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FORESTRY, GEOLOGY AND HYDROLOGY INVESTIGATIONS FROM ERTS-1 IMAGERY IN TWO AREAS OF ECUADOR, SOUTH AMERICA

TITLE OF INVESTIGATION:	Forestry, Geology, and Hydrological Investigations from ERTS-1 Imagery in Two Areas of Ecuador, South America
PRINCIPAL INVESTIGATOR:	Néstor Vega Moreno (1972) Technical Director Junta Nacional de Planification Quito, Ecuador
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PREFACE

Despite heavy cloud cover ERTS-1 imagery of Ecuador has proved to be exceedingly useful for several types of natural resource interpretations. Using cloud-free portions of ERTS imagery in the Oriente and Guayas River basin areas of the country, we conducted investigations in forestry, geology and hydrology. Analyses of the ERTS imagery depended on standard image interpretation techniques and the interpretations were checked against 1:40,000 scale black-and-white aerial photographs, a 1:160,000 scale airphoto mosaic, and by low altitude aircraft overflights and field work.

Based on the work in forestry, we found that in the Oriente area well drained forests containing commercially valuable hardwoods can be recognized confidently and delineated quickly on the ERTS imagery. This conclusion is based on checking the ERTS image interpretations with air photos, low altitude reconnaissance overflights, and field work in the area. We conclude from this work that ERTS imagery can provide a significant amount of the information on vegetation, soils and drainage necessary to plan large regional development projects.

The work in geology in the Oriente area led to the following conclusions: that even in the tropical rainforest ERTS can provide an abundance of inferential information about large-scale geologic structures (e.g., the major fractures that seem to control several of the oil fields); that ERTS imagery is better than normal aerial photography for recognizing linears in this area; and that working iteratively among ERTS images, photo mosaics, and 1:40,000 photography provides a vital link for extracting the maximum amount of information from each type of imagery and for training interpreters, who are accustomed to standard photography, how to use ERTS imagery; and that major inferences about the geomorphic development of the area can be drawn from ERTS imagery (e.g., recognizing the capture of the Rio San Miguel by Rio Aguarico).

From the work in hydrology, we conclude that monitoring and control of annual inundation of portions of the Guayas River Basin would be greatly aided by repeated ERTS coverage during the period January through May each year. In this connection, the imagery is particularly useful for updating the changes in distributary channels and estimating the numbers and types of civil works necessary to control flooding. In the Santa Elena area, the imagery could be useful for monitoring and estimating soil moisture and aid in assessing the need for irrigation water in the period June through December.

FORESTRY, GEOLOGY AND HYDROLOGY INVESTIGATIONS FROM ERTS-1 IMAGERY IN TWO AREAS OF ECUADOR, SOUTH AMERICA

1.0 INTRODUCTION

The areas selected for investigation and discussed in this report differ slightly from those mentioned in the ERTS-A proposal to NASA, dated April, 1971. This modification has been necessary because of the quality of ERTS imagery received and the percentage of cloud cover found on each image.

The forestry and geology investigations were performed in the eastern (Oriente) region of Ecuador as proposed. The hydrologic studies were, however, performed in the western region of the country.

1.1. General Physiography and Climatology of Ecuador

Ecuador is a relatively small, some 270,000 square kilometers, but diverse country located in the northwestern portion of South America. It straddles the equator and is bordered to the north by Colombia, to the south and east by Peru, and to the west by the Pacific Ocean.

There are three major physiographic provinces which make up the country. These are:

- The Coastal Plain - an area which is tropically humid in the north, semi-arid to arid in the south, and has an intermediate area, the Guayas River Basin, which is normally inundated during four months of the year and has no rainfall during the remaining eight months.

From east to west, the coastal region is generally compounded of a relatively flat coastal plain partially dissected by perennial and intermittent rivers and streams, a low series of dissected north-south trending coastal mountains, and a larger north-south trending river basin. The eastern limit of the coastal region is formed by the western flank of the Andean Cordillera.

° The Sierra - In Ecuador the general elevation of the Andean Mountain system is approximately 3,000 meters mean elevation and is a classic system of high rugged bordering volcanoes, high plains and inter-mountain valleys.

The principal use of the land is agricultural with a distinct division according to climatic conditions. The southern Sierra of Ecuador is in general very dry. The central portion of the Ecuadorian Andes is extremely wet (one of the highest rainfall regions in the world). The northern Sierra is temperate with moderate rainfall occurring between October and March.

- The Oriente - This easternmost region of Ecuador is essentially a series of interconnecting fluvial plains and is the extreme western portion of the Amazon basin. The climate can be described as tropical rain forest in nature and the vegetation is mixed rain forest and tropical savanna.

1.2 Study Objectives and Applications

This investigation has been directed toward the testing of the use of ERTS imagery for forestry, geology and hydrologic mapping at a reconnaissance level. This data has then been used as a first step in establishing an information base from which to select development priorities in (a) a moist, tropical area with varying vegetation, soils and geomorphological characteristics, (b) a semi-arid region with a need for water resource development, and (c) an agricultural river basin with a need to control water resources for revegetation purposes and the prevention of annual floods.

The applications objectives of this program have been designed to provide missing information necessary to resource development in Ecuador and should be applicable to other similar environments throughout the world.

2.0 METHODOLOGY OR APPROACH

2.1 General Statement

Progress of this investigation has been a rather straightforward but phased approach. Those phases were:

- PHASE I - Training of Ecuadorian professionals in the interpretation of satellite and other remote sensing imagery.
- PHASE II - Gathering of pertinent existing imagery and aerial photography of study areas.
- PHASE III - Review and selection of available ERTS imagery for further studies.
- PHASE IV - Enlargement of selected ERTS imagery and interpretation of those images.
- PHASE V - Field investigations of portions of the study areas.
- PHASE VI - Final interpretation of imagery and the preparation of the final report.

2.2 Detailed Description of Phased Activities

PHASE I - The Training Program

Ecuador sent six professionals to Berkeley, California to attend a seventeen-day, 146-hour training program in the use and interpretation of ERTS imagery given by Earth Satellite Corporation. The Ecuadorian professionals attending the program all had several years experience and the technical fields represented were:

- Civil Engineering
- Geology and Mining
- Hydrology
- Photogrammetry/Cartography

The objectives of the course were:

First - to teach students how to use ERTS-1 imagery and other forms of remote sensing data in making inventories of earth resources;

Second - to provide each student with relevant background information pursuant to the first objective, such as physical principles involved, uses and limitations of various sensor systems, etc.

The course work stressed the interrelationship of imagery interpretation with existing known data and with field investigations.

PHASE II - Existing maps, reports, aerial photography were collected and reviewed to aid in the ERTS evaluation as well as to indicate if ERTS might provide additional resource data not available from more conventional sources.

PHASE III - Review and Selection of Available ERTS Imagery

The imagery was examined and files prepared for each frame and its coverage by bands. The image quality in regard to cloud cover and to area of useful image was rated and recorded. On the basis of this list, four or five priority areas were selected for more detailed analysis. The quality of ERTS imagery and its location are shown on Table 1 and Figure 2 which follow.

PHASE IV - Two frames were selected for detailed study:

- Frame 14510, 7 February 1973, located in Lago Agrio region of the Oriente. This frame was selected for the forestry and geology interpretations, and enlargements of bands 6 and 7 were made to a scale of 1:250,000.
- Frame 15034, 17 March 1973, located in the Peninsula Santa Elena and lower portion of the Guayas River Basin in the

coastal region, was selected for the hydrological studies. Bands 4 and 7 were enlarged to a scale of 1:250,000.

The photographic enlargements were made by the Military Geographic Institute using semi-map paper and standard photographic procedures.

PHASE V - After the ERTS imagery was interpreted and the existing information reviewed, field inspections of the test sites were made. These were performed by road traverses and aerial inspection from low-flying aircraft. Textural-tonal variations and other anomalous features were inspected and their resolution to ground truth rated.

PHASE VI - The final phase of activities for this program has been the preparation of this report and the final preparation of pertinent maps and graphics.

3.0 PARTICIPATING ECUADORIAN AGENCIES

The following Ecuadorian governmental agencies have participated in this program:

- The National Planning Board
- The Military Geographic Institute
- The Institute of Hydraulic Resources
- The National Hydrology and Meteorology Institute
- The Institute for Land Reform and Colonization
- The Forestry Service
- The Ministry of Agriculture
- The Ministry of Natural Resources
- The National Service for Geology, Mines and Petroleum
- The Commission for the Development of the Guayas River Basin

4. FORESTRY INVESTIGATIONS

4.1 Physical Setting and Existing Information

The forestry and vegetation analysis of the Ecuador ERTS frames was accomplished by a selected team of Ecuadorian scientists. The team selected two ERTS frames, #14510 and #14513, dated 7 February 1973 for detailed study in bands 5, 6 and 7. Cloud cover on the frames of this date was approximately 30 percent.

The frames covered a portion of the Oriente region east of the Andes approximately 0°00' latitude and W77°30' to W76°30' longitude. This region in eastern Ecuador consists mostly of tropical hardwood forests. In addition, there exist in certain localities parcels of agriculture and petroleum exploration activity. The quality and quantity of commercially valuable woods is variable. A determining factor in this region is soils and topography. Little botanical or soils information, however, is available for this region. In the face of the current lack of knowledge, efforts are being made by JuntaPlan to increase the data base of information in order to implement a colonization project for this region in the near future. It was our objective, in part, to determine the feasibility of extracting useful data from existing ERTS coverage which would be applicable to the further development of the colonization project sought by JuntaPlan.

4.2 Techniques of Interpretation

To prepare for interpretation of the ERTS frames, we first examined existing aerial photo mosaics provided by IGM. The photographic quality of the mosaic enabled us to gain another level of knowledge of the ERTS coverage that we had not previously had. Vegetation types and conditions were, of course, represented in more detail on the aerial photo index mosaics than on the single ERTS frames.

Examining the ERTS frames mosaic together, we selected from the aerial photo mosaic strips of aerial photos which transected areas of contrast relative to vegetation types and water courses represented on the ERTS frames. We selected strips which transected areas of contrast in both bands 5 and 7 of the ERTS frames. The aerial photos selected were 1:40,000 scale prints, 9 x 9 inch format, produced from Aerographic Infrared film. The dates of photography ranged from 1968 to 1970.

The ERTS frames were enlarged to a scale of 1:250,000 to facilitate interpretation of greater detail than was possible on the 1:1,000,000 contact prints from NASA.

Transparent acetate overlays were placed on the enlargements of bands 5 and 7. Each scientist on the team delineated what he interpreted to be vegetation types and water courses as represented on the imagery in contrasting tones of gray and texture differences.

In addition, each scientist made delineations of contrasting vegetation types and topographic areas on the 1:40,000 aerial photo sample strips. The location of each photo strip was delineated on the ERTS frame so that the additional detail observed on the aerial photos could be related to observed or interpreted differences on the ERTS frames.

This method of interpreting the ERTS coverage seemed to provide the scientists with the broadest and most detailed information available about the region prior to going to the field.

4.3 Results of Interpretation and Field Analysis

After each member of the team finished his delineation of the enlarged ERTS frames, each overlay was superimposed one on another to determine the consistency of interpretation of contrasting features by each member of the team. The correspondence of each overlay to the group of overlays was very high. We found that at this level of interpretation at least we were in agreement as to the location of various features on the landscape.

The additional information gained by interpreting and delineating the 1:40,000 scale aerial photos was significant. We found that changes in vegetation types were highly correlated with changes in topography in this region. In fact, we determined from our interpretation of the aerial photography that large crowned commercially important tree species were occurring most frequently over undulating terrain of low rolling hills. In addition, we determined that the more level topographic regions supported forest stands with a high frequency of smaller diameter hardwoods and palmettos.

The above interpretation led us to infer that the level terrain produced deeper soils than the hilly regions and was probably more suited to agricultural activities.

Comparing the ERTS images with the aerial photography, we found that the high value forest types occurring on the hilly topography were identified on the ERTS images as dark toned granular textured regions. In contrast, the flat terrain lesser value forest areas were light-toned and smooth-textured. These interpretations were best made from bands 6 and 7 rather than from band 5.

Water courses and drainage patterns were also better determined from band 7 than from any other ERTS bands.

To confirm our interpretations of vegetation type and topography, we made a field trip to Santa Cecilia, in the central portion of our ERTS coverage. We made observations from the air in low-flying aircraft and from the ground along existing access roads while in the area. The observations were made along predetermined routes which corresponded to the coverages of our sample 1:40,000 scale aerial photography.

We found our ERTS and aerial photo image interpretations to be almost 100 percent correct. Vegetation types did indeed change with topography. Furthermore, the extent and condition of the changes were very predictable from the ground and from the air with the delineated overlay of the ERTS frame in hand.

The three-part interpretation of ERTS frames, aerial photography, and field confirmation extended our knowledge of ground conditions within the ERTS frames over 20,000 square miles of terrain. The confidence level of this knowledge is determined to be very high.

4.4. Conclusions and Recommendations

From our initial interpretation of these ERTS images we have concluded that the Ecuadorian government can indeed benefit from the use of ERTS images for the purpose of providing vegetation and soils information for undeveloped natural areas.

Intelligent interpretation of high quality images and well planned field visits to clarify and classify interpretations can go a long way in gathering data needed for planning purposes.

Based on this work, our recommendations for including ERTS in planning forestry and agricultural development projects are the following:

- ° Use ERTS enlargements in bands 6 and 7 for interpretation in the region of the proposed colonization project.
- ° Prepare vegetation and soils maps from image interpretation and field checks to identify areas of potential agricultural, industrial and forest product developments.
- ° Attempt to use automated interpretation methods such as digital tape analysis to research further the data contained in ERTS coverage.
- ° Pursue the use of ERTS images throughout all of Ecuador where cloud-free coverage exists.

In addition to the interpretation exercises described in this report, we also used multispectral combining techniques on existing positive transparencies of the selected frames. Due to the marginal photographic quality of these particular transparencies we were unable to produce acceptable color composites of this area. If better quality images become available, however, we would certainly recommend the use of these color-combining techniques to enhance the ERTS imagery obtainable from existing files.

From a cost-benefit standpoint, we conclude that the benefit of using even existing ERTS images and the interpretive techniques for gathering data over so large an area far exceeds the low costs involved. In two weeks time (approximately 30 man-days) we had obtained information that would have taken several man-years to obtain by methods traditionally employed.

5.0 GEOLOGICAL INVESTIGATIONS

5.1 Physical Setting and Existing Information

Of the 10 ERTS frames over Ecuador, only two (taken 7 February 1973) have any area at all clear of clouds. Lago Agrio (ID-1199-14510) has a clear patch 100km x 90km; Puyo, immediately to the south (ID-1199-14513) has a slightly smaller patch. Our analysis was focused initially on Lago Agrio because of ease of access for field checking and because hostile Indians in the Puyo area preclude any field checking there (Figure 1 and Table I). Other data used in this phase of the work included a 1:160,000 scale photo mosaic and 1:40,000 scale black-and-white photography.

Band 7 is the best for analysis; band 6 is fair, and bands 5 and 4 are useful only for the location of the new roads (all culture is post-1965, the date of the aerial photography).

Good 1:40,000 black-and-white aerial photography exists in

AVAILABLE ERTS IMAGERY ECUADOR 10 SEPT. 1973

ERTS FRAME NUMBER	DATE	BAND NUMBER	% CLOUD COVER	% FRAME USABLE	LAND MARK
15025	17 Mar./73	4,5,7	95	0	Esmeraldas
15022	17 Mar./73	5,6,7	50	10	San Lorenzo
14510	7 Feb./73	4,5,6,7	30	25	Lago Agrio
14513	7 Feb./73	4,5,7,6	40	30	Puyo
15034	17 Mar./73	4,5,6,7	20	30	Santa Elena
15040	17 Mar./73	5,6,7,4	10	10	Río Alamor
15031	17 Mar./73	5,7,6,4	80	5	Bahía de Caráquez
14565	23 Oct./72	4,5,6	95	-	Ambato
14562	23 Oct./72	4,5,7	95	5	Quito
14560	23 Oct./72	4,5,7	75	2	Carchi

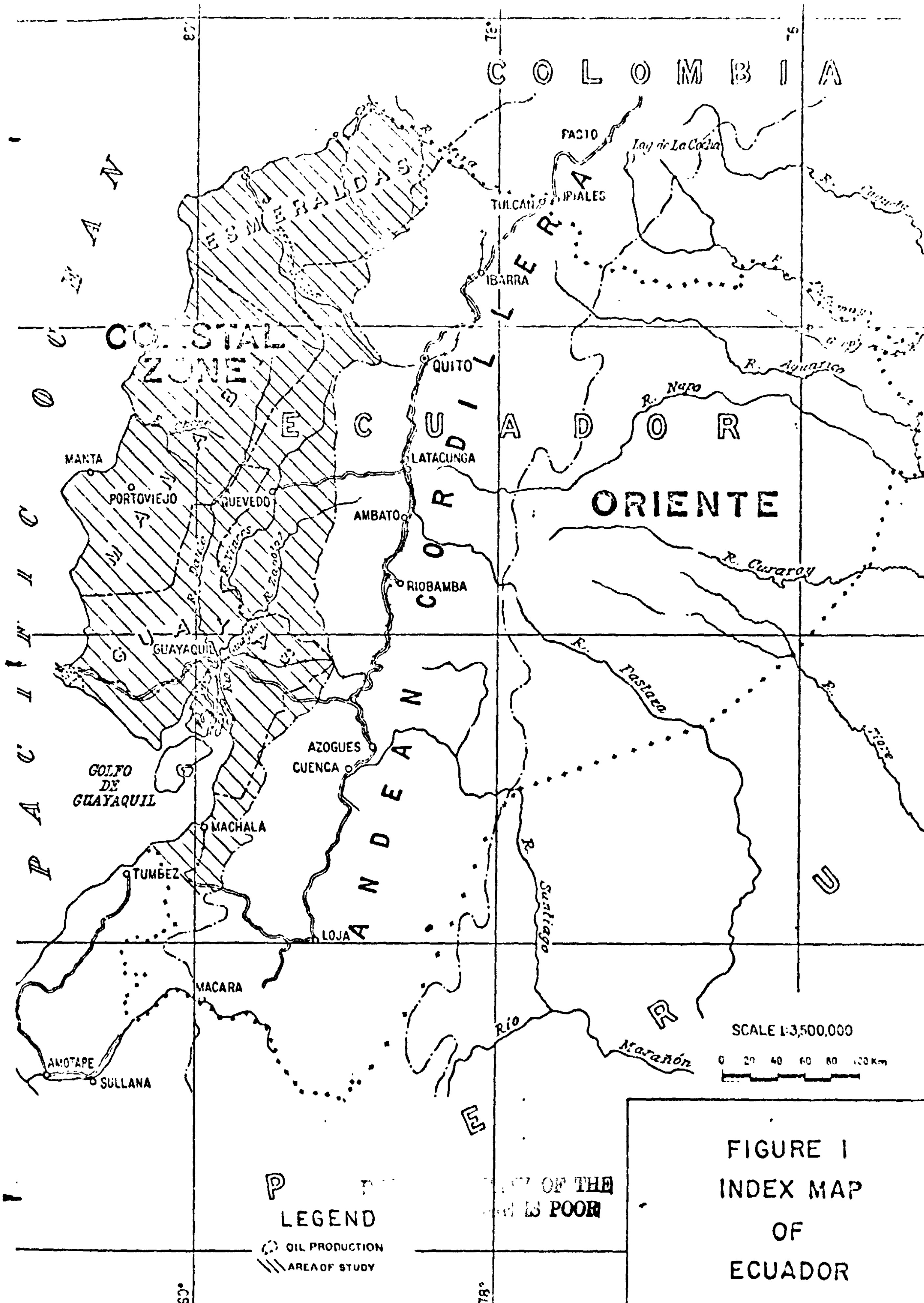
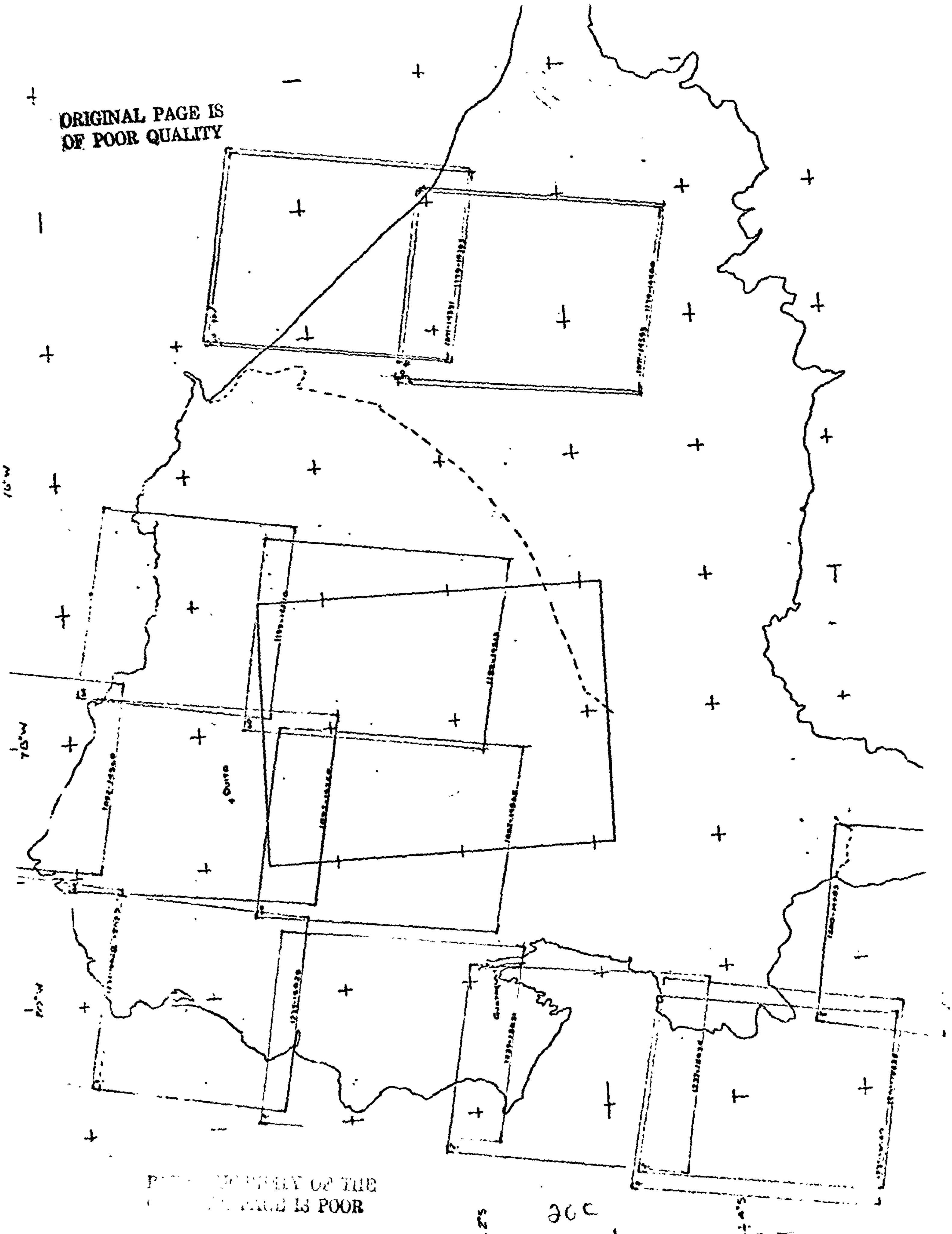


FIGURE I
INDEX MAP
OF
ECUADOR



Quito along with a good but uncontrolled photo mosaic at 1:160,000 scale. The rest of this discussion will be concerned with band 7 of the one ERTS frame (Lago Agrio) and the conventional aerial photography.

Centrally, in this ERTS frame are four main rivers which are essentially flowing east-west into the Amazon Basin. From north to south these are the Rio Putamayo and Rio San Miguel (which together from the boundary with Colombia), the Rio Aguarico and the Rio Napo (the last named being by far the largest). Towns, or even villages, are few and far between and, with the exception of Lago Agrio Texaco's oil operations base, are all on the river systems. The base of Santa Cecilia, originally the base for all early exploration of northern Oriente, is now used by the Ecuadorian Army as a base for their operations. On the Rio Negro, the town of Coca (under clouds in this ERTS frame) is at the junction of the Rio Coca and Rio Negro. Downstream about 35 km is the airfield of Limocoocha, near an arrow-shaped lake slightly north of the river.

Airfields exist at Lago Agrio Santa Cecilia, Coca and Limococha, and service fields for STOL aircraft exist at each oil field. Roads exist to service the oil fields. The main access from Quito enters the Oriente at Aguarico via Baeza, passing to the north of Santa Cecilia directly east to the pipeline center of Lago Agrio. At this town, roads branch to the south, with subsidiary roads to the north and further to the east. About 30km south of Lago Agrio a road branches east directly to the

Sushufindi oil field (22km away), and the main road passes to the south-southwest to Coca about 40km further on, running down the axis of the large Sasha oil field. All roads are gravel cobbles, based often on corduroy (timber) base in boggy ground, but suitable for jeep or rough auto travel.

5.2 Results of ERTS Interpretation

The dominant tone contrasts on band 7 are patches of evenly darker tone distributed across a background of light, evenly toned jungle. (These will be referred to as "dark" and "light" tone terrain types.) Based on air and ground check, darker tones represent a taller and more diverse forest, while the lighter toned are low, even jungle with many tall palms. Other features are the rivers (black) and a few gologically significant lakes (Lago Agrio, especially), and the roads and closely adjacent native farming which image light on band 7 and dark on band 5. One anomalous signature is that of a new road possibly cleared and not yet surfaces (as of 7 February 1973) running south from the main road to Rio Aguarico about 16km west of Santa Cecilia.

The Oriente is essentially a very flat outwash plain about 350 meters sea level, sloping to the east and southeast into the Amazon Basin. From a more geological point of view, the dark areas were slightly higher in elevation (10-20 meters relief), more closely dissected, and better drained. The roads curved in these areas, taking advantage of the contours to avoid a cut-and-fill, but the main road cuts showed a crude stratigraphy from top bottom of muddy clays (2-5 meters), pebbly or gritty clays (2 meters), and a basal muddy "conglomerate" characterized by large water-worn rounded boulders 10-15 cm in diameter, variously distributed approximately 1 to 4 per cubic meter of mud. (In the Arizona area in the United States, these "mud flows" are locally termed "fanglomerates.")

The lighter toned areas were heavy clay, very slight relief, heavily water-logged, with poor drainage and much standing water. Despite this water, which images black on band 7, the overall tone was lighter doubtless due to a combination of broader-leafed bush vegetation (white reflection) in the flat country in contrast to the shadowed areas (sun elevation 49°) in the dissected higher relief, taller-timbered areas. For the relative distribution of these two terrain types, see Drawing No. 3 (attached) which is now at the same scale, 1:1,000,000, as the ERTS frame.

5.2.1 Geological Structure - Lineament Analysis

The striking feature of both the ERTS frame and the 1:160,000 photo mosaic is the even, featureless character of the Oriente jungle and by these four almost parallel main rivers running east into the Amazon.

Detailed analysis of ERTS was keyed to the anomalous orientation (north 45° east) of the 2km long, thin lake, Lago Agrio, lying about 6km north of the Rio Aguarico. On this same trend was Santa Cecilia at the river, and to the northeast the ERTS frame showed a thin track or road continuing across the San Miguel toward the Putamayo as a thin vegetation anomaly (lighter). In all this, " Lago Agrio trend" could be traced on ERTS for at least 90km. This significant structural trend was verified using the 1:160,000 scale mosaic and the parent 1:40,000 scale photos, which predate any road-building and farming activities.

The resulting detailed geological analysis revealed the following points:

- Lago Agrio was the sole remnant of an old bed of the San Miguel River (southeastern San Miguel) which tapped the headwaters of what is now the Aguarico River. River capture occurred at what is now called Santa Cecilia, and the more active Aguarico took the headwaters of the southeastern San

Miguel. The intervening channel dried up, became overgrown with new jungle, leaving only Lago Agrio.

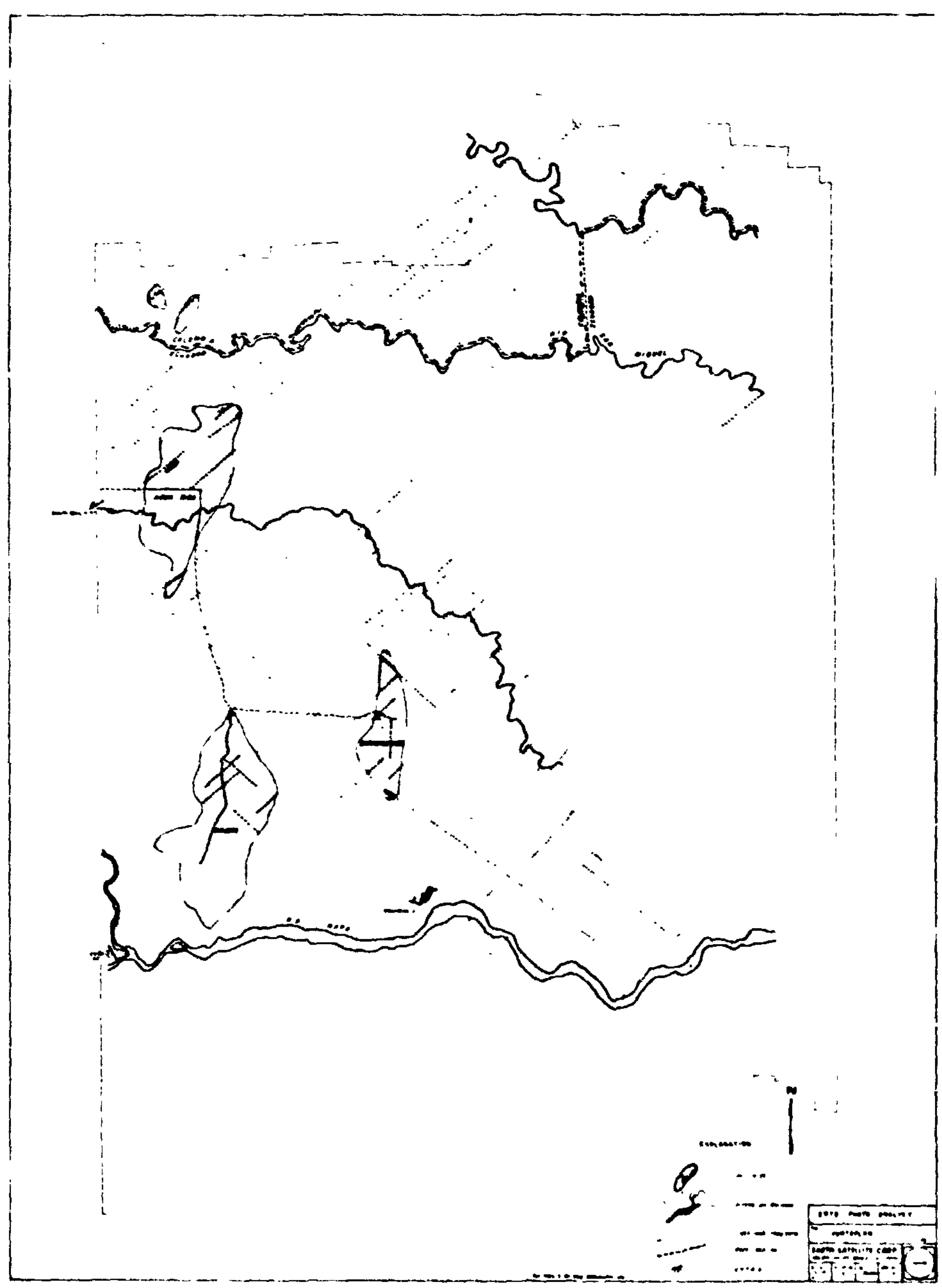
- This N50°E trend can also be found in many other places in the Oriente, and 45 to 50 parallel structures were recognized and located on this ERTS frame (see Drawing No. 1, attached).
- South of Sushufindi, the structures (7) ran more northwesterly with a few (4) approximating a north-south trend at the northern edge of the Sa ha field.

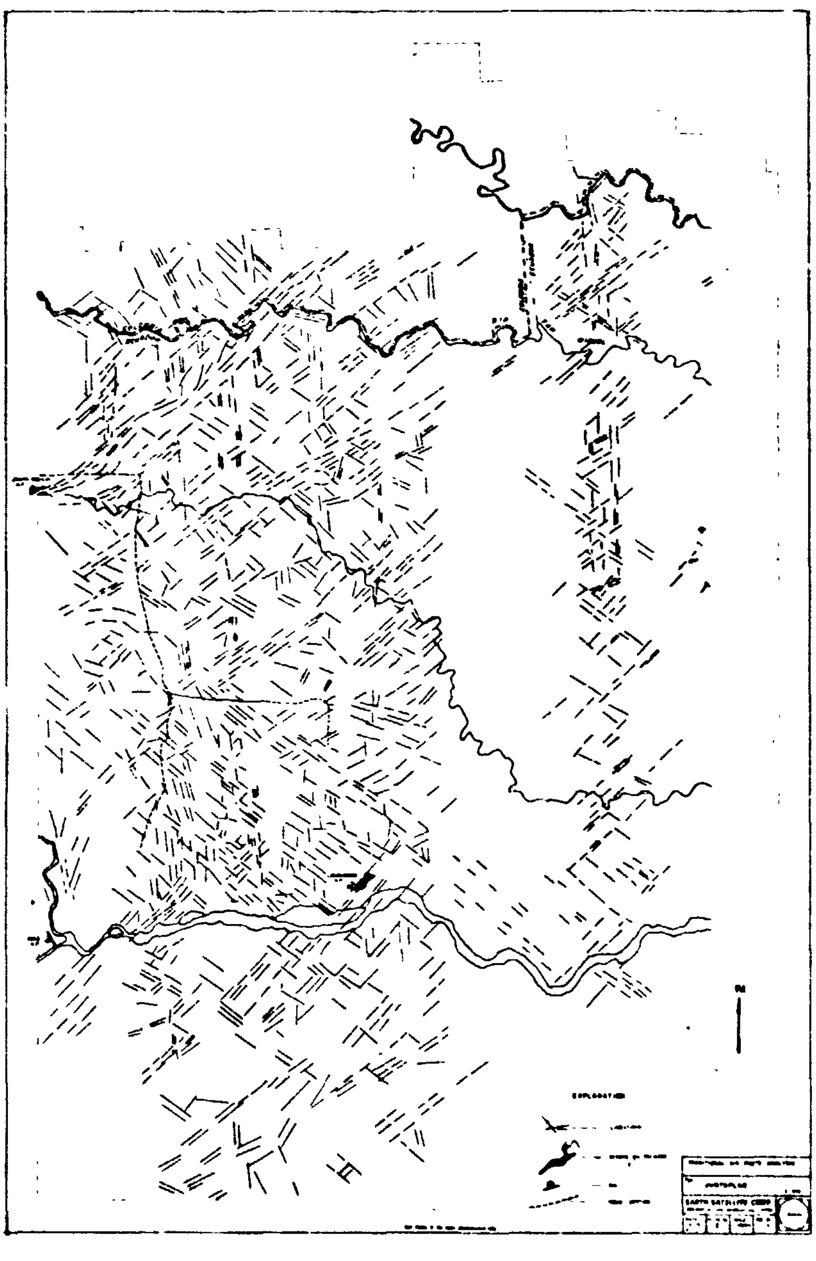
5.3 Review of 1:40,000 Scale Photography with New Insights from ERTS Analysis

In order to confirm this structural analysis based on ERTS imagery, an analysis of the 600 1:40,000 scale air photos was undertaken. Linears were defined and transferred to the photo mosaic (a 1:160,000 reduction of a compilation of some 1965 photography), now prepared as Drawing No. 2.

The two types of terrain recognized on ERTS were readily observable at the 1:40,000 scale, not so much as darker tones but as more rugged terrain and flat terrain. These broad areas were outlined and their bound[illegible] transferred to the same 1:160,000 scale base now prepared as Drawin[illegible] 3.

Principal findings are:





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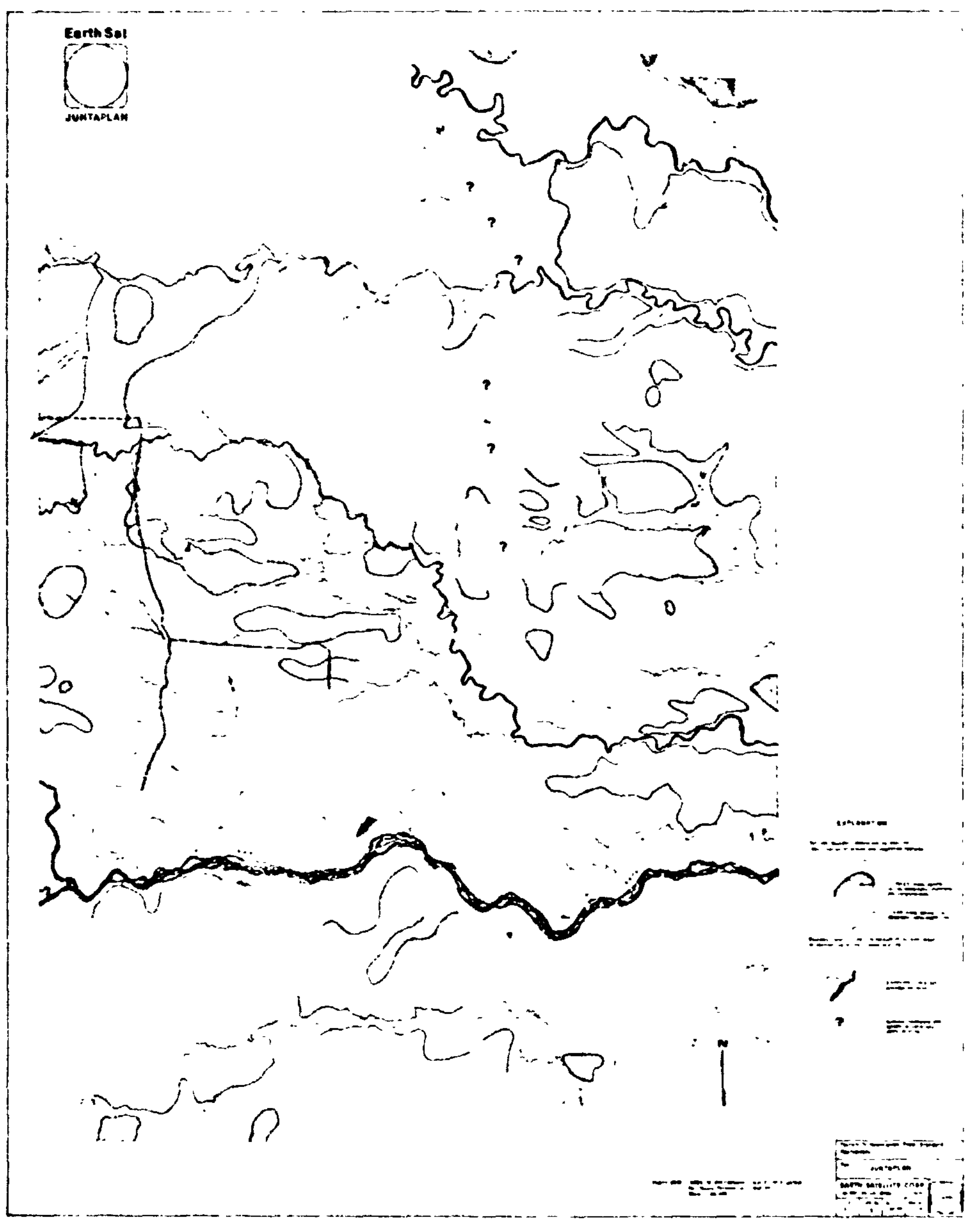
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- N50°E trend (Lago Agrio) is confirmed both in direction and in geographic position.
- Lago Agrio now clearly lying in an old river bed along this major structure.
- More north-south linears in regular photography.
- Northwest trend confirmed in lower sector south of Sushufindi but also commonly present elsewhere.
- Essentially ERTS filters out noise detail and links the structural information so that major structures are more clearly seen.
- Photo reduction of the 1:160,000 scale to 1:1,000,000 ERTS scale as positive transparencies enable both the original ERTS and its analysis to be concurrently viewed.
- The progression from the ERTS overview and analysis logically back to 1:40,000 scale photography with new insights gained from ERTS enables the same features to be verified, transferred to the intermediate scale (1:160,000), and back down to ERTS scale for overlays. This repetitive iteration in scales is a vital link both for establishing the validity of the ERTS analysis and as a vehicle for training interpreters more accustomed to traditional 1:40,000 scale data.

6.0 HYDROLOGICAL INVESTIGATIONS

Frame 15034 images portions of two distinct hydrological provinces in the coastal region of Ecuador. These are:

- The lower regions of the Guayas River Basin, the largest river in South America draining into the Pacific Ocean;
- Portions of the Santa Elena Peninsula, an arid region where the lack of water is the primary barrier to agricultural development and the expansion of the tourist industry.

6.1 Guayas River Basin Interpretation

The lower Guayas River Basin has two distinctive seasons: January through May or June (the wet season), and June through December (a very dry season).

The hydrologic problems are relatively straightforward: a need during the wet season to control annual flooding of farm land, and the need to irrigate agricultural crops during the dry season.

The ERTS interpretation was done by using both band 4 and band 7 imagery. Interpretation was done on both positive transparencies and prints at a scale of 1:1,000,000 and prints of the band 7 at a scale of 1:500,000.

Standard photo interpretation techniques were employed. Shape, tonal and textural variations were of equal importance to the interpreter.

Clouds covered over 50% of all the ERTS imagery received; dry-season imagery would have been extremely valuable for comparison purposes had it been available.

The ERTS imagery used during this study was taken on March 17, 1973 during the annual floods and indicates the following:

- That substantial and dynamic changes have recently occurred in the landforms and channel patterns within the river basin. This is most obvious when the band 7 imagery is compared to existing (1968) 1:50,000 scale topographic maps, which reveals a marked difference in the distributary patterns and areas susceptible to flooding.
- That it is possible to map in considerable detail land areas being inundated by flood waters and to determine the areal extent of flooding.

From the first-noted indication above, it is obvious that the patterns of flooding change over several years - probably from year-to-year and during a particular season.

Thus, repetitive ERTS coverage would provide an excellent tool for keeping track of these changes and hopefully lead to a mechanism for predicting these changes that have such a profound impact on society and agriculture in the area.

The interpreted and field check data have been transferred to existing 1:50,000 scale maps and are attached as part of this report (see pocket maps).

It is the opinion of the investigators that repeated ERTS coverage of the Guayas River Basin would be a valuable tool in the planning of needed civil works to control the waters of this river system and raise the agricultural yield of this region to its fullest potential. The imagery is also an excellent tool for monitoring inundation prior to completion of flood control and irrigation works, as well as an excellent source of information for updating maps of this dynamic area.

6.2 <u>Peninsula Santa Elena Interpretation</u>

The peninsula Santa Elena is an arid to semi-arid region. Today, the primary industry of the region is tourism. Some petroleum is produced, but it is of poor quality and yields are low.

The peninsula has not always been arid. During the first twenty or 30 years of this century a large percentage of Ecuador's truck crops and dairy products were produced in this region.

The major hindrance to development in this area is therefore the lack of a dependable source of water for:

° human and animal consumption

° agricultural irrigation.

The potential sources of water [illegible] fulfill the first, and possibly the second, nee[illegible]

- Diversion of waters from the Rio Doule (a major river in the Guayas River Basin*),
- The exploration and development of groundwater resources.
- The control of waters from the Valdivia River, the only perennial stream in this region.
- The conversion of sea water to fresh water.

Examination of ERTS frame 15034, band 7 and band 4, indicates that on 17 March 1973 over large portions of the area the soil moisture content is quite high. It is also indicated that none of the intermittent streams of the region contain any water of any quantity. The situation in the Valdivia River Basin is unknown because of cloud cover.

A hydrogeological interpretation of a portion of the ERTS band 7 photo indicates that:

- the major fault system in this region can be delineated,
- lithologic variations are mappable, and
- areas of relatively high soil moisture content are mappable.

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* This solution would have to be seriously studied as it would drastically reduce available water needed for irrigation within the Guayas Basin and would most probably be extremely expensive.

This ERTS interpreted data should be of value to those government agencies interested in general geologic mapping and the exploration and development of sources of groundwater.

This interpretation is presented in Figure 3 of this report.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Forestry

Based on the work in forestry, we found that in the Oriente area well-drained forests containing commercially valuable hardwoods can be recognized confidently and delineated quickly on the ERTS imagery. This conclusion is based on checking the ERTS image interpretations with air photos, low altitude reconnaissance overflights, and field work in the area. We conclude from this work that ERTS imagery can provide a significant amount of the information on vegetation, soils and drainage necessary to plan large regional development projects.

We conclude that the Ecuadorian government can indeed benefit from the use of ERTS images for the purpose of providing vegetation and soils information for undeveloped natural areas.

Intelligent interpretation of high quality images and well planned field visits to clarify and classify interpretations can go a long way in gathering data needed for planning purposes. Based on this work, our recommendations for including ERTS in planning forestry and agricultural development projects are the following:

- Use ERTS enlargements in bands 6 and 7 for interpretation in the region of the proposed colonization project.
- Prepare vegetation and soils maps from image interpretation and field checks to identify areas of potential agricultural, industrial and forest product development.
- Attempt to use automated interpretation methods such as digital tape analysis to research further the data contained in ERTS coverage.
- Pursue the use of ERTS images throughout all of Ecuador where cloud-free coverage exists.

In addition to the interpretation exercises described in this report, we also used multispectral combining techniques on existing positive transparencies of the selected frames. Due to the marginal photographic quality of these particular transparencies, we were unable to produce acceptable color composites of this area. If better quality images become available, however, we would certainly recommend the use of these color-combining techniques to enhance the ERTS imagery obtainable from existing files.

7.2 Geology

The work in geology in the Oriente area led to the following conclusions:

- That even in the tropical rainforest ERTS can provide an abundance of inferential information about large-scale geologic structures (e.g., the major fractures that seem to control several of the oil fields);

- That ERTS imagery is better than normal aerial photography for recognizing linears in this area;
- That working iteratively among ERTS images, photo mosaics, and 1:40,000 photography provides a vital link for extracting the maximum amount of information from each type of imagery and for training interpreters, who are accustomed to standard photography, how to use ERTS imagery;
- That major inferences about the geomorphic development of the area can be drawn from ERTS imagery (e.g., recognizing the capture of the Rio San Miguel by Rio Aguarico).

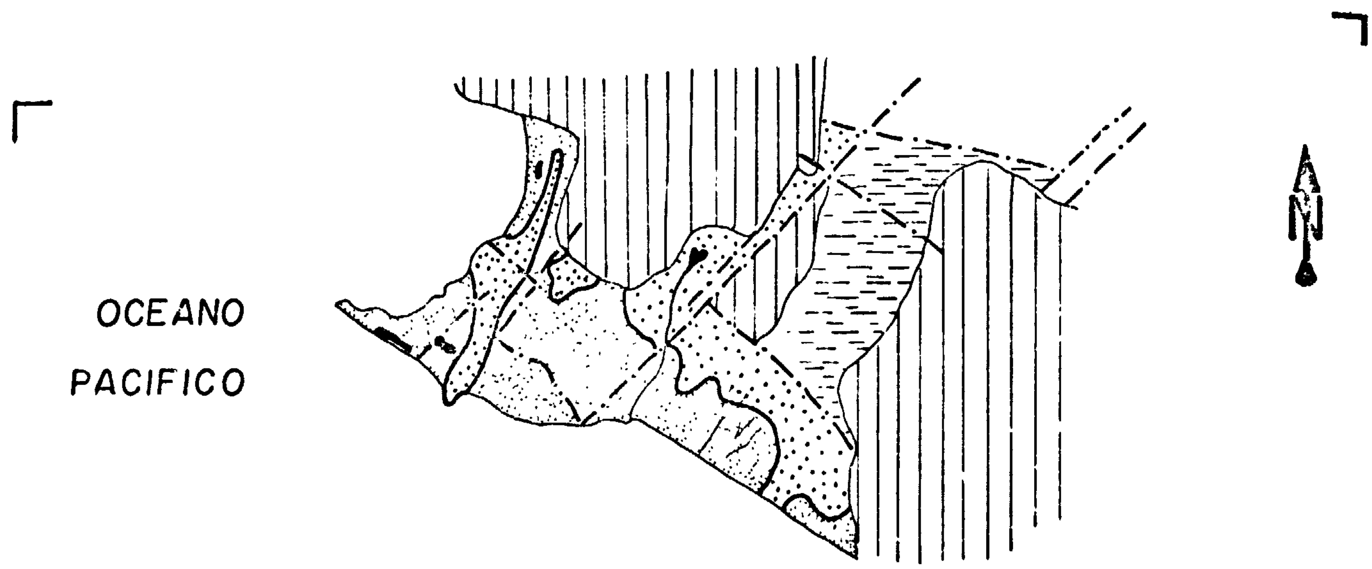
7.3 Hydrology

Planning and controlling annual inundations of portions of the Guayas River Basin would be greatly aided by constant ERTS imaging of the river basin during the months of January through May of each year. This coverage would permit accurate estimations of the needed civil works to prevent flooding. In this connection, the imagery is particularly useful for updating maps of the distributary system of the Guayas River Basin and of any other river with a similarly rapidly changing channel pattern.

Monthly imaging during June through December by band 7 imagery would permit estimations of soil moisture content and would aid in assessing the need for and quantity of water needed for irrigation.

INTERPRETACION HIDROGEOLOGICA DE LA PENINSULA DE SANTA ELENA (PROVINCIA DEL GUAYAS-ECUADOR-), EN BASE A ERTS Nº 182 BANDA 7

ESCALA 1:1'000.000



LEYENDA

- Zona cubierta por nubes.
- Depósitos de agua.
- Sistemas de Fractura.
- Drenaje.
- Contacto Geológico.
- Depósitos de Costa o Recientes.
- " Competentes ≃ areniscas.
- " Medianamente Competentes ≃ arcillas