cover a surface area of 73,740 Has, located immediately following the High Sierras; they occupy the lower parts of the high sierra and differ from the latter in that they present a hilly aspect of somewhat rounded forms.

This hilly unit offers a strongly undulating, craggy relief; it is subjected to very strong erosion and hence there is no appreciable edaphic development. It is constituted primarily of rocky outcrops with very scant surface soil, formed under in-situ conditions, or deposited in colluvio-alluvial form in the unit's lower parts. No soil profiles were described, since the area is of little agricultural importance.

O22. Belen Grouping ("Consociation") /168

They cover an area of 25,720 Has, located at the foot of the hill country of the Eastern Range. The relief is inclined, at times gently rolling. Soils are of moderate or little depth, limited by the rock content of the lower horizons. The texture of the two upper horizon is determined by very light material with sparse vegetation cover; the are isolated instances of dryland crops. The modal profile of this type of soils has been classified as Lithic Ustipsamments.

MODAL PROFILE 29

A. INFORMATION ON SAMPLING SITE

Profile number: 29
Soil name: "Belén" grouping ("consociation")
Taxonomic classification: Lithic Ustipsamments
Observation date: October 17, 1975
Author: Moisés Ureña Espinoza
Location: 2 Km S of Kollpa Khucho Belén, 5 Km N of the Oruro-La Paz road, 20 Km E of the town of Sica Sica; Aroma province, La Paz County.
Elevation in meters: 3,820 above sea level
Form of the terrain:
a) Physiographic position of the site: fan
b) Form of surrounding land: foot of hill country
Slope at profile location: inclined /169
Vegetation or land use: Area covered by native vegetation, with paja brava and tola predominating; there are also small areas dedicated to growing potatoes and barley.

B. GENERAL SOIL INFORMATION

Starting material: soils formed by colluvio-alluvial processes, with sandstone as parental material.

Drainage: excessively drained
Humidity of the profile: dry
Depth of phreatic layer: very deep
Presence of rocks on the surface: very rocky
Presence of rocky outcrops: moderately rocky
Evidence of erosion: Natural, laminar and in moderate furrows
Presence of salts or alkali: moderate influence of salts
Human influence: Area used for grazing - especially sheep - and occasional agricultural activity.

C. BRIEF PROFILE DESCRIPTION

Profile formed of gravel, rocks and stones, with sparse amounts of fine sand; the third horizon is very similar to the first, formed of gravel and rock.

D. PROFILE DESCRIPTION

B1 0-50 cm. Shows no diagnostic epipedon. /170
Reddish coffee (5YR 5/3) when humid; coarse sandy texture with abundant gravel and rocks; without agglomerate structure; very few, very fine roots; the horizon limit is sharp and irregular (no sample taken)

E2 50-90 cm. No diagnostic horizon apparent.
Dark coffee (10YR 4/3) when humid; fine, sandy texture; weak structure of crumbly type; slightly adherent and slightly plastic when wet, loose when humid, soft when dry; frequent, fine and medium-sized pores; low content in angular and rounded gravel; strongly calcareous; few, fine roots; horizon limit neat and undulating.

C 90-150 cm. Horizon formed by gravel and stone (no sample taken)

LABORATORY ANALYSIS

PROFILE NO. 29

Depth in cm		0-50	50-90	90-150			
Texture		A	A	GRAVA Y PIEDRA			
pH			8.5				
Electric conductivity, mmohs cm			190				
Free carbonates			PP				
Soluble cations in me./100 gr.	Ca^{++}		-				
	Mg^{++}		-				
	Na^{+}		-				
	K^{+}		-				
Cation exchange data in me. /100 gr.	Ca^{++}		11.2				
	Mg^{++}		1.3				
	Na^{+}		2.00				
	K^{+}		0.54				
T. B. I.			15.04				
C. I. C.			15.04				
% Base Saturation			100				
Phosphorus (Olsen)			6.0				
Acids me /100 gr.			-				

Testure: Franco = F; Y = Clay; L = Lime and A = Sand

03. Toloma Grouping ("Consociation") /172

This grouping is formed by an undulating relief, corresponding to terraces located between the hill countries in the Eastern Range; it covers an extension of 28,565 Has; soils are generally deep, sandy in the upper two horizons and clayish at greater depths; the typical profile in this unit has been classified as Vertic Ustorthents

MODAL PROFILE 25

A. INFORMATION ON SAMPLING SITE

Profile number: 25
Soil name: "Toloma" grouping ("consociation")
Taxonomic classification: Vertic Ustorthents
Observation date: October 16, 1976
Author: Moisés Ureña Espinoza
Location: 2 Km W of the road linking Kolla Khuchu Belén and Luribay; 20 Km NW of the town of Sica Sica; region of the Toloma farm, Aroma province, in La Paz County
Elevation in meters: 3,980 above sea level
Form of the terrain:
a) Physiographic position of the site: undulated terrace
b) Form of surrounding land: undulated terraces between hills
Slope at profile location: slightly inclined
Vegetation or land use: soils used in agricultural activity, for crops of potato, barley and quinua; there is also growth of natural vegetation, such as paja brava and tola. /173

B. GENERAL SOIL INFORMATION

Starting material: soils formed by alluvial sediments derived from sandstones.
Drainage: moderately well drained
Humidity of the profile: almost dry

Depth of phreatic layer: very deep

Presence of rocks on the surface: rocky

Presence of rocky outcrops: none

Evidence of erosion: Natural, laminar; moderate.

Presence of salts or alkali: without influence of the development of vegetation

Human influence: Agricultural and livestock activity, with over-grazin on dryland soils

C. BRIEF PROFILE DESCRIPTION /174

The arable layer and the 2nd horizon are quite similar and formed of light textures; the 3rd horizon is clayish and compact, derived from clayish sandstones; they show well formed pressure surfaces.

D. PROFILE DESCRIPTION

Ap 0-25 cm. Shows no diagnostic epipedon.
Dark red coffee (5YR 3/3) when humid; sandy texture with small amounts of gravel and slightly stoney; without agglomerate structure; slightly adherent and slightly plastic when wet, very friable when humid, loose when dry; few, medium-sized pores; small amounts of gravel and stones of quarcitic nature in angular and rounded shapes; few pores; moderate biological activity; very few, very fine roots; horizon limit neat and flat.

Au 25-60 cm. There is no diagnostic horizon.
Dark red coffee (5YR 3/2) when humid; coarse, sandy texture with little gravel; no structure; slightly adherent and slightly plastic when wet, very friable when humid, loose when dry; few pores; very little gravel present, and angular and rounded quarcite stones; moderate biological activity: very few. very fine roots: horizon limit neat and flat.

Bt 60-150 cm. Yellowish red (5YR 5/6) when humid; frequent spots, medium-sized and defined, dark brown in color; clayish texture; strong structure in medium-sized, angular blocks; very adherent and very plastic when wet, friable when humid, hard when dry; presence of continuous cutanes, thin and of argillic nature; few, fine pores; low proportion of carbonates; limited biological activity.

LABORATORY ANALYSIS

PROFILE NO. 25

Depth in cm		0-25	25-60	60-150			
Texture		A	A	Y			
pH		6.0	6.5	8.6			
Electric conductivity, mmohs cm		41	31	320			
Free carbonates		A	A	P			
Soluble cations in me./100 gr.	Ca^{++}	-	-	-			
	Mg^{++}	-	-	-			
	Na^{+}	-	-	-			
	K^{+}	-	-	-			
Cation exchange data in me. /100 gr.	Ca^{++}	2.8	3.3	11.2			
	Mg^{++}	0.9	1.0	4.0			
	Na^{+}	0.28	0.56	3.60			
	K^{+}	1.0	1.0	2.48			
T. B. I.		4.98	5.86	21.28			
C. I. C.		5.18	6.06	21.28			
% Base Saturation		96	97	100			
Phosphorus (Olsen)		3.0	0.5	3.0			
Acids me /100 gr.		0.2	0.2	-			

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

04. Luribay Grouping ("Consociation") /176

It is one of the most important units from the point of view of agricultural production; located between the hill countries in the Eastern Range, forming narrow valleys; the relief is generally gently sloped, subject to irrigation throughout most of the year; it covers an area of 6,570 Has.

Soils are deep and are the result of recent depositions from colluvio-alluvial processes; the horizons are very disturbed. Microclimatic conditions are very favorable and make the development of intensive agriculture possible. The typical profile described for this unit has been classified Mollic Ustifluvents.

MODAL PROFILE 26

A. INFORMATION ON SAMPLING SITE

Profile number: 26
Soil name: "Luribay" grouping ("consociation")
Taxonomic classification: Mollic Ustifluvents
Observation date: October 16, 1975
Author: Moisé Ureña Espinnoza
Location: 7 Km SE of the town of Luribay; close to the confluence of the Lejre and Luribay rivers; Loayza province, La Paz County
Elevation in meters: 2,845 above sea level
Form of the terrain:
a) Physiographic position of the site: bottom of valley /177
b) Form of surrounding land: foot of hill in narrow valley
Slope at profile location: slightly inclined
Vegetation or land use: soils used in the intensive mode of agriculture, the crops are corn, potatoes and vegetables, in addition to temperate or subtropical climate fruit trees, with species of the prunus genus dominating.

B. GENERAL SOIL INFORMATION

Starting material: soils derived from colluvio-alluvial sediments of lutite and sandstone origin.
Drainage: somewhat excessively drained
Humidity of the profile: dry
Depth of phreatic layer: very deep
Presence of rocks on the surface: moderately rocks
Presence of rocky outcrops: none
Evidence of erosion: Natural, laminar, light
Presence of salts or alkali: soils are neutral or without salt influence
Human influence: Development of intensive agriculture, with vegetable crops and fruit trees

C. BRIEF PROFILE DESCRIPTION

Profile of deep soils containing gravel throughout; stones are also present in the 2nd and 4th horizon; has good physical characteristics for root development of plants /178

D. PROFILE DESCRIPTION

Ap 0-30 cm. Anthropic epipedon.
Coffee (7.5 YR 5/2) when humid; open, clayish-sandy texture, with gravel; weak structure of crumbly type; slightly adherent and slightly plastic when wet, very friable when humid, soft when dry; many, medium-sized and large pores; contains an abundance of gravel in angular and rounded shapes; many medium-sized and thick roots; horizon limit neat and flat.

Au 30-65 cm. Shows no diagnostic horizon
Coffee (7.5YR 5/4) when humid; open, coarse sandy texture with abundant gravel and stones; lacks agglomerate structure; non-adherent and non-plastic when wet, loose when humid or dry; gravel and stones

are meteorized and either angular or rounded in shape; good biological activity; few, large roots; horizon limit neat and flat (no sample taken).

Bt 65-75 cm. Coffee (7.5YR 5/4) when humid; open, clayish texture with gravel; weak structure in sub-angular blocks; adherent and plastic when wet, very friable when humid, slightly hard when dry; very little gravel, of angular or rounded shape; few, fine and medium-sized pores; little biological activity; very few large roots; horizon limit neat and flat.

C 75-200 cm. Coffee (7.5YR 5/2) when humid; sandy texture, with gravel and stones; lacks agglomerate structure; non-adherent and non-plastic when wet; gravel, as well as rocks and stones predominate; very few, medium-sized roots (no sample taken). /179

LABORATORY ANALYSIS

PROFILE NO. 26

Depth in cm		0-30	30-65	65-75	75-200		
Texture		FYA	AF	FY	A		
pH		7.0		7.2			
Electric conductivity, mmohs cm		360		340			
Free carbonates		A		A			
Soluble cations in me./100 gr.	Ca^{++}	-		-			
	Mg^{++}	-		-			
	Na^{+}	-		-			
	K^{+}	-		-			
Cation exchange data in me. /100 gr.	Ca^{++}	12.6		9.0			
	Mg^{++}	6.8		7.2			
	Na^{+}	0.48		0.72			
	K^{+}	0.77		0.70			
T. B. I.		20.65		17.62			
C. I. C.		20.85		17.72			
% Base Saturation		99		99			
Phosphorus (Olsen)		1.5		0.5			
Acids me /100 gr.		0.2		0.1			

Texture: Franco = F; Y = Clay; L = Lime and A = Sand

V CONCLUSIONS

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1. The multispectral images obtained from LANDSAT-1, processed in photgraphy format, are excellent material for interpretation of soil studies at survey level. It was possible, by this means, to determine the soil units physiographically grouped within the area covered by the Desaguadero image.

2. This study identified 24 soil units, represented on the appended soil map; their most outstanding characteristics have been described and their modal profiles have been classified according to their SOIL TAXONOMY, as follows

SYMBOL	MAPPING UNIT	TAXONOMIC CLASSIFICATION (Modal Profiles)
V11	Volcanic Cones	Unclassified
V12	Footing of volcanic cones	Psamments
V21	Volcanic lavas	Unclassified
V22	Eroded lavatic meseta	Unclassified
V31	Grouping: Ojansi	Spodic Cryopsamments
V32	Grouping: Cosapa	Spodic Cryopsamments
V33	Grouping: Bofedal	Aquic Cryopsamments
V34	Grouping: Depresión	Spodic Psammaquents
A11	Grouping: Huayllamarca	Lithic Ustochrepts

SYMBOL	MAPPING UNIT	TAXONOMIC CLASSIFICATION (Modal Profiles)
A12	Complex:	
	Topohoco	Lithic Ustipsamments
	Techos	Andic Ustochrepts
	Las Lomas	Aridic Haplustalfs
A13	Complex:	
	Chuquichambi	Tipic Ustipsamments
	Pichuco	Lithic Ustipsamments
	Romero	Aridic Haplustalfs
	Comanche	Aridic Ustochrepts
A21	Grouping: Sulloma	Entic Durothids
A22	Grouping: Erodadas	Typic Ustipsamments
A23	Las Dunas	Unclassified
A24	Complex:	
	La Oveja	Duric Camborthids
	Chijini	Vertic Camborthids
	Tolar A	Ustertic Camborthids
	Tolar B	Fluventic Ustochrepts
	El Rio	Lithic Ustorthents
A25	Grouping:	
	Conchillas	Typic Natrargids
	Hornillos	Vertic Camborthids
A26	Association:	
	Cap. Castrillo	Typic Psammaquents
	C. de Carangas	Aquic Salorthids
	Kolla	Typic Salorthids
	La Cantera	Typic Natrargids
A27	Association:	
	Patacamaya	Typic Cryopsamments

SYMBOL	MAPPING UNIT	TAXONOMIC CLASSIFICATION
A28	Grouping: Corocoro Sud	Lithic Ustorthents
01	Serranias Altas	Unclassified
021	Serranías Colinosas	Unclassified
022	Grouping: Belén	Lithic Ustipsamments
03	Grouping: Toloma	Vertic Ustotthents
04	Grouping: Luribay	Mollic Ustifluvents

VII SUMMARY /184

The soil study submitted in this thesis was performed on the basis of the interpretation of the photographic images derived from the data accumulated by the Multispectral Scanner on board the LANDSAT-1 satellite. It corresponds to the area covered by the image designated Desaguadero, with a surface of 32,395 Km^2. A total of 24 units or large soil groups were identified at survey level, and have been confirmed in the field to a limited extent; the description of these units provides general information on the most outstanding characteristics.

This study basically used two images on a 1:250,000 scale covering the same area: the black and white image of band 7, and the geometrically corrected false color composite image.

The focus during this work concentrated on two aspects:

1. To make known in summary form the detection system of the Multispectral Scanner and the obtention of the different photographic images used for interpretation.

2. A description of the most important materials and instruments used to perform the work, with special emphasis on the photographic products of LANDSAT-1.

3. A presentation of the methodology, or the phases followed during the work, adjusting to the peculiar characteristics of the images and the level at which the soil studies were performed. /185

4. Field work consisted primarily in confirming the units delineated by image interpretation, by means of transect courses and the location of the most representative modal profiles in the sampling areas. Finally, by extrapolating this information to similar areas of the image during the final reinterpretation.

5. The resulting map, on a 1:250,000 scale, shows a physiographic legend, in which soil units are expressed by modal profiles classified according to soil taxonomy.

APPENDIX 1

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BASIC CHARACTERISTICS OF THE MODAL PROFILES THAT MADE IT POSSIBLE TO CLASSIFY ACCORDING TO SOIL TAXONOMY

V31. Ojsani Grouping ("Consociation"): Spodic Cryopsamments
V32. Cosapa Grouping ("Consociation"): Spodic Cryopsamments

The two modal profiles of these two groupings have the same taxonomic classification and differ only in the physiographic location of each unit or soil aggregate.

At each level of classification, the outstanding characteristics are:

ORDER ENTISOL	- Recently deposited soils lacking horizon development - Light textures whose color resembles that of the parental material - They show no diagnostic horizons
SUBORDER PSAMMENTS	- Horizons formed of loose sand with gravel - Well drained soils
GRAET GROUP CRYOPSAMMENTS	- Soil temperature of cryogenic regime (most of the year the temperature remains between 0°C and 8°C)

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SUBGROUP SPODIC CRYOPSAMMENTS	- Upper horizon clear or albic when dry, with tendency towards Espodosols (integrated towards Espodosols)

V33. Bofedal Grouping ("Consociation"): Aquic Cryopsamments

ORDER	- Recently deposited soils
ENTISOL	- Deep profile, with light textures and lacking structure
SUBORDER PSAMMENTS	- Textures formed of very uniform coarse sand throughout the depth of the profile
GREAT GROUP CRYOPSAMMENTS	- Soil temperatures of cryogenic regime
SUBGROUP AQUIC CRYOPSAMMENTS	- Soils either nearly flooded or very humid - second horizon strongly gleyzed

V34. Depresión Grouping ("Consociation"): Spodic Psammaquents

ORDER	- Little developed soils
ENTISOL	- Upper horizons formed of light textures
SUBORDER AQUENTS	- The phreatic layer is superficial - Presence of spots in the upper horizon - Soils almost saturated with water throughout their depth. /188
GREAT GROUP PSAMMENTS	- Textures formed of fine sand and open, fine sand, lacking structure in the first two horizons
SUBGROUP SPODIC PSAMMAQUENTS	- Albic upper horizon - Tendency in the soils to develop towards Espodosols (dark color for the lower horizons, black for the fourth horizon)

A11. Huallamarca Grouping ("Consociation"): Lithic Ustochrepts

ORDER INCEPTISOL	- Soils either little or incipiently developed (Inceptum = incipient) - Horizon colors very similar to that of parental material
SUBORDER OCHREPTS	- Presence of an ochric epipedon - A little developed Bt horizon
GREAT GROUP USTOCHREPTS	- Edaphic humidity limiting vegetation development (humidity deficiency for 60 contimuous days or more than 90 cumulative days)
SUBGROUP LITHIC USTOCHREPTS	- The lithic contact appears at 60 cm of depth. (Parental material strongly weathered forming the C horizon, but showing familiar features of the mother rock) /189

A12. Complex: Topohoco: Lithic Ustipsamments
Techos: Andic Ustochrepts
Las Lomas: Aridic Haplustalfs

TOPOHOCO AGGREGATE: LITHIC USTIPSAMMENTS

ORDER ENTISOL	- Soils result from subrecent depositions - Horizons or soil layers formed of light material (no appreciable horizon development)
SUBORDER PSAMMENTS	- Upper horizon formed of sand with gravel and stones - Shows a little developed ochric epipedon

GREAT GROUP USTIPSAMMENTS	- Edaphic humidity limits vegetation development (corresponds to a ustic humidity regime)
SUBGROUP LITHIC USTIPSAMMENTS	- Presence of lithic material formed of gravel, rocks and stones

TECHOS AGGREGATE: ANDIC USTOCHREPTS

ORDER INCEPTISOL	- Little developed soils - Shows strong resemblance to parental material
SUBORDER OCHREPTS	- Presence of a little developed ochric epipedon over a Bt cambic horizon - Shows no argillic horizon
GREAT GROUP USTOCHREPTS	- Edaphic humidity limits vegetation development; corresponds to ustic regime /190
SUBGROUP ANDIC USTOCHREPTS	- Influence of pyrochlastic materials with presence of tobaceous features, currently very eroded - Some of the characteristics of the Andepts are observed

LAS LOMAS AGGREGATE: ARIDIC HAPLUSTALFS

ORDER ALFISOL	- Concentration of alluvial clay in the Bt horizon - Presence of an ochric epipedon over a cambic one

SUBORDER USTALFS	- Soils with a deficit of edaphic humidity, corresponding to a ustic humidity regime, with a tendency towards an aridic regime. - High saturation in bases throughout the horizon's profile
GREAT GROUP HAPLUSTALFS	- The absence of plintite, duripan or petrocalcic horizons makes this classification possible, since no other identifying characteristics are available
SUBGROUP ARIDIC HAPLUSTALFS	- The soils correspond to a ustic humidity regime, but show aridic characteristics in regions of arid climate; this made it possible to intergrade the Aridisols /191

COMPLEX: Chuquichambi: Typic Ustipsamments
Pichuco: Lithic Ustipsamments
Romero: Aridic Haplustalfs
Comanche: Aridic Ustochrepts

CHUQUICHAMBI AGGREGATE: Typic Ustipsamments
PICHUCO AGGREGATE: Lithic Ustipsamments

These two aggregates of the soil complex have similar typical profiles, and for this reason they have the same taxonomic classification up to the great group level; they differ only at the subgroup level.

ORDER ENTISOL	- Recent soils in which there is no horizon development There are no diagnostic horizons

SUBORDER PSAMMENTS	- Horizons formed of sandy textures with different percentages of gravel content
GREAT GROUP USTIPSAMMENTS	- Has a ustic humidity regime, a limiting factor in the development of vegetation /192
SUBGROUP TYPIC USTIPSAMMENTS	- Has the typical characteristics of the Ustipsamments; the qualities of other suborders are not observed

PICHUCO AGGREGATE:

SUBGROUP LITHIC USTIPSAMMENTS	- There is a lithic contact at a depth of 25 cm, formed of gravel and stones

ROMERO AGGREGATE: ARIDIC HAPLUSTALFS

The typical profile of this aggregate has the same taxonomic classification as the "Las Lomas" aggregate, since it has characteristics similar to those already described for that aggregate.

COMANCHE AGGREGATE: ARIDIC USTOCHREPTS

ORDER INCEPTISOL	- Incipiently developed soils - Horizon color similar to that of parental material
SUBORDER OCHREPTS	- Has an ochric epipedon - A little developed cambic horizon (Bt) was observed
GREAT GROUP USTOCHREPTS	- Soils with a deficit of edaphic humidity, corresponding to the ustic regime - High saturation in bases /193

SUBGROUP ARIDIC USTOCHREPTS	- Soils correspond to a ustic humidity regime, but because they present climatic conditions of arid regions, they were integrated into the Aridisols, showing some of their characteristics

A21. SULLOMA GROUPING ("CONSOCIATION"): ENTIC DUROTHIDS

ORDER	- Soils located in arid climate regions
ARIDISOL	- Shows a calcic subhorizon
	- The potential evapotranspiration is greater than the rainfall
SUBORDER	- They show no argillic or natric horizons
ORTHIDS	- Formation of an ochric epipedon
GREAT GROUP DURORTHIDS	- It has a strongly hardened second horizon, possibly because of the carbonate content and the influence of volcanic sinter, currently very eroded
SUBGROUP ENTIC DURORTHIDS	- The sand content in the lower horizons has made it possible to intergrade the order of Entisols

A22. ERODADAS GROUPING ("CONSOCIATION"): TYPIC USTIPSAMMENTS

ORDER	- Soils of recent formation /194
ENTISOL	- Presence of a little developed ochric epipedon
	- Very light upper horizons resulting from sequential depositions
SUBORDER PSAMMENTS	- Light textures formed of open, coarse sand to fine sand down to 75 cm depth

GREAT GROUP USTIPSAMMENTS - Soils are within a ustic humidity regime, remaining dry for 60 consecutive days or for over 90 cumulative days in most years

SUBGROUP TYPIC USTIPSAMMENTS - Presents the typical characteristics of the ustipsamments, and no other qualities that would allow identification in other subgroups

A24. COMPLEX: LA OVEJA: DURIC CAMBORTHIDS
CHIJINI: VERTIC CAMBORTHIDS
TOLAR A: USTERTIC CAMBORTHIDS
TOLAR B: FLUVENTIC USTORCHREPTS
EL RIO: LITHIC USTORTHENTS

The first three aggregates of this complex are similar up to the great group level; they differ only at the subgroup level. They are described together, below

ORDER - Soils in arid regions /195
ARIDISOL - Potential evapotranspiration is greater than the rainfall
- Low content in organic matter

SUBORDER ORTHIDS - There is no argillic horizon

GREAT GROUP CAMBORTHIDS - There is an ochric epipedon over a cambic horizon

SUBGROUP DURIC CAMBORTHIDS - Hardened Bs3 horizon at 50-66 cm depth

CHIJINI AGGREGATE:

SUBGROUP VERTIC CAMBORTHIDS	- Second horizon clayish, with fissures present; has been intergraded in vertisols

TOLAR A AGGREGATE:

SUBGROUP USTERTIC CAMBORTHIDS	- Signs of humidity deficiencies, due to the ustic regime associated to very weak vertic characteristics; this constitutes and intergrade of them. /196

TOLAR B AGGREGATE: FLUVENTIC USTOCHREPTS

ORDER INCEPTISOL	- Soils little or incipiently developed - Horizons retain the color of the parental material
SUBORDER OCHREPTS	- Has an ochric epipedon - The cambic subhorizon is little developed
GREAT GROUP USTOCHREPTS	- Soils show a deficit of humidity for vegetation development, corresponding to the ustic regime. - High saturation in bases
SUBGROUP FLUVENTIC USTOCHREPTS	- Soils are of alluvial formation, with the content in organic matter decreasing irregularly with depth. Because of this characteristic they have been intergraded into the Fluvents

EL RIO AGGREGATE: LITHIC USTORTHENTS

ORDER ENTISOL	- Soils of subrecent formation with very little horizon development - Soils formed of light sediments, with the third horizon formed of gravel and stones
SUBORDER ORTHENTS	- There is an ochric epipedon over a cambic one
GREAT GROUP USTORTHENTS	- Soils are within a ustic humidity regime, remaining dry for 60 consecutive days, or for over 90 cumulative days in most years /197
SUBGROUP LITHIC USTORTHENTS	- There is a lithic contact at a depth of 55 cm, formed of gravel and stone

A25. CONCHILLAS GROUPING ("CONSOCIATION"): TYPIC NATRARGIDS
HORNILLOS : VERTIC CAMBORTHIDS

CONCHILLAS AGGREGATE: TYPIC NATRARGIDS

ORDER ARIDISOL	- Soils of arid regions under the influence of the arid climate - Potential evapotranspiration is greater than the rainfall - Low organic matter content
SUBORDER ARGIDS	- There is a natric subhorizon with argillic characteristics
GREAT GROUP NATRARGIDS	- A natric horizon was observed below an ochric epipedon

SUBGROUP TYPIC NATRARGIDS	- Shows the typical characteristics of the natrargids and there are no other observable qualities that would allow identification in other subgroups /198

HORNILLOS AGGREGATE: VERTIC CAMBORTHIDS

ORDER ARIDISOL	- Soils of arid regions - Potential evapotranspiration greater than the rainfall - Low organic matter content
SUBORDER ORTHIDS	- There is no argillic horizon
GREAT GROUP CAMBORTHIDS	- Has a little developed cambic horizon
SUBGROUP VERTIC CAMBORTHIDS	- At a depth of 54 cm there is an argillic horizon of vertic characteristics, which made it possible to intergrade the vertisols

A26. ASSOCIATION: CAP. CASTRILLO: TYPIC PSAMMAQUENTS
C. DE CARANGAS: AQUIC SALORTHIDS
KOLLA: TYPIC SALORTHIDS
LA CANTERA: TYPIC NATRARGIDS

CAP. CASTRILLO AGGREGATE: TYPIC PSAMMAQUENTS

ORDER ENTISOL	- Soils of recent formation, by the Desaguadero rive - There are no diagnostic horizons

SUBORDER AQUENTS	- Very humid soils, with the phreatic layer at little depths; this phreatic layer rises almost to the surface with the rise of the Desaguadero river /199
GREAT GROUP PSAMMAQUENTS	- Corresponds to soils formed of loose sand horizons
SUBGROUP TYPIC PSAMMAQUENTS	- Shows the typical characteristics of the Psammaquents and there are no other observable qualities to allow differentiation into other subgroups

C. DE CARANGAS AGGREGATE: AQUIC SALORTHIDS

KOLLA AGGREGATE: TYPIC SALORTHIDS

These two soil aggregates show similar classification characteristics down to the great group level; they differ only at the subgroup level.

ORDER ARIDISOL	- Soils or arid regions - Potential evapotranspiration is greater than the rainfall
SUBORDER ORTHIDS	- There is no argillic horizon
GREAT GROUP SALORTHIDS	- There is a salic horizon below the ochric epipedon
SUBGROUP AQUIC SALORTHIDS	- Very humid soils - The phreatic layer is at little depth; some features were observed that indicate the fluctuation of this phreatic layer

KOLLA AGGREGATE: TYPIC SALORTHIDS /200

SUBGROUP TYPIC SALORTHIDS	- Shows the typical characteristics of the Salorthids and there are no other observable qualities that would permit differentiation into other subgroups

LA CANTERA AGGREGATE: TYPIC NATRARGIDS

The typical profile of this aggregate shows characteristics similar to those described for the "Conchillas" aggregate and hence, the same taxonomic classification already described for that aggregate

A27. PATACAMAYA GROUPING ("CONSOCIATION"): TYPIC CRYOPSAMMENTS

ORDER ENTISOL	- Soils of recent formation - There are no diagnostic horizons
SUBORDER PSAMMENTS	- Horizons formed of open, sandy textures, down to 50 cm of depth - There is no appreciable development in its horizons
GREAT GROUP CRYOPSAMMENTS	- The soils remain at the low temperatures of a cryogenic regime, in which soil temperatures vary between 0°C and 8°C /201

SUBGROUP TYPIC CRYOPSAMMENTS	- Shows the typical Cryopsamments characteristics and there are no other qualities that would make identification with other subgroups possible.

A28. COROCORO SUD GROUPING ("CONSOCIATION"): LITHIC USTORTHENTS

ORDER ENTISOL	- Recent soil forming terraces - Shows light textures down to 40 cm; at greater depth clay with abundant gravel and stones is found.
SUBORDER ORTHENTS	- The organic matter content decreases gradually with depth - There is an ochric epipedon
GREAT GROUP USTORTHENTS	- These soils remain dry for 60 consecutive days or over 90 cumulative days in most years (ustic humidity regime)

SUBGROUP LITHIC USTORTHENTS	- The gravel content and the presence of stones in the second horizon have been the characteristics to consider, as a lithic soil /202

O22. BELEN GROUPING ("CONSOCIATION"): LITHIC USTIPSAMMENTS

Shows characteristics similar to those of the already described Topohoco and Pichuco aggregates, and therefore have the same taxonomic classification; they differ only in their physiographic location

O3. TOLOMA GROUPING ("CONSOCIATION"): VERTIC USTORTHENTS

ORDER ENTISOL	- Recent soils formed of light material to a depth of 60 cm
SUBORDER ORTHENTS	- The organic matter content decreases gradually with depth - There are no diagnostic horizons
GREAT GROUP USTORTHENTS	- These are soils that remain dry for 90 cumulative days or over 60 consecutive days in most years (ustic humidity regime)
SUBGROUP VERTIC USTORTHENTS	- The third horizon (60-150 cm) is formed of an illuvial clayish horizon, with strong structure and showing cutanes of argillic nature; this characteristics has allowed intergrading into the vertisols

O4. LURIBAY GROUPING ("CONSOCIATION"): MOLLIC USTIFLUVENTS /203

ORDER ENTISOL	- Recent soils with disturbed horizons - Shows onthropic epipedon, with characteristics tending to a mollic one

SUBORDER FLUVENTS	- Stratified alluvial soils with irregular organic matter content - There is no lithic contact
GREAT GROUP USTIFLUVENTS	- These are Fluvents within a ustic humidity regime; in the latter, soils remain dry under natural conditions for 90 cumulative days or over 60 consecutive days in most years
SUBGROUP MOLLIC USTIFLUVENTS	- The anthropic epipedon shows characteristics tending to mollic; therefore it has been intergraded into molisols

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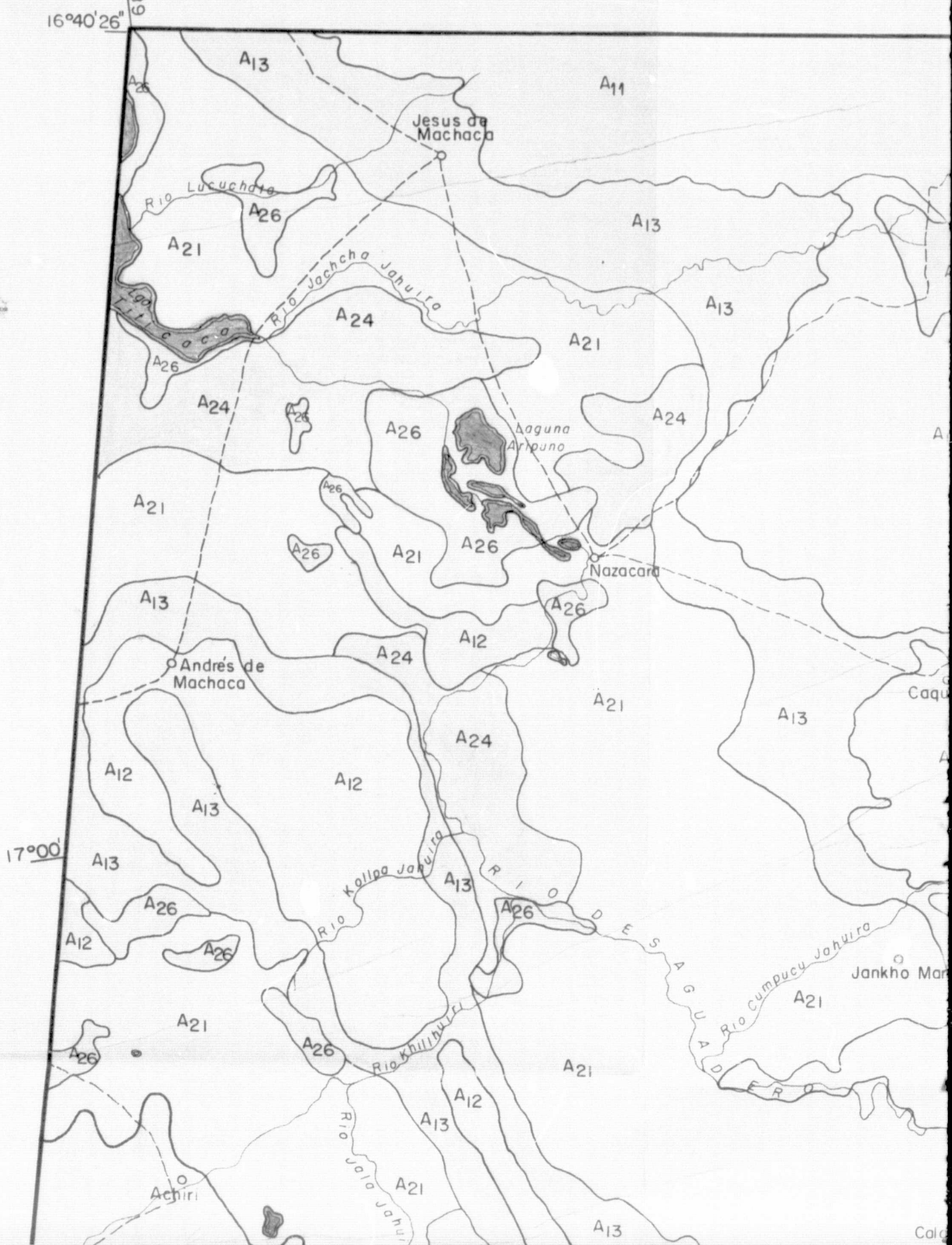
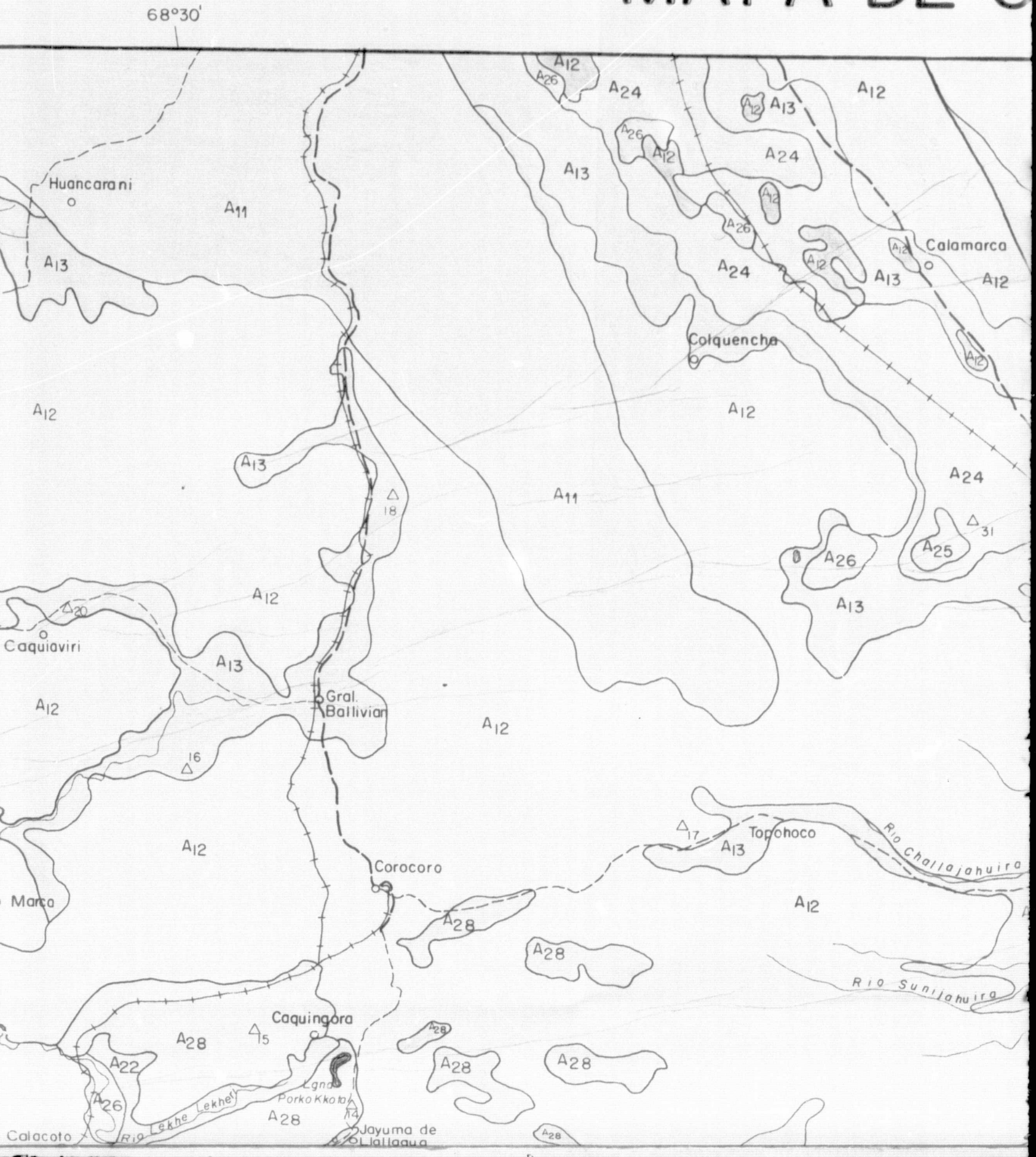
FOLDOUT FRAME

DESAGUADERO

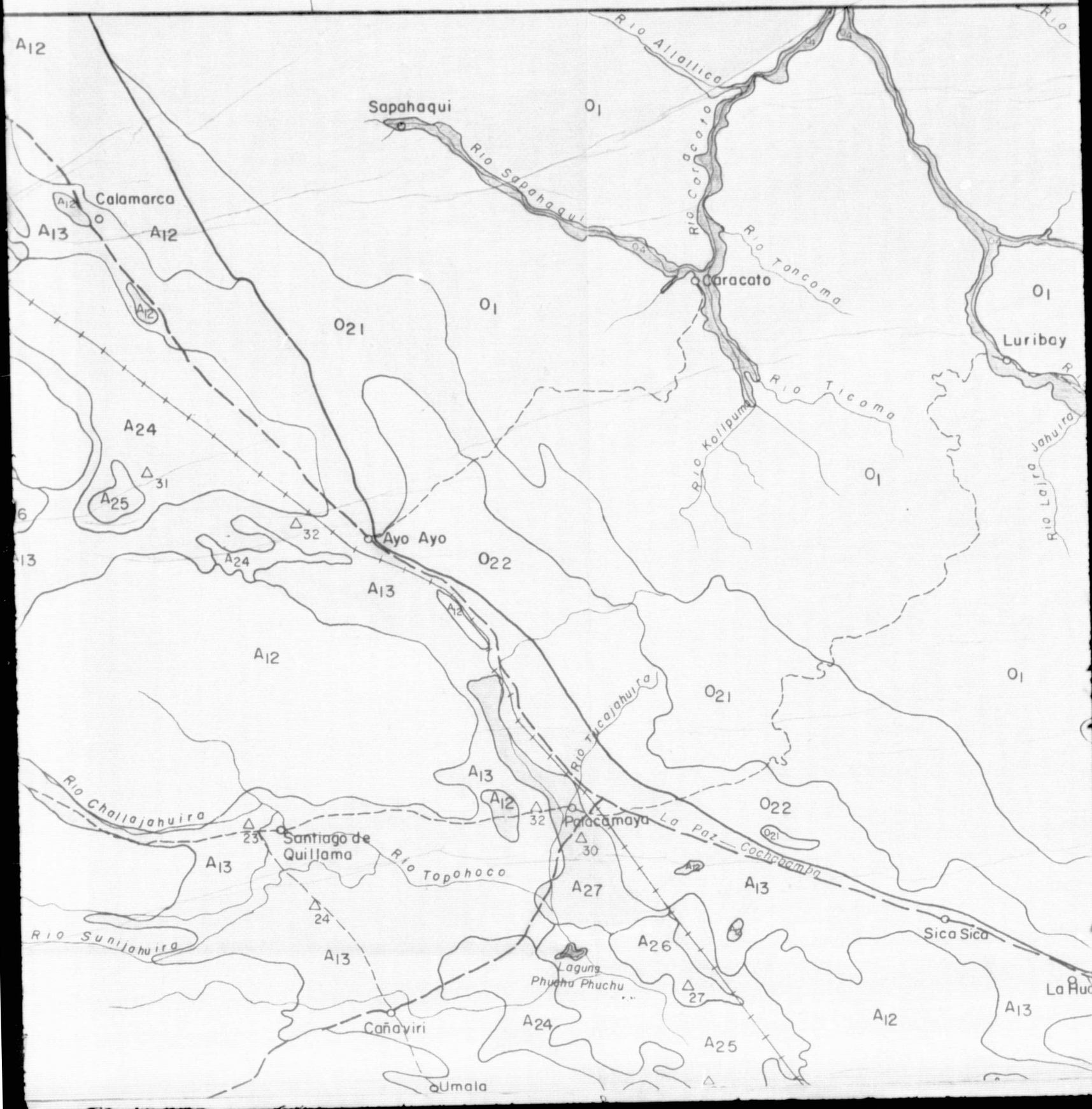


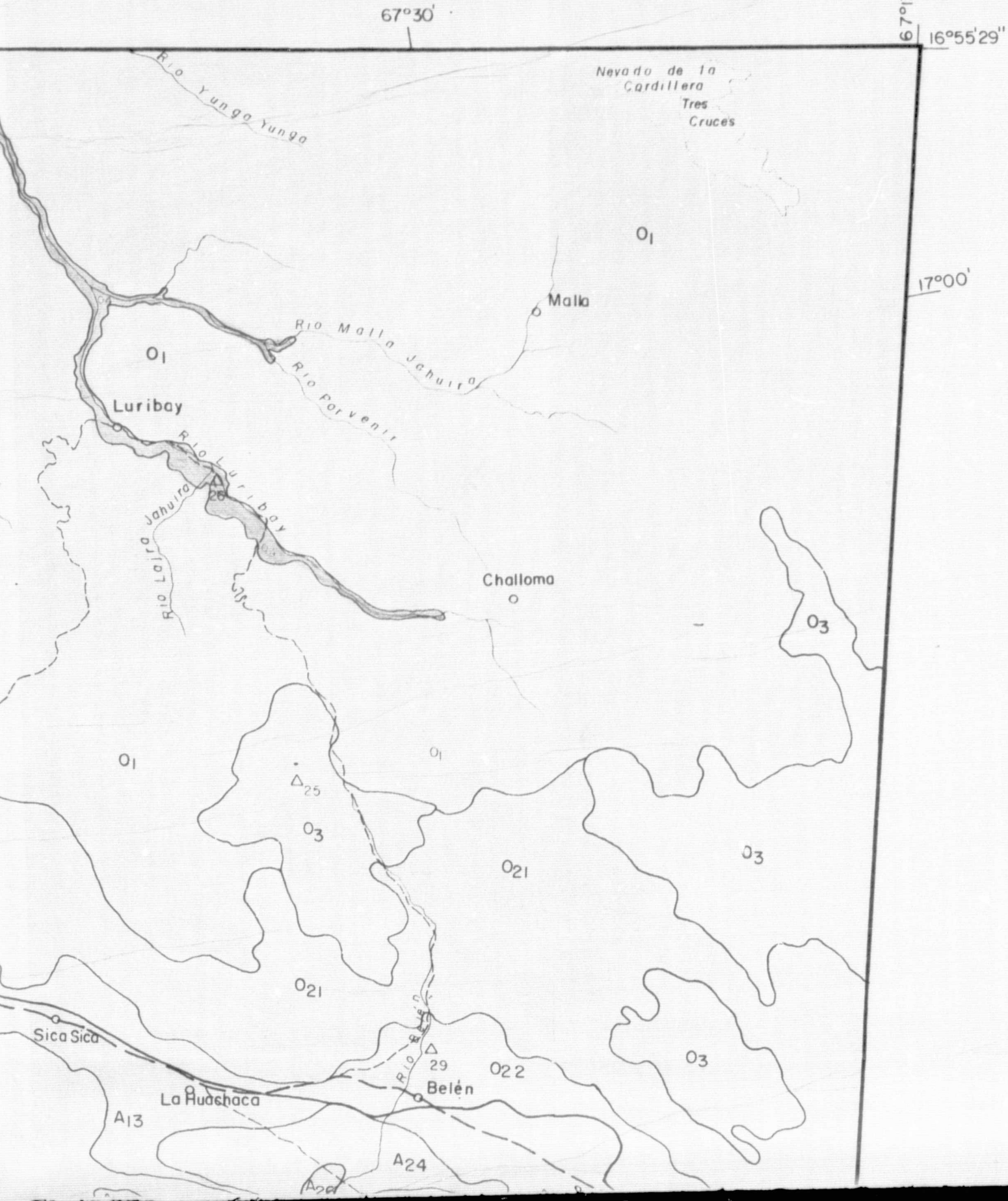
MAPA DE S



FOLDOUT FRAME 3

DE SUELOS





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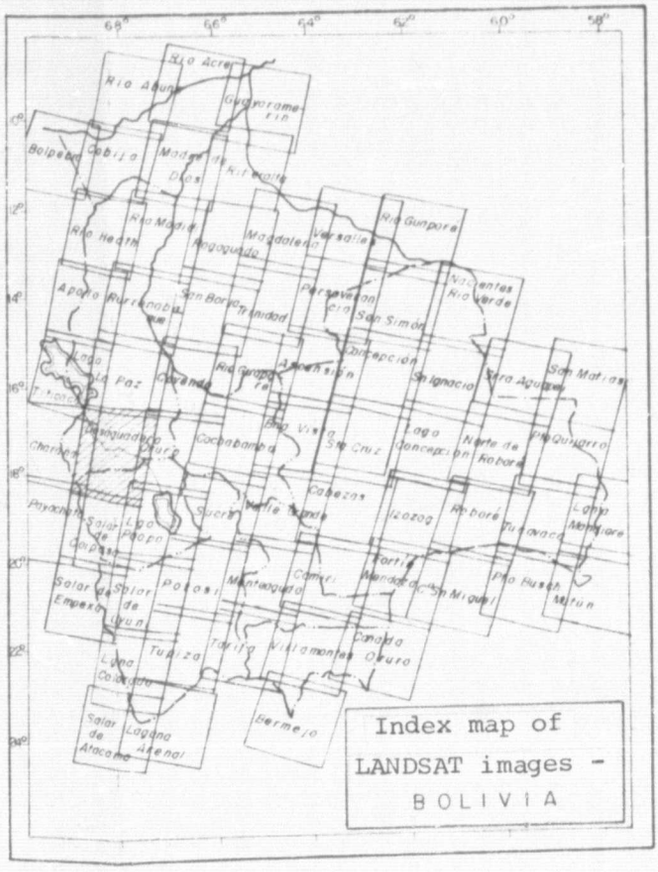
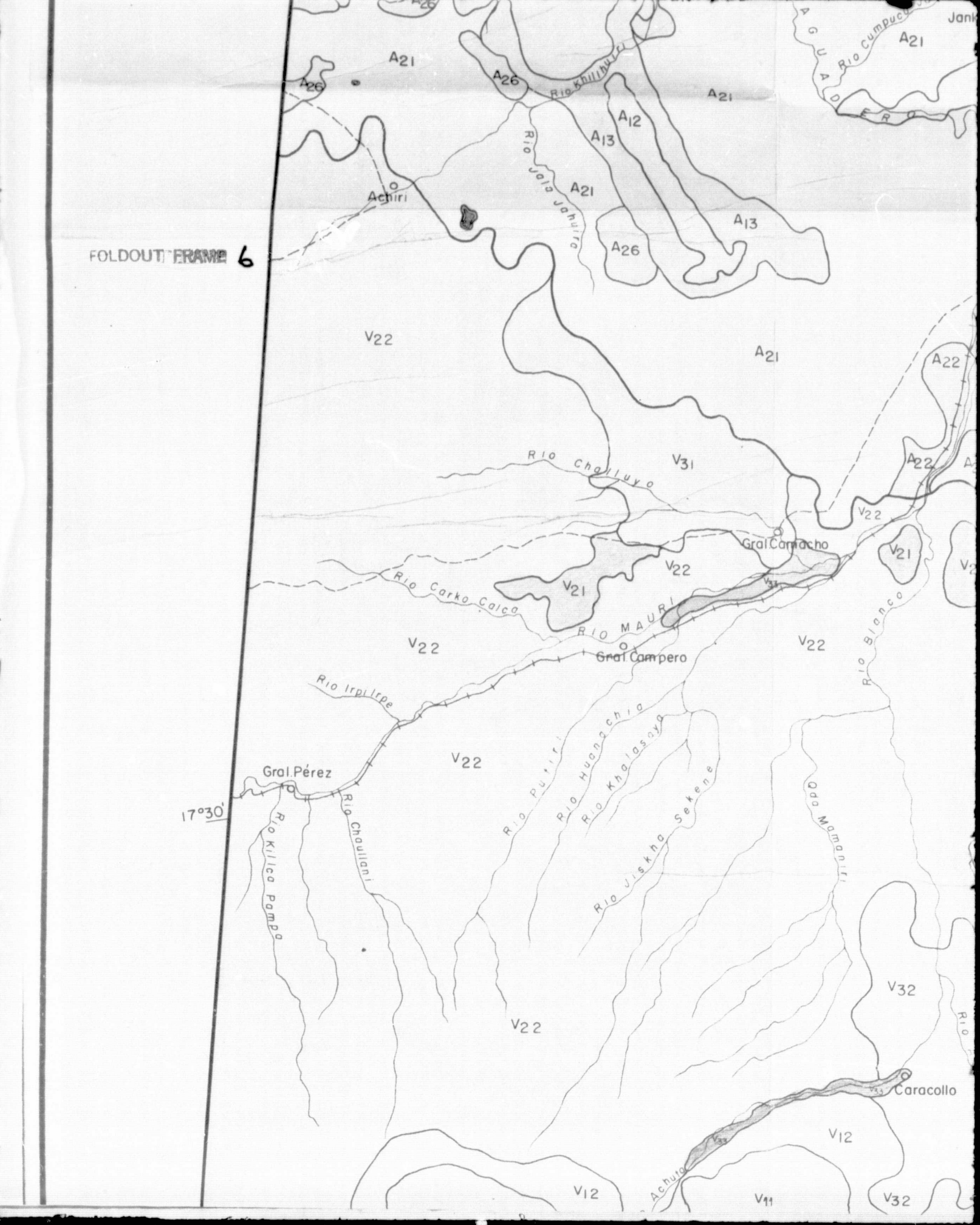
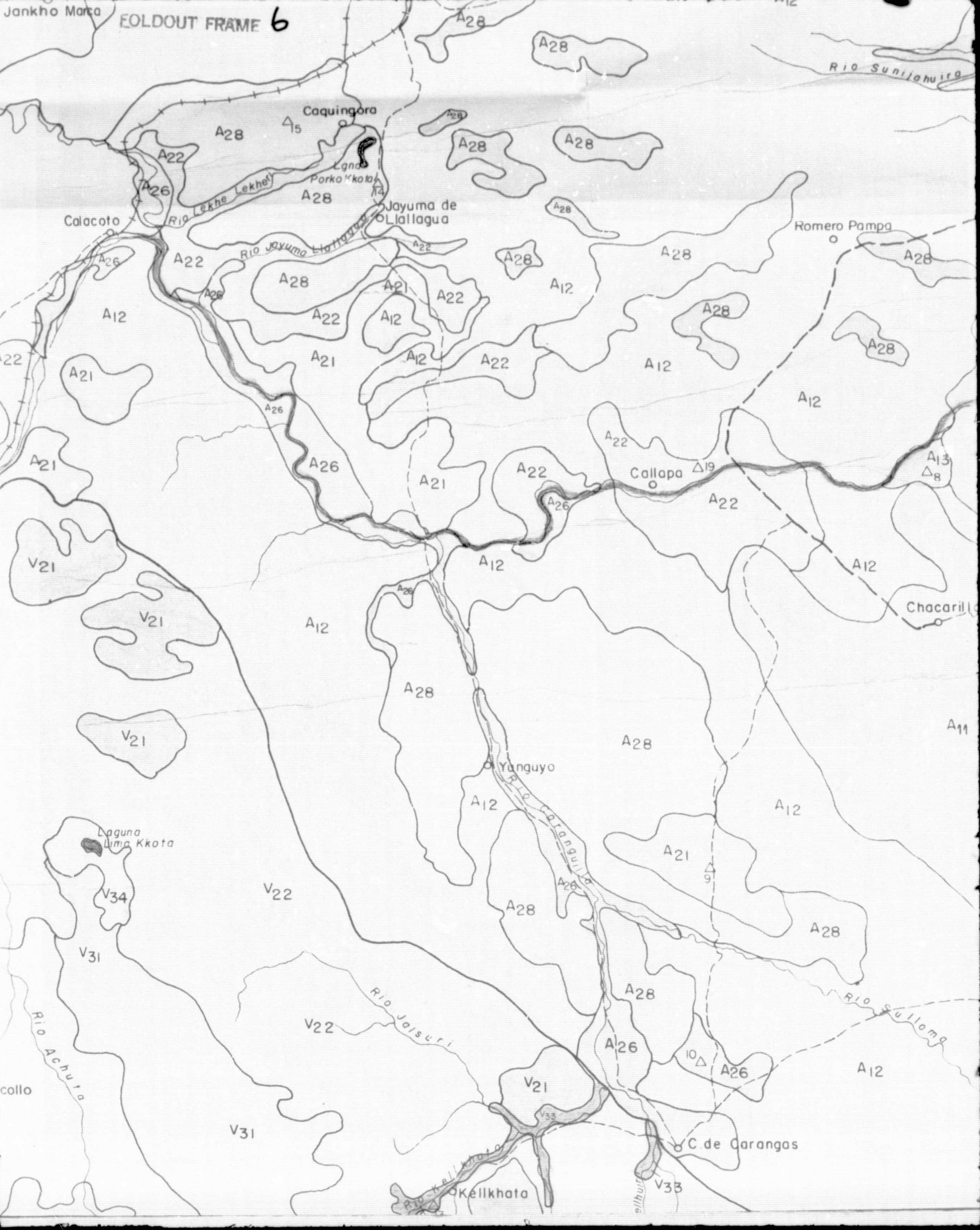
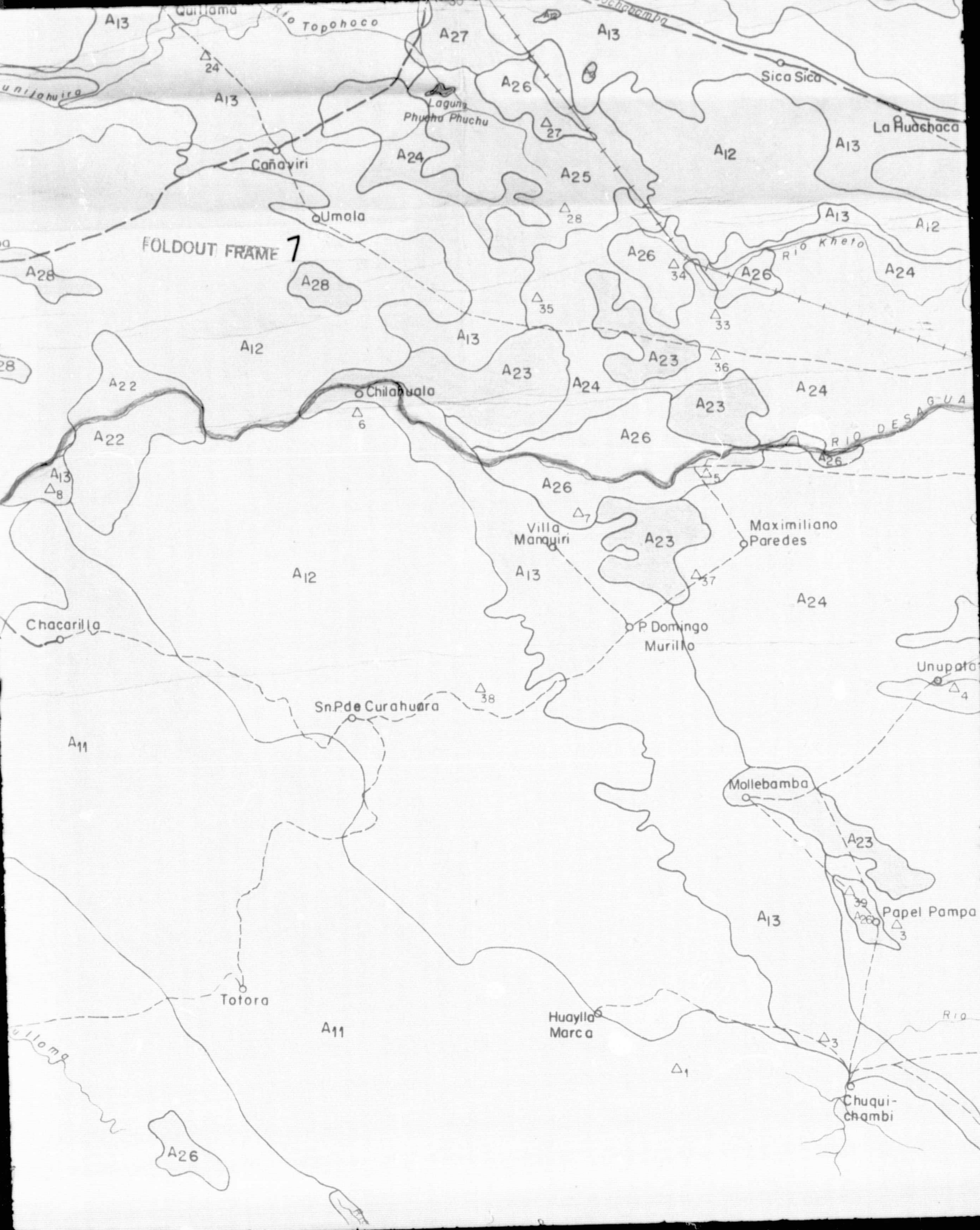


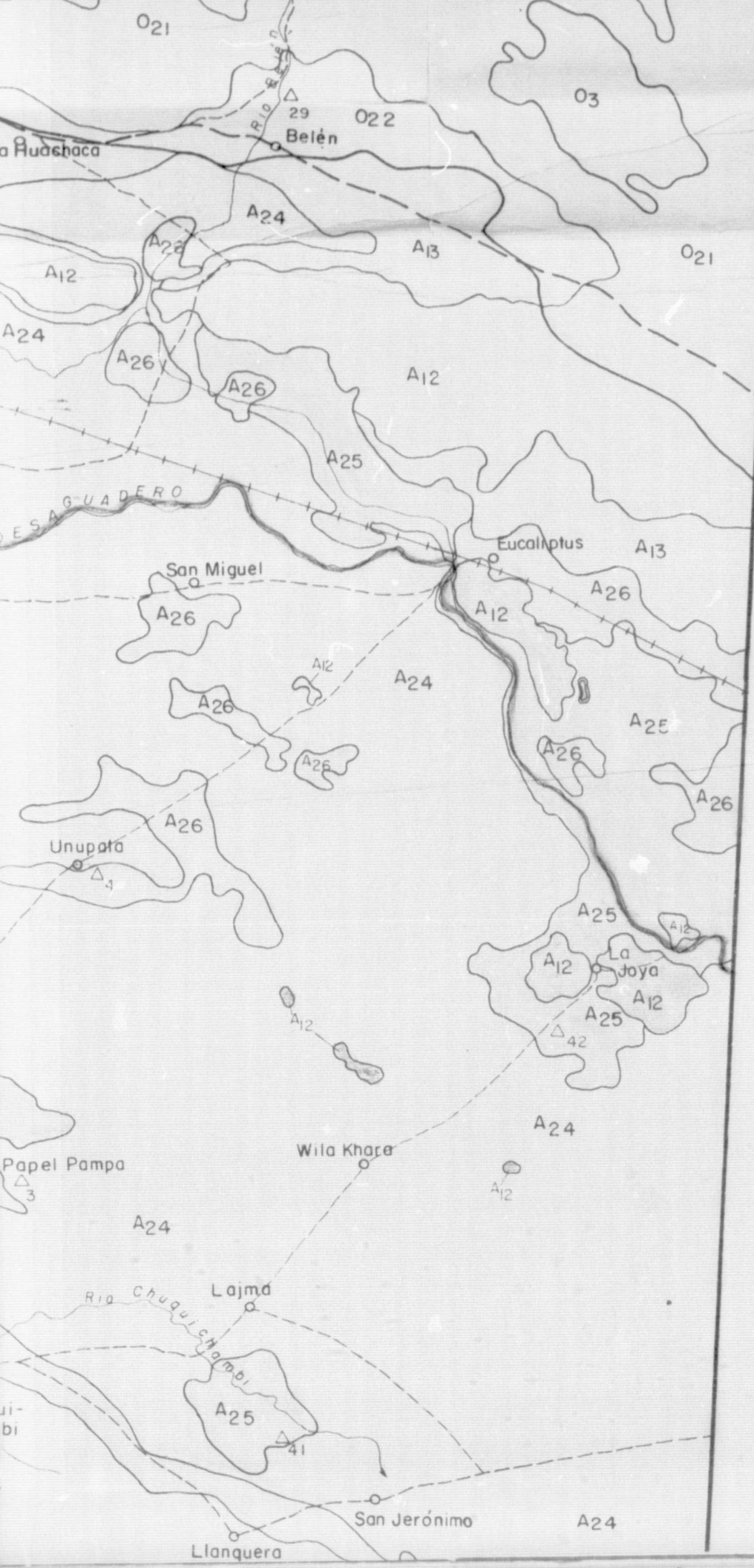
CONVENTIONAL SYMBOLS

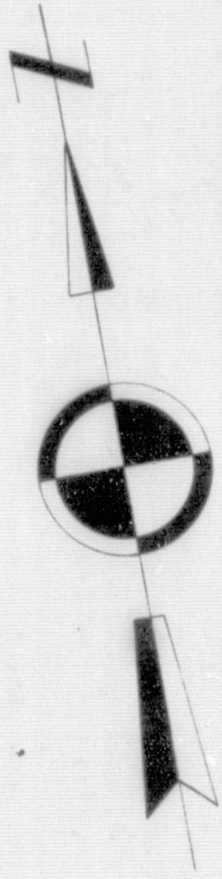
Important towns	○
Highway	————
Secondary road	— — — —
Railroad	+++++++++
Rivers	
Lakes	


FOLDOUT FRAME 6
A21
A26
A12
A13
A22
V22
V31
V21
V32
V12
V11
Río Khillhuiri
Río Jala Jahuira
Río Cumpucuni
Río Challuyo
Río Carko Calca
RIO MAURI
Río Irpi Irpe
Río Puiri
Río Huanachia
Río Khaglasaya
Río Jiskha Sekene
Río Killca Pampa
Río Chaullani
Qda Mamaniri
Río Blanco
Achiri
Gral Camacho
Gral Campero
Gral Pérez
Caracollo
Achura
17°30'


FOLDOUT FRAME 6
Jankho Marca
Caquingora
Laguna Porko Kkota
Jayuma de Llallagua
Río Jayuma Llallagua
Río Lekhe Lekhe
Calacoto
Romero Pampa
Río Sunilahuira
Callapa
Chacarilla
Yanguyo
Río Carangua
Laguna Lima Kkota
Río Jaisuri
Río Achura
Río Suillome
C. de Carangas
Kellkhata
Río Kellkhata
A28
A22
A26
A12
A21
A13
A11
V21
V22
V31
V34
V33


FOLDOUT FRAME 7
Quillama
Río Topohoco
Sica Sica
La Huachaca
Laguna Phuchu Phuchu
Cañaviri
Umala
Río Khoto
Chilahuala
Río Desaguadero
Villa Manquiri
Maximiliano Paredes
Chacarilla
P. Domingo Murillo
Unupata
Sn.Pde Curahuara
Mollebamba
Papel Pampa
Totora
Huaylla Marca
Chuquichambi
A11
A12
A13
A22
A23
A24
A25
A26
A27
A28





GREAT LANDSCAPE	LANDSCAPE	PH
WESTERN OR VOLCANIC RANGE V	VOLCANOES V1	Foot
	VOLCANIC LAVA MESETA V2	S
	PLAINS V3	Well
		Salt

Secondary road

Railroad

Rivers

Lakes

Permanent snow

International boundaries (approximate)

Profile location

Soil lines

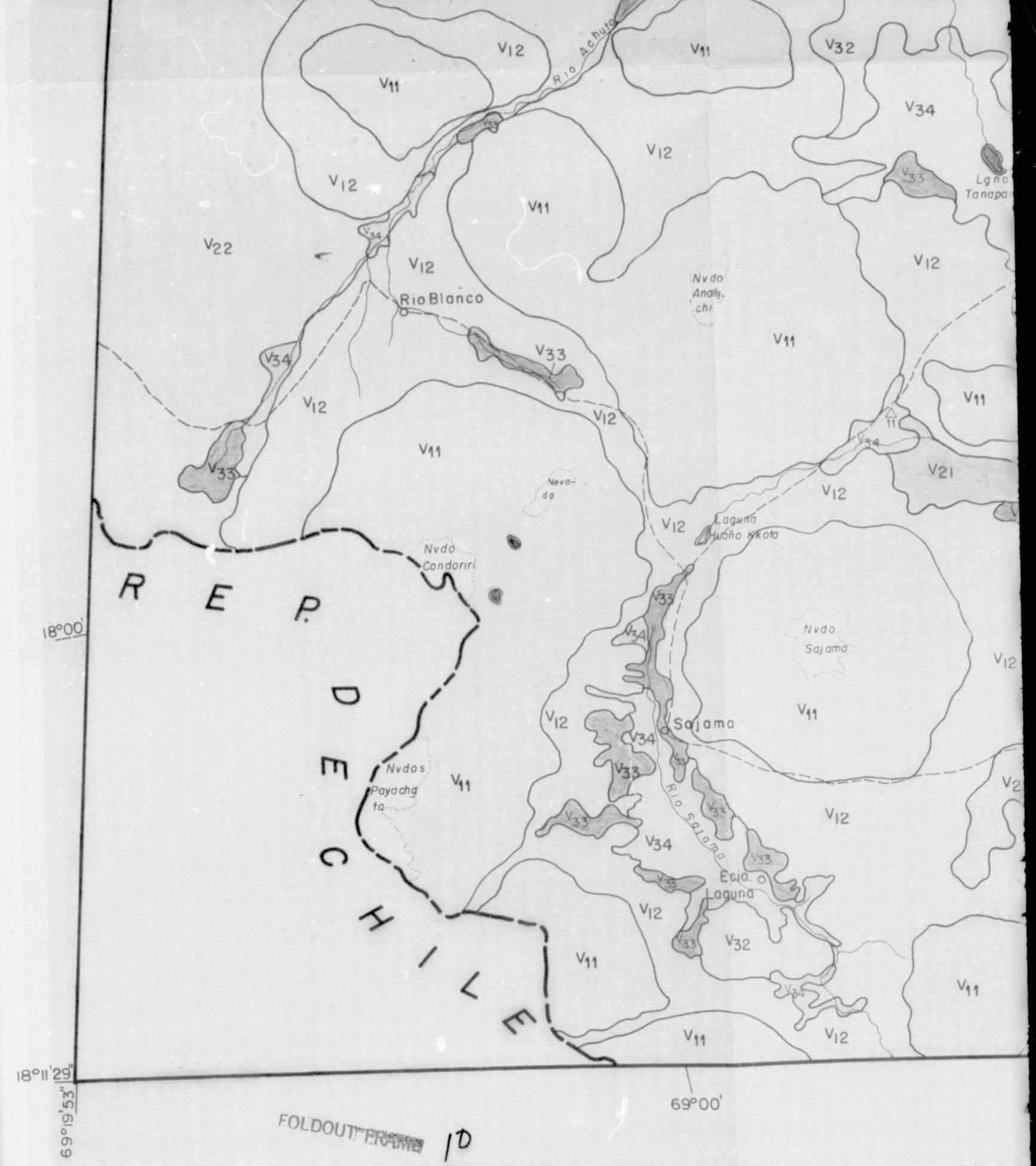
FOLDOUT FRAME 9

LANDSAT DESAGUADERO IMAGE

Soil Study at Survey Level	
Soil Map Based on the interpretation of LANDSAT Image 1010-14033 of August 2, 1972	Approximate Scale: 1:250,000 Prepared by: Moisés Ureña Espinoza La Paz, December 1976

LEYENDA FISIOGRAFICA DE SUELOS

OSCAPE	PHYSIOGRAPHIC UNIT	MAPPING UNIT	TAXONOMIC CLASSIFICATION (Modal Profiles)	SURFACE, Has	SYMBOL ON THE MAP
ANOES V 1	Volcanic Cones V11	Volcanic Cones		128.358	V_{11}
	Foot of volcanic cones V12	Foot of volcanic cones	Psamments	137.156	V_{12}
ANIC MESETA V2	Little dissected V21	Volcanic lavas		47.782	V_{21}
	Strongly dissected V22	Eroded Lavatic Meseta		402.524	V_{22}
AINS V3	Undulated V31	Grouping Ojsani	Spodic Cryopsamments	53.710	V_{31}
	Well drained flat plain V32	Grouping Cosapa	Spodic Cryopsamments	47.510	V_{32}
	Hydromorphic soils V33	Grouping Bofedal	Aquic Cryopsamments	12.866	V_{33}
	Salt mines and salt pans	Grouping			



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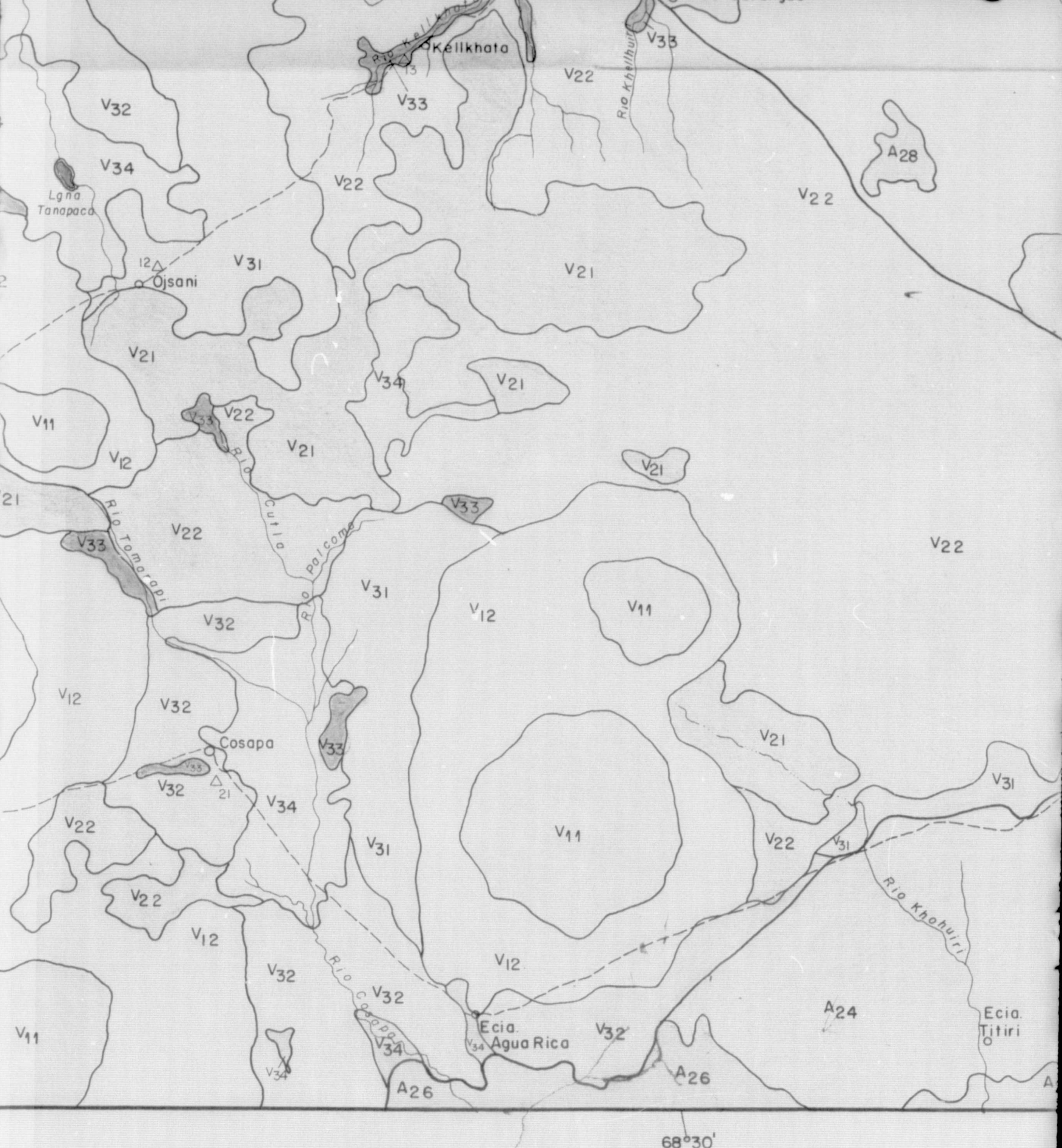

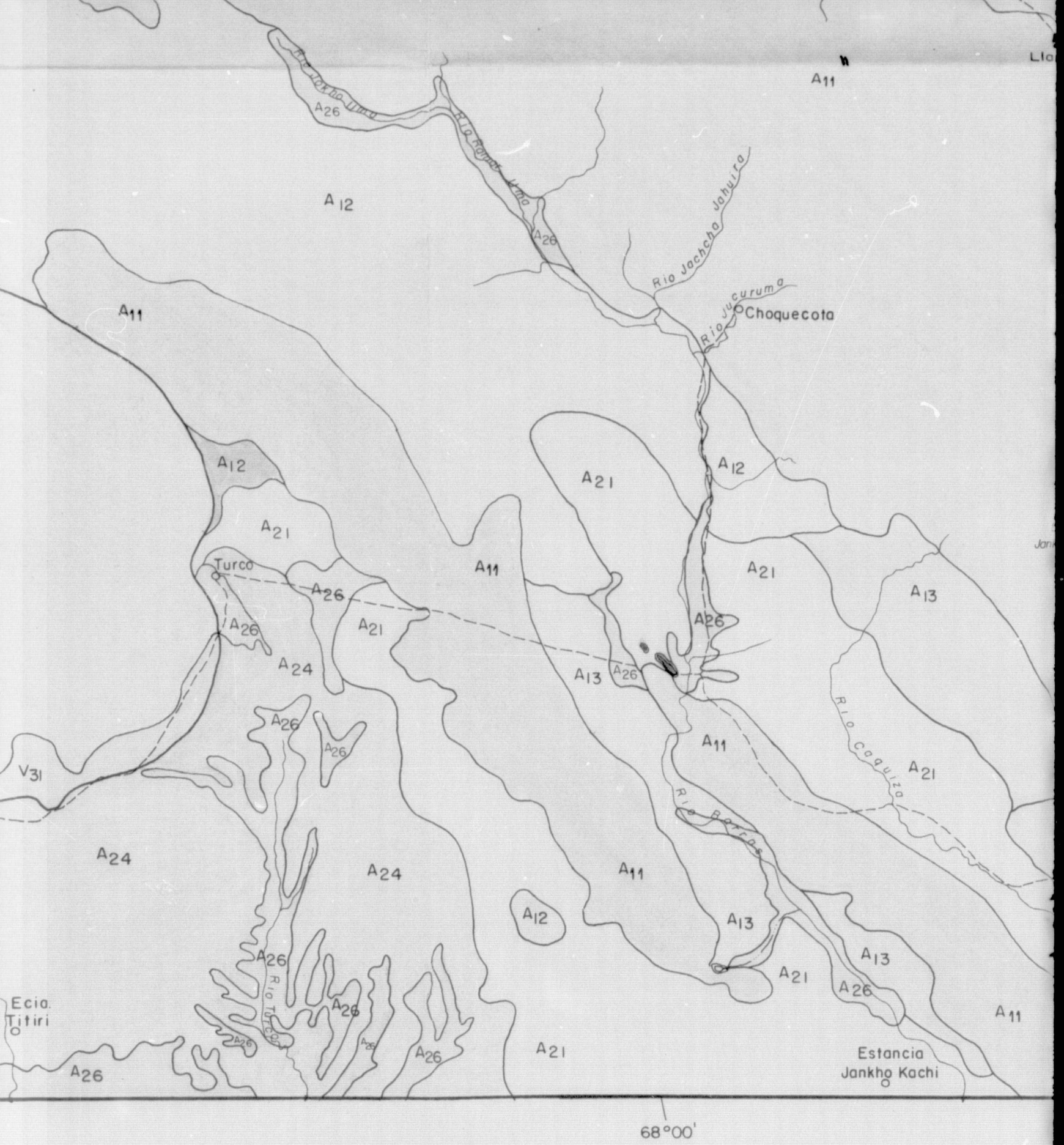

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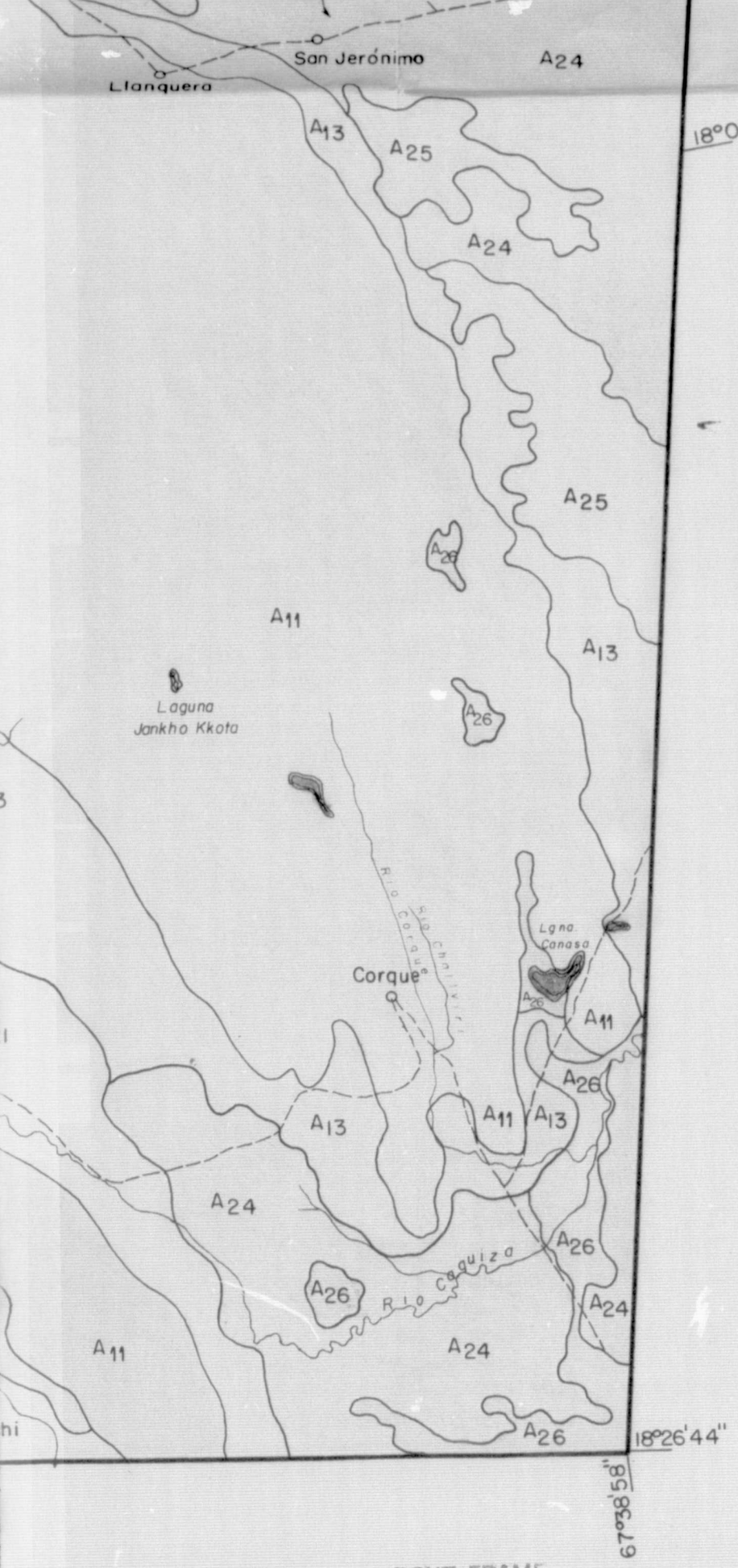

	V3	Hydromo
		Salt mines
		Hill
HIGH PLATEAU A	HILL COUNTRY A1	Low hil
		Foot
		On
HIGH PLATEAU A	PLAINS A2	Ba
		D
		Fla
		Tempora
		Sal and
		Re
		Te
CORDILLERA ORIENTAL O	High hill country 01	
	LOW HILL COUNTRY 02	Low hi
		Foot of
	Undulated ter 03	
	Narrow valley 04	

FOLDOUT FRAME

13

		Spodic Cryopsamments	47.510	
Hydromorphic soils V33	Grouping Bofedal	Aquic Cryopsamments	12.866	V_{33}
Salt mines and salt pans V34	Grouping	Spodic Psammaquents	35.358	V_{34}
Hill country A11	Grouping	Lithic Ustochrepts	365.466	A_{11}
Low hill country A12	Complex Toponoco Techos Las Lomas	Lithic Ustipsamments Andic Ustochrepts Aridic Haplustalfs	595.536	A_{12}
Foot of hills A13	Complex Chuquichamba Pichuco Romero Comanche	Typic Ustipsamments Lithic Ustipsamments Aridic Haplustalfs Aridic Ustochrepts	232.836	A_{13}
Ondulado A21	Grouping Sullome	Entic Durorthids	207.275	A_{21}
Badlands A22	Grouping Erodadas	Typic Ustipsamments	27.790	A_{22}
Dunes A23	Las Dunas		14.475	A_{23}
Flat plain A24	Complex La Oveja Chijini Tolar A Tolar B El Rio	Duric Camborthids Vertic Camborthids Ustertic Camborthids Fluventic Ustochrepts Lithic Ustorthents	316.410	A_{24}
Temporarily flooded A25	Grouping Conchillas Hornillos	Typic Natrargids Vertic Camborthids	39.905	A_{25}
Salt mines and salt pans A26	Associaton Cap.Castrillo C de Cardingas Kolla La Cantera	Typic Psammaquents Aquic Salorthids Typic Salorthids Typic Natrargids	94.235	A_{26}
Recent A27	Grouping Patacamaya	Typic Cryopsamments	3.870	A_{27}
Terraces A28	Grouping Corocoro Sud	Lithic Ustorthents	65.515	A_{28}
h hill country 01	Serranias Altas		268.950	O_1
Low hill country 021	Serranias Colinosa		73.740	O_{21}
Foot of hills 022	Grouping Belén	Lithic Ustipsamments	25.720	O_{22}
Undulated terraces 03	Grouping Toloma	Vertic Ustorthents	28.565	O_3
Narrow valleys 04	Grouping Lurribay	Mollic Ustifluvents	6.570	O_4