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FINAL REPORT
GEOTHERMAL RESOURCES PROJECT-STAGE ONE

PART 1

PROJECT SUMMARY

USAID Loan

Prepared for
GOVERNMENT OF NICARAGUA
Ministry of Economy, Industry and Commerce

By
D.E. Heilner and L.T. Braun
TEXAS INSTRUMENTS INCORPORATED
Services Group

February 1971

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PREFACE

This Final Report on STAGE ONE of the Nicaraguan GEOTHERMAL RESOURCES PROJECT is submitted to the Government of Nicaragua by TEXAS INSTRUMENTS INCORPORATED in Spanish and English versions.

The report is the work of several authors and consists of ten parts, or chapters, each of which is bound separately, as follows:

Part 1 - PROJECT SUMMARY, by D. E. Heilner and L. T. Braun

Part 2 - REGIONAL GEOLOGY: Thermal Manifestations of Western Nicaragua, by John B. Thigpen

Part 3 - SURFACE GEOLOGY: San Jacinto-Tisate-Najo Area, by John B. Thigpen

Part 4 - SURFACE GEOLOGY: South Volcan Momotombo Fumaroles, by John B. Thigpen

Part 5 - GRAVITY AND MAGNETIC SURVEYS, by Mario Mazzolini

Part 6 - ELECTRICAL GEOPHYSICAL SURVEYS in Relation to the Location of Geothermal Power Resources in Northwestern Nicaragua, by George Keller and Norman Harthill

Part 7 - GEOCHEMISTRY of the Nicaraguan Geothermal Project Area, by R. Bennett

Part 8 - TEMPERATURE GRADIENT WELLS at San Jacinto and South Volcan Momotombo, by R. Bennett

Part 9 - DEEP BOREHOLE TEST at the South Volcan Momotombo Fumarole Area, by John B. Thigpen

Part 10 - CONCLUSIONS AND RECOMMENDATIONS, by Texas Instruments Staff and Consultants

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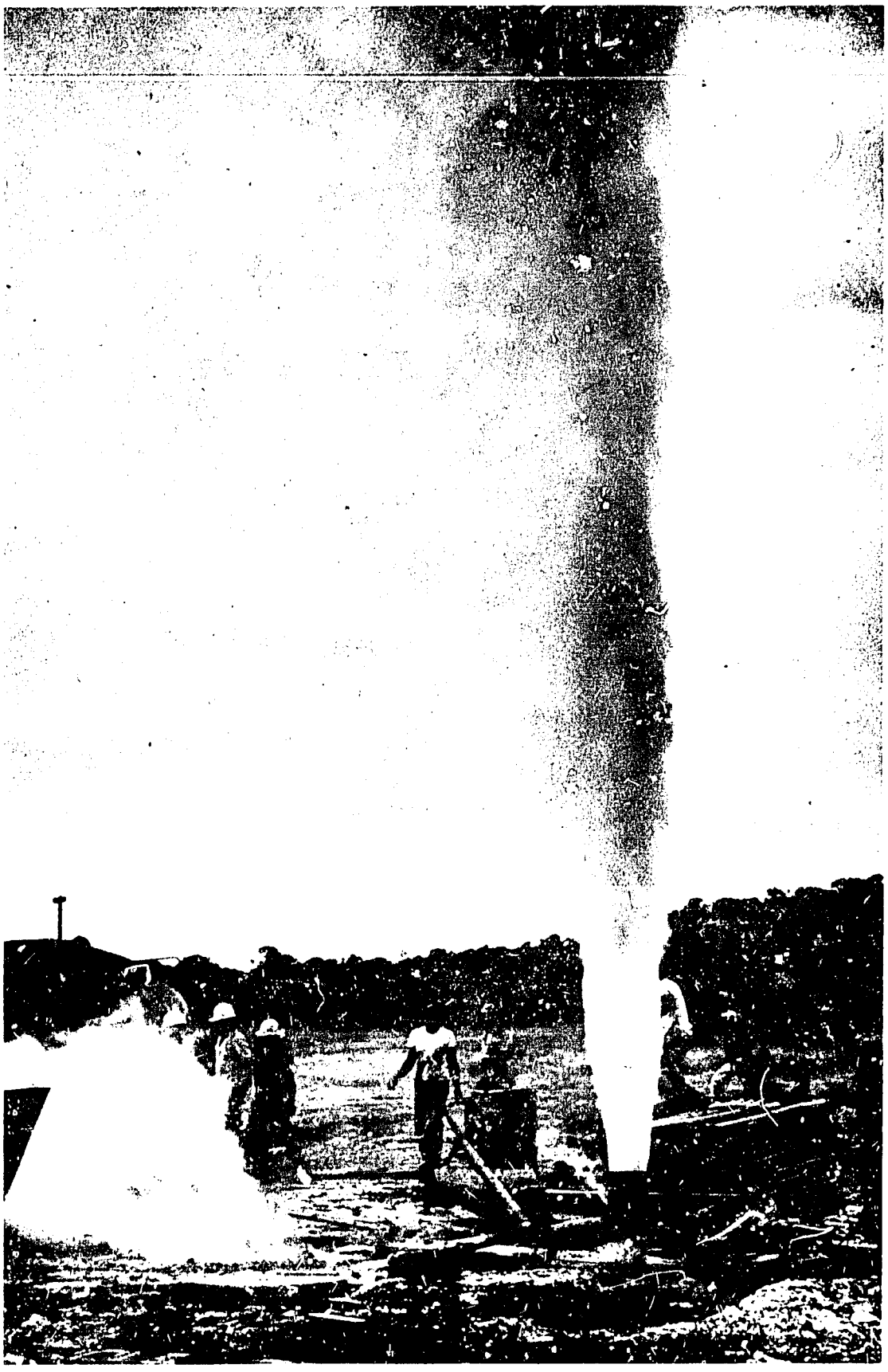

Initial eruption of deep borehole MT-1 from 9 5/8 inch casing, 4 Dec. 1970, Momotombo geothermal prospect.

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Erupcion inicial del pozo profundo MT-1 desde la encajada de 9 5/8 pulgadas, 4 Dec. 1970, perspectiva geotermal de Momotombo.

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FINAL REPORT-NICARAGUAN GEOTHERMAL RESOURCES PROJECT-STAGE I

INTRODUCTION

In June 1969, after approximately 18 months of negotiations, the Government of Nicaragua entered into a contract with Texas Instruments Incorporated to carry out a survey of the geothermal resources of western Nicaragua. The cost-plus-ten-percent fixed fee contract was originally valued at U.S.$455,479.00. This figure was later amended to U.S.$639,400.00. The objective of the survey was to complete Stage I of a three-stage program which was outlined by the Government as follows:

Stage I - Location and delineation of a potential geothermal field or fields.

Stage II - Proving of a potential geothermal field or fields by deep exploratory drilling.

Stage III - Design and development for steam and power production.

The studies involved in Stage I were financed through a USAID Loan Agreement with the Government of Nicaragua. The Government's direct contribution to the survey included a duty- and tax-free environment, project vehicles and fuel, office space, laboratory services, and administrative, technical, and other personnel.

Stage I studies were completed in February 1971. The results and recommendations are presented in a series of ten chapters which collectively comprise the Final Report on Stage I. The ten chapters, or parts, are listed in the foregoing Preface.

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Figure 1 is an index map of western Nicaragua showing the locations of the two fumarole areas in which detailed investigations were made, at South Volcan Momotombo and San Jacinto-Tisate, as well as the reconnaissance gravity-magnetometer survey which crossed the major northwesterly trending geologic features of the project area.

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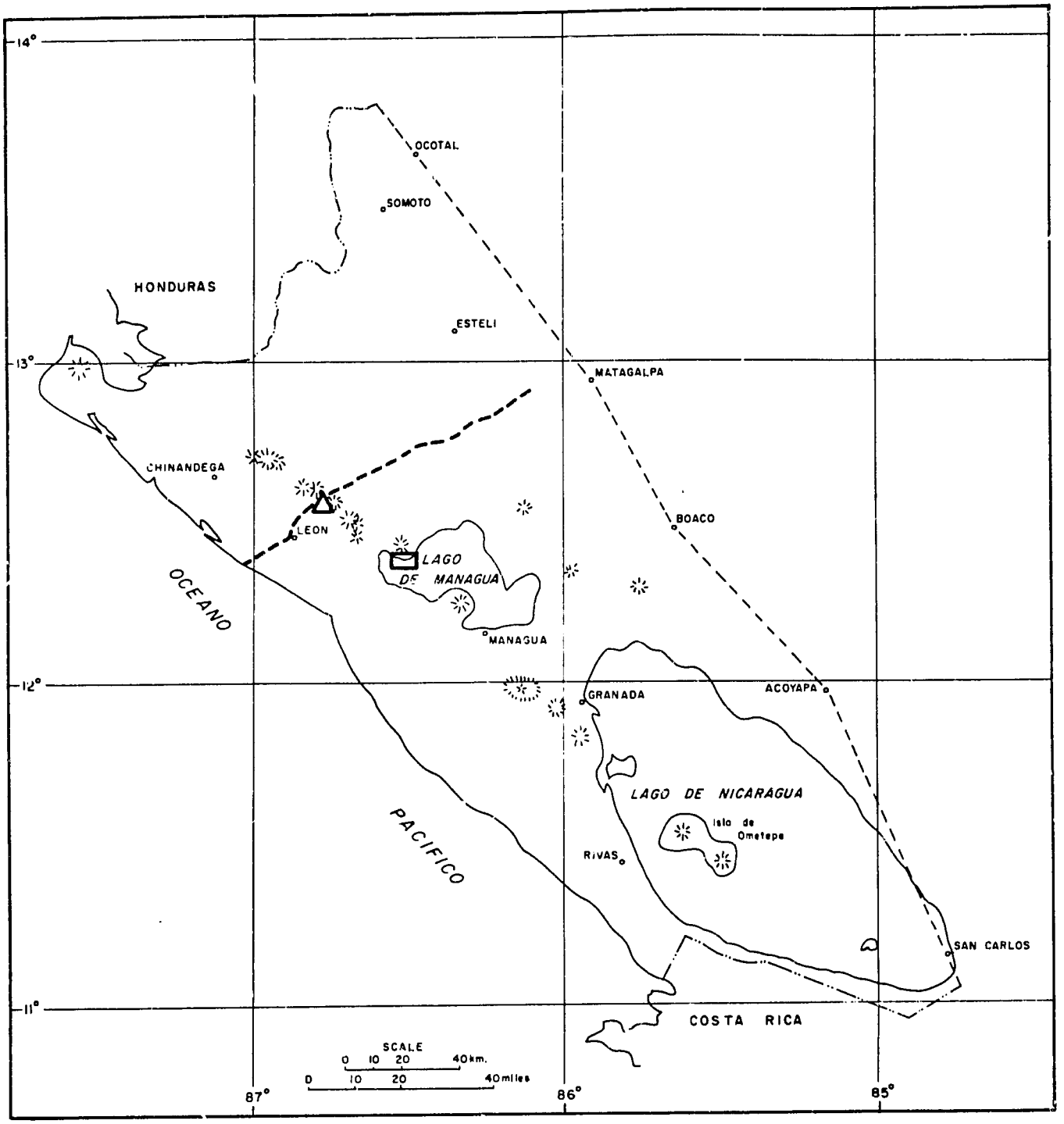

FIGURE I INDEX MAP

NICARAGUAN GEOTHERMAL RESOURCES PROJECT STAGE I

▭ SOUTH VOLCAN MOMOTOMBO FUMAROLES

△ SAN JACINTO – TISATE FUMAROLES

-- RECONNAISSANCE GRAVITY - MAGNETOMETER SURVEY

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PROJECT PERSONNEL

The Geothermal Survey was carried out under the overall authority of the Executive Director, who was appointed by the Government of Nicaragua. The Executive Director was also the Director of the National Geological Service. This post was filled by Dr. Eduardo Rodenzo C. until January 1970, then by Eng. Pablo Martinez N., and finally by Eng. Orlando Rodriguez M., in January and February 1971.

Mr. William H. Slack was Texas Instruments' resident Project Manager until November 19, 1969, at which time he resigned for personal reasons. Mr. Donald E. Heilner was then appointed Project Manager, and the project was completed under his guidance. Mr. L. T. Braun represented Texas Instruments during contract negotiations, and later served as home office liaison.

Consultants

Texas Instruments employed the services of three well-known experts in the several disciplines relating to geothermal energy. The Consultants provided guidance through field and home-office consultations, and contributed to Part 10 (Conclusions and Recommendations) of this Final Report. The three Consultants were:

Dr. Frederick A.F. Berry, University of California (Berkeley).

Dr. Gunnar Bodvarsson, Oregon State University.

Dr. George V. Keller, Colorado School of Mines.

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On several occasions, Dr. Donald E. White of the United States Geological Survey, acting as advisor to USAID, met with Texas Instruments personnel and their Consultants.

Other project personnel were as follows:

Texas Instruments Personnel

John Thigpen:	Mr. Thigpen served throughout the duration of the project. Initially, he carried out the regional geological survey of western Nicaragua, and later completed the detailed geological surveys of the Momotombo and San Jacinto-Tisate fumarole areas. He assisted in the drilling program.
Frank L. Doyle:	Mr. Doyle joined the project in July 1969 and left in June 1970. During this period he contributed to the geological survey of the San Jacinto-Tisate and Momotombo areas.
Richmond Bennett:	Mr. Bennett joined the project in January 1970, as Geochemist. He conducted the geochemical survey and supervised the laboratory analyses of geochemical samples. Later he supervised the drilling and testing of the temperature gradient bores.
Mario Mazzolini:	Mr. Mazzolini was attached to the project from February 1, 1970 to July 14, 1970, during which time he carried out several gravity and magnetic surveys, both on regional and detailed levels.
Jonathan Herrod:	Mr. Herrod joined the project on May 3, 1970 in the capacity of driller and remained until December 14, 1970.
Frank Cherniwchan:	Mr. Cherniwchan joined the project on October 25, 1970 in the capacity of driller and remained until December 22, 1970.
Wilbur Sellgren:	Mr. Sellgren was engaged as a driller from July 25, 1970 to September 10, 1970.
David Woods:	Mr. Woods joined the project on November 14, 1970 in the capacity of driller and remained until December 12, 1970.
Miguel Robelto:	Mr. Robelto served as accountant for the project from mid-June 1969 until project completion.

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Independent Contractors

Norman Harthill:	As a member of GROUP SEVEN, an independent geophysical consulting firm with headquarters in Golden, Colorado, Mr. Harthill conducted the electrical geophysical surveys under supervision of George Keller.
Sveinn Scheving:	Mr. Scheving was an independent contract driller from Iceland who was employed by the project from April 16, 1970 to July 1, 1970.
P. J. Moore:	Mr. Moore, an independent contract driller and Drilling Consultant worked from November 25, 1970 to field work completion December 14, 1970.

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Government of Nicaragua Personnel

The following personnel from the National Geological Service were in attendance at the end of the project:

Lorna de Campos - Bilingual Secretary

Alicia de Clayton - Secretary

Elisa Lopez - Office Assistant

Manuel Z. Melendez - Driver

Francisco J. Morales - Driver

Luis A. Yescas - Draftsman

Texas Instruments wishes to acknowledge the assistance provided by many officials in the Government of Nicaragua, particularly Dr. Luis Mejia Gonzalez - General Coordinator of Technical Assistance and International Organizations.

USAID

Texas Instruments acknowledges the assistance of Mr. Carl Forsberg, Chief Engineer, and of Mr. Alexander Gregg, Assistant Officer of USAID.

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TECHNICAL SUMMARY

The investigations undertaken by Texas Instruments to locate and delineate a potential geothermal field or fields in western Nicaragua included compilation of data on thermal manifestations, regional and detailed geologic mapping, geophysical and geochemical surveys, drilling of shallow temperature-gradient wells, and drilling of a deep borehole test. Parts 2 through 10 of this Final Report describe these investigations and present the data obtained, with its interpretation, as well as Texas Instruments' conclusions and recommendations. A brief summary of each part, or chapter, follows:

Regional Geology: Thermal Manifestations of Western Nicaragua

The geology of Western Nicaragua is dominated by the Nicaraguan Depression, a northwest-trending tilted fault block or graben. Along the southwest margin of the depression occur a chain of volcanic massifs and individual composite volcanoes of Quaternary age. Some of the volcanoes are intermittently active. Upper Cretaceous to Pliocene sedimentary rocks occur in the south part of the area west of the depression. Tertiary volcanic rocks, with minor igneous intrusions, Paleozoic metamorphic rocks, and Miocene sedimentary rocks in the north part, cover the area east of the depression.

A regional evaluation of thermal manifestations in Western Nicaragua from Sept. 1969 to July 1970 revealed numerous fumaroles, hydrothermally altered areas, thermal springs, and thermal water wells.

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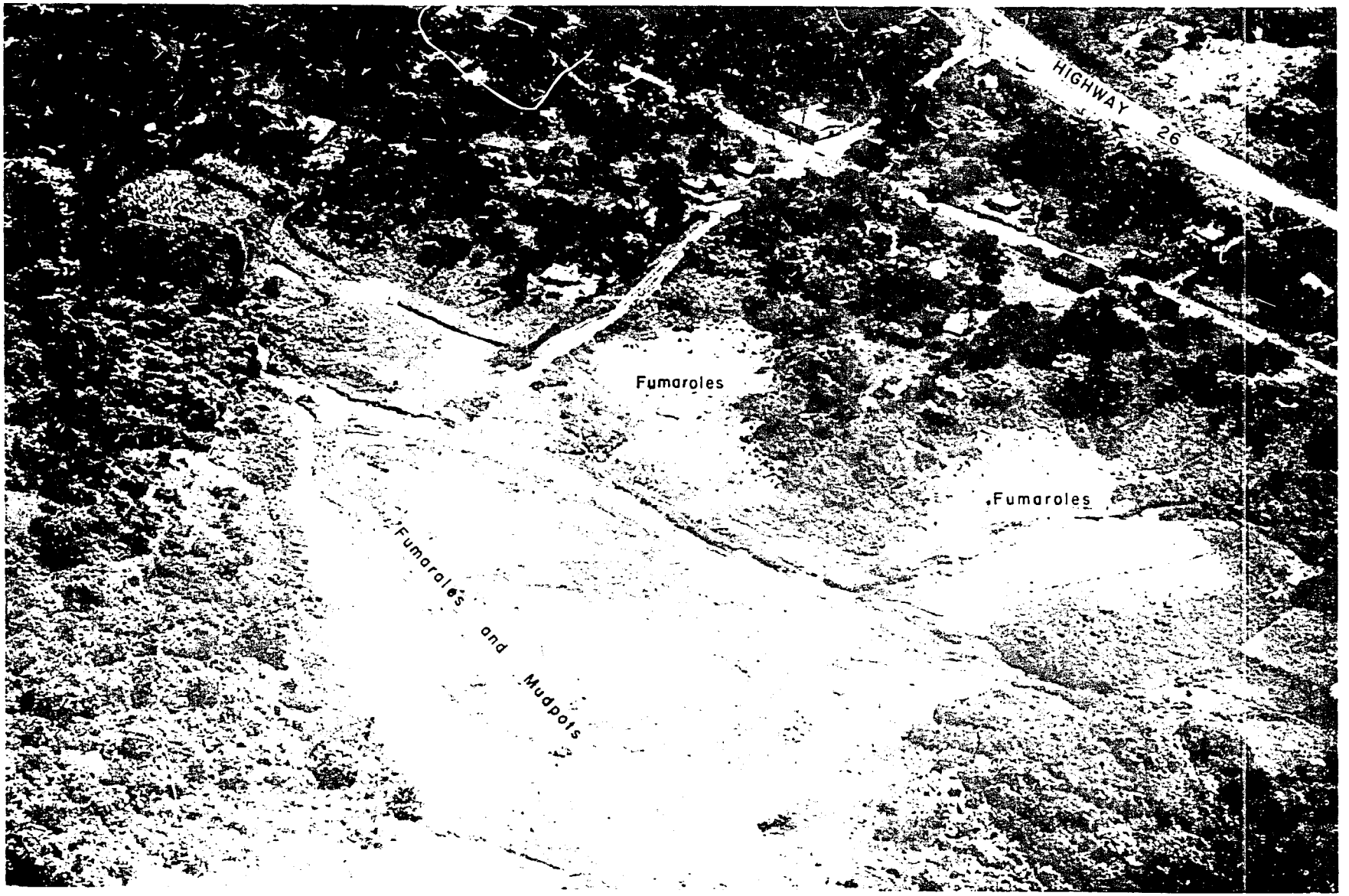

Aerial view of San Jacinto fumarole area looking east, with San Jacinto village beyond.

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Vista aerea este del area fumarola de San Jacinto, con el pueblo de San Jacinto detras.

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These thermal manifestations are mostly associated with the young volcanoes and the adjacent Nicaraguan Depression, indicating a higher than normal heat flow. The heat flow in the Pacific Coastal Plain and Interior Highlands is apparently near normal since few thermal manifestations are present.

Ten thermal areas, with varying attributes, indicate potential present or future geothermal power prospects. Five of these areas consist mainly of fumaroles, two of fumaroles and thermal springs, two of thermal springs, and one of thermal wells.

The two most favorable thermal areas, South Volcan Momotombo fumaroles and San Jacinto-Tisate fumaroles, were selected for detailed geological, geophysical, geochemical, and drilling investigations.

Surface Geology: San Jacinto-Tisate-Najo Area

Hydrothermally altered areas, active fumaroles and minor thermal springs occur in localized zones at the village of San Jacinto, at Tisate 2.5 km. north of San Jacinto, and at Najo about 4.5 km. northwest of Tisate. All of these areas are on the eastern flank of the Quaternary Volcanic Range of Northwestern Nicaragua.

Thermal activity is well developed but is not as extensive nor as intensive as at the South Volcan Momotombo fumaroles.

These thermal areas, particularly the San Jacinto-Tisate area, show favorable possibilities as a geothermal power prospect.

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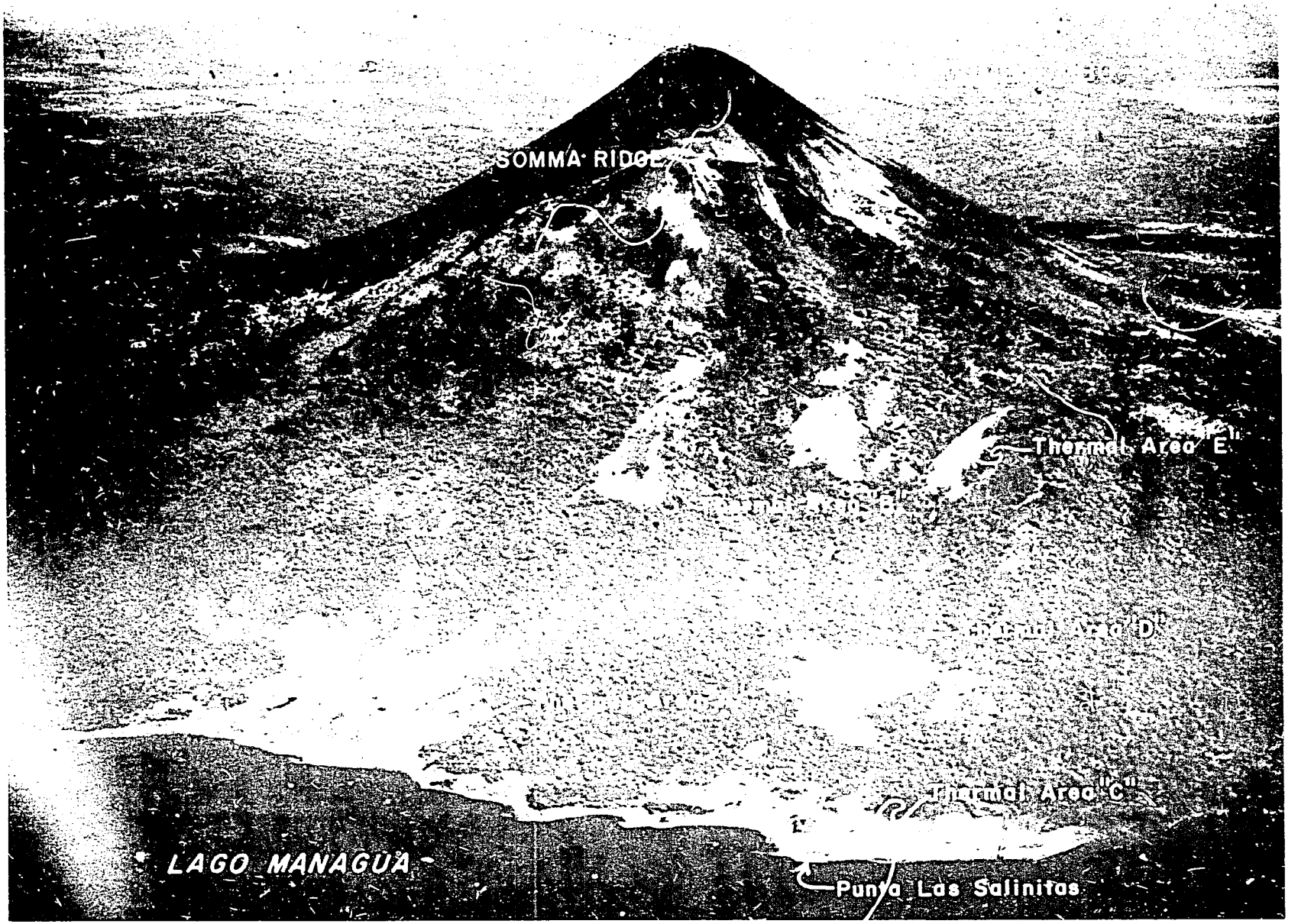

Aerial view of South Volcan Momotombo fumarole area looking north.

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Vista aerea norte del area fumarola de Volcan Momotombo Sur.

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Surface Geology: South Volcan Momotombo Fumaroles

Hydrothermally altered areas, active fumaroles, and minor thermal springs occur on the south slopes of Volcan Momotombo near the shore of Lake Managua. This typical composite volcano is a still semi-active link in the chain of Quaternary volcanoes of Western Nicaragua.

Alteration is more extensive and pronounced and current fumarolic activity is more vigorous than at any other thermal area in Western Nicaragua.

This thermal area shows favorable possibilities as a geothermal power prospect, and is probably more favorable than any other known thermal area in Western Nicaragua.

Gravity and Magnetic Surveys

A program of gravity and magnetic surveys was conducted in Western Nicaragua to determine the expression of major geologic features in terms of regional gravity and magnetic patterns, as well as to determine the effects of near-surface variation in rock densities and magnetic materials over selected thermal areas.

A reconnaissance gravity-magnetometer survey was made along a line extending across the Pacific Coastal Plain, the Volcanic Range, and the Nicaraguan Depression. Detail surveys were made in the San Jacinto and South Volcan Momotombo thermal areas.

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The west dipping gravity regional indicates seaward tilting of the Pacific Coastal Plain. A gravity maximum near San Jacinto in the Volcanic Range is associated with a large mass of high-density igneous rocks. Greatest thickness of sediments in the Nicaraguan Depression appears to coincide with the axis of a major negative northwesterly trend about 20 kilometers east of San Jacinto. Farther east, gravity gradients indicate gentle folds.

The thermal areas of San Jacinto and South Volcan Momotombo correlate with local gravity and magnetic negative trends.

Electrical Geophysical Surveys

Four types of electrical geophysical surveys were conducted in northwestern Nicaragua to assist in the location of areas suitable for the development of geothermal power:

1. Resistivity profiling delineated the extent of surficial ground saturated with hot water in the San Jacinto-Tisate area.

2. Resistivity depth soundings determined the depth of hot-water-saturated rock at San Jacinto-Tisate, along the road to Mina Limon and along the shoreline of Lake Managua near Volcan Momotombo.

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3. Dipole resistivity mapping delineated the region of conductive rock associated with the occurrence of hot water in greater detail and to greater depths.

4. Electromagnetic sounding provided more definitive information about the depth to which porous, hot-water-saturated rocks probably occurs in the geothermal systems at San Jacinto-Tisate and South Volcan Momotombo.

The electromagnetic survey was extended to obtain information about the regional setting of the geothermal activity, along a traverse from El Sauce to the Pacific Coast near Leon.

Geochemistry

During the geochemical investigation of that part of Western Nicaragua whose geothermal resources were the object of this evaluation, 130 water samples and 52 gas samples were collected and analyzed.

The geochemical results and geologic relationships indicate that the relative importance of the several thermal areas studied, ranked in order of decreasing potential, is as follows:

1. South Volcan Momotombo
2. San Jacinto-Tisate
3. Volcan Casita
4. Volcan Telica-Najo
5. Lake Jiloa-Lake Apoyeque
6. Volcan Mombacho
7. Hacienda California
8. Tipitapa
9. San Luis

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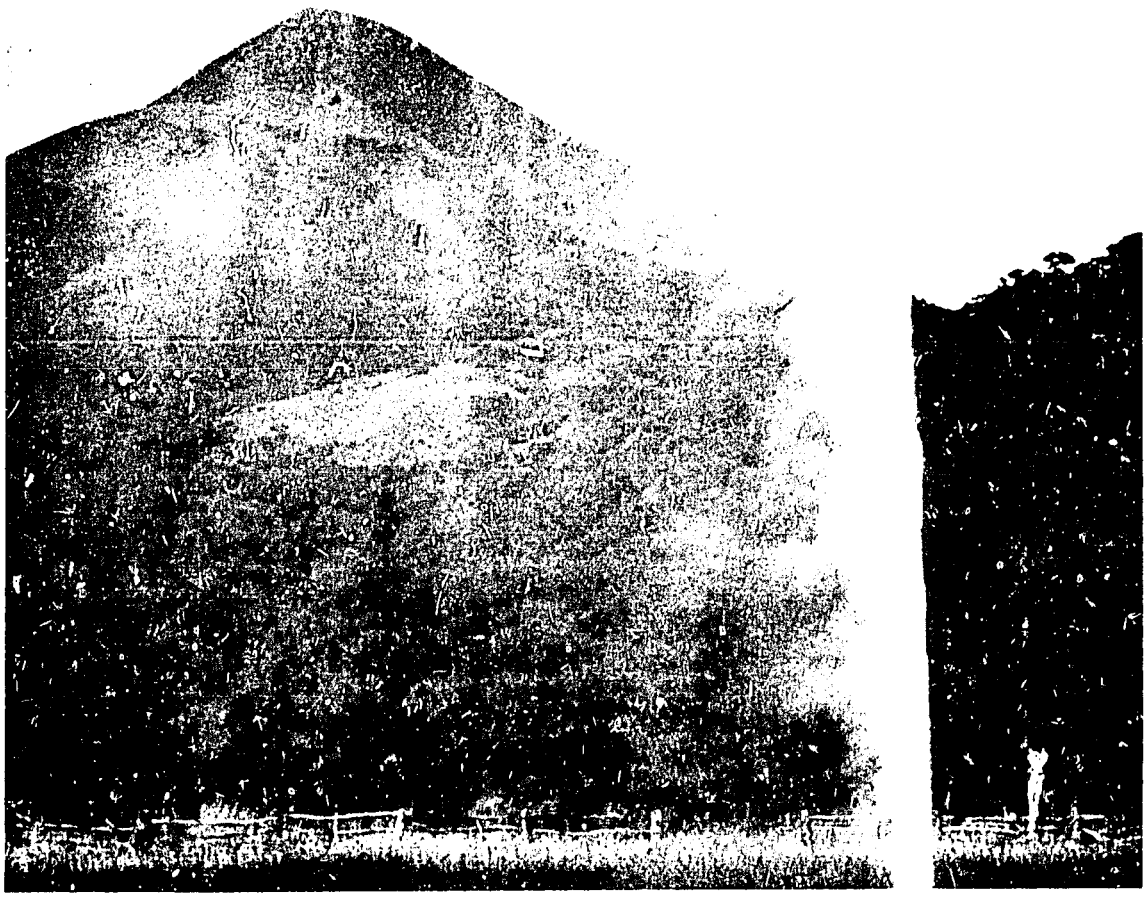

Momotombo gradient hole M-1A in eruption. Volcan Momotombo in distance.

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Momotombo pozo gradiente M-1A en erupcion. Volcan Momotombo al distancia.

Temperature Gradient Wells

As a result of geochemical, geologic, and geophysical studies in Western Nicaragua, the San Jacinto and South Volcan Momotombo thermal areas were determined to have the greatest potential for development of geothermal energy.

Six temperature gradient wells were drilled at San Jacinto and eight at South Volcan Momotombo to obtain lithologic samples and additional data needed to quantify and evaluate the areal resistivity survey.

The temperature data indicate that the South Volcan Momotombo prospect has a larger volume heat source than the San Jacinto prospect; the South Volcan Momotombo heat source has either a lesser depth or a higher base temperature than the San Jacinto heat source.

All of the South Volcan Momotombo gradient wells, except two, were plugged with cement as a safety measure. One of the unplugged wells was blowing hot water and steam at the time field operations were completed in December, 1970.

Deep Borehole Test

During the final part of Stage I of the Nicaragua Geothermal Resources Project it was deemed necessary to supplement the project data by drilling a deep test hole to determine

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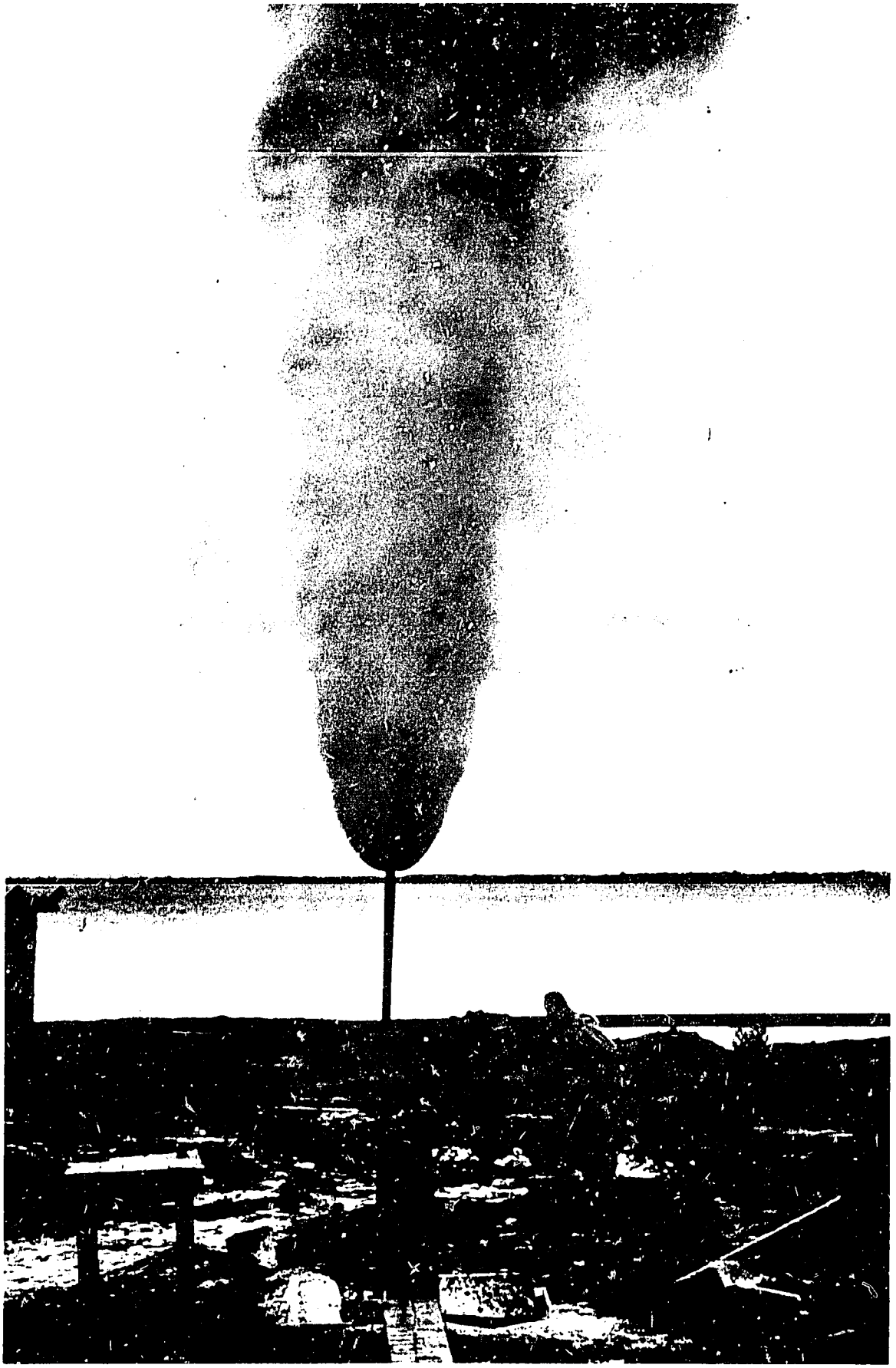

Deep borehole MT-1 erupting from 2 inch pipe 13 Dec. 1970.

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Erupcion del pozo profundo MT-1 desde tubo de 2 pulgadas 13 Dec. 1970.

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the base temperature of the steam reservoir at the South Volcan Momotombo Area. The Momotombo area was selected instead of the San Jacinto-Tisate area on the basis of geological, geophysical and geochemical data.

The test hole (MT-1) was drilled to a total depth of 1995 feet with the available marginally adequate drilling equipment.

The hole erupted violently 11 hours after completion. This and subsequent eruptions consisted mostly of steam with some admixed water.

Temperatures of up to 209° C were measured at a depth of 725 feet. A cave-in prevented deeper temperature measurements.

The gross lithology penetrated is of interlayered basaltic-andesitic lava flows and pyroclastic deposits to a depth of 215 feet. Below 215 feet occur pyroclastic deposits, often intensely altered, with minor andesitic and basaltic lava flows.

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Conclusions and Recommendations

On the basis of the investigations described in this Final Report on Stage I, Texas Instruments' Staff and Consultants concur in the conclusion that the South Volcan Momotombo fumarole area shows strong indications that it can be developed into a commercial reservoir of geothermal energy. The San Jacinto-Tisate fumarole area also appears to be a potentially commercial reservoir of geothermal energy.

It is strongly recommended that Stage II of the Nicaraguan Geothermal Resources Project be carried out in order to prove one or both of the two potential geothermal fields named. Specific recommendations regarding procedure and location of sites for deep exploratory drilling are presented in Part 10 of this report.

Respectfully submitted,

Donald E. Heilner, Project Manager
Services Group
Texas Instruments Incorporated

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