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STATISTICAL MAPPING OF SHEET AIQUILE SE-20-9 (NATIONAL MAP) MAKING USE OF ERTS IMAGES

by

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16. Abstract

This report is about new possibilities of remote sensing by means of satellites to do research on natural resources. These imageś make it possible to carry out integrated studies of natural resources in the shortest time possible and with small investments . This report is complete with various maps and a complete description of each. With the use of these satellites, scientists can hopefully plan development projects at the national level.

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ERTS Technology Satellite Project - Geological Service of Bolivia

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1.0 Introduction

Remote sensing by means of satellites has opened new possibilities in research on natural resources. The images sent by satellite, as a result of their peculiar features, make possible to carry out integrated studies of natural resources in the shortest time and with small investments, in comparison with other conventional methods.

The present study demonstrates the feasibility of obtaining statistical maps recorded on basic maps of cartographic accuracy, produced by the Military Geographic Institute. This means that, after demonstrating the feasibility of adaptation of ERTS images, we could have available 1:250,000-scale statistical maps of the entire country in the near future.

This information will make possible rational planning of development projects at the national level.

2.0 Working method /128

The stages followed in the present study are as follows:

- Monoscopic interpretation of ERTS images, multispectral system, red and infrared band (MSS-5, MSS-7), since they are the most versatile in the evaluation of resources generally.

- Compilation of geological, geomorphological, hydrological and mining data obtained in the preceding stage on traced copies, at the approx-

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imate scale of 1:250,000.

- Adaptation and transfer of the data previously recorded on precise-scale basic maps by means of optical-mechanical methods. The geographic location and compilation of Sheet Aiquile SE-20-9, prepared by the Military Geographic Institute, is illustrated in Figure No. 1.

3.0 Information obtained

3.1 Geomorphology

The purpose of a geomorphological survey is to provide a concise and systematic regional picture of the relief and of the phenomena related to it.

Since surface relief is a very important element of geographic development, knowledge of it constitute a highly valuable tool in the rational utilization of natural resources by man, because of the relation existing between the geomorphological features of a place and the other environmental factors. Geomorphological maps are of great value for the preparation of soil maps and soil engineering maps, for the study of industrial and urban development projects.

Geomorphological maps provide engineers, planners and other specialists with information that is used in determining the location of roads, protection of existing structures, selection of areas for the installation of dams, reservoirs, tunnels and other engineering works.

One should also mention the great importance of these maps in the exploration or search for new mineral deposits, where certain geomorphological features constitute excellent guides to the selection of areas having economic potential and then to the development of exploration programs.

Major geomorphological units

To the south of parallel 17° 30', the Eastern Andes mountain range in Bolivia obviously changes its aspect entirely, becoming lower and flatter than the sector to the north of that latitude. This change appears to be the result of the geotectonic weakness line of Ichilo-Ivirizu de Rod, which approximately follows 17° 30' south latitude, extending to the west through Lake Titicaca with the dislocation described by Norman Newel under the name of "Huacullani Fault". From this brief description it appears that the area under study has morphological features totally opposite to the country to the north, where especially glaciation has been more intense than in the south. Here elevations do not exceed 4,000 m., and evidence of peneplains or erosion surfaces appears very regularly from Arampampa to Villazón.

A.K. Lobeck regards as major structural forms those originated from diastrophic forces; thus, taking into account the geological structure prevailing in each region, he identifies the following major forms or secondary relief features.

1. - Plateaux
2. a) Dome-shaped mountains
   b) Mountain massif
   c) Mountains with ridges or marked folds
   d) Mountain systems.

The stratified rocks which form the upper part of the crust in a given place may be arranged horizontally or have been subjected to folding and fractures of varying intensity.

In the former case, when the diastrophic movements that affected them have been of the epeirogenic type only, geomorphologists talk of plateaux. In the latter case, depending on whether there was folding, fractures, or both phenomena together, the results are as follows:

a) When the top layers have formed an arch, locally protruding above the surrounding rocks, it is called dome-shaped mountain.
b) When, as a result of faults, different blocks have been formed, which have moved with respect to one another, there is a mountain massif.
c) If, as a result of tangential forces, the layers are folded forming anticlinals and synclinals, we have a relief with mountains with ridges.
d) When both folding and faults are the predominant features, the resulting landscape will be a mountain system.

From a careful examination of the map, it appears at first sight that the area has been subjected to intense folding and fractures, evidenced by the presence of anticlinal and synclinal structures and innumerable fractures, such as fault cliffs and features related to possible dislocations. Basically, the landscape under study would be referred to as a mountain system.

The presence of peneplains or flattened surfaces indicates that the region was subjected to intense erosion, mainly due to the action of running waters which levelled the country into a flat shape.

These features are indicative of an advanced stage of development. Nevertheless, other features, such as relief inversions, sharp dividing lines and deep valleys, reveal that the relief of the region was rejuvenated.

The elevations at which such peneplains are found in the region tend to decrease toward the east.

For example, at Ocurí-Maragua the altitude is 4,548 m. above sea level, at Presto approximately 3,180 m., at Mojocoya 2,900 m.

This decrease in altitude raises two questions: Were there two or more stages in levelling? Or is this unevenness due to fracturing into blocks? /130

When we are able to answer these questions, it will then be possible to pinpoint in the chronology of the earth the various tectonic events and to determine when the most important changes in the landscape took place, primarily with respect to the paleozoic block and the sub-Andean belt.

Minor geomorphological units

Subsequently, the mountain system was subjected to the destructive agents of the earth's surface, which shaped and created the infinite number of existing minor features. In their action, the distructive agents produced erosion features, such as dip-slopes, peneplains, hills, plateaux, ridges, etc. (see legend).

Of the four destructive agents which are involved in all work of this kind, running waters considerably affected the shaping of the landscape, contributing to a large extent to the development and geomorphological evolution of the area.

Rocky cliffs or slopes, ravines or gorges are forms of destruction caused by river erosion.

Of course, all the destructive agents were preceded or accompanied by the universal activity of bad weather, which can be regarded as a preparatory agent for the subsequent action of the agents, removing the material detached or weakened by the former.

For the identification of the minor structures, use was made of the international nomenclature prepared by the International Geographic Union (IGU), Sub-committee on the world geomorphological map. It is clear, because it is arranged in chronological-genetic order, in which the structures require no additional explanation. The great processes and agents which originated structures, both destructively and by deposit, are analyzed chronologically.

PRACTICAL APPLICATION OF THE STRUCTURES

We shall limit ourselves to consider those structures which offer practical applications, without proceeding to discuss each of them, which would draw us away from the purpose of the present study.

The greatest nickel deposit of San José de Tocantins (Brazil) was discovered thanks to the location of a peneplain, related to the profound effects of meteorological agents on peridotite (Pécora, W - Deposits of Nickel, Cobalt, Manganese silicates in the vicinity of San José de Tocantins, Brazil) USGS Bull. 935-E-1944.

W. Fisher, of the Geological Service of the United States, has pointed out that "a high percentage of known mineral deposits is associated to faults or fractures". For the reasons noted above, areas of peneplain and showing marked fractures have been selected to receive priority consideration in a future exploration program.

The fractures and fault cliffs must also receive great attention /131 in taking decisions as to the installation of civil engineering works, because they are weak areas in which the ground is usually fractured and unstable.

Structures such as ravines or gorges appear to be appropriate places for the installation of dams, reservoirs or basins for irrigation purposes or for the potential installation of hydroelectric power plants.

Passes, fords or gaps (see legend) constitute natural passages which can be used by technicians and planners in designing roads, railroads, etc. These areas are well defined in the geomorphological map that was obtained (Fig. 2) and will be used as a basis for the planning of civil engineering works in this region.

3.2 HYDROLOGY

The ERTS satellite images, especially those corresponding to the infrared band of the multispectral system, enable experienced interpreters to obtain an important mass of information in the field of hydrology. Data were obtained concerning:

- Hydrographic basins and sub-basins

- Drainage analysis.

BASIN AND SUB-BASIN MAP

In view of the importance of water resources as sources of irrigation and energy production, and making use of the wide coverage of ERTS images, which make possible regional interpretations - a primary factor in the study of hydrographic basins - they have been defined with the following results (Fig. 3).

AMAZON BASIN (A)

Approximately 90% of the drainage system of the Aiquile sheet involves tributaries of the Mamorè river and therefore belongs to the Amazon basin.

The geographic area affected by it corresponds to the N-NE and E sectors of the region under study, with an area of 16,588.7 Km^2.

Within it, the following sub-basins have been identified:

Río Caine sub-basin (A-1)

The main water-collecting stream, río Caine, is located at the NW end of the sheet and runs along the eastern side of the Toro Toro synclinal. Genetically, it corresponds to a subsequent river, which receives the waters of the rivers Laguna Mayu, Rodeo, Challapampa and Molinero. Its principal tributary is the San Pedro river, and Rio Grande originates at their confluence.

The area of this sub-basin is 1,432.5 Km^2.

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Río Mizque sub-basin (A-2)

It corresponds to the central sector of río Mizque, receiving as its main tributaries the rivers Salto Mayu, Pojo and Comarapa, the last-mentioned joining it at the latitude of the town of Saipina. This sub-basin is important because it provides irrigation for the agriculture of the area.

The area affected by the sector studied measures 3,447.5 Km^2.

San Pedro and Chayanta river sub-basin (A-3)

The rivers Guadalupe and Chayanta, which begin in the western and south-western area of the Aiquile sheet, follow an anomalous course to NW, in contrast with the general tendency which is toward to southeast. This leads to the hypothesis of a diversion phenomenon, related to a lifting which took place to the SW of the area under study, in combination with the deposit of lava and rocks of the Los Frailes plateau.

Because of its origin, río Chayanta is important from the economic viewpoint because it forms tin seams.

The total area of the sub-basin is 4,558.7 Km^2.

Río Grande sub-basin (A-4)

It is the most important in the region because of the volume of water collected by the río Grande, which receives the waters of the rivers Zudañez, Mojocoya, Presto, Lagar and other smaller ones.

Río Chico sub-basin (A-5)

This small sub-basin is located in the south-central area of the sheet and joins rio Grande at the level of the Arce bridge.

RIO DE LA PLATA BASIN (B)

Its influence is limited to the SW sector, where there is formed the sub-basin of río Ravelo.

Río Ravelo sub-basin (B-1)

It originates at the place bearing the same name and receives the waters of the rivers Tamayu and Pirca.

DRAINAGE ANALYSIS

For the purpose of obtaining information in addition to the geologic interpretations and of determining their relation to the regional tectonic structure, a drainage analysis of the hydrographic system of the area under study was carried out.

Basically, the arrangement of the water streams, their geometric relations and the density of the drainage system were studied. The results obtained are as follows: /133

AREA I. TRELLIS OR NETWORK CONFIGURATION

It reflects a marked structural control, in which the main water-collecting streams correspond to subsequent rivers which run along areas of weakness caused by faults or fold axes.

On the basis of the drainage density data, this area was subdivided into two sub-areas.

I A - Low-density trellis configuration

A predominance of permeable rocks, probably arenaceous, as compared with pelitic rocks, is suggested.

I B - Medium-density trellis configuration

Probably developed on arenaceous-argillaceous rocks.

AREA II. DENDRITIC CONFIGURATION

Related to a lithological control of semi-permeable or impermeable rocks. Two sub-areas can be distinguished.

II A - Medium-density dendritic configuration

Possibly related to intercalations of sandstone and lutites, with prevalence of the former.

II B - High-density dendritic configuration

Suggests a predominance of pelitic rocks.

AREA III - SUBPARALLEL CONFIGURATION

This type of drainage indicates lithologic control or fractures of sedimentary rocks.

AREA IV - RECTANGULAR CONFIGURATION

The tributaries enter at right angles, which indicates control exercised by diaclases.

DRAINAGE ANOMALIES

The streams which deviate from the general tendency of the drainage system are so regarded.

Their importance is due to the relation between structural controls, location of igneous rocks and/or cave-in of folds.

Their features are briefly described below. /134

1-2 ANNULAR ANOMALIES

Imply relation to domes located in depth. Their importance is due to their connection to potentially favorable areas for mineral deposits.

3-4 RADIAL ANOMALIES

They produces centrifugal configurations which may indicate igneous rocks or structural rises, which, in view of their geographic position in relation to known mineral deposits (Maragua-Ocurí) may be economically important.

5 - SUDDEN CHANGES IN THE GENERAL TREND OF DRAINAGE

They are found in the area of río Chayanta and are probably related to diversion due to rising.

6-9 CURVED DEFLECTIONS OF RIVERS

They determine probable cave-in of anticlinal folds.

10-4 ANOMALOUS WIDENING OF RIVERS

Correspond to synclinal folds.

12-18 DOUBLE DEFLECTIONS

Produced by structural control of longitudinal faults in a general direction N-S to NW-SE and readjustment faults in direction E-W.

19 REGIONAL ALIGNMENT OF A MAJOR RIVER

Is represented by río Quiroga and río Chico, which delimit the area of the Aiquile ridgeline.

20-29 ALIGNMENT OF RIVERS

It indicates structural control and they run along the weak or fracture lines.

30 DOUBLE DEFLECTION OF RIVERS

It is a typical example of anticlinal with double cave-in.

31 MINOR SIMPLE DEFLECTIONS

They are controlled by faults and/or diaclase areas.

32 SIMPLE PARALLEL ALIGNMENTS /135

They indicate lithological control.

3.3 GEOLOGY

This study mainly covers two basic aspects:

- The structural interpretation, which made possible to locate, define and distinguish the configuration of some folds, faults and features of great magnitude, and especially areas with complex tectonics.

- The lithological analysis which made possible to locate, define and describe litho-stratigraphic units at the system level and to find their relation in space and in their order of succession (Fig. 4).

STRATIGRAPHY

From the stratigraphic viewpoint, a differentiation was made at the "System" level, considering the limitation imposed by the scale. Each of the systems is briefly described below:

A) Ordovician system - Rocks of the Ordovician system occupy a greater area than those of the other systems, and are characterized by being rocks with many folds.

Lithologically, this system is composed of lutites interspersed with sandstone and quartzite.

B) Silurian system - Sediments from this system are widely found in the area under study and include the following lithological units:

- At the base, tilithic sediments without stratification.
- Phyllite particles
- Quartzite
- Lutite
- Sandstone at the top.

C) Devonian system - Surface material of the Devonian system is well exposed in the eastern region of the area. Lithologically, this system is composed of lutite at the base and sandstone at the top.

D) Carboniferous system - Carboniferous rocks rise to the surface to the east of Aiquile and to the north of Presto. The lithological composition of the Carboniferous system is as follows:

- Lower part: Sandstone, partly interspersed with conglomeratic banks.

- Middle part: Several layers of tilite, with sandstone particles folded in all directions.

- Upper part: Sandstone.

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E) Permian system - Permian sediments rise to the surface in the northwest part of the area, more precisely to the south of Toro-Toro.

Lithologically, the Permian system is composed of alternate calcareous rocks and margarite.

F) Cretaceous system - Above the paleozoic rocks and at discordant angles in some cases and with faults in others, there are isolated remnants of rocks of the Cretaceous system, the majority composing nuclei of synclinals, of which the synclinal structures of Toro-Toro and Río Caine are noteworthy for their great size.

Lithologically, the Cretaceous system is mainly composed of sandstone, margarite, clay, calcareous rocks and lutite.

G) Tertiary system - Tertiary sediments are found exposed in the synclinal of Río Caine and in the belt located between Aiquile to the north and Presto to the south. There are also tertiary sediments to the west and to the south of Mojocoya.

Within this system, a tentative differentiation was made between the clastic sediments and extruded igneous rocks, designated by the letters T, TL, whose lithological composition is as follows:

(T) Conglomerate, sandstone and lutite.

(TL) Lava, which lies in disorder above the folded rocks.

Intrusive bodies - There are two intrusive bodies in the vicinity of Ocurí and another close to Colquechaca, and they are of the subvulcanic type. These igneous rocks are estimated to date from the meso- or neotertiary period, because of structural relations as well as potassium-argon radiometric analysis (data recorded in Geobol Bulletin II).

H) Quaternary system - The quaternary system is composed of accumulations and deposits of unconsolidated material, consisting of gravel, sand and clay, which has been classified according to its origin or morphological aspect as follows:

Undifferentiated deposits

Landslides

Colluvial-fluvial deposits

Alluvial deposits

Terraces

The lithological contacts in the images show a greater or lesser degree of accuracy in their delimitation, as for example: extruded igneous rocks of considerable size can be differentiated from the sedimentary-metamorphic system; the distinction between paleozoic rocks instead becomes difficult, because of their lithological similarity and because they show ill-defined photogeological features.

a) Tonal anomalies /139

b) Geomorphic anomalies

a) These anomalies interpreted in satellite images may correspond to areas which have suffered from the action of bad weather, areas affected by great features or their intersections, sulphur-containing areas, metamorphic halos, concentration of vegetation; in some cases they may be rock formations. Two tonal anomalies have been interpreted in the region of Aiquile: one to the west of Maragua, located in an area containing Sn minerals, and the other in the vicinity of río Mozque, which possibly contains meteoric rocks; for these reasons, field work is always recommended and is indispensable to recognize and formulate clear ideas concerning such anomalies.

b) These are anomalous configurations of the ground which are directly or indirectly related to endogenous processes, especially magma formation, as a result of which dome-like shapes can be observed in the ERTS images, sometimes with some small igneous rocks surfacing, for example in the area of Ocurí.

In nearby areas it has been established that these anomalies are related to the location of mineral deposits, and therefore it was deemed essential to carry out field reconnaissance for future mining exploration.

Target areas for exploration

By combining the data obtained from the interpretation and knowing the genesis of the minerals existing in the region covered by the sheet, an attempt was made to find whether there is a direct connection between the structural features shown on the map and the mineral deposits. On the other hand, indications concerning the significance of features can be obtained by a comparative analysis of the maps showing the features and the regional distribution of the minerals. In some cases, this can be determined empirically by simple superimposition of the two types of information. Two areas studied on ERTS images were selected for field reconnaissance as promising areas for mineral prospecting:

a) Tonal and geomorphic anomalies, hydrothermal alterations, igneous and vulcanic rocks.

b) Areas with large features and their intersections.

In the region of Aiquile, the following can be regarded as examples: the two tonal anomalies, the igneous rocks of Ocurí, the features of Aiquile, the feature of Marcoma, the feature of Toro-Toro, the feature of Toracarí-Río Chayanta and the intersections of these large features which show areas suitable for mining. Example: mining district of Asiento-Boston (Pb-Sb), Foster (Sn-Ag-Pb), Yaco (Pb-Ag), Titiri (Sn-Ag).

3.5 Soil

Up to the present time soil studies have been very sporadic in Bolivia, a feature which raises a variety of problems for national and international agencies in charge of planning the development of the country. /140
The ERTS images constitute a highly valuable instrument to evaluate these resources in a rather short time, in comparison with the conventional methods.

Process

Basically, this work consisted of three mapping stages: an initial exploratory mapping, a complementary mapping in which new units were created, and a third stage of field work.

As can be imagined, the map prepared on the basis of the first mapping will show a modest accuracy because it is highly general, and for this reason a second mapping was carried out, and the map presented here is its result (Fig. 7).

Interpretation

The rule adopted in the interpretation was the physiognomical analysis, which consists in identifying different landscapes with reference to the area of the country, although it cannot be identified physiographically.

Classification

As mentioned above, in the first stage of mapping a classification based on natural features was established; each mapping category or unit is identified by a letter and one or two digits, on the basis of visual and/or deductive criteria, since this classification shows what is found in nature.

This study is based entirely on interpretation techniques and therefore is mainly based on physiography. Therefore physiography is used in the map legend as much as possible. This can be done in two ways:

1. In field work, to be subsequently modified in the final map.

2. As a basic map for the final legend of the map, where the physiographic legend is expanded to include the description of the profile of the ground.

The second alternative was selected, considering that it records better the information concerning the landscape, since when we use physiography we are describing geographically different landscapes; these landscapes are related, with soil differences.

Map Legend

C - Mountain Region

C1 - Mountain Region

C2 - Sub-Mountain Region /141

C3 - Hill Region

C4 - Direct Plateau

C5 - Slopes with surfacing rocks.

F - Slopes, Valleys, Terraces

F1 - Slopes - alluvial formations - colluvial areas - sloping relief.

A - Alluvial Plains

A1 - Recent alluvial areas, flat or nearly flat relief.

A2 - Recent alluvial areas, including colluvial deposits.

A3 - Floods with small hills or remnants of hills.

A4 - Alluvial, sub-alluvial terraces with reference to the present datum level.

Soil Description

Relation between soil, original material and physiography

The types of soil have been grouped first in accordance with definite landscapes; soils with different original materials have been mapped in accordance with the form of their deposits and the type of rocks from which they originated.

1 - Landscape C

Composed of residual material, it is composed of old, high and steep terraces, with slopes susceptible of severe and moderate erosion. The rocks are lutite predominantly and sandstone, which have produced very superficial soil located on slopes.

2 - Landscape F

This soil is of colluvial-alluvial origin, with slopes ranging between 12% and 25%. The natural vegetation is largely composed of thorny xerophytic species alternating with some crops of the annual type.

3 - Landscape A

This is soil developed by sedimentation of the material eroded from landscape C and deposited in this landscape; the majority of the crops in the region are located in this area; because of its edaphic nature, this is soil which is suitable for all types of crops ecologically adapted to the area.

This land is characterized by good and deep soil with good drainage, /142
classified as inceptisol in the seven-digit U.S. classification system.

Conclusions

1. - The transfer of statistical information obtained from an ERTS image, mass-processed, onto an accurate cartographic map, is feasible.

2. - The preparation of statistical maps where there are ERTS images, and of cartographic maps in 1:250,000 scale will make possible the development and preparation of geological, geomorphological, mineral-rich area distribution, soil and hydrological maps.

3. - The preparation of statistical maps by using ERTS is extremely cheap, in comparison with conventional methods, since these maps can be obtained in the scale mentioned above in a relatively short time.

4. - The information obtained in the interpretation of ERTS images, together with the compilation of existing information, makes possible to prepare more detailed maps.

5. - Because of the cartographic features of ERTS images, they can be used as basic maps in those areas in which there are no conventional maps, since the internal geometric discrepancies in the image are not considerable.

REFERENCES

HERFINDAHL, O. C., 1970. Natural resources in economic development. Texts of the Latin American Planning Institute (Los recursos naturales en el Desarrollo Económico. Textos del Instituto Latinoamericano de Planificación). Ed. Universitaria S.A. Santiago, Chile.

I.G.U. International Geographic Union- Commission on applied Geomorphology- Sub-Commission on geomorphological Mapping, 1968. The unified key to the detailed Geomorphological Map of the world. Folia Geographica, Vol. II, Kracovia.

U.N. - GEOBOL, 1965. Pilot Mining Survey of the Mountain Range and Plateau - (Levantamiento Minero Piloto de la Cordillera y Altiplano). Geological Service of Bolivia. La Paz, Bolivia.

N.A.S.A., 1973. "Symposium on significant results obtained from the Earth Resources Technology Satellite. Vol. I: Technical presentations - Section A - ERTS Project, La Paz, Bolivia.

BOLIVIA AIQUILE

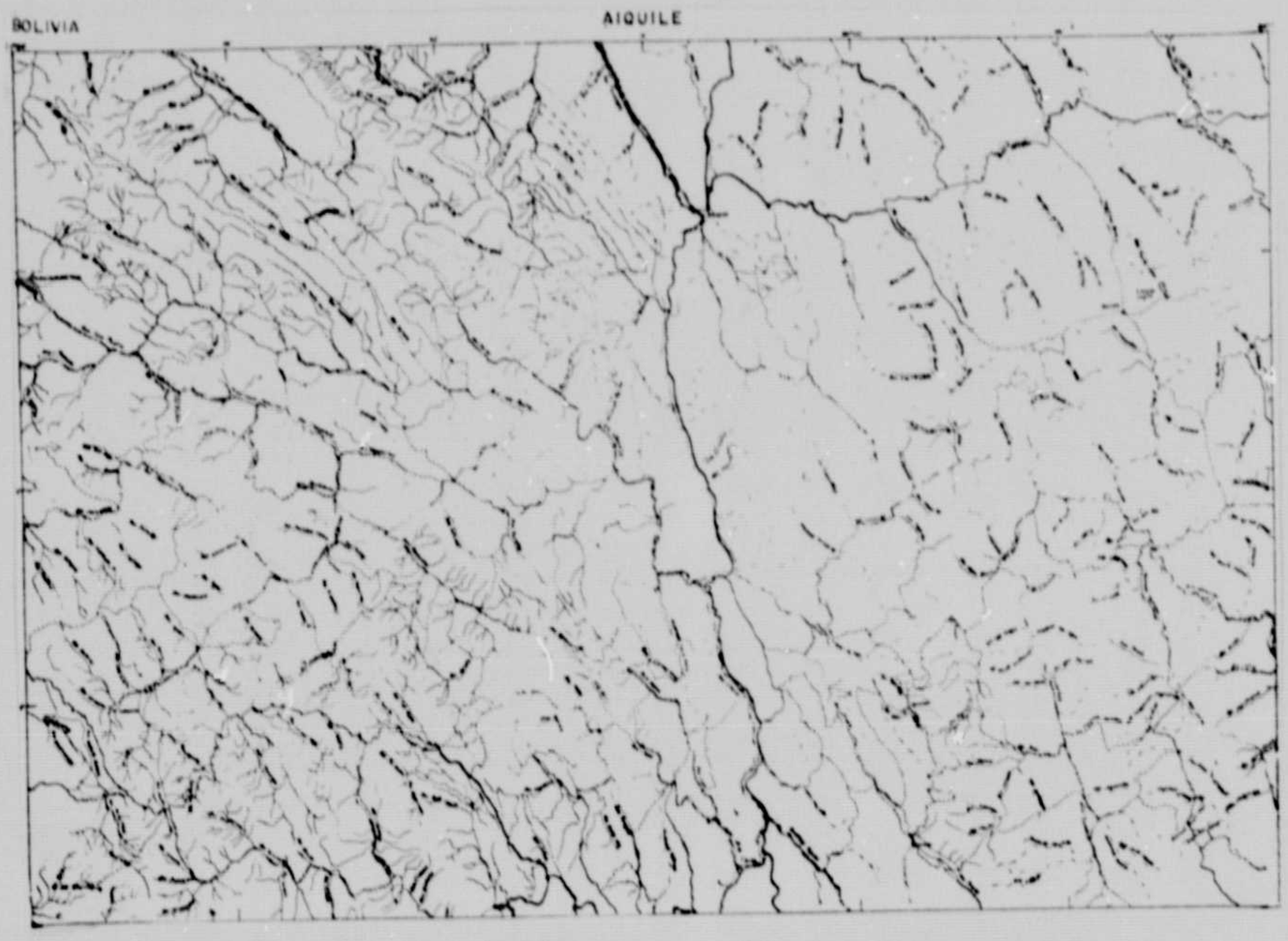


Fig. 1 - Compilation of topographic sheet SE-20-9 I.G.M.

AIQUILE GEOMORPHOLOGICAL MAP

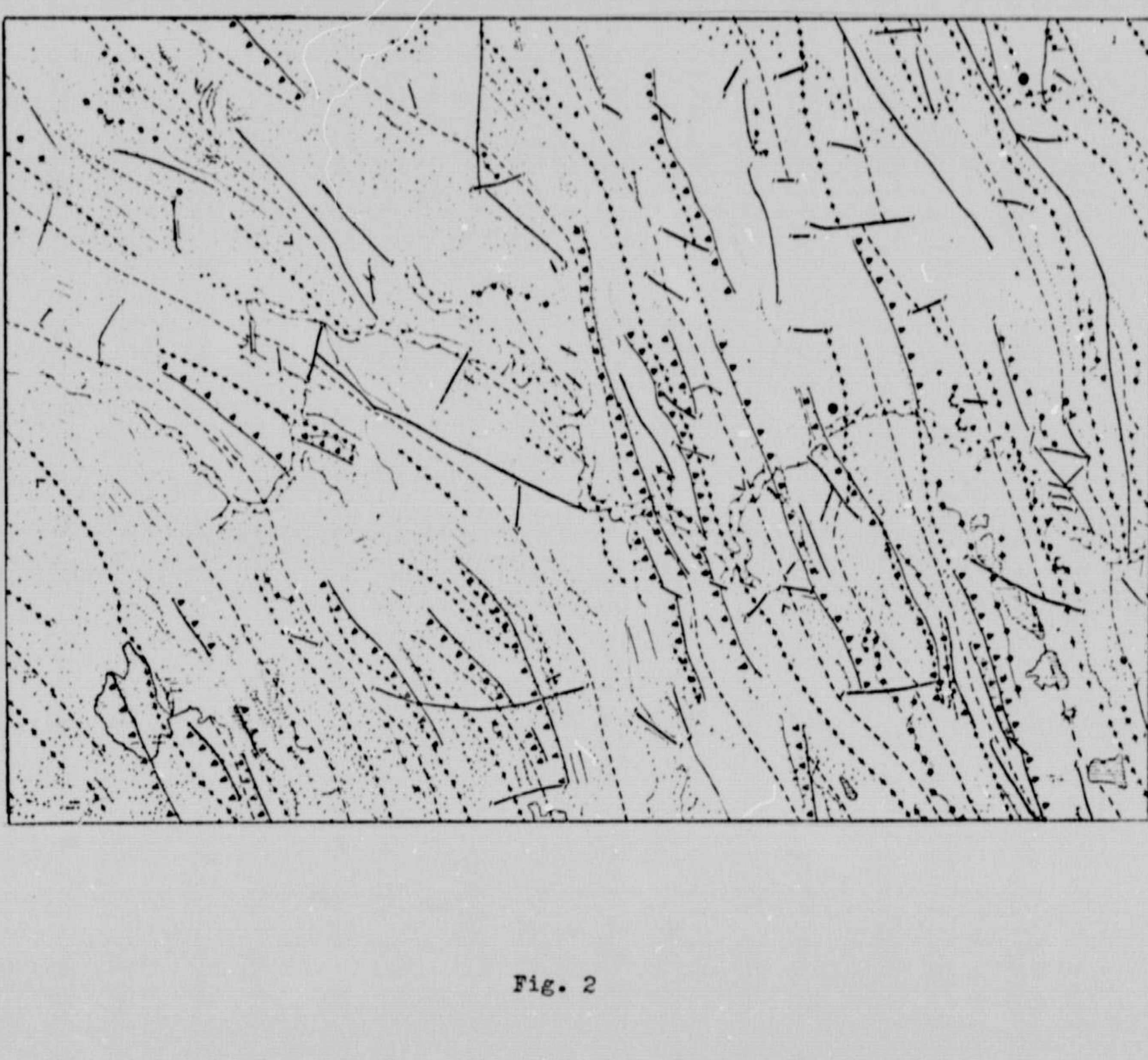


Fig. 2

AIQUILE

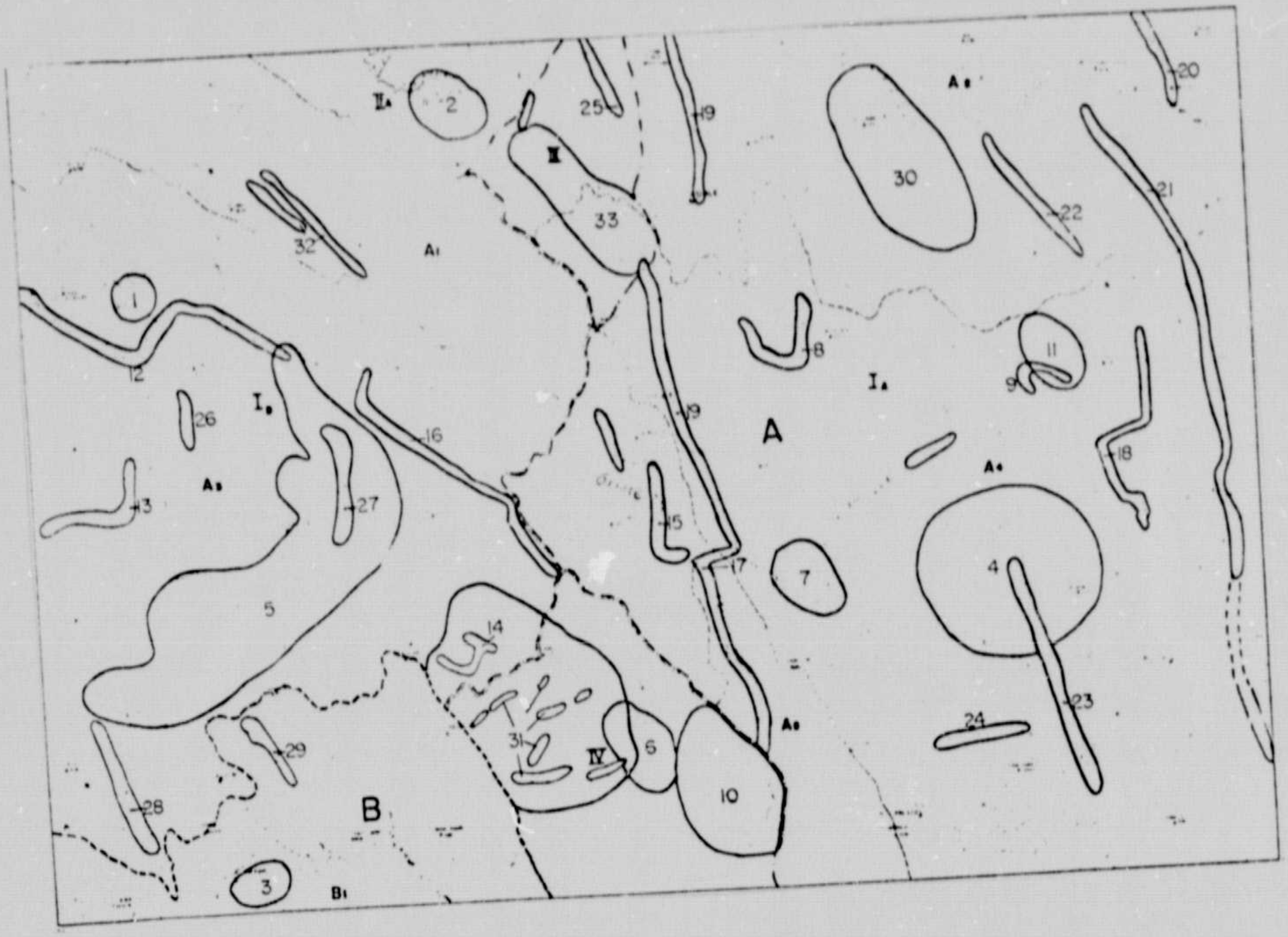


Fig. 3

AIQUILE GEOLOGICAL MAP

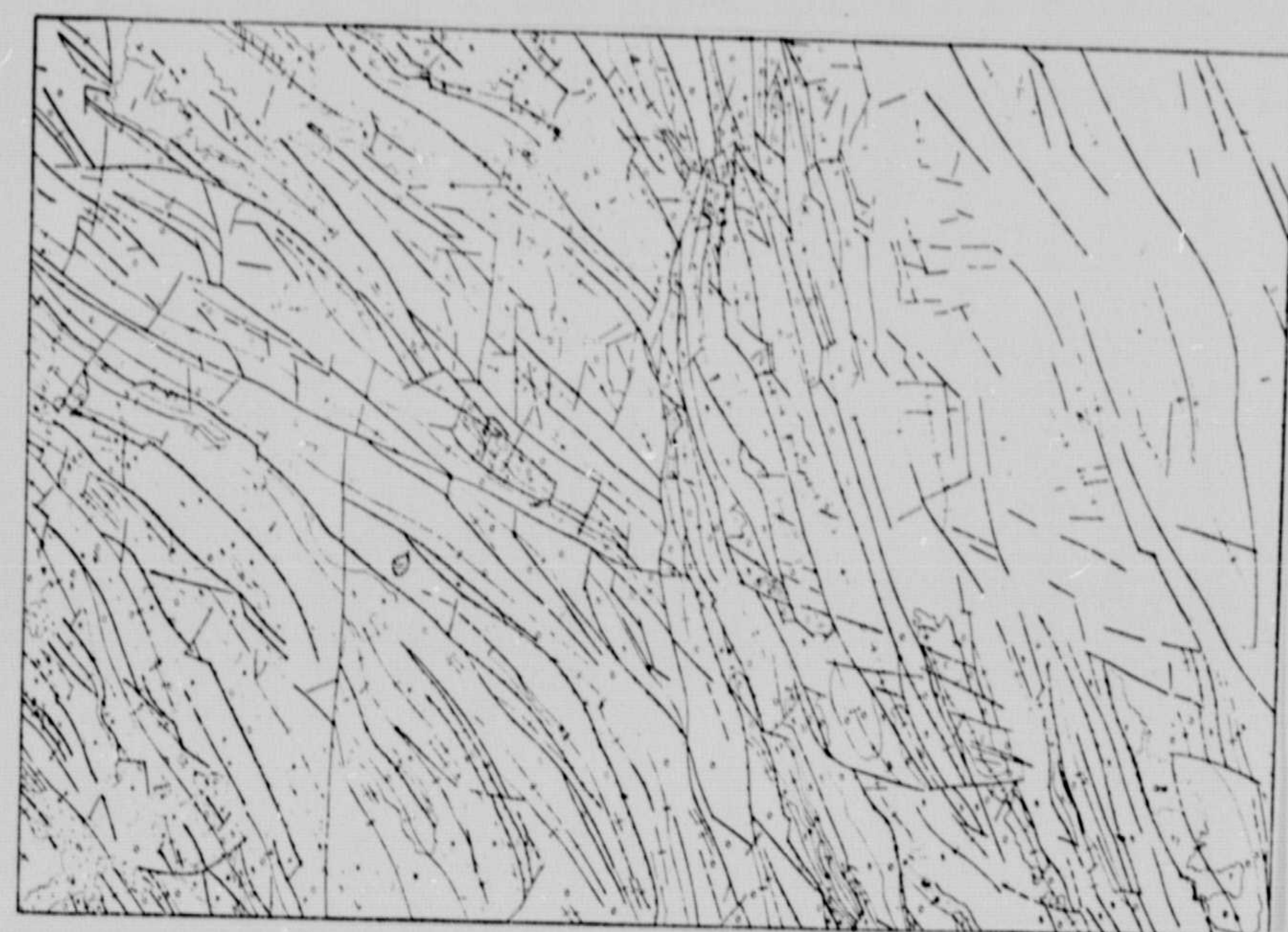


Fig. 4

AIQUILE STRUCTURAL MAP

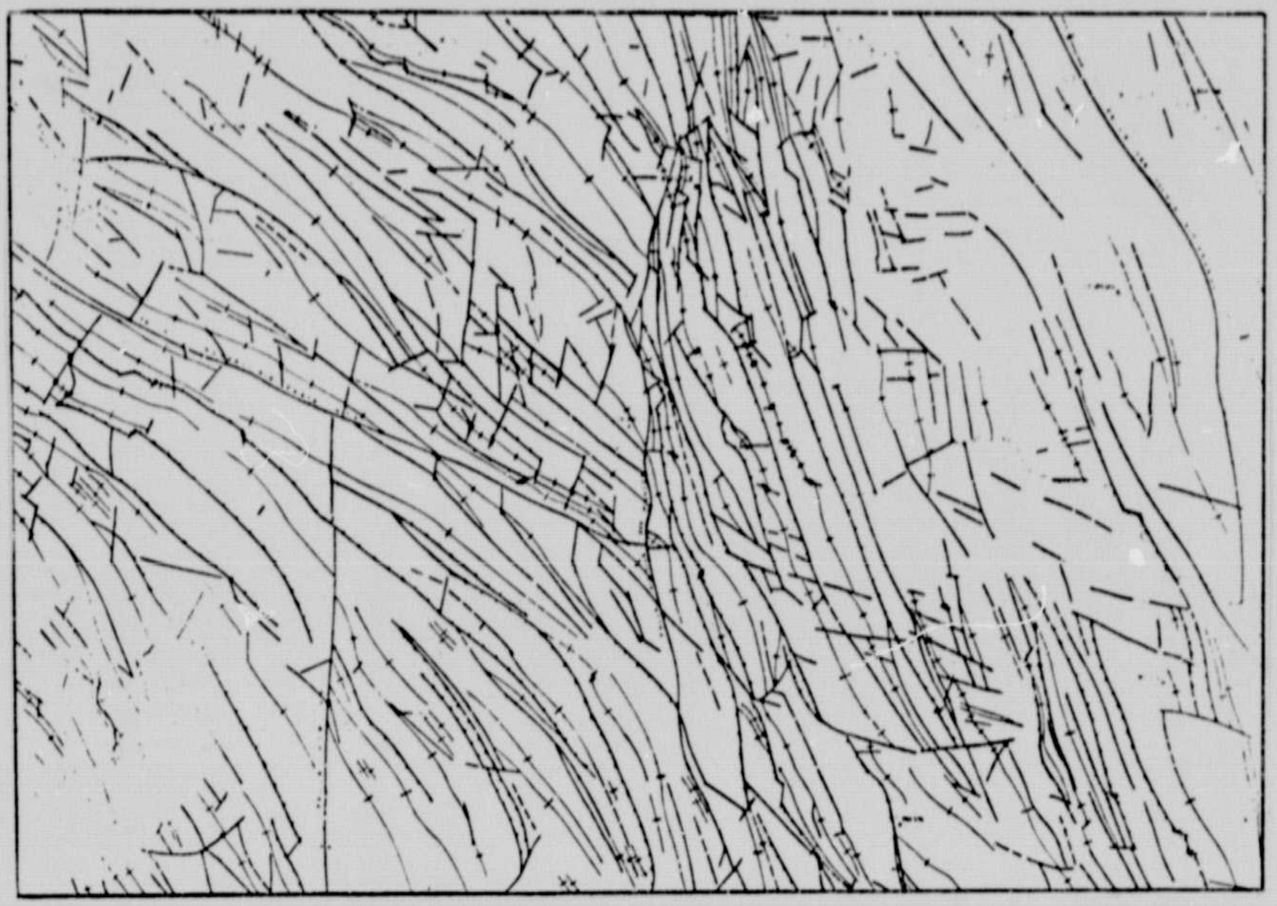


Fig. 5

AIQUILE FEATURE MAP

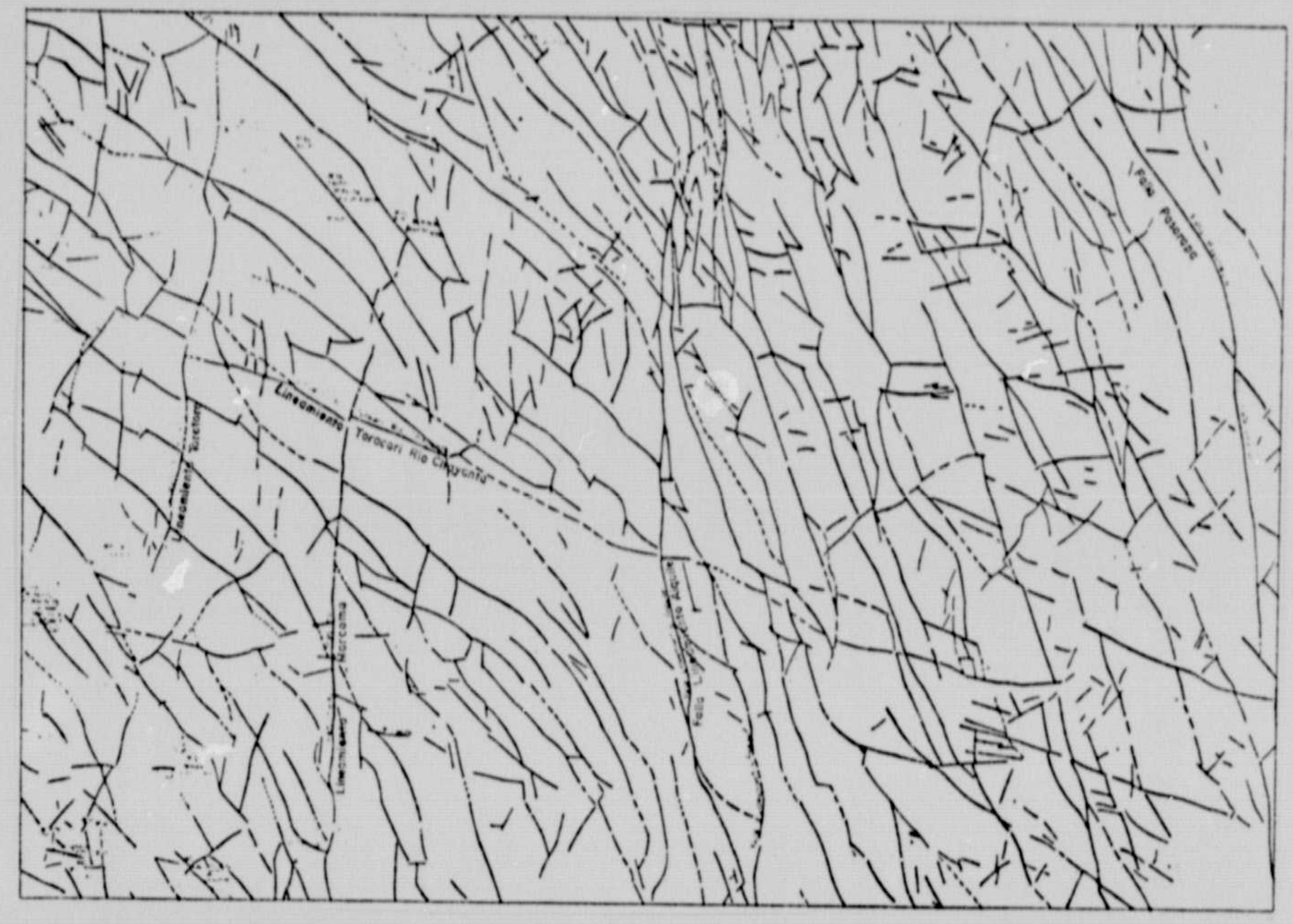


Fig. 6

AIQUILE SOIL MAP

Fig. 7

ANNEX: MAP REFERENCE

GEOMORPHOLOGICAL MAP

Figure 2

Legend

Endogenous Structures

A) Neotectonic Structures

I) Ancient, inactive

1) Fault cliffs (with known data)

2) Lines as possible faults f———f

II) Recent, Active

1) Anticlinals + + +

2) Synclinals — — —

B) Structures of vulcanic origin

I) Deposit structures - Eruption through fissures

1) Lava plateaux

Exogenous Structures

A) Erosion structures

I) Destruction-produced structures

1) Dip slopes

Dip Slope with 5° - 10° degree slope in

a) Sedimentary rocks

32-33 Simple parallel alignments

(lithological control)

Basins

Sub-basins

Anomalies

Drainage configurations

Geological Map

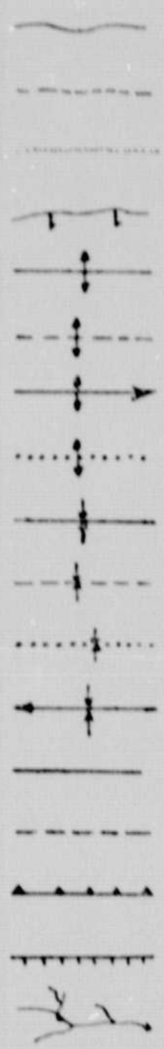
Figure 4

References

QUATERNARY	Qnd	Undifferentiated deposits
	Qd	Landslides
	Qcf	Colluvial-fluvial deposits
	Qa	alluvial deposits
	Qt	Terraces
	x x Ti x x	Intrusive
TERTIARY	TL	Lava
	T	Conglomerates, sandstone and lutite
CRETACEOUS	K	Sandstone, multicolored margarite and lutite
PERMIAN	P	Calcareous rocks and margarite
CARBONIFEROU	C	Sandstone, interspersed with tilite and lutite
DEVONIAN	D	Lutite and sandstone
SILURIAN	S	Sandstone, quartzite and lutite
ORDOVICIAN	O	Lutite interspersed with sandstone; siltite and quartzite

Conventional Geological Symbols

Figure 4



- Lithological contact
- Approximate lithological contact
- Covered lithological contact
- Conspicuous layers
- Anticlinal axis
- Approximate anticlinal axis
- Anticlinal axis with cave-in direction
- Covered anticlinal axis
- Synclinal axis
- Approximate synclinal axis
- Covered synclinal axis
- Synclinal axis with cave-in direction
- Fault
- Approximate fault
- Inverted fault, the projections indicate the upper block
- Normal fault, the projections indicate the fallen block
- Rivers

Structural Map

Figure 5

References

Structural Symbols

Fault line

Probable fault line

Inverted fault line

Probable inverted fault line

Normal fault line

Anticlinal axis

Anticlinal axis with cave-in

Probable anticlinal axis

Synclinal axis

Synclinal axis with cave-in

Probable synclinal axis

Topographic Symbols

Rivers

Intermittent rivers

Towns

Feature Map

Figure 6

References

- - - Inferred lines

— — Probable lines

——— Lines or faults

Anomalies generally

Igneous rocks

⚒ Sn. Mineral deposits in operation

Pb. Abandoned mineral deposits

Au. Placer being explored

Au. Abandoned placer

o Thermal watersheds

Soil Physiognomical Map

Figure 7

Legend

C - Mountain Region

C1 - Mountain Region

C2 - Sub-Mountain Region

C3 - Hills

C4 - Dissected Plateau

C5 - Slopes with surfacing rocks

F - Slopes - Valleys - Terraces

F1 - Slopes, alluvial formations, colluvial formations, sloping relief.

A - Alluvial Plains

A1 - Recent floods, flat or nearly flat relief

A2 - Recent flood, including colluvial deposits

A3 - Floods with small hills or remnants of hills

A4 - Alluvial terraces, depressed with reference to the present datum level.