- The volcanic activities of Apoyo occurred within a short period of time after the main volcanic activities of the Masaya Group, and the big eruptions of pumice were three times.

- Pumice eruption in Apoyeque and Apoyo occurred nearly at the same time.

- The main volcanic activities from the late Pleistocene to the Recent such as Asososca, Nejapa and Ticomo were at least three times stronger.

4.1.3 Structural Geology and Geologic History

For the discussion of the structural geology and geologic history of the Nicaraguan Depression which includes the Study Area, the generalized cross sections (Fig. 4.1.8-12) and palaeogeographical Maps (Fig. 4.1.14) were prepared. These were based on the results of the review and analysis of existing study reports and geological data listed in Table 4.1.1, field geological reconnaissance accompanied with satellite image and aerophoto interpretation and electrical prospecting. The major purpose of this discussion was to investigate the hydrogeologically impermeable layers underlying the Las Sierras Group, such as El Salto Formation and other Tertiary sedimentary rocks.

Major findings on the geology of the study area are as follows:

a. Pre-Late Cretaceous

Until the beginning of the Upper Cretaceous, lands in Western Nicaragua were mostly of mafic intrusions; peridotite, gabbroic and diabasic rocks, and Nicoya complex: graywacke, chert and basalt. In particular, the basement rocks in the surrounding area of the Study Area is presumably composed mainly of mafic intrusions.

This estimation is based on the following:

- Among the explosive ejecta from the volcano Masaya, gabbroic rocks (xenolith) are seen, which is somehow different from mafic intrusion beneath the caldera.

- Among the explosive ejecta from the volcano Apoyo, peridotite or gabbroic rock fragments are involved.

- Near the center of the volcano Mombacho, the diabasic rocks are found in the detritus.

- Coarse-grained gabbroic blocks are found among the explosive ejecta of the volcano Telica.

b. Late Cretaceous to Late Miocene

At the early stage of the Upper Cretaceous, transgression progressed from the southeastern area of the Pacific Coastal Plain toward the Nicaraguan Depression area. It is presumed that this transgression continued up to the Middle Miocene, but another presumption is also possible, that is the sedimentary environment in the transgression area repeatedly changed from marine condition to brackish or embayments and terrestrial conditions sometime between the Cretaceous and Paleocene, and the Eocene and Oligocene, respectively.

Through this transgression, deposition of the Rivas, Brito and Masachapa Formations, the Tamarindo Group and the El Fraile Formations occurred in ascending order, forming the geosyncline. The axial ridge of this geosyncline continued side expansion, folding or uplifting, providing new sources of clastic debris.

At the stage from the Late Oligocene to the Miocene, the dimentary environment changed from shallow depth marine to deltaic or terrestrial conditions (existence of fossil tree trunks in the basal parts of El Fraile Formation).

On the other hand, in the northeastern marginal area of this transgression, which is also the northeastern marginal area of the Nicaraguan Depression, Tertiary volcanic activities progressed widely and strongly (Matagalpa and Coyol Groups). At the stage of the Late Miocene, the volcanic activities of the

Tamarindo Group occurred in the northwestern area of the Pacific Coastal Plain.

c. Late Miocene to early Pliocene

At the end of the Miocene, the sedimentary basin was strongly uplifted and folded with dioritic rocks intruding along the axial ridge of the uplifting (Rivas Anticline).

The uplifted terrestrial area had been strongly weathered and eroded. After this regression stage, the Nicaraguan Depression zone and partial areas of the Pacific Coastal Plain were occupied by shallow depth marine by the transgression of the Early Pliocene (Fig. 4.1.14). The development of a small island near Managua city during the transgression stage can be inferred from the following :

- Some accidental blocks of brown hard tuffaceous shale among the explosive ejecta (pumice) from Apoyeque, which can be estimated to originate from the Brito Formation, are seen on the cuesta of the Sierras de Mateare.

- In the Brasiles Valley, Managua city and Sabana Grande areas, high electric resistivity values of 57-990 ohm-m, presumably from Paleocene Tertiary sedimentary rocks, were obtained by electric prospecting.

d. Early Pliocene to Late Pliocene

Under the Palaeogeographical conditions shown in Fig. 4.1.14, the deposition of the El Salto Formation has progressed through the Pliocene age. The existence of fossil shells (Gastropoda and Pelecypoda) suggests that the marine condition was shallow to some of embayment.

In Tipitapa, the existence of the El Salto Formation consisting of tuffaceous sand and silt with fossil shells (principally Gastropoda) was confirmed at about 200 meters below the Las Sierras Group in the test borehole (TP-8) carried out by the United Nations in 1973.

According to the electric prospecting results near the above test borehole site in this Study, the geophysical boundary between the Las Sierras Group and El Salto Formation was at 135 meters below the ground surface. The electric resistivity values were low at 28 ohm-m in the Las Sierras Group and 1.3 ohm-m in the El Salto Formation. Similarly, low electric resistivity values indicating the existence of El Salto Formation were also obtained at other prospecting points and some were confirmed by the test drilling work (JI-5) conducted in this Study. The detailed description of the test well drilling results is given in later sections.

The main part of the sedimentary basin developed into a terrestrial flat plain in the early Late Pliocene period. However, Figure 4.1.15 shows the still observable narrow and shallow sea trench along the northeastern margin of the Nicaraguan Depression, and an inland lake of brackish-water.

Almost Simultaneously, big volcanic eruptions from the Las Sierras Group started near the center of the basin, while sporadic volcanic eruptions occurred in the northeastern margin of the Nicaraguan Depression (Fig. 4.1.15).

e. Early Pleistocene to Middle Pleistocene

The above mentioned volcanic activities of the Plio-Pleistocene mostly ended at the early Middle Pleistocene period. The main part of the Upper Las Sierrras Group is composed of volcanic ejectas with well sorted but weakly consolidated layers of tuffaceous sandstone and siltstone. It is, therefore, considered that the sedimentary environment of the Upper Las Sierras Group was mainly influenced by the brackish water that resulted from the transgression at the end of the Early Pleistocene.

After the sedimentation of the Upper Las Sierras Group, a sharp geotectonic movement with upliftings, faultings, gentle foldings and depressions occurred widely at the Nicaraguan Depression zone, resulting in the relative uplifting of the Pacific Coastal Plain and the Interior Highlands, and the subsidence of the Nicaraguan Depression zone (Fig. 4.1.16).

However, a part of the Sierras de Managua protruding into the Nicaraguan Depression remains unchanged from the subsidence, except for the mountainous area with sharply eroded valleys that it forms. The main fault systems formed by this geotectonics are as follows:

Boundary Faults of the Graben

The boundary faults of the Nicaraguan Depression are well defined as shown in Fig. 4.1.17. In the south and west of Lake Managua, the Mateare Fault Scarp extends 70 kilometers along the northeastern faces of the Sierras de Managua. The southeasternward direction of this faulting zone can be traced by the faults along the northeastern limb of the Rivas anticline. The fault systems along the opposite northeastern boundary of the Nicaraguan Depression are more regular and are traceable continuously from the Gulf of Fonseca to the southeastern tip of Nicaragua.

Throughout most of its length, it can be marked by a sharp break between the Interior Highlands and the lake shores and Alluvial sediments of the graben.

Faults Oblique to the Depression

These fault systems are common near both margins of the Nicaraguan Depression and within the belt of the Quaternary volcanoes. Many of these are north-south and northeast-southwest fractures with minor deplacements, and some control the sub-chains of the Quaternary volcanoes (Fig. 4.1.16).

Main Chain of the Quaternary Volcanoes

The main chain of the Quaternary volcanoes indicates the existence of a tension fracture zone that was formed in connection with the development of the Nicaraguan Depression.

The deeper portion of this fracture zone may reach a magma reservoir.

As shown in Fig. 4.1.17, the Quaternary volcanic activities along the above mentioned fault and fracture systems have continuously progressed from the Middle Pleistocene to the Recent age. The importance of the Quaternary volcanic activities has already been pointed out.

The earthquake in Managua on December 23rd, 1972 (Richter scale of 5.6, surface-wave magnitude of 6.2) and its aftershock strongly affected the central area of about 27 square kilometers. Within this area, over 11,000 people were killed, 20,000 injured and about 75% of the houses were destroyed. Aftershock studies confirmed that at least four sub-parallel faults of northeast-southwest direction, spaced 270 to 1,150 meters apart, slipped in a predominantly sinistral (left lateral) sense during the earthquake. It is quite evident that these faults are primarily of the tectonic origin.

Table 4.1.1 LIST OF TOPOGRAPHICAL, GEOLOGICAL AND HYDROGEOLOGICAL DATA COLLECTED

1. Satellite image and aero-photo.

    1) NASA LANDSAT-1 3 sheets (MSS Panchromatic)

    2) Aero-photo 1/25.000 59 sheets (Panchromatic)

2. Geological study reports and relevant data

    1) Physiography and Geology of Adjacent Region to the Nicaragua Canal Rout. By C. Willard Hayes. 1898.

    2) Petroleum Geology of Pacific Coast of Nicaragua
    By: Dr Han Swolf. 1959.

    3) Volcanic History of Nicaragua
    By Alexander Mcbirney and Howel Williams
    University of California Publication in Geological Cience
    Volume 55, 1965.

    4) Geology of Western Nicaragua (Photogeologic Evaluation).
    By Thomas E. Bretz and others, 1969.

    5) The Geology of Western Nicaragua
    Tax Improvement and Natural Resources Inventory Project
    Nicaragua. Final Technical Report Volume IV, 1972.

    6) Geologic and Seismological Aspects of the Managua Nicaragua, Earthquake of December 23th, 1972 by R.D. Brown, Jr. P.L Ward and George Plafker, 1973.

    7) Seismic and Fault. Hazard studies for Banco Central de Nicaragua. By Woodward-Lundgren and Associates, 1975.

    8) Estratigrafia y Tectonica de Managua, Nicaragua por Juan Kuang S. 1973. Instituto Geográfico Nacional.

    9) Estructura Geológica, Historia Tectonica y Morfología de America Central por: Gabriel Dengo. Instituto Centroamericano de Investigación Tecnologia INdustrial (ICATI) de Guatemala.

    10) Region de Managua, Tectonica y Sismicidad Ministerio de Economía, Industria y Comercio, 1973.

    11) Reporte Final del Proyecto de Recursos Geotermicos Etapa I Partes 5,6,8,9, para el Gobierno de Nicaragua. Ministerio de Economía, Industria y Comercio. Por George Keller y -- Norman Harthil, 1970-1971.

    12) Mapa Geologico Preliminar 1:1.000.000 Ministerio de Obras Públicas Instituto Geográfico Nacional, 1971.

    13) Mapa Geológico de Nicaragua 1:50.000 Hojas 2952-III, 2953-II 2952-II, 2952-IV, 2953-III, 2952-I.

14) República de Nicaragua 1:1.000.000.

15) Nicaragua 1:250.000 Managua, Granada, San Carlos

16) Nicaragua 1:50.000 Mateare (2952-IV) Tipitapa (2952-I), Nindirí (2952-II), Managua (2952-III), San Rafael del Sur (2951-IV), Masaya (2951-I).

3. Study Report and Relevant Data for Groundwater Development in the Study Area

1) Recursos de Aguas Subterraneas para Managua, 1971. By Hazen and Sawyer.

2) Informe sobre el proyecto de la Segunda Etapa del Plan (1971). By Hazen and Sawyer-Chan.

3) Investigaciones de aguas subterráneas en la Región del Pacífico de Nicaragua (1973) por Naciones Unidas.

4) Hidrogeología Evaluación de recursos de agua subterránea área Los Brasiles-Chiltepe (1972) por el Ministerio de - Economía, INdustria y Comercio.

5) Mas Agua para Managua, 1971 por Hazen and Sawyer.

6) Proyecto Mas Agua para la Nueva Managua Fase I (1979) por Montgomery-Chan.

7) Proyecto mas agua para la Nueva Managua Fase III (1981) Montgomery-Chan.

8) Parte I Plan Maestro de Mejoras y Ampliaciones al Sistema de Distribución. (1984) por Hidrotecnia S.A.-Hazen and Sawyer.

9) Parte 2 Revisión del Esquema TISMA y Factibilidad de otras Fuentes de Suministro (1984).

10) Parte 3 Primera Etapa del Plan Propuesto (1984) Hidrotecnia S.A.-Hazen and Sawyer.

11) Parte 4 Desarrollo de Fuentes de Suministro de Agua (1988) Por Hidrotecnia S. A.

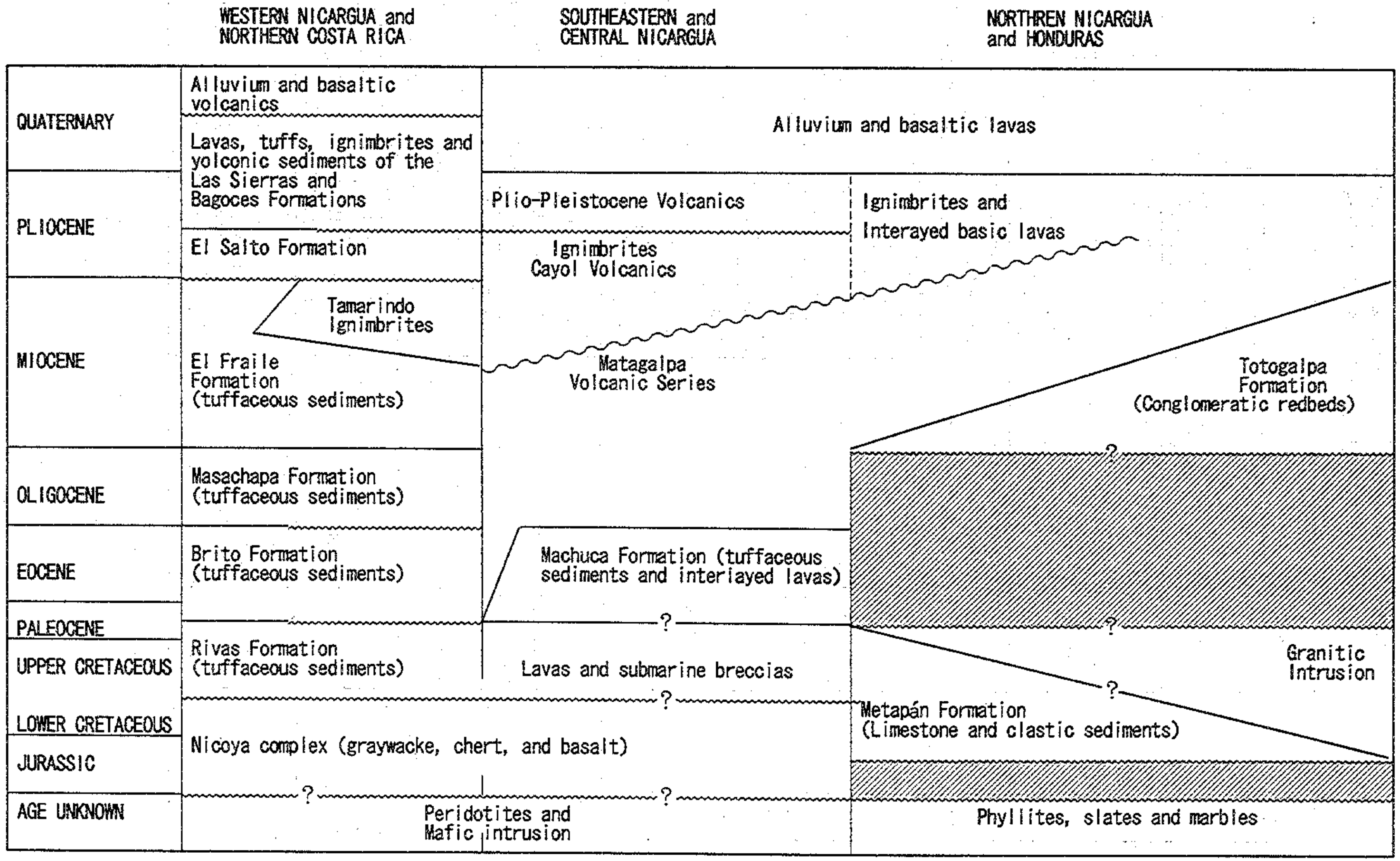
12) Parte 5 Implementación y Factibilidad del Proyecto (1985) Hidrotecnia-Hazen and Sawyer.

13) Informe Hidrogeologico 1990 U.S.R.-NICARAGUA

14) Estudios Hidrogeologicos y de costos de Extracción del Agua Subterranea del Proyecto Los Brasiles por Proconsult Ingenieros S.A.

15) Estudio Hidrogeologico y Evaluación de los Recursos de Agua Subterránea del área del Complejo de Desarrollo Azucarero Tipitapa-Malacatoya. (1984). Por Proconsult Ingenieros S.A.

Cuadro 4.1.2 Relaciones estratigráficas de Nicaragua y regiones adyacentes
Table 4.1.2 Stratigrphic Relations of Nicaragua and Adjacent Regions



Cuadro 4.1.3 Estratigrafia del área de estudio
Table 4.1.3 STRATIGRAPHY OF THE STUDY AREA

Edad Geológica GEOLOGIC AGE		Nombre de las Unidades Rocosas geólogicas NAME OF GEOLOGIC ROCK UNITS			Litologia LITHOLOGY
Cuaternatio QUATERNARY	Holoceno HOLOCENE		Aluvio ALLUVIUM	Qal	Sedimentos arena y arcilla con material piroclástico, depósitos de escombros. SAND AND CLAY SEDIMENTS WITH PYROCLASTIC MATERIAL, DEBRIS DEPOSITS
			Volcánicos Holocénicos HOLOCENE VOLCANICS	QvH	Lavas Basalticas-Andesiticas BASALTIC-ANDESITIC LAVAS Flujos piroclásticos y depósitos piroclásticos caidos. PYROCLASTIC FLOWS AND PYROCLASTIC FALL DEPOSITS.
	Pleistoceno PLEISTOCENE		Volcánicos Pleistocénicos PLEISTOCENE VOLCANICS	QvP	Depósitos piroclásticos caidos con flujos piroclásticos y lavas. PYROCLASTIC FALL DEPOSITS WITH PYROCLASTIC FLOWS AND LAVAS.
			Volcánicos Apoyo APOYO VOLCANICS	QvA	Depósitos piroclásticos caidos y flujos (pomez) con rava dacitica. PYROCLASTIC FALL DEPOSITS ANS FLOWS (PUMICE) WITH DACITIC LAVAS
			Grupo Volcánico Masaya MASAYA GROUP VOLCANICS	QvM	Lavas basálticas (dura y porosa-auto brechada) BASALTIC LAVAS (HARD AND POROUS-AUTO BRECCIATED) Flujos piroclásticos y depositos piroclásticos caidos PYROCLASTIC FLOWS AND PYROCLASTIC FALL DEPOSITS
Terciario TERTIARY	Plio-Pleistoceno PLIO-PLEISTOCENE	Grupo Las Sierras LAS SIERRAS GROUP	Grupo Superior Las Sierras UPPER LAS SIERRAS GROUP	TQps(S)	Aglomerado Básaltico-Andesitico, toba brecha, toba, suelo fósil, arena y limo tobácea BASALTIC-ANDESITC AGGLOMERATE, TUFFBRECCIA TUFF, FOSSIL SOIL, TUFFACEOUS SAND AND SILTE
			Grupo Medio Las Sierras MIDDLE LAS SIERRAS GROUP	TQps(M)	Aglomerado basáltico-andesitico, compacto brecha tobácea, toba, flujo piroclástico. BESALTIC-ANDESITIC COMPACT AGGLOMERATE, TUFFBRECCIA, TUFF, PYROCLASTIC FLOW.
			Volcánicos Plio-Pleistocénicos PLIO-PLEISTOCENE VOLCANICS	TQpl	lavas basálticas andesiticas en las proximidades de las Calderas Masaya y Apoyo. BASALTIC-ANDESITIC LAVAS IN NEAR MASAYA AND APOYO CALDERAS.
	Plioceno PLIOCENE-(EOCENE)		Formacion El Salto y Sedimentos Terciarios EL SALTO FORMATION & OTHER TERTIARY SEDIMENTARY ROCKS	TPS	TUFFACEOUS SANDSTONE & SILTSTONE WITH FOSSIL SHELLS. (BROWN TUFFACEOUS SHALES.)

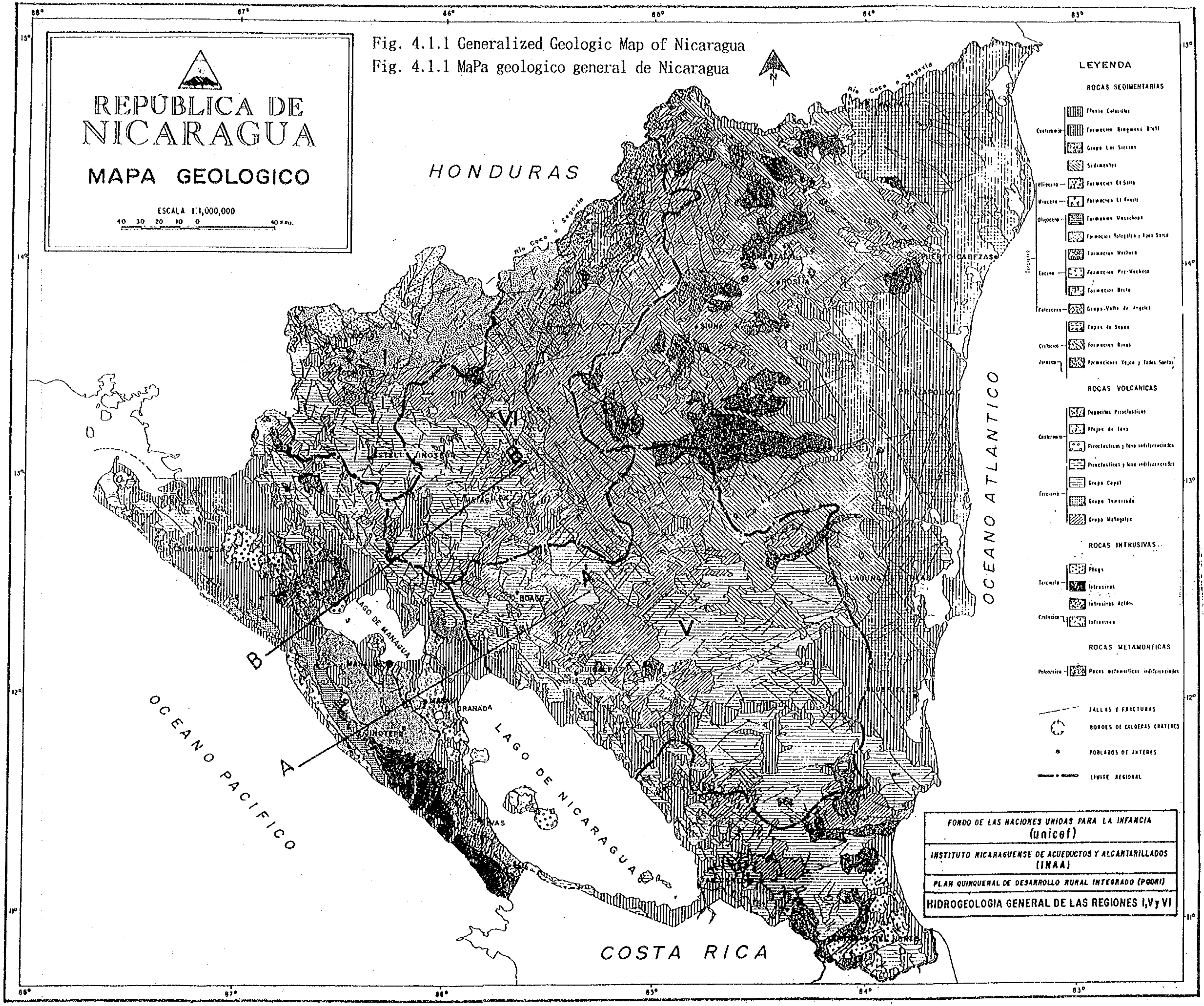


Fig. 4.1.1 Generalized Geologic Map of Nicaragua

Fig. 4.1.1 MaPa geologico general de Nicaragua

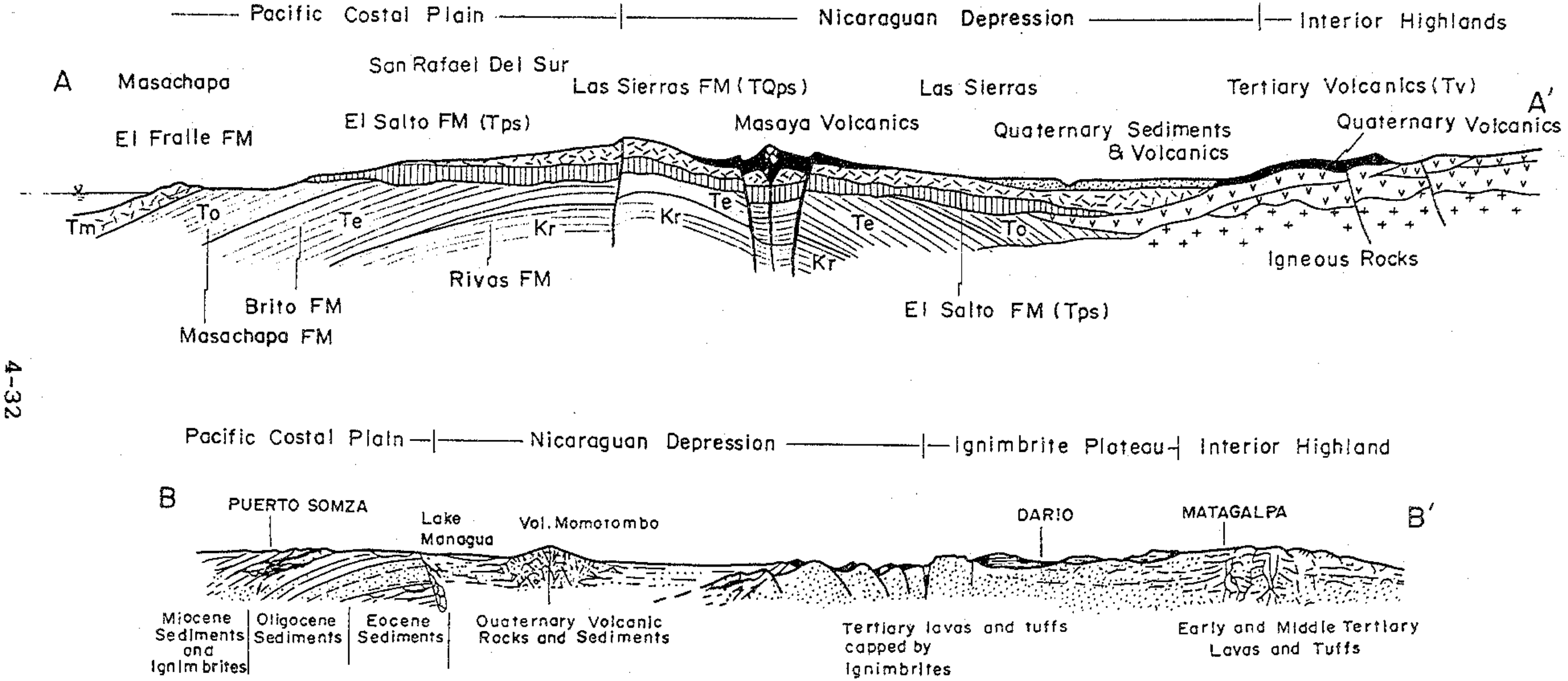


Fig. 4.1.2 Generalized Cross Sections

A

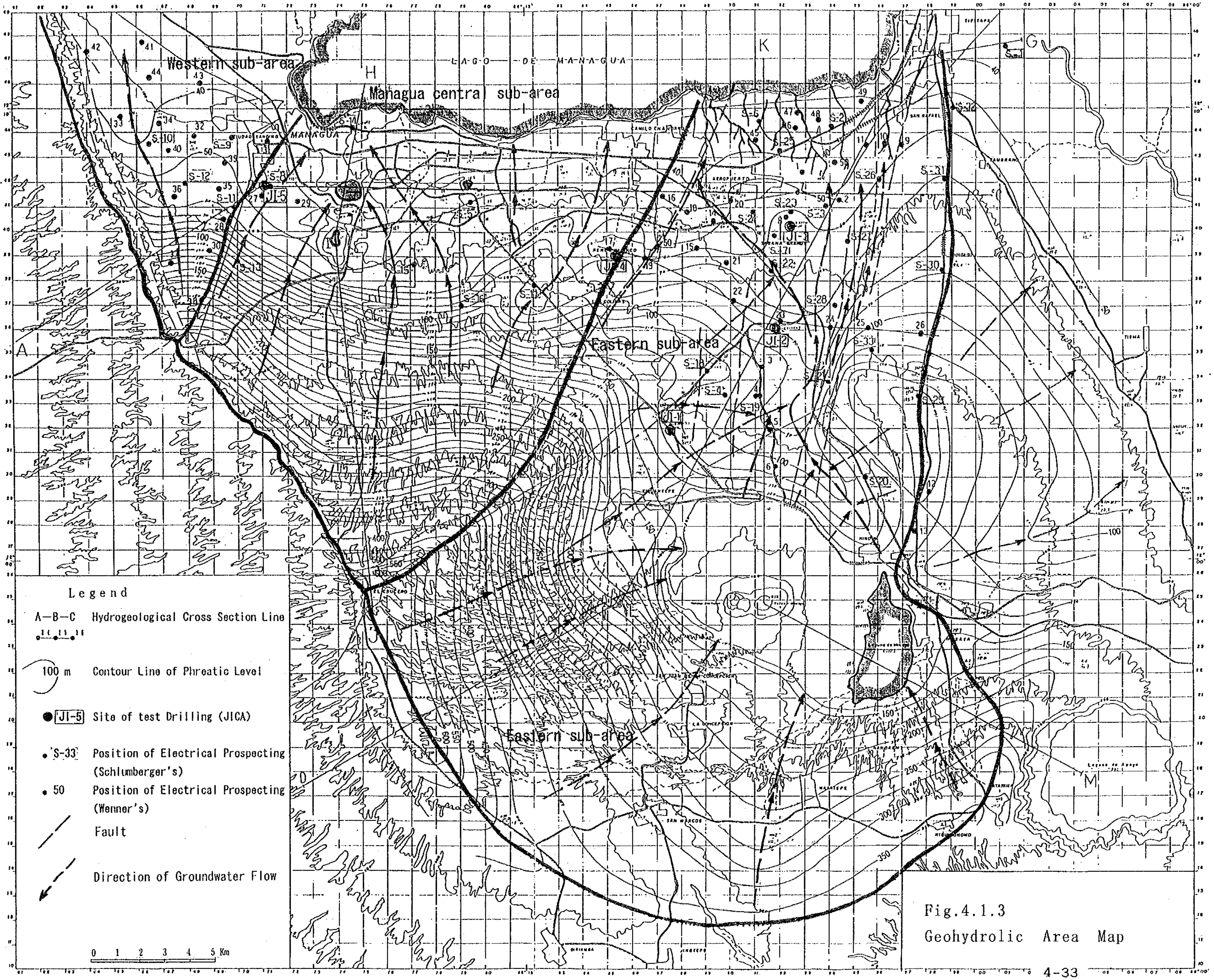
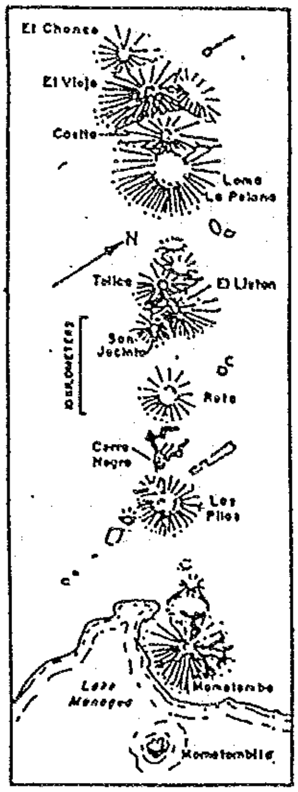


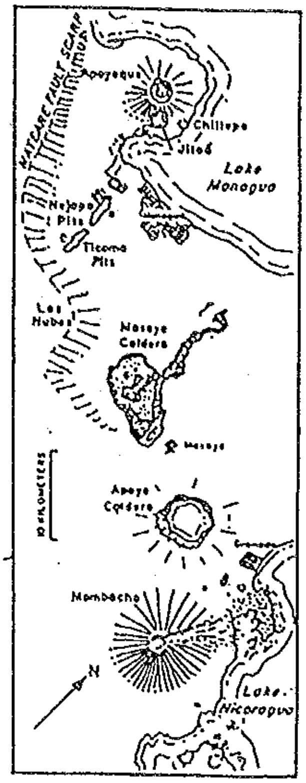
Fig.4.1.3
Geohydrolic Area Map

Fig. 4.1.4



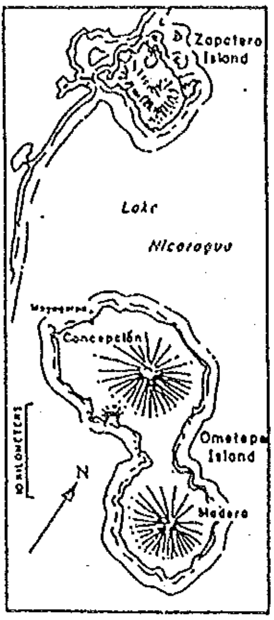
Volcanoes of the
Marabios Range .

Fig. 4.1.5



Volcanoes Between Lake Managua
and Lake Nicaragua .

Fig. 4.1.6



Volcanoes in
Lake Nicaragua .

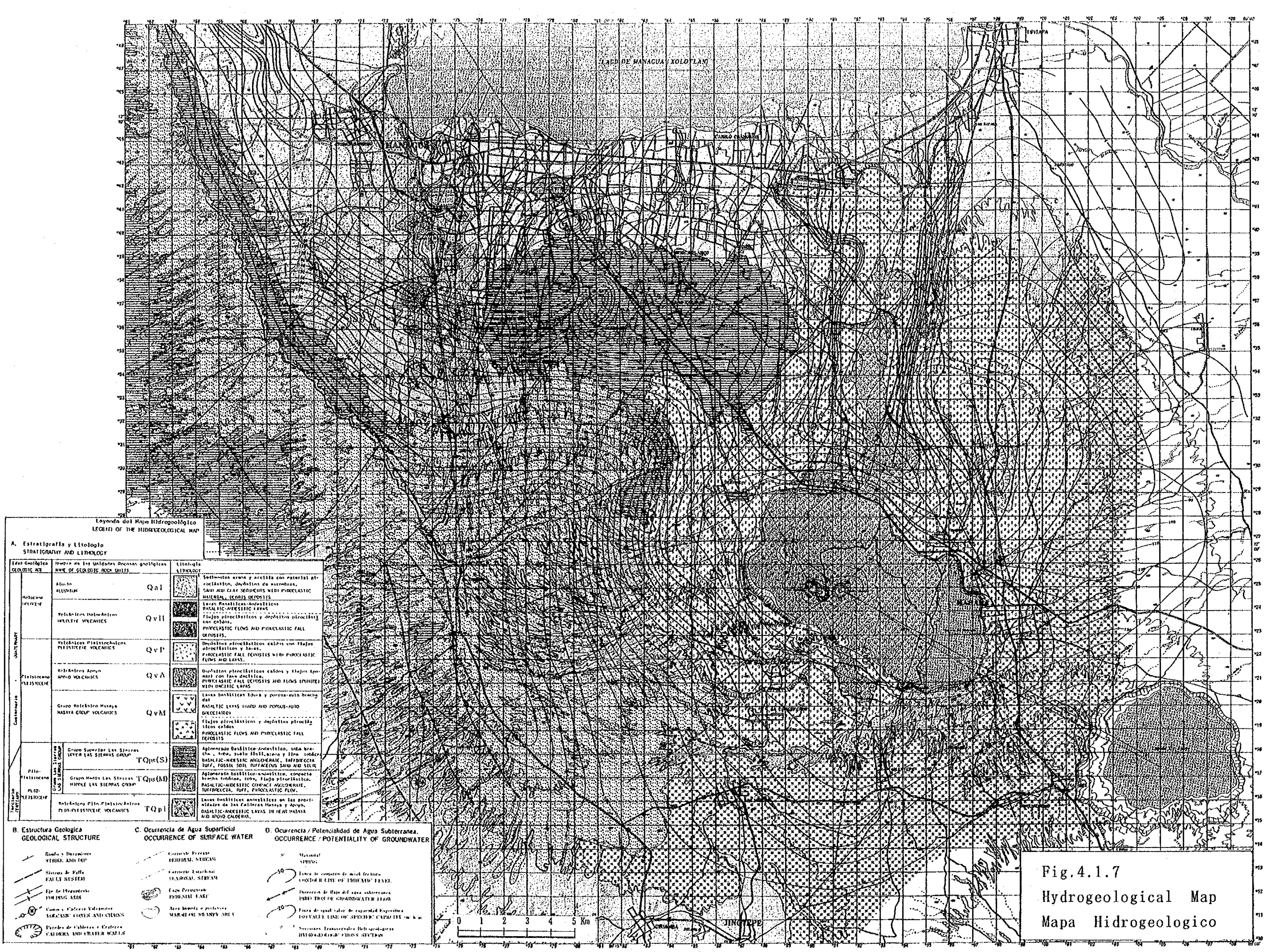


Fig.4.1.7
Hydrogeological Map
Mapa Hidrogeologico

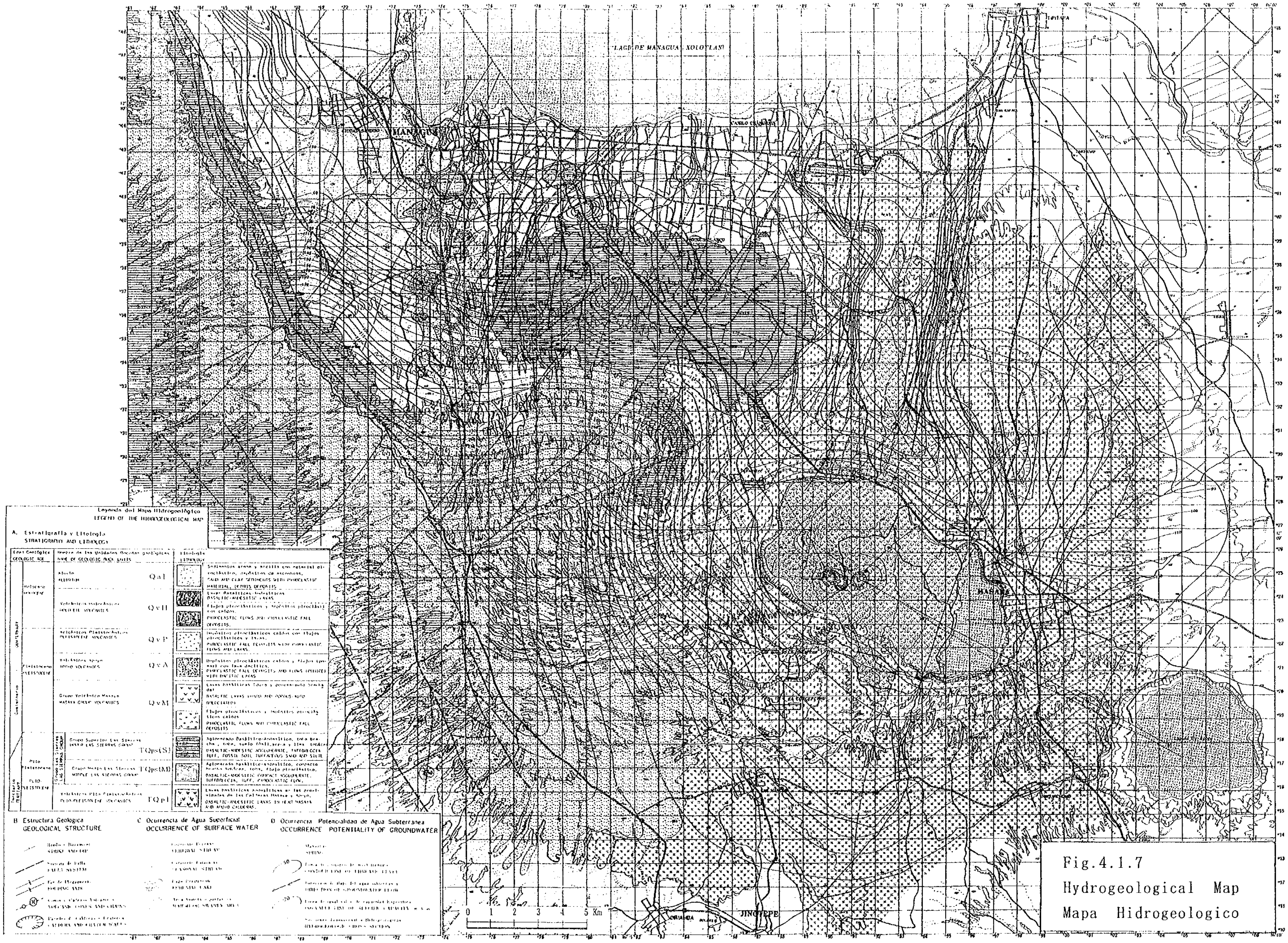


Fig.4.1.7
Hydrogeological Map
Mapa Hidrogeologico

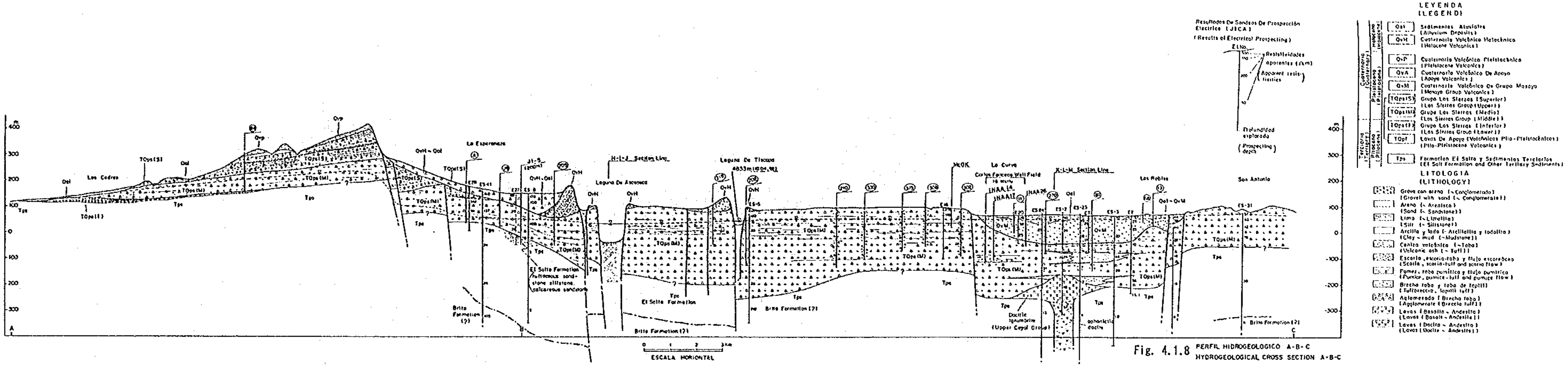


Fig. 4.1.8 PERFIL HIDROGEOLOGICO A-B-C
HYDROGEOLOGICAL CROSS SECTION A-B-C

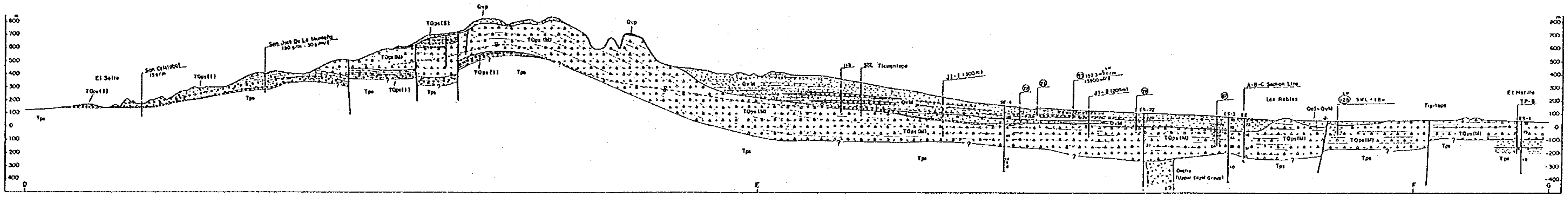


Fig. 4.1.9 PERFIL HIODROGEOLOGICO D-E-F-G
HYDROGEOLOGICAL CROSS SECTION D-E-F-G

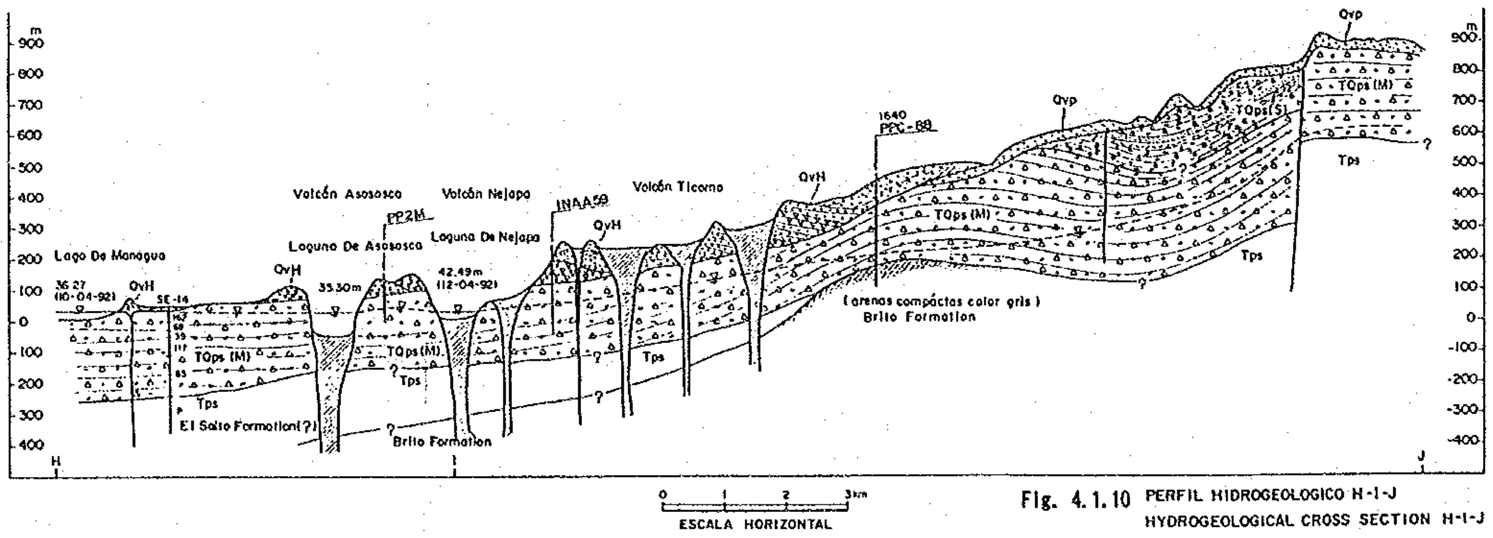


Fig. 4.1.10 PERFIL HIDROGEOLOGICO H-I-J
HYDROGEOLOGICAL CROSS SECTION H-I-J

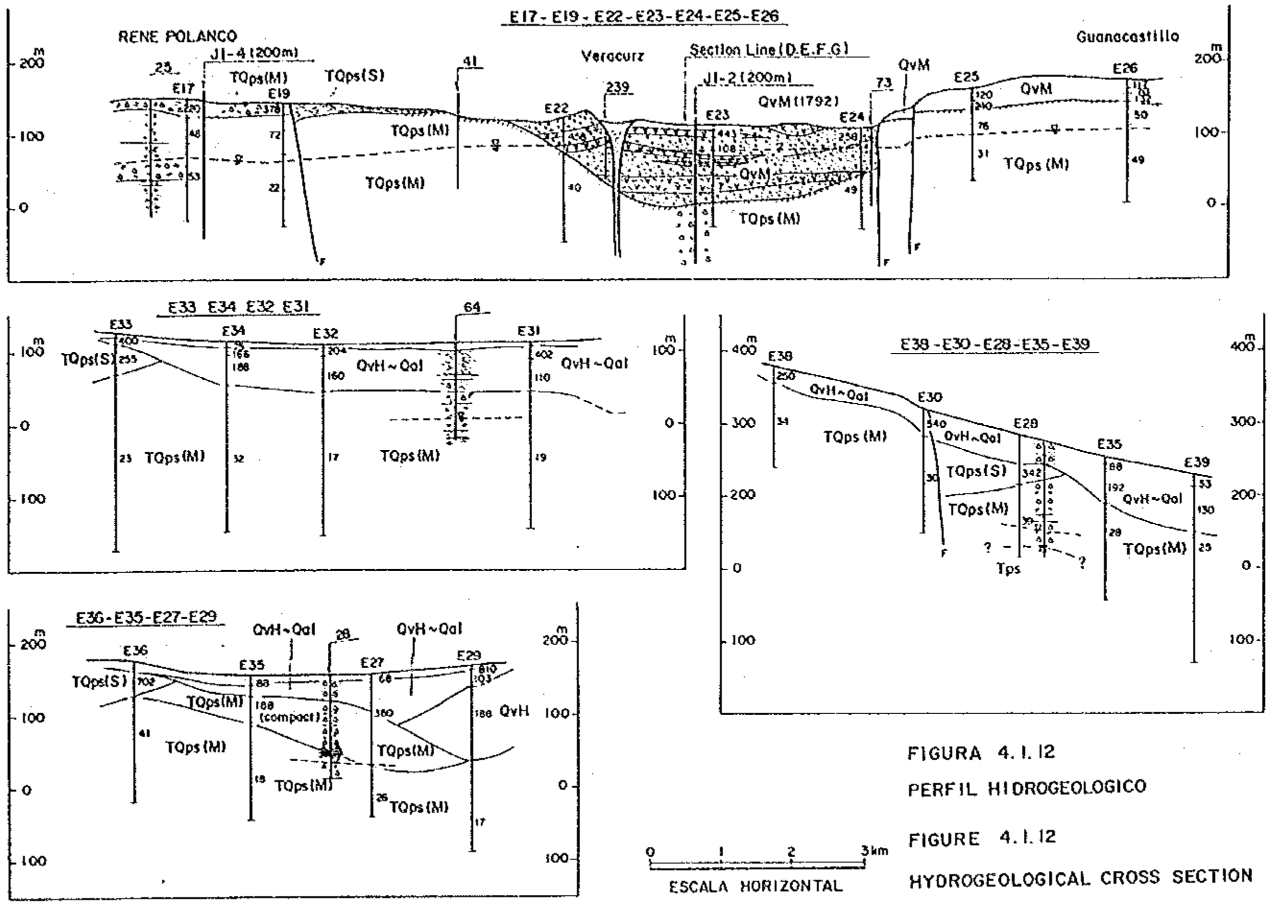


FIGURA 4.1.12
PERFIL HIDROGEOLOGICO

FIGURE 4.1.12
HYDROGEOLOGICAL CROSS SECTION

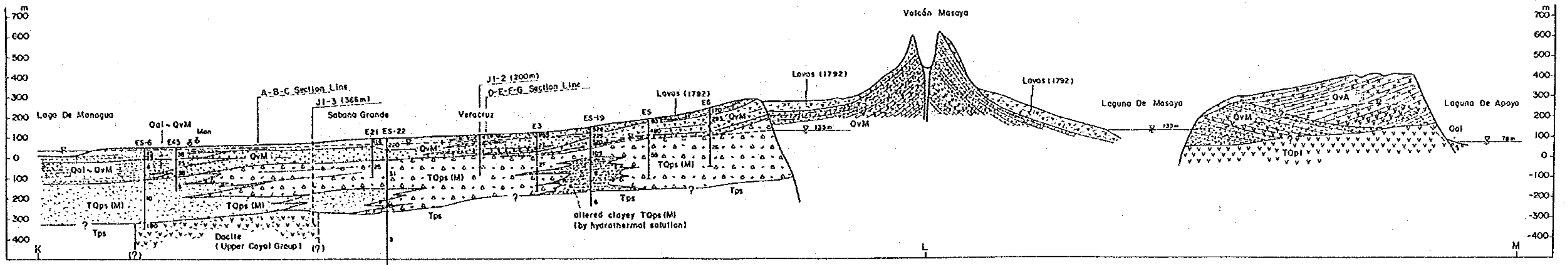


Fig. 4.1.11 PERFIL HIDROGEOLOGICO K-L-M
HYDROGEOLOGICAL CROSS SECTION K-L-M

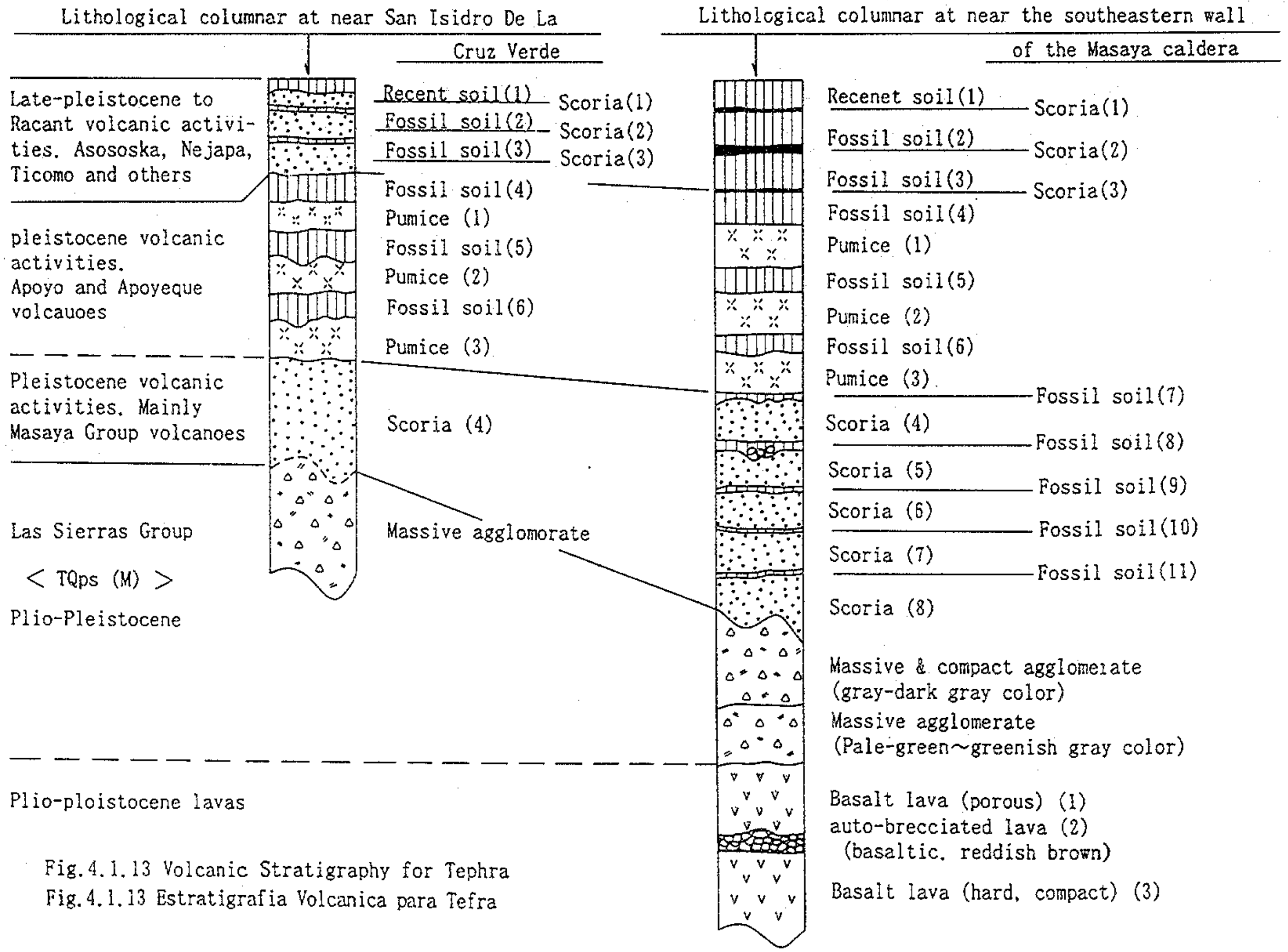


Fig.4.1.13 Volcanic Stratigraphy for Tephra
Fig.4.1.13 Estratigrafia Volcanica para Tefra

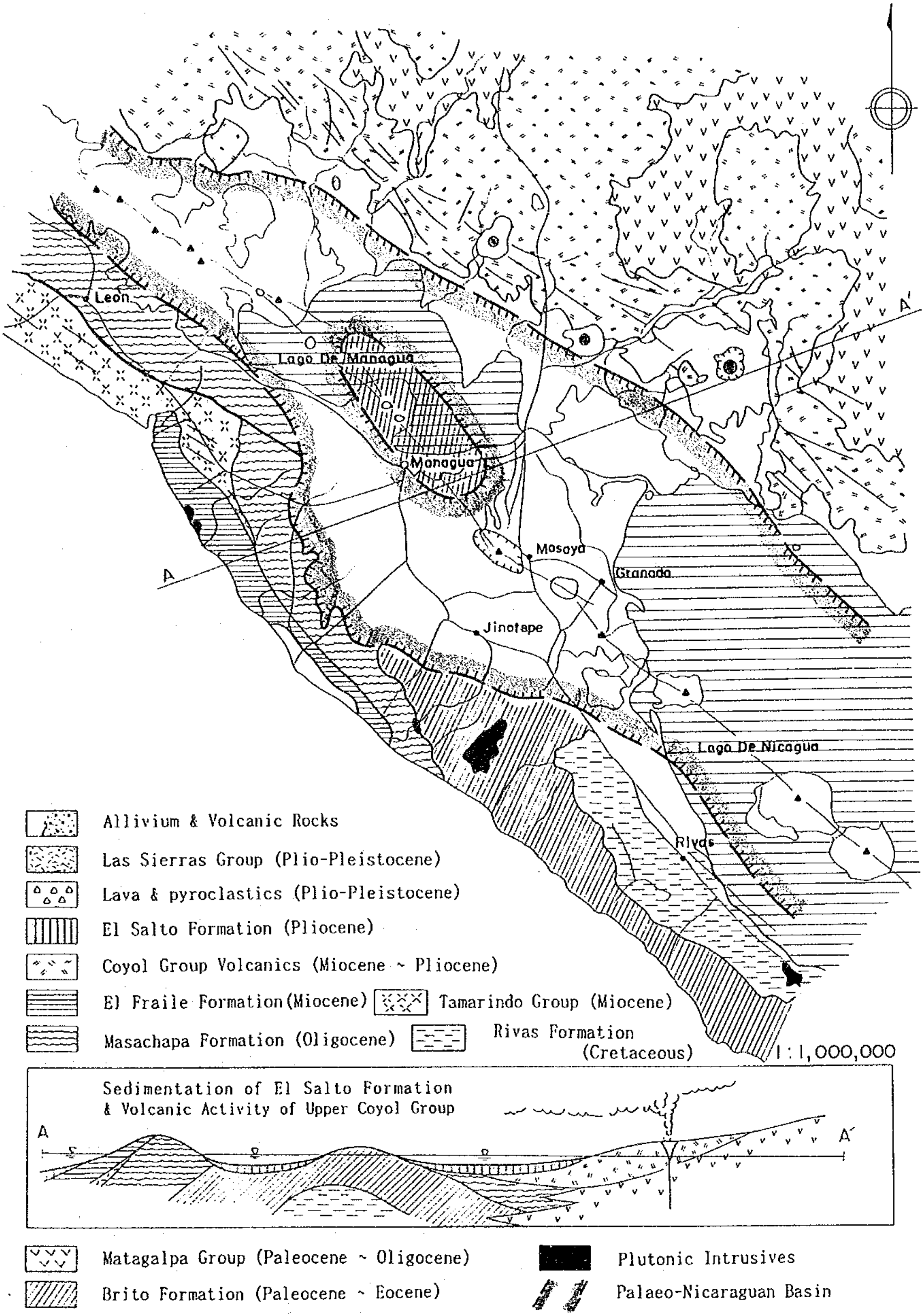


Fig. 4.1.14 Palaeogeographical Map (Early Pliocene)
Mapa Paleografico (Inicio del Plioceno)

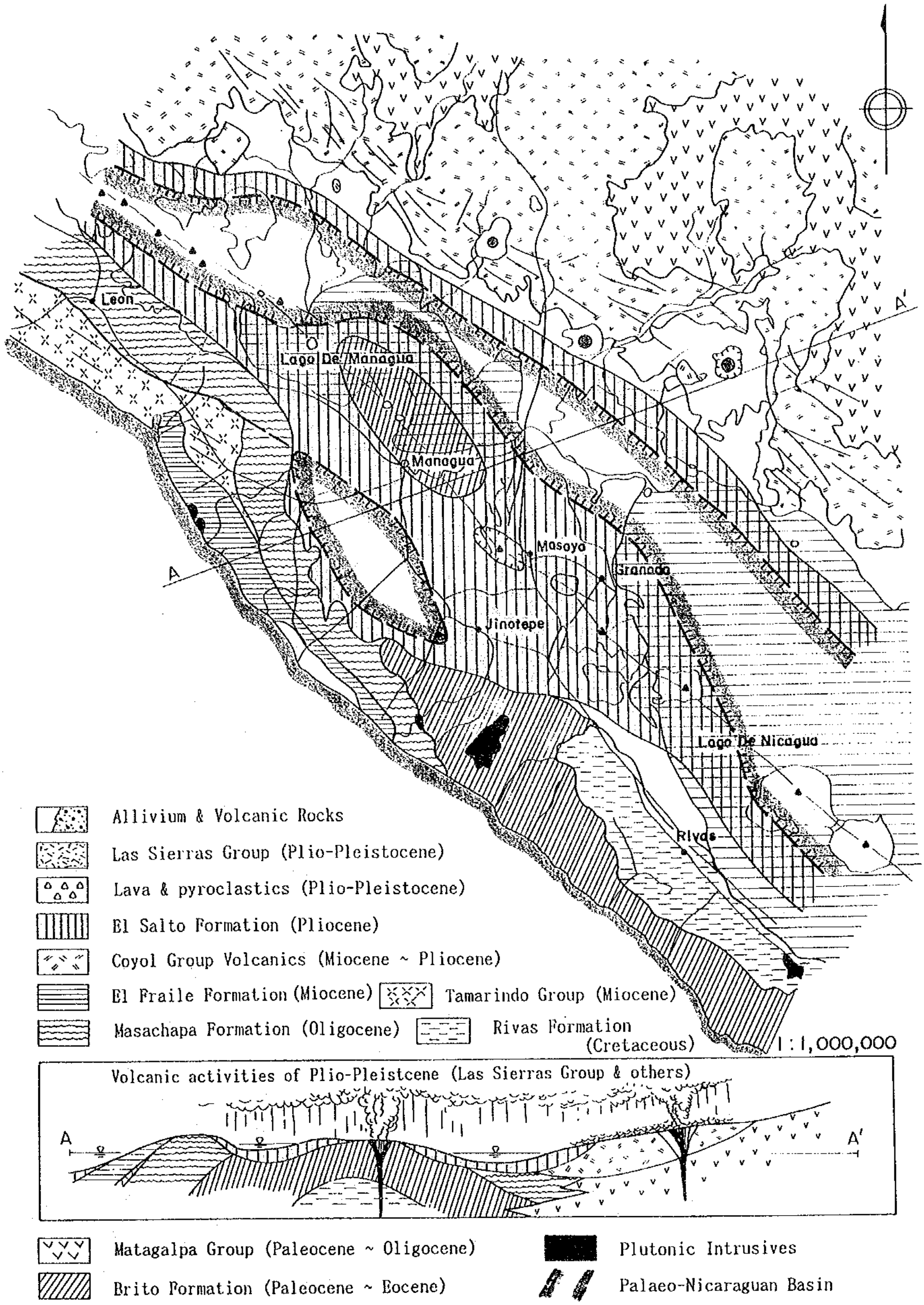


Fig. 4.1.15 Palaeogeographical Map (Late Pliocene)
Mapa Paleografico (Fines del Plioceno)

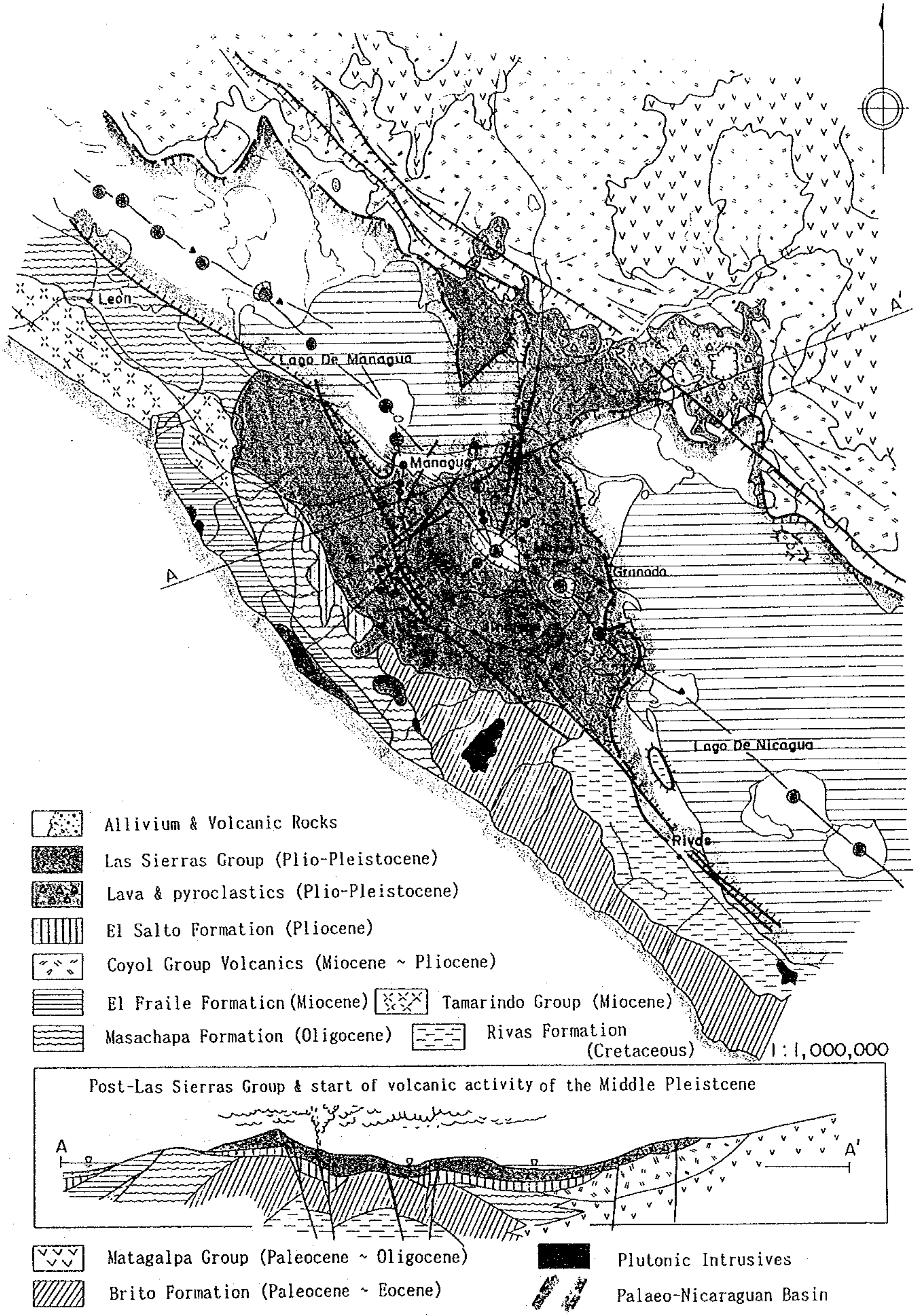


Fig. 4.1.16 Palaeogeographical Map (Middle Pleistocene)
Mapa Paleografico (Mediados del Pleistoceno)

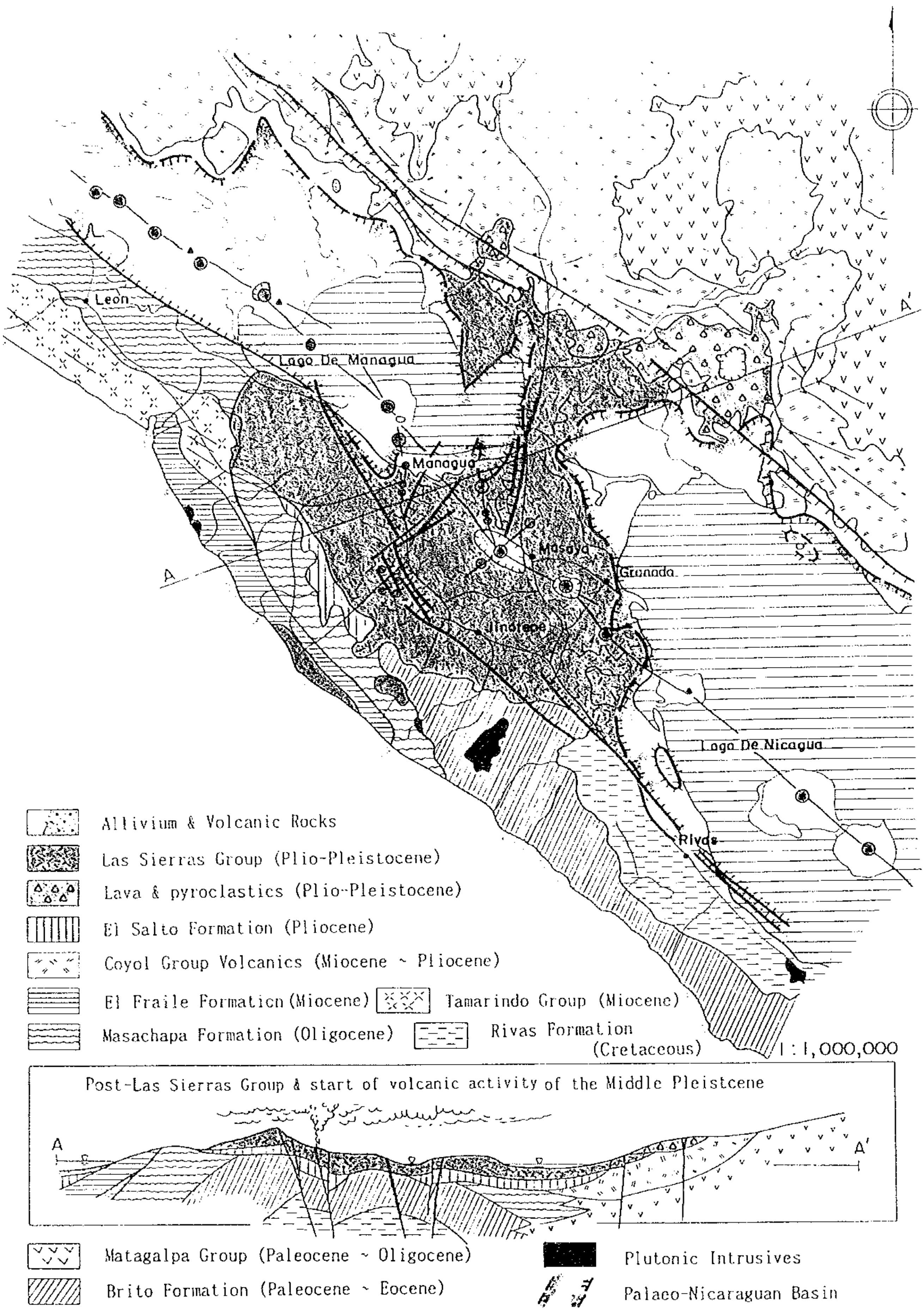


Fig. 4.1.16 Palaeogeographical Map (Middle Pleistocene)
Mapa Paleografico (Mediados del Pleistoceno)

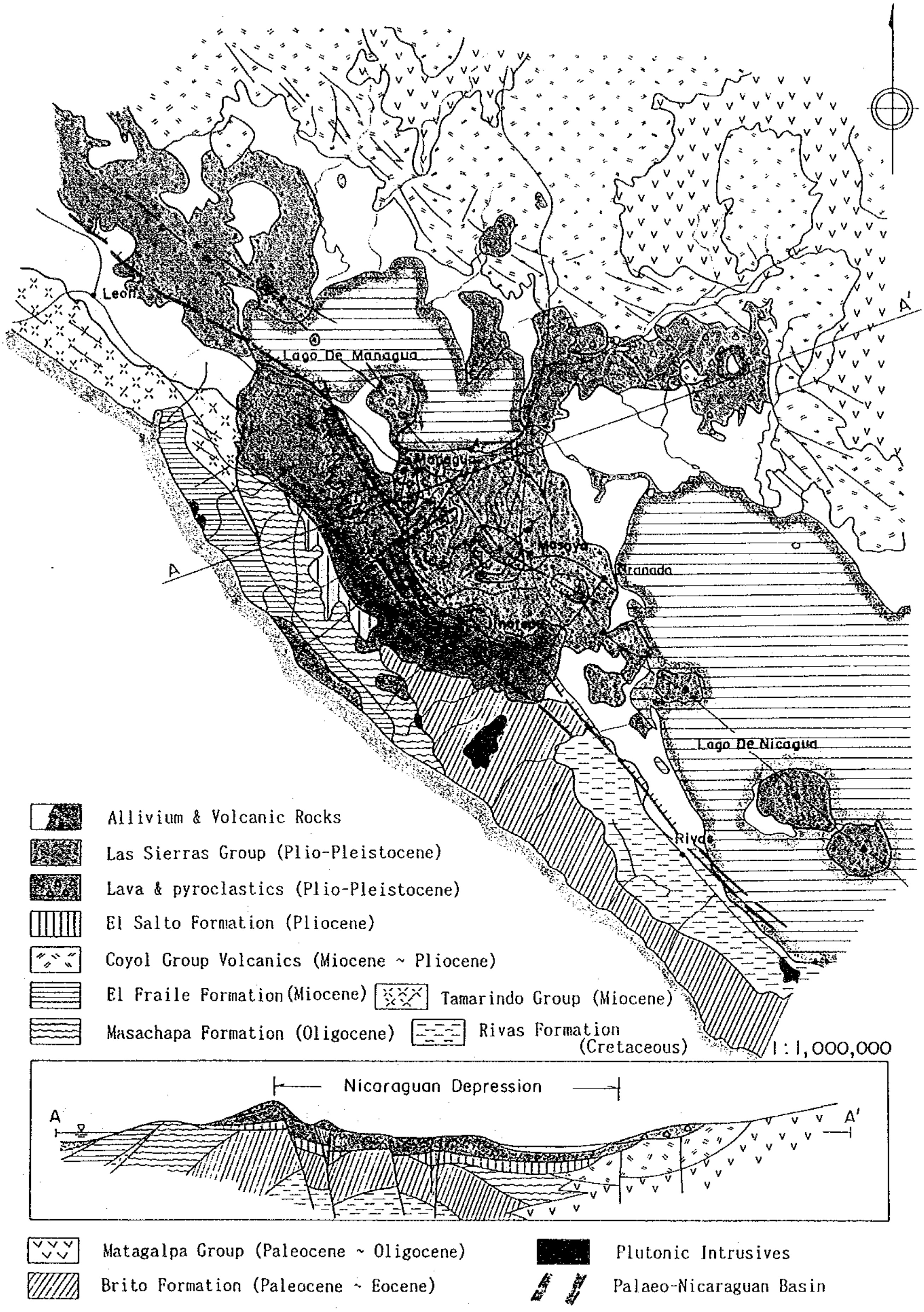


Fig. 4.1.17 Palaeogeographical Map (Late Pleistocene to Recent)
Mapa Paleografico (Finales del Pleistoceno-Reciente)

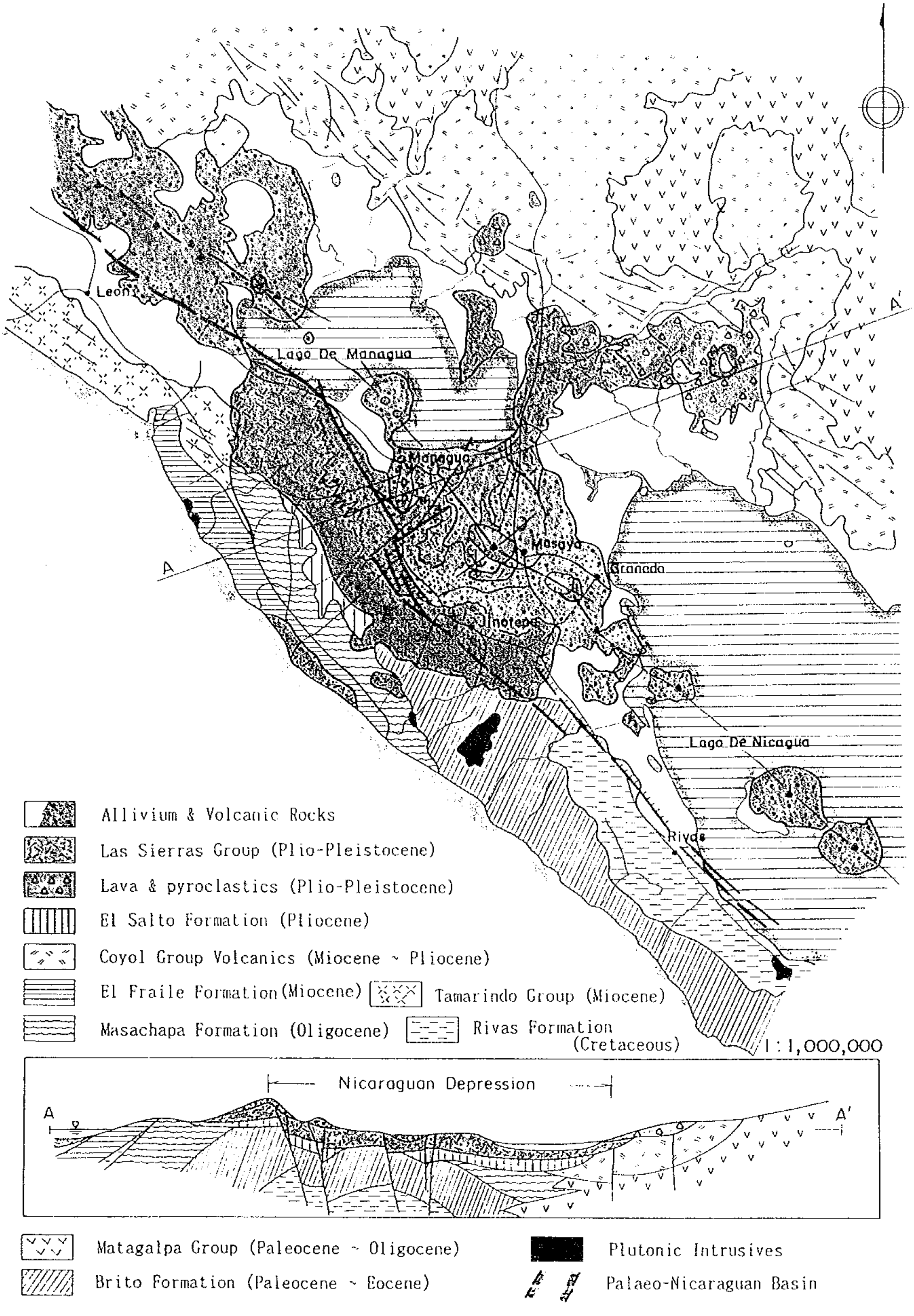


Fig. 4.1.17 Palaeogeographical Map (Late Pleistocene to Recent)
Mapa Paleografico (Finales del Pleistoceno-Reciente)

4.2 Climate

4.2.1 Meteorological Station

Meteorological records were principally collected from the Instituto Nicaraguense de Recursos Naturales y del Ambiente (IRENA) and the Instituto Nicaraguense de Estudios Territoriales (INETER).

Research was conducted on the twelve stations shown in Fig.4.2.1, located in the Study Area. The station with the lowest elevation, 56m above sea level, is at A.C. Sandino (Airport) and the highest, 910m, is at Hacienda Casa Colorada. Table 4.2.1 shows the location of and the periods and items observed at each station. The observation period was very limited and records were missing in many cases. Observations were only continually and accurately conducted at the A.C. Sandino and Masatepe Stations.

4.2.2 Temperature, Humidity and Evaporation

The outline of the monthly climatic condition, shown in Table 4.2.2, indicates slight variations in the monthly average and seasonal temperature in all stations. The lowest temperature is 25.6°C in December and the highest is 28.8°C in April, in A.C. Sandino Station. This difference gradually increased at the higher places in Masatepe Station, where the lowest is 23.1°C in January and the highest is 26.0°C in May.

Relative humidity basically varies from 65% to 84% in stations with higher elevation and from 70% to 89% in stations with lower elevation. The lowest value is observed in March, gradually increasing upto September.

Annual evaporation varies from 1807 mm to 2691 mm, almost corresponding to the elevation of the stations. The highest evaporation was observed in March, the driest month.

4.2.3 Rainfall

(1) General

Table 4.2.3 and Fig. 4.2.2 show the monthly rainfall distribution. The rainy season mainly starts from May to October, and sometimes even until November, although the rainfall amount in the latter month is small. The peak of the rainy season falls in May, September and October, depending on seasonal condition. Monthly rainfall was observed to vary from 150 and 350 mm. The amount of rainfall in June and July is always smaller than other rainy months, varying from 100-200 mm.

More than 70% of the annual rainfall is observed in the rainy season. Fig. 4.2.3 shows the relationship between rainfall and the elevation of each station. The average annual rainfall almost corresponds to this relation. Fig. 4.2.4 shows the variation in the annual rainfall of the 4 stations; Managua Plantel, A.C. Sandino, Masatepe and Casa Colorada. The average annual rainfall in A.C. Sandino Station is 1100 mm and varies annualy from 800 mm to 1400 mm.

The average annual rainfall in Masatepe Station is about 1500 mm and varies from 800 mm and 2000 mm. The comparison of the 5-year average of these rainfalls shows that a higher amount of rainfall corresponds with the adequate ratio calculated by the total average, however, this ratio can not be used in dry years like 1976-1979.

On the other hand, it is difficult to point out the increasing or decreasing tendencies of the annual rainfall.

(2) Monitoring and monthly rainfall in 1992

An automatic rainfall recorder was installed at La Concepción. The following table summarizes the monthly rainfall at this station and other monthly rainfall records collected from INETER. Details of the monitoring is described in the Supporting Report.

Rainfall in 1992 unit:mm

Station	EL.	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	SUM
La Concepción	540	0	0	80	255	147	44	138	262	926
Airport	56	0	0	87	159	139	62	143	111	701
Masaya	210	1	0	85	252	166	50	203	116	873
San Ishidro	290	0	0	89	291	115	86	-	-	-
Masatepe	450	1	29	128	-	148	64	-	-	-
Casa Colorada	910	0	35	64	188	133	79	166	-	-

These results show the following points concerning the rainy condition in 1992:

(a) This year is relatively drier than others.

(b) Maximum daily rainfall of 206 mm was observed at La Concepción in October, the second one, around 60 mm, was observed at the Airport and San Isidro in May, and Masaya in October.

(c) Rainfall hardly varies due to local condition, however, annual rainfall is roughly linear in elevation except in Casa Colorada Station.

(3) Relation of the stations

On the basis of the monthly rainfall records collected from INETER, the areal rainfall in 1972-1991 were estimated. Since many monthly rainfall records were missing or lost, these data have to be estimated to determine if it favorably correlates with the records of other stations. Basically, the annual rainfall and elevation of the observed stations are roughly linear. In addition to this, the correlation of each station selected by record history was analyzed as shown below.

Reg.No.	Station	El.(m)
27	Airport	56
50	Asososca	50
45	Las Jinotepes	470
46	La Primavera	600
47	Casa Colorada	910
49	Masatepe	450
115	Masaya	250

Correlation coefficient(%)

	27	50	45	46	47	49	115
27	*	*	*	*	*	*	*
50	80	*	*	*	*	*	*
45	69	85	*	*	*	*	*
46	65	88	91	*	*	*	*
47	54	70	85	77	*	*	*
49	75	83	81	83	71	*	*
115	84	82	-	66	44	83	*

confidence limit 95%

The results show that the annual rainfall at the Casa Colorada station does not correlate with the others. The data in the Airport station does not correlate with the data of the stations in Sierras de Managua.

(4) Annual Isohyet

An annual isohyet is shown in Fig. 4.2.1. Rainfall contour lines are basically prepared according to topographical conditions: 1100 mm-line was drawn from Lake Asososca to Sabana Grande Area, 1300 mm-line from Ticuantepe to Lake Masaya. Sierras de Managua is considered to have the highest rainfall in the Study Area at around 1600-1700 mm. The rainy condition in this mountainous area and the area around La Concepción and Masatepe is complicated. Topographic characteristics highly affect point rainfall.

(5) Rainfall Probability

29 and 21 of the annual rainfall records of A.C. Sandino Station and Masatepe Station, respectively, were used in the probability analysis by the Hazen plot method. Fig. 4.2.5 and 4.2.6 show the Hazen plot method calculation in each station. A 50% probability was achieved, 1100 mm and 1400 mm in A.C. Sandino and Masatepe stations, respectively.

The 20, 33, 50, 67, 80 % annual rainfall probability in both stations and the estimated rainfall in other stations are shown in Table 4.2.4. These values were used in making future estimates by model simulation.

4.2.4 Evapotranspiration

Potential evapotranspiration is generally considered as 80% of A-class pan evaporation.

The following table summarizes the annual potential evapotranspiration and rainfall in the Airport, Masaya and Masatepe stations.

unit:mm

Year	Airport		Masaya		Masatepe	
	ET	Rain	ET	Rain	ET	Rain
1970	1776	1082	-	-	1470	2155
1971	2001	1276	-	-	1333	1701
1972	1757	694	-	-	1509	1198
1973	1873	1742	-	-	1610	1986
1974	1727	856	-	-	1435	1502
1975	1770	1365	-	-	1332	1466
1976	2045	744	-	-	1417	827
1977	2066	816	-	-	1456	915
1978	1936	1008	1667	1110	1424	1093
1979	1794	1058	-	-	-	-
1980	1870	1448	-	-	1321	1445
1981	1996	1286	1480	1721	1454	1541
1982	2121	1352	1536	1532	1384	1688
1983	2060	807	1687	1204	1520	1289
1984	2068	1151	1613	1346	1488	1448
1985	1967	1260	1664	1138	1540	1200
1986	1873	774	1560	902	1509	1235
1987	1963	1103	1756	1458	-	-
1988	1734	2185	1648	1964	-	-

The potential evapotranspiration itself is higher than the annual rainfall. Evaporation is considered to continue even in the dry season, and consumes a high percentage of rainfall.

Table 4.2.1 List of Meteorological Station

	Station	Reg.No	Lat.	Long.	El(m)	Period	Item
1	Managua de Plantel	22	12.09	86.17	60	52-81	PTEH
2	A.C. Sandiano	27	12.08	86.1	56	58-89	PTHESV
3	Santa Rosa	43	12.09	86.09	60	62-66	PTEH
4	Las Jinotepes	45	12.04	86.19	470	63-84	P
5	La Primavera	46	12.01	86.14	600	63-89	P
6	Casa Colorada	47	11.58	86.18	910	63-90	P
7	Masatepe	49	11.54	86.08	450	63-87	PTHESV
8	Asososca	50	12.53	86.18	80	63-89	P
9	RURD	89	12.06	86.16	200	72-88	PTHVSE
10	SAIMSA	104	11.57	86.05	310	72-73	P
11	Masaya	115	15.59	86.06	250	77-89	PHET
12	Campos Azules	129	11.53	86.08	470	83-89	PTEHSV

*** Observation Items

P: Precipitation (mm)
T: Mean Temparature (C)
E: Evaporation (mm)
H: Relative Humidity (%)
S: Sunshine hours (hr)
V: Wind Velocity (m/sec)

Table 4.2.2 Outline of Climatic Condition

STATION: MANAGUA PLANTEL DE CARRETERA

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	52-81	2	2	6	11	141	205	111	113	203	244	53	8
TEMPERATURA MEDIA (C)	52-67	26.6	27.2	28	29	29.2	27.8	27.5	27.9	27.8	27	27	27
EVAPORACION (mm)	54-67	220	230	272	264	263	187	202	205	188	164	179	195
HUMEDAD RELATIVA (%)	52-67	71	70	68	68	73	78	77	77	77	79	74	72

STATION: A.C. SANDINO

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	58-89	4	2	4	6	128	208	141	146	207	205	51	11
TEMPERATURA MEDIA (C)	57-89	25.8	26.6	27.9	28.8	28.7	26.8	26.4	26.5	26.3	26.1	26	25.6
EVAPORACION (mm)	69-89	215	236	286	288	242	168	165	160	145	145	151	176
HUMEDAD RELATIVA (%)	58-89	71	67	66	65	72	82	82	82	84	84	80	75
INSOLACION (hours)	58-89	227.3	231.6	263.1	238.7	208.3	147.6	164.6	185.4	171.5	187.3	210.8	223.1
VELOCIDAD MEDIA DEL VIENTO (m/s) h=8 m	57-89	3.2	3.6	3.8	3.6	2.8	2.1	2.4	2.2	1.8	1.4	1.8	2.6

STATION: SANTA ROSA

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	62-86	2	1	0	3	144	200	148	170	191	240	52	26
TEMPERATURA MEDIA (C)	62-66	27.2	28.2	28.9	28.9	29.7	28.1	27.6	28.7	28.6	28.3	27.5	27.2
EVAPORACION (mm)	62-66	243	268	333	273	297	185	190	211	159	168	171	193
HUMEDAD RELATIVA (%)	62-66	74	75	74	75	68	76	75	74	82	81	81	78

STATION: LAS JINOTEPES

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	63-84	5	1	0	26	154	243	127	156	228	215	49	13

STATION: LA PRIMAVERA

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	63-89	13	5	7	19	183	235	176	163	253	231	68	29

STATION: HACIENDA CASA COLORADA

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	63-90	18	10	10	26	217	292	161	185	345	306	125	43

STATION: MASATEPE

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	63-87	15	6	7	19	207	211	164	184	298	255	91	32
TEMPERATURA MEDIA (C)	64-87	23.1	23.8	24.9	25.8	26	24.8	24.5	24.6	24.5	24.1	23.6	23.2
EVAPORACION (mm)	63-87	151	178	236	242	188	121	119	132	119	116	119	132
HUMEDAD RELATIVA (%)	63-87	80	76	73	72	76	85	86	85	87	87	85	82
INSOLACION (hours)	74-87	245.9	238.6	267.3	247.9	206	127.6	160.6	168.3	162.8	184.6	205.7	224.9
VELOCIDAD MEDIA DEL VIENTO (m/s) h=8 m	74-87	1.4	1.5	1.5	1.6	1.1	1.1	1.2	1	0.8	0.8	0.9	1.4

STATION: ASOSOSCA

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	63-89	2	0	3	15	164	195	103	125	209	217	49	7

STATION: R.U.R.D.

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	72-88	4	2	7	15	187	175	130	159	212	204	48	5
TEMPERATURA MEDIA (C)	64-87	26.2	26.9	27.8	28.7	28.4	27	26.7	26.7	26.4	26.4	26.3	26.2
EVAPORACION (mm)	72-88	243	271	329	318	266	173	198	196	170	185	175	212
HUMEDAD RELATIVA (%)	72-88	65	62	59	59	66	77	76	78	80	79	74	69
BRILLO SOLAR (hours)	72-88	259.5	244.2	269.5	248	201.7	166.4	178.8	196.9	179	204.5	230.2	246.4
VELOCIDAD MEDIA DEL VIENTO (m/s) h=8 m	72-88	5.1	5.3	5.2	4.9	3.6	3.2	4.1	3.5	2.8	2.7	3.3	4.2

STATION: SAIMSA

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	72-73	0	0	0	0	308	611	353	380	310	520	98	3

STATION: MASAYA

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	77-89	7	4	4	7	174	212	186	209	244	255	62	15
TEMPERATURA MEDIA (C)	77-89	25	25.9	27	27.9	28.1	26.5	26	26.4	26	25.8	25.5	25
EVAPORACION (mm)	77-89	172	194	243	234	202	147	145	150	128	135	134	144
HUMEDAD RELATIVA (%)	77-89	71	67	64	61	67	80	81	81	82	82	80	75

STATION: CAMPOS AZULES

PARAMETERS	PERIODO	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.
PRECIPITACION (mm)	83-89	9	48	5	4	152	267	214	216	252	269	90	45
TEMPERATURA MEDIA (C)	83-89	22.7	23.4	24.3	25.5	25.6	24.3	23.8	23.8	23.7	23.6	23.5	22.8
EVAPORACION (mm)	83-89	161	151	224	206	199	129	119	123	116	131	117	131
HUMEDAD RELATIVA (%)	83-89	81	75	71	70	77	87	87	86	89	87	86	84
INSOLACION (hours)	83-89	267.8	240.2	264.5	239.8	229.5	172.6	166.7	198.1	179.3	207.4	196.1	207.8
VELOCIDAD MEDIA DEL VIENTO (m/s) h=8 m	83-89	5.3	4.9	3.5	3.7	3.2	3.2	3.7	3.7	3.6	3.2	3.8	4.8

Table 4.2.3 Monthly Rainfall

AVERAGE CHART OF PRECIPITATION, FOR ESTATION AND PERIOD

STATION	PERIOD	ELEVATION	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AGO.	SEP.	OCT.	NOV.	DIC.	TOTAL
PLANTEL DE CARRETERA	52-81	60 msnm	2	2	6	11	141	205	111	113	203	244	53	8	1099
A. C. SANDINO	58-89	56 msnm	4	2	4	6	128	208	141	146	207	205	51	11	1113
SANTA ROSA	62-73,83-86	60 msnm	2	1	0	3	144	200	148	170	191	240	52	26	1177
LAS JINOTEPES	63-84	360 msnm	5	1	0	26	154	243	127	156	228	215	49	13	1217
LA PRIMAVERA	63-89	600 msnm	13	5	7	19	183	235	176	163	253	231	68	29	1382
HACIENDA CASA COLORADA	63-90	910 msnm	18	10	10	26	217	292	161	185	345	306	125	43	1738
MASATEPE	63-87	450 msnm	15	6	7	19	207	211	164	184	298	255	91	32	1489
ASOSOSCA	63-89	80 msnm	2	0	3	15	164	195	103	125	209	217	49	7	1089
R. U. R. D.	72-88	200 msnm	4	2	7	15	187	175	130	159	212	204	48	5	1148
SAIMSA	72-73	310 msnm	0	0	0	0	154	206	177	190	155	260	98	2	1242
MASAYA	77-89	250 msnm	7	4	4	7	174	212	186	209	244	255	62	15	1379
CAMPOS AZULES	83-89	470 msnm	9	48	5	4	152	267	214	216	252	269	90	45	1571

Table 4.2.4 Probability Rainfall

Provability Calculation

(1) Airport N=29

No.	Rain	Fn(%)
1	2185	98.27
2	1742.	94.82
3	1448	91.37
4	1423.	87.93
5	1383.	84.48
6	1368.	81.03
7	1365	77.58
8	1352.	74.13
9	1286.	70.68
10	1276.	67.24
11	1267.	63.79
12	1260.	60.34
13	1151.	56.89
14	1103	53.44
15	1082	50
16	1058.	46.55
17	1008.	43.10
18	935.5	39.65
19	856	36.20
20	822.2	32.75
21	816.1	29.31
22	806.7	25.86
23	780.7	22.41
24	776.2	18.96
25	774.2	15.51
26	763.3	12.06
27	746.6	8.620
28	744.4	5.172
29	693.5	1.724

Av. 1113.

(2) Masatepe N=21

No.	Rain	Fn(%)
1	2155	97.61
2	2068	92.85
3	1986	88.09
4	1875	83.33
5	1846	78.57
6	1834	73.80
7	1701	69.04
8	1688	64.28
9	1541	59.52
10	1502	54.76
11	1466	50
12	1448	45.23
13	1289	40.47
14	1235	35.71
15	1200	30.95
16	1198	26.19
17	1178	21.42
18	1093	16.66
19	1068	11.90
20	915	7.142
21	827	2.380

Av. 1481.

Probability Rainfall by Hazen Plot

Unit:mm

Block Location No.	Return Period				
	Non-exceedance			Exceedance	
	20%	33%	50%	67%	80%
1. Asososca	880	980	1100	1250	1350
2. Las Jinotepes	960	1070	1200	1360	1470
3. La Primavera	1100	1250	1400	1650	1800
4. Casa Colorada	1180	1340	1500	1770	1930
5. A.C. Sandino	880	980	1100	1250	1350
6. Ave. of 5&7	960	1070	1200	1360	1470
7. Masaya	1040	1160	1300	1480	1600
8. Masatepe	1100	1250	1400	1650	1800

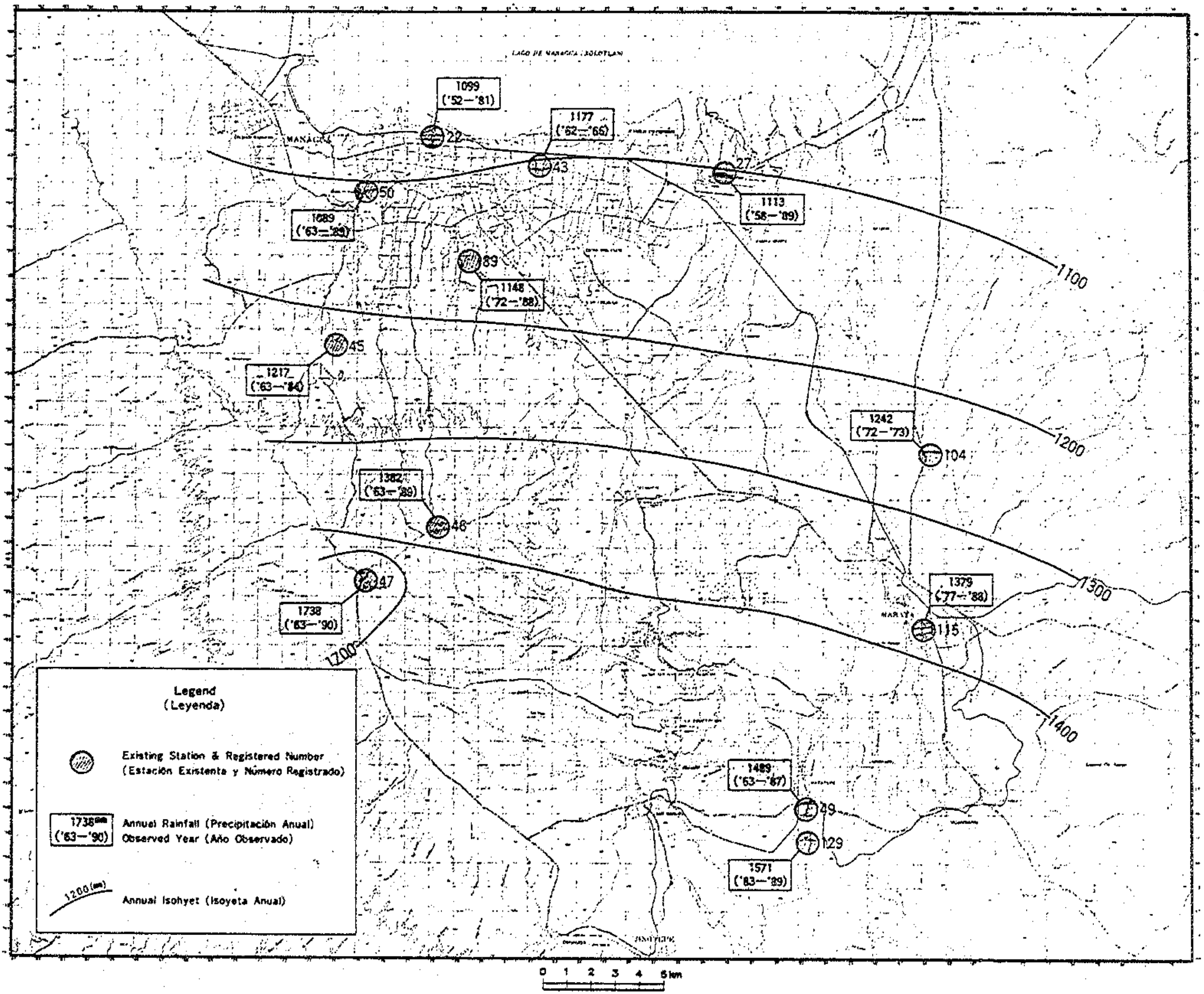


Fig. 4.2.1 Location of Meteorological Station

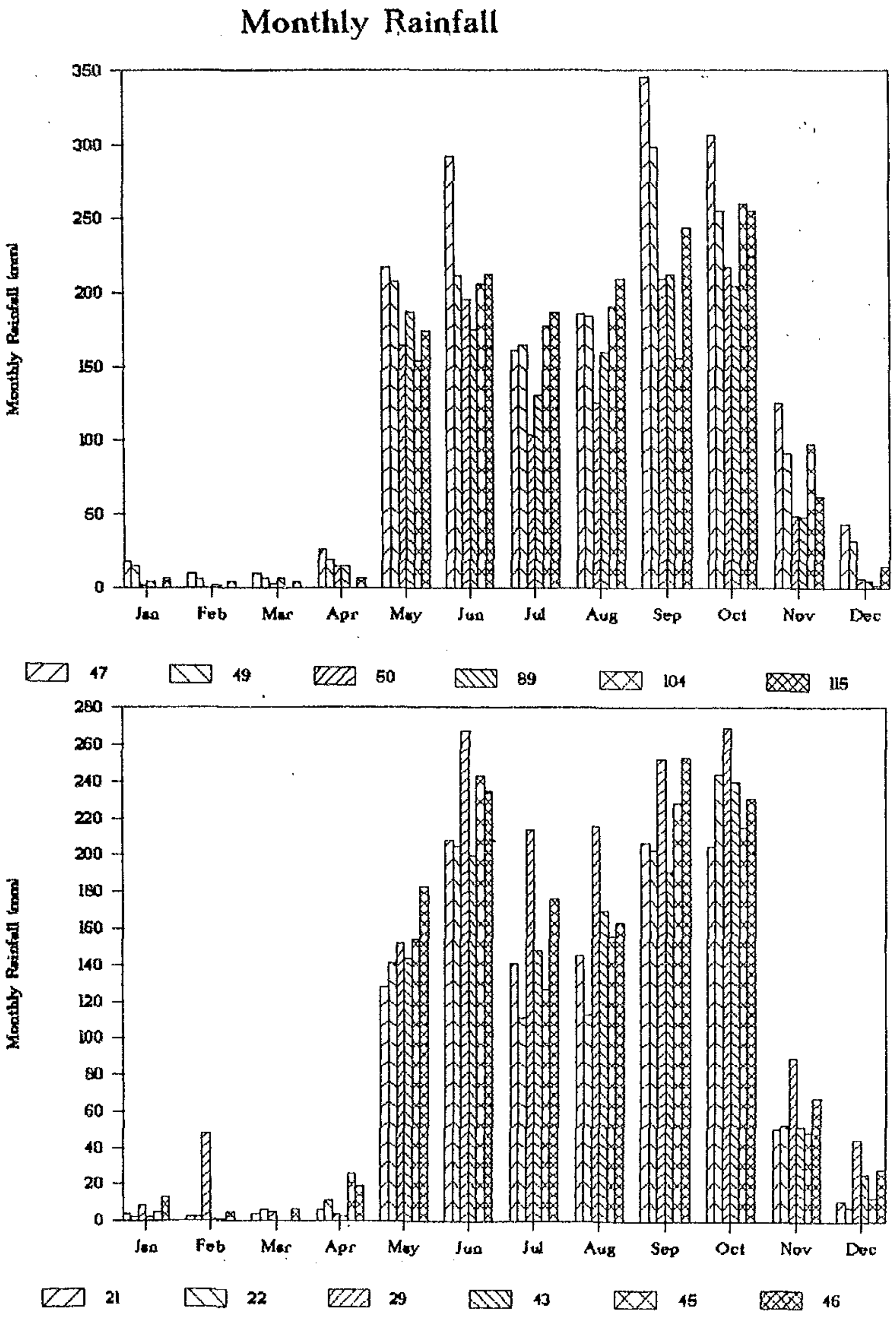


Fig. 4.2.2 Monthly Rainfall

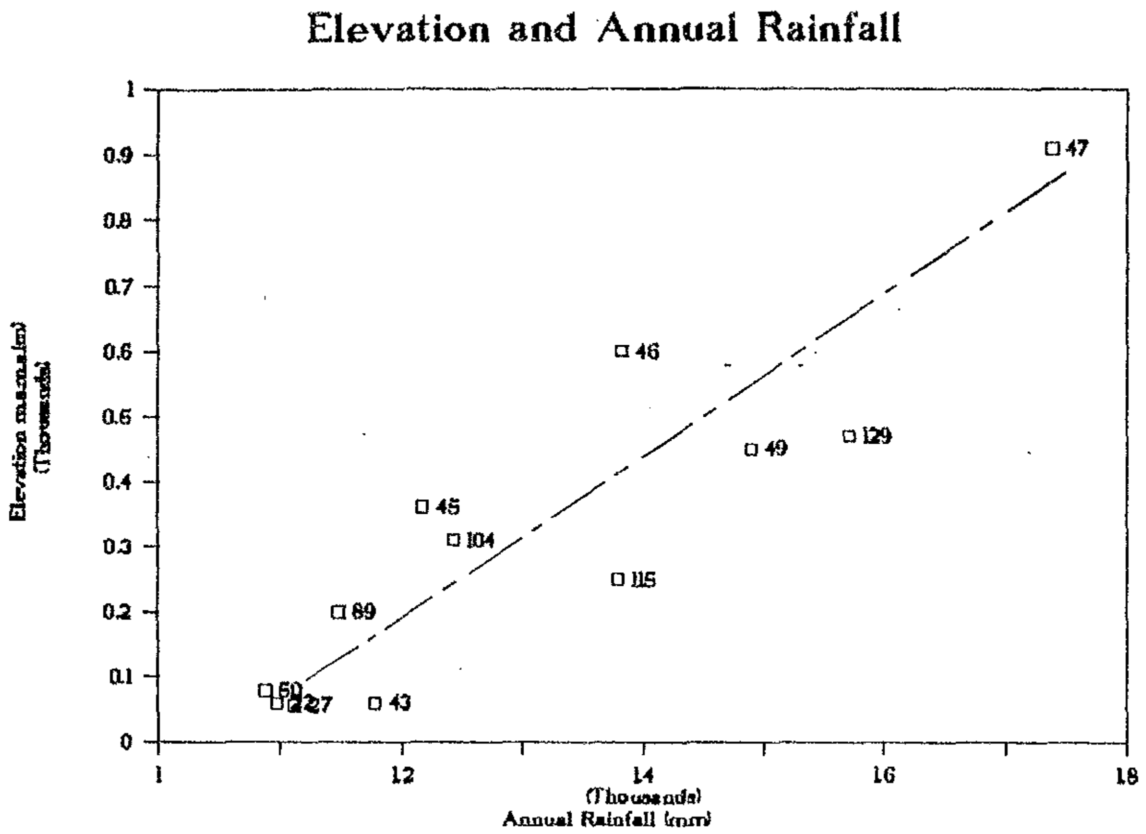


Fig. 4.2.3 Elevation and Annual Rainfall

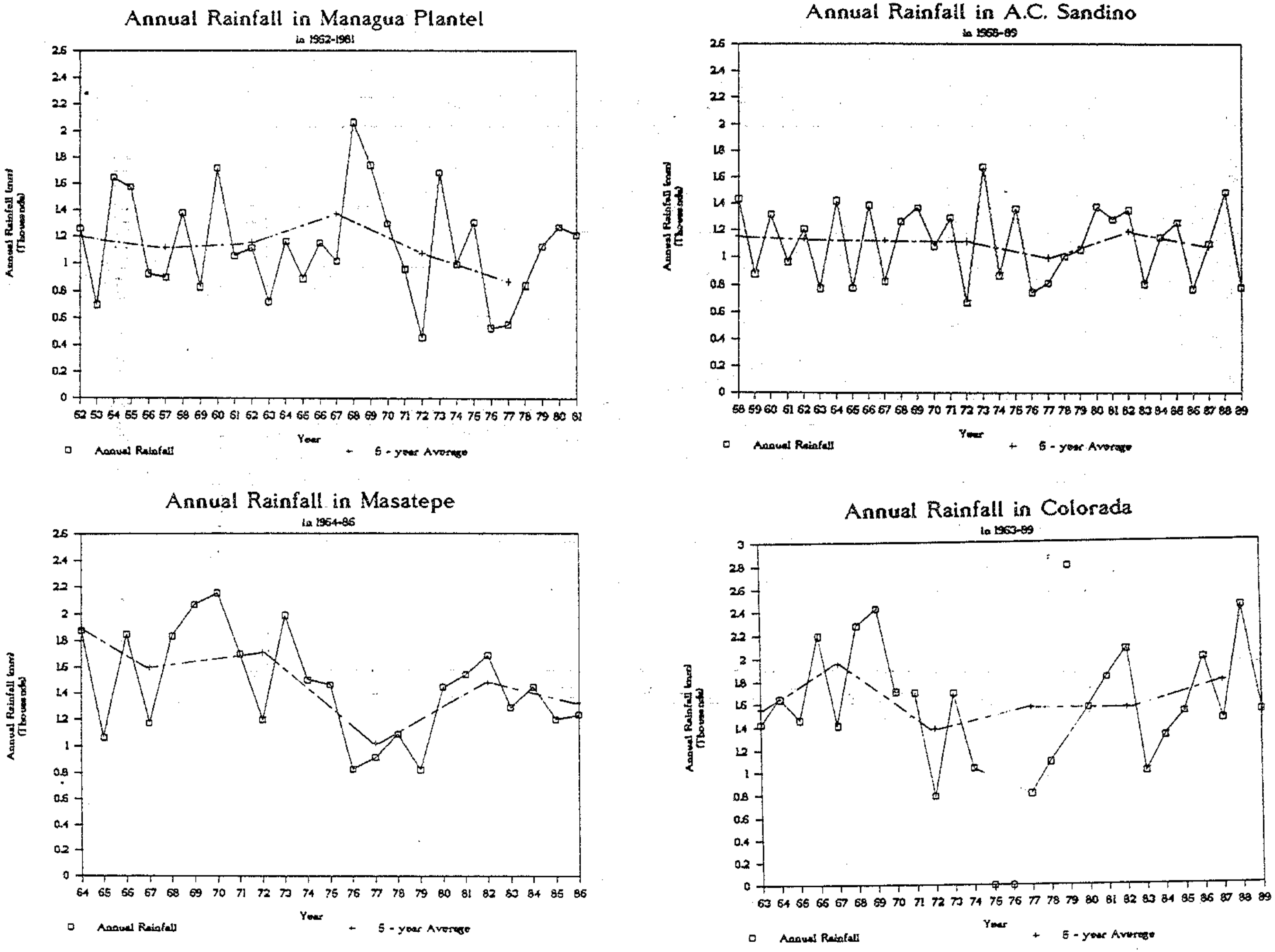


Fig. 4.2.4 Long-term Annual Rainfall

STATION:A.C.SANDINO
No. : 27
EL. : 56m

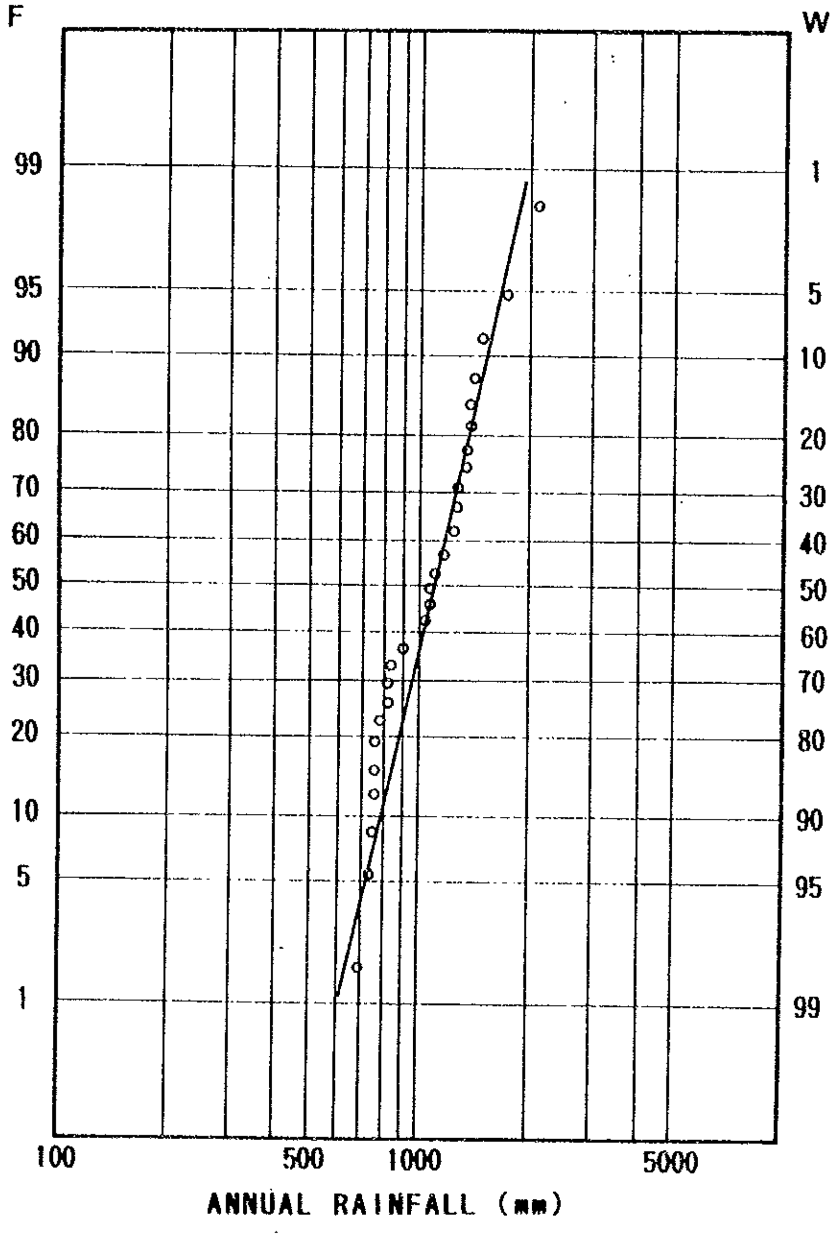


Fig. 4. 2. 5 PROBABILITY RAINFALL (1)

STATION: MASATEPE
No. : 49
EL. : 450m

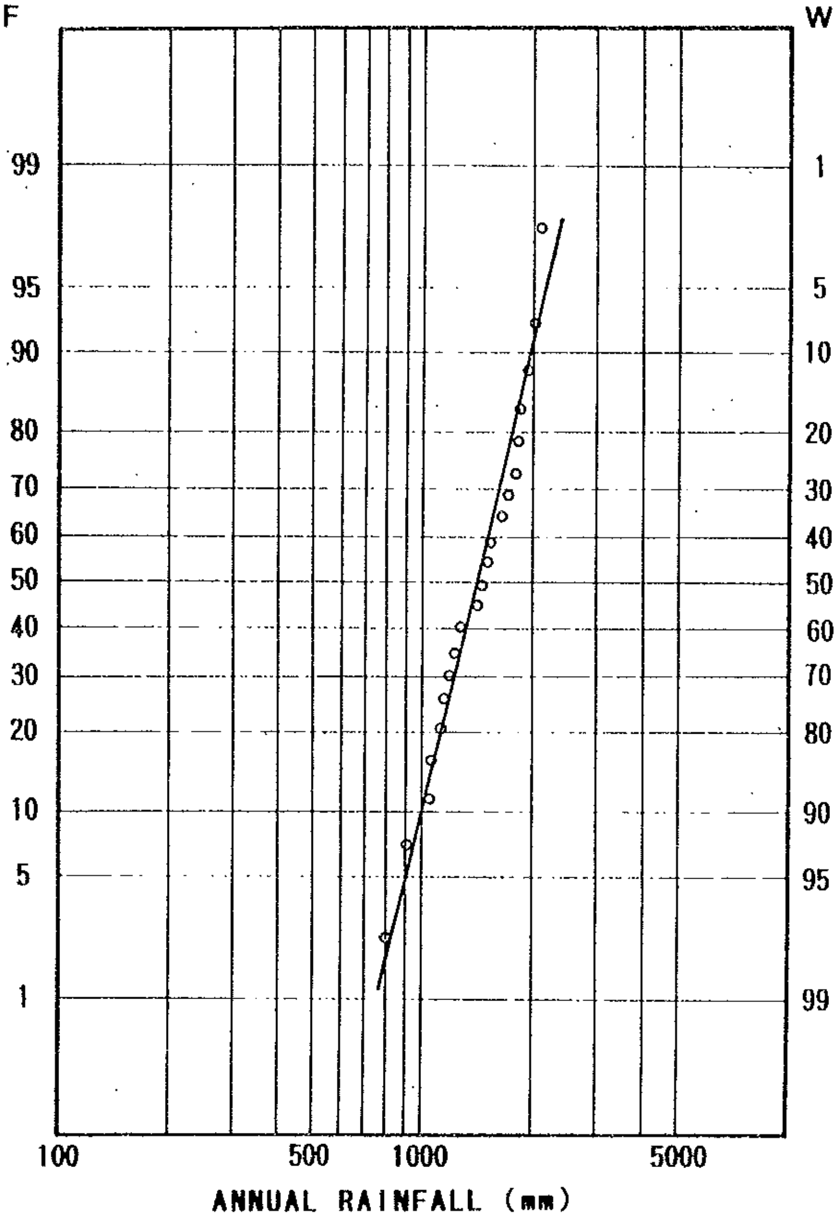


Fig. 4. 2. 5 PROBABILITY RAINFALL (2)

4.3 Surface Water

4.3.1 General

The surface waters studied in the Study Area were that of lakes, seasonal rivers and springs and their locations are briefly mentioned in Section 4.1.

(1) Drainage System

The drainage system in the Study Area is divided into four, namely sub-quenca I, II, III, IV, from west to east as shown in Fig. 4.3.1, and they are almost overlaid by the Southern catchment area of Lake Managua.

Sub-quenca I covers the area from Ciudad Sandino to the western edge of Lake Asososca. Sub-quenca II covers most of the Managua City area, Lake Asososca at the western end and Airport at the eastern end. Sub-quenca III covers a very narrow area around Sabana Grande and extends to the mountainous area at the northern side of Sierras de Managua. Sub-quenca IV covers the Sabana Grande lowland area and a part of Volcanic Masaya.
The catchment area of these sub-quencas is summarized below.

Sub-quenca I	120 km^2
Sub-quenca II	222 km^2
Sub-quenca III	136 km^2
Sub-quenca IV	183 km^2
Quenca of Lake Masaya	219 km^2
Total	880 km^2

(2) Lakes and springs

There are principally six lakes in the Study Area and general information on these lakes and their surveyed elevation (April 10,1992) are summarized in next page.