CHAPTER 11 FUTURE INVESTIGATION PLAN

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11.1 Preface

Chapter 5 deals with the estimated reserves of geothermal energy and the scale of potential geothermal power generation of the entire triangular district embracing the identified area including COP-1, COP-2 and COP-3 and the geothermal manifestation areas, such as Termas de Copahue, identified by the joint survey of JICA and the competent Government agencies of the Argentine Republic.

In the same Chapter, the optimum scale of geothermal power generation in the Project area is worked out as 30 MW. In this case, the scale of the confirmed area will not be sufficient to generate 30 MW, and geothermal energy generation from the remaining part of the entire triangular district will be required. It is necessary, therefore, to undertake a survey in the entire triangular district to substantiate the power requirements.

This Chapter discusses a plan for carrying out such a survey.

11.2 Knowledge of Steam Dominant Geothermal Reservoir in Project Area

In COP-1, COP-2 and COP-3, a steam dominant reservoir is encountered at a depth ranging from 800 to 1,100 m. The three wells are found in andesitic volcanic rocks of the Las Mellizas Formation.

COP-2 has the highest temperature, followed by COP-1 and COP-3 in that order. In terms of the relationship with rupture, the higher temperature well exists near the large rupture.

From the foregoing observations, it is highly probable that steam dominant reservoir is formed in the vicinity of the WNW-ESE ruptures.

Geochemically, the gas compositions of the Termas de Copahue and Las Maquinas are similar to those of COP-1, COP- 2 and COP-3, and there is great possibility of steam dominant reservoir occurring near the Termas de Copahue and Las Maquinas.

At present, a binary geothermal power plant is operated through the use of steam from COP-1. Jose L. Sierra, Franco D'Amore, Hector Panarello and Graciela Pedro, in their reports, discuss the properties of this steam dominant reservoir in terms of changes over time in the water-gas ratio, CO_2 density, H_2S-H_2 ratio, $\delta^{18}O$ and other properties of steam. These analyses provide an important viewpoint for the future development of steam dominant reservoir.

11.3 Investigation of Confirmed Area

In the confirmed area, it is necessary to determine the extent of the geothermal reservoir already identified and how geothermal fluids occur in the rupture system.

To define the extent of the known geothermal reservoir, it is proposed to carry out a field survey by the Mise-a-la-mass method using COP-2 and COP-3 as electrodes.

In order to determine the occurrence of geothermal fluids in the rupture system, exploratory wells with the production sizes will be drilled in the direction of ruptures at locations selected by taking the results of the survey by the Mise-a-la-mass method into full consideration. In this case, it is necessary to drill inclined wells.

A steam dominant geothermal reservoir may be encountered at a greater depth than 800 m below the ground level and in such a case, loss of circulating water may be caused in the entire well, making it impossible to continue drilling by the mud water circulation method. If this happens, the air-entrained mud water circulation method is recommendable to continue drilling as deep as possible so as to complete the well as planned. The final depth of the casing tip is necessary to be less than 800 m and it is necessary to ensure full-hole cementation. It is not considered to be required to insert a production casing which may be reduced in diameter depending on the conditions of layers with a resulting increase in friction. However, if sedimentary rocks are encountered as in COP-2, a production casing may need to be inserted. It is important to decide on whether to insert a casing depending on the conditions of well drilling.

(1) Mise-a-la-masse Method

Electrode Well: COP-1 and COP-3

Arrangement of measuring points:

A total of 100 measuring points is to arranged in an area with a radius of 1 km from the electrode wells.

Method of measurement:

Measurement of current potential is to be taken twice at each measuring point by switching the electrode wells. With the electrode well as an electrode and an infinite electrode set at other positions, the potential at the measuring points is to be measured by charging the electrodes with electricity.

(2) Drilling of Exploratory Well

Drilling length:	1,200 m
Inclination of well:	30°C from the vertical
Final diameter:	8 5/8 in.
Final casing depth:	800 m

11.4 Investigation of Whole Area

From its geological structure and a series of previous geophysical explorations, geochemical surveys and other investigations conducted in it, the triangular area is considered to contain geothermal reservoir. To date, however, no borehole has been drilled in this area to establish the occurrence of such reservoir. The stratigraphical sequence of the triangular area does not vary widely from that of the identified area. It is conceivable that brittle parts of the Las Mellizas Formation have developed many fissures due to ruptures, etc. to form geothermal reservoir.

In the proposed survey, an exploratory well with the production size is proposed to be drilled at a location near Las Maquinitas and where rupture systems are believed to intersect and where fissures are presumably found in abundance, in order to determine the occurrence of geothermal fluids.

Simultaneously, an electrical survey is also proposed to be carried out by the CSAMT method in the entire triangular area including the identified zone.

When the exploratory well succeeds in emitting steam, a survey is to be undertaken by the Mise-a-la-mass method using the well as an electrode to determine the position of the next exploratory well.

Two or three small-diameter geological boreholes are to be drilled to define the extent of geothermal reservoir. From the borehole explorations the drilling position of production wells is to be determined.

(1) CSAMT Method

6 survey lines and 60 survey stations

(2) Drilling of Exploratory Well

Drilling length:	1,200 m
Inclination of well:	30°C from the vertical
Final well diameter:	8 5/8 in.
Final casing depth:	800 m

(3) Mise-a-la-masse Method

Electrode well: Exploratory well
Arrangement of measuring points:
A total of 100 measuring points is to be arranged in an area with a radius of 1 km from the electrode wells.

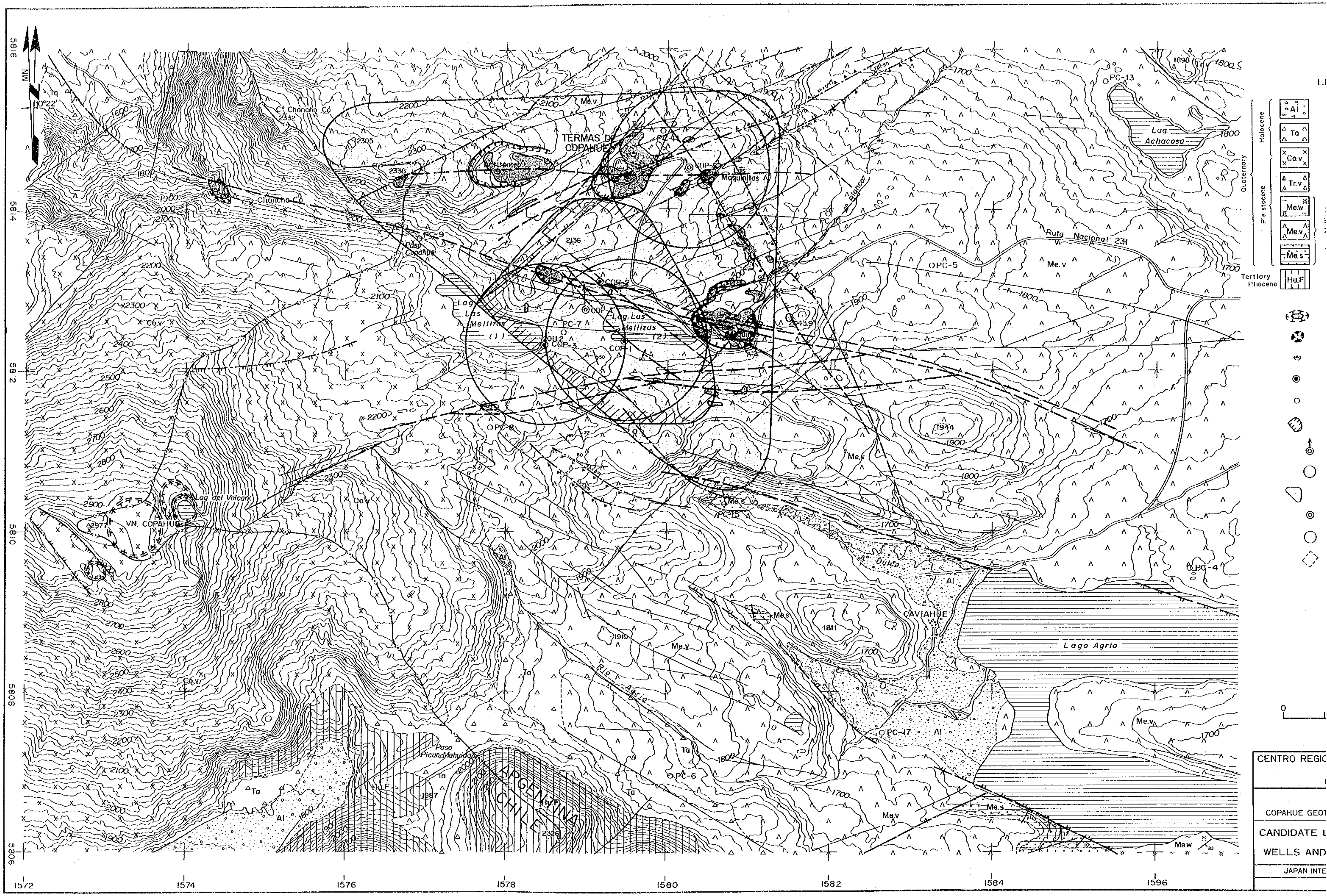
Method of measurement:
Measurement of streaming potential is to be taken at each measuring point with the exploratory well as an electrode and an infinite electrode set at another position by charging the electrodes with electricity.

(4) Structural drilling well

A structural drilling well with a final diameter of NQ is to be drilled with equipment supplied by JICA. A drilling length of about 800 m will be sufficient to serve the purpose of determining temperature distributions. However, a drilling length of nearly 1,000 m is required to determine the occurrence of steam. When a major layer causing loss of circulating mud water is encountered during drilling, the drilling is stopped immediately and when the necessary temperature is recovered, a production test is to be conducted to assess the geothermal energy potentials. Fig. 11-1 illustrates the survey and well drilling locations considered appropriate at the present time.

11.5 Other Investigations

With a view to recording changes over time in the production of geothermal fluids from COP-1 and COP-3 and defining the properties of the steam dominant reservoir, it is preferable to undertake periodical analysis of the properties of steam from successful wells found in future surveys, such as well head pressure, amount of steam, temperature, water-gas ratio, H_2S-H_2 ratio, CO_2 content and $\delta^{18}O$.



TERMAS DE COPAHUE
Cº Chancho Co
2332
Chancho Co
Paso Copahue
PC-9
PC-4
COP-2
COP-1
COP-3
PC-7
OPC-8
PC-15
OPC-5
OPC-13
OPC-6
OPC-17
OPC-4
Maquinitas
Lag. Las Mellizas (1)
Lag. Las Mellizas (2)
Lag. Achacosa
Ruta Nacional 231
Lag. del Volcan
VN. COPAHUE
2977
1944
1811
CAVIAHUE
Lago Agrio
Rio Agrio
A. Dulce
Paso Picun Mahuida
ARGENTINA
CHILE
Me.v
Me.s
Me.w
Co.v
Ta
Al
Hu.F
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Pleistocene
Quaternary
Tertiary
Pliocene
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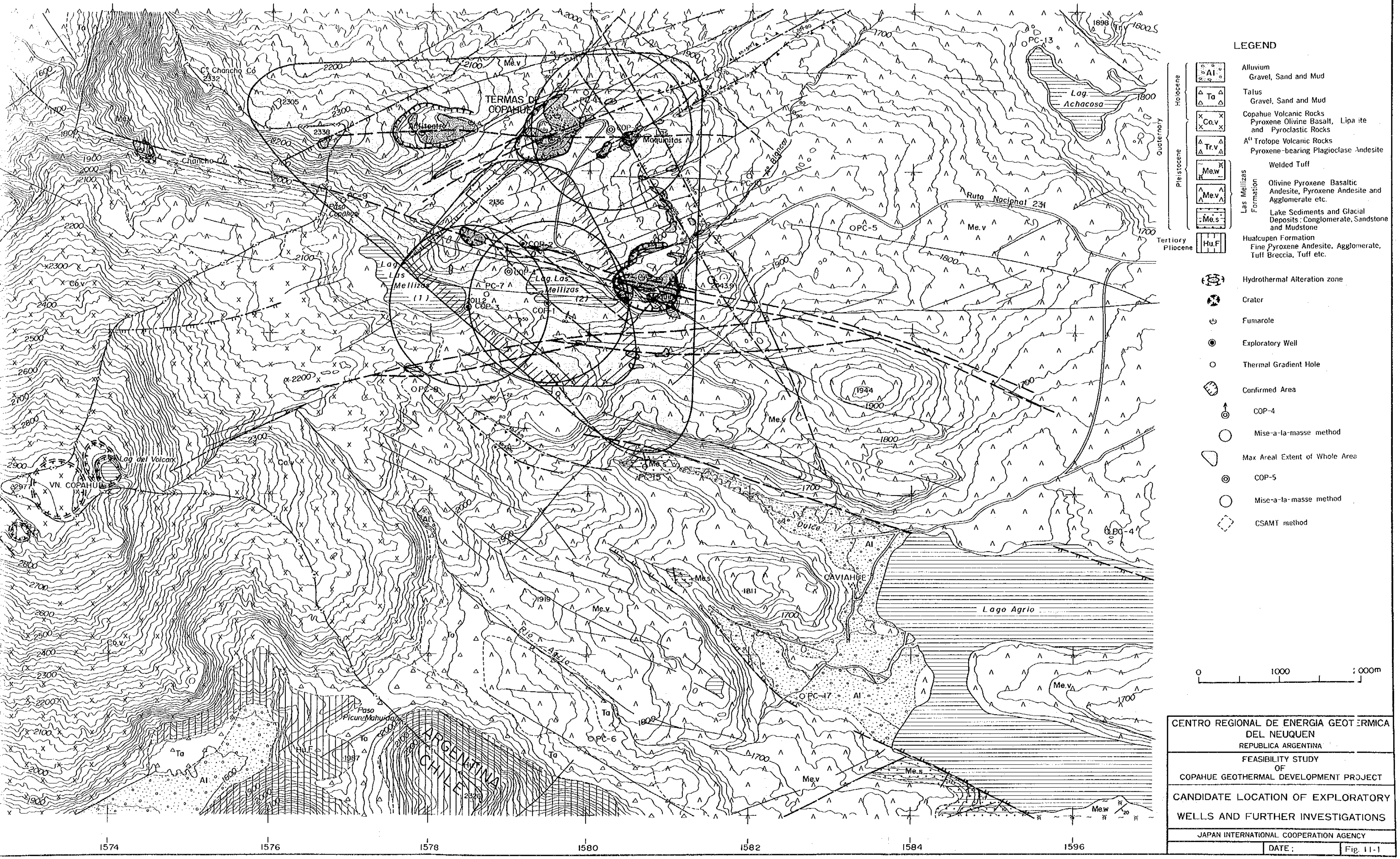

CENTRO REGIONAL DE ENERGIA GEOTERMICA DEL NEUQUEN

REPUBLICA ARGENTINA

FEASIBILITY STUDY OF COPAHUE GEOTHERMAL DEVELOPMENT PROJECT

CANDIDATE LOCATION OF EXPLORATORY WELLS AND FURTHER INVESTIGATIONS

JAPAN INTERNATIONAL COOPERATION AGENCY

DATE ; | Fig. 11-1

LIST OF COLLECTED DATA

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a. Topographic Map and Aerial Photograph

a 1. Topographic Map, scale 1 : 500,000

a 2. Topographic Map, scale 1 : 200,000

a 3. Topographic Map, scale 1 : 100,000

a 4. Topographic Map, scale 1 : 40,000

a 5. Topographic Map, scale 1 : 20,000

a 6. Aerial Photograph, 60 sheets

a 7. Aerial Photograph (mosaic), 2 sheets

a 8. LANDSAT Imagery, 2 sheets

a 9. Topographic Section of Lag. Las Mellizas

b. General

b 1. Scope of Work for the Feasibility on the Geothermal Neuquén Development Project in the Argentine Republic, Prov. del Neuquén, COPADE, May 1983.

b 2. Algunas Consideraciones Para el Desarrollo de la Energía Geotérmica *en la Provincia del Neuquén*, República Argentina.

b 3. Antecedents-Objectives and Request for Technical Cooperation for the Development of the Geothermal Fields of the Province of Neuquén (Argentine Republic) Report, March 1985.

b 4. Programa Nacional de Nuevas Fuentes de Energía, Secretaría de Energía, Octubre 1986.

b 5. Uso Racional Energía Nuevas Fuentes, Secretaría de Energía, Noviembre 1986.

b 6. Uso Racional Energía Nuevas Fuentes, Secretaría de Energía, Junio 1987.

b 7. Bases para el Estudio de Factibilidad Técnico-Económico en el Area de Geotérmia Provincia del Neuquén.

b 8. Atlas de la Provincia del Neuquén.

b 9. Energía Geotérmica, Italo B. Simonato, 1974.

b10. Antecedentes y Estado Actual de la Investigación Geotérmica en la República Argentina, Italo B. Simonato, Abril 1983.

b11. Antecedentes y Estado Actual de la Investigación Geotérmica en la República Argentina, Italo B. Simonato, Mayo 1983.

b12. Precipitación Total Media Anual, Cuenca del Río Agrio, 1987.

c. Geothermal Investigation

c 1. Estudios de Prospección Geotérmica en el Area de Copahue-Informe Final, LATINOCONSULT/ELC-Electroconsult, Julio 1980. (Anexo I, II, III)

c 2. Estudio de Factibilidad Geotérmica en Copahue : Primera Etapa Informe Final, LATINOCONSULT/ELC-Electroconsult Julio 1981.

c 3. Estudio de Factibilidad Geotérmica en Copahue : Prospección Geoeléctrica Profunda Informe Final, LATINOCONSULT/ELC-Electroconsult, Mayo 1982.

c 4. Pozo COP-1 : Interpretación de Resultados Informe Final.

c 5. Pozo Geotérmico Capahue II Informe.

c 6. Evolución Volcano-Tectónica del Complejo Efusivo Copahue-Caviahue y su Modelo Geotérmico Preliminar, Pesce, A.H. 1987.

c 7. Estudio de Mercurio, CO_2 y T. en Suelo : Area Geotérmica Copahue, Pedro, G., Sierra, J.L., and García, S.I.

c 8. Informe Final Sobre la Perforación del Pozo Geotérmico E.G. Nq. Ces 1 en Copahue - 1976, Comisión de Estudios Geotérmicos, Grupo de Trabajo Copahue.

c 9. Informe Preliminar Pozo Geotérmico E.G. Nq. Ces 1, Comisión de Estudios Geotérmicos, Grupo de Trabajo Copahue, Angel Del Vo y Luis E. Galardi.

c10. Geological Map of Argentina (1/750,000).

c11. Mapa Minero 1970-1971 (1/750,000)

c12. Geological Map of Neuquén (1/500,000), COPADE.

c13. Mapa Geológico de Detalle (1/20,000), LATINOCONSULT/ELC-Electroconsult.

c14. Mapa Geológico de Chile (1/1,000,000), 1980.

c15. Atlas Físico de la República Argentina, Volumen 1, P.132 - 137, 1981.

c16. Algunos Aspectos Sobre la Mineralogía de Alteración del Pozo COP II, Mas, L.C.

c17. VII Congreso Geológico Argentino, Auspiciado por la Asociación Geológica Argentina, Abril 1978.

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c20. Análisis Químico de Gases (1 sheet), de aguas y Condensados Acuosos (2 sheets), Jurio, R.L., 1977.

c21. Análisis Químico de Agua, COP-I : 1987/1,2,4 COP-II : 1987/1,2,4 (6 sheets)

c22. Análisis Químico de Gases, Nov. 1986 (1 sheet).

c23. Calculation of Reservoir Temperatures and Steam Fraction in Geothermal Reservoirs by Gas Composition, D'Amore, F. and Truesdell, A.H.

c24. VES curve and Data sheets of Electrical Exploration, CREGEN, 1987 (17 points, under Analysis)

c25. Informe Trabajo Gravimétrico Para Energía Geotérmica, Hoja Copahue Escale 1:25,000.

c26. Gravedad Relativa (K=2.15, 2.00ug/m), 2 sheets.

c27. Residual (Gravity), 1 sheet.

c28. Data of Thermal Gradient Holes: (1) Perfil Litologico del Pazo G. Ng. ct 1 - 17 (except Pazo 11,12,16), (2) Detailed Data.

c29. Distribución del Flujo de Calor Campo Geotérmico de Copahue, Mas, L.C.

c30. Informe Estudio de Factibilidad Geotérmica de Copahue - Ira. ETAPA Junio 1981.

c31. Geologic Columnar Section of COP-I.

c32. Geologic Columnar Section of COP-II.

c33. Logging Chart, (1) COP-I (Inducción Latero 237.1 - 947 m), (2) COP-II (Latero 250 - 1,159 m), (Spectra y Densidad 675 - 1,163.1 m, BHC 675 - 1,136.7 m).

c34. Wellbore Temperature Data of COP-II (13 April 1986).

c35. Production data of COP-I and COP-II.

c36. Table of Well Head Pressure, Temperature and Flow Rate for COP-I and COP-II.

c37. Logging Data of COP-I and COP-II (Static, Injection and Production Logging by Amerada Gauge).

c38. Sierra, J.L, D'Amore, F., Panerello, H. and Pedro, G (1990): Reservoir Characteristics of the Vapor Dominated Geothermal Field of Copahue, Neuquén, Argentina, as Established by Isotopic and Geochemical Techniques.

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d 2. Anuario Energía Eléctrica 1984-1985 (Secretaría de Energía)

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d 5. Informe Estadístico 1986 (DNC. AyEE)

d 6. Informe Estadístico Oct. 1987 (DNC. AyEE)

d 7. Plan Energético Provincial, Período 1987-2000 Subsector Eléctrico - Tomo 1 y 2 (EPEN)

d 8. Plan Energético Provincional - Avance Primera Parte : Proyección de la Demanda (EPEN. Dic 1985)

d 9. Anuarios 1984/1985/1986/1989 (EPEN)

d10. Datos Estadísticos (Evaluación de Dólar y Precios al Consumidor) (Instituto de Economía Eléctrica)

d11. Evaluación Tecnico-Económica de una Central Térmica con Aprovechamiento del Gas Aventado en el Area Rincón de los Sauces - Filo Morado, Agosto, 1989

d12. Los Hidrocarburos en la Provincia del Neuquén, Abril 1991

E. Civil Engineering and Environment

e 1. Plan General de Manejo del Parque Provincial Copahue Agusto, 1988

e 2. Sightseeing guide "Copahue - Caviahue"