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GERENCIA DE PROTECCION RADIOLOGICA
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CNEA-NT 22/87

HYDROGEOLOGICAL FEATURES
OF A ROCKY MASSIF TO BE

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Wetten, Cristian**; Grassi, Jose Ivan*

COMISION NACIONAL DE ENERGIA ATOMICA

BUENOS AIRES - ARGENTINA

1987

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GERENCIA DE PROTECCION RADIOLOGICA Y SEGURIDAD

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Wetten, Cristian**; Grassi, Jose Ivan*

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BUENOS AIRES
1987

HYDROGEOLOGICAL FEATURES OF A ROCKY MASSIF

TO BE USED AS A NUCLEAR REPOSITORY

Wetten** C. and Grassi* J.I.

ABSTRACT

The Sierra del Medio rocky massif is situated in the central west sector of a probably closed Cainozoic sedimentary basin.

Sierra del Medio behaves as an area having a positive relief which receives rainfalls and spreads it over the superficial smaller basins around it. From the geological and geophysical points of view it is believed that the massif is separated from the adjacent basin water bearing formations by fractures belonging to the direct type.

It is formed by Paleozoic migmatites of granitic to tonalitic composition intruded by acidic, mesosilicic and basic dikes. Ectinite xenoliths can also be found.

The different hydrogeological units in the rocky massif under study were defined preliminary in geological, geophysical, mechanical and chemical detailed studies.

Tentative isopiezometric curves are shown and geophysical profiles are analyzed.

RESUME

Le massif rocheux de Sierra del Medio est situé dans le centre-ouest d'un bassin sédimentaire Cénozoïque probablement fermé.

Il se comporte comme une zone en relief recevant les eaux de pluie et les répandant sur les bassins superficiels plus petits que l'entourent. Les considérations géologiques et géophysiques conduisent à penser que le massif est séparé du bassin adjascent renfermant des niveaux aquifères par des failles normales.

Le massif est constitué de migmatites paléozoïques de composition granitique ou tonalitique recoupées par des filons de roches acides à basiques; on y rencontre également des enclaves d'ectinites.

Les différentes unités hydrogéologiques dans le massif rocheux étudié ont été délimitées par des études géologiques, géophysiques, mécaniques et chimiques détaillées. La contribution présente un essai de cartographie piézométrique et l'analyse des profils géophysiques.

1: INTRODUCTION

This paper describes the most important results derived from different geological investigations carried out at Sierra del Medio and the preliminary hydrogeological studies of this rocky massif.

Sierra del Medio is situated in the central-northern sector of the Province of Chubut, Argentina between 69°38' and 69°55' western longitude and 42°02' and 42°12" southern latitude (Fig. N°1).

This orographic unit is a block of 25 km. length and 8 Km. width. Its maximum height is 1,350 m.a.s.l. at Las Chivas hill situated almost in the widest part of this massif. The mean level difference from plains ("pampas") surrounding Sierra del Medio to its highest point is of about 450m.

The major axis of Sierra del Medio runs with a north-western south-eastern trend; in general its relief is smooth with short and shallow gaps enclosed by rounded hills.

The regional hydrogeological investigation (1) was developed over a quite heterogeneous area where its geographical boundaries are: North, latitude 42°00', South, latitude 42°30' South; East, longitude 69°00' West, longitude 70°00' West covering an area of about 4,600 km² that extends over part of Gastre and Cushamen departments in the Province of Chubut. Based on data obtained from 50 water points located all over Sierra del Medio and from the different groundwater static levels measured in 12 geological exploration drillholes, the first detailed hydrogeological features of the rocky massif are outlined.

2. RESULTS OF PREVIOUS INVESTIGATIONS.

Different aspects of the various stages of research carried on at Sierra del Medio can be summarized:

- a) Taking into account structural stereoscopic photointerpretation, helped by geomorphological-neotectonic, geophysical and geological studies of Sierra del Medio massif, a central area of 100 km² delimited by Alderete, Los Sauces, Guzmán and Escobar posts (shepherd dwellings) was determined (1) and further investigations in detail were centred on it (3,4 and 7).
- b) Those mentioned detailed studies have had a geological-petrographical, topographical - geomorphological, structural (geostatistical) and geophysical character. The underground investigations were performed thanks to 12 shallow and deep drillholes (300 m. and 750 m.). Four deep drillholes were situated almost symmetrically in an area surrounding the highest topographic point (Las Chivas hill, 1,350 m.a.s.l.).

- c) From drillholes and surface data, a three dimensional rocky mass discontinuity variability model has been proposed on the basis of a computerised approach. According to geological standards, faults, joints, master joints and dikes are enclosed as discontinuities. Hydraulic injection tests and permeability measuring logs in every drillhole have been programmed as following stages and their peizometric level data will be taken as a base in order to study the fluid movement in depth.

3. SURFACE GEOLOGY

The differentiated lithological units are migmatites and dikes.

MIGMATITES: Sierra del Medio is formed by rocks of tonalitic composition (Mamuil Choique Formation) being the result of a migmatization process on old biotitic and amphibolitic schists (Cushamen Formation). At the same time the tonalitic migmatites have been partially or totally granitized in some sectors.

The main mineralogical constituents of migmatites are: quartz, plagioclase, potassic feldspar and biotite. It is impossible to determine the migmatite age due to the fact that stratigraphical relationships have not been found. According to Ravazzoli and Sesana (1977), they would belong to the Lower Palaeozoic, according to Proserpio (1978) they would be Carbonic and to Nullo (1978), to the pre-Cambrian-Permian Carbonic period.

DIKES: Various pegmatitic, rhyolitic-dacitic and microdioritic dikes were recognized. These microdiorites are described as follows:

- a) Pegmatitic dikes: They are present as sets of dikes distributed all over the Sierra. Their thickness varies from a few centimetres to 2 m. Their predominant trend is north western/south eastern with a north eastern dip from 15° to 25°. There are also local subvertical dikes. Their mineralogical composition is quartz, feldspar and moscovite. Although their texture is almost constant in a few outcrops they may become aplitic in their central stripe. Their contacts with host rock are generally diffusive but they can be easily observed.
- b) Rhyolitic-dacitic dikes: Several acidic dikes have been observed in a couple of places in the Sierra; the biggest one is to the west of "El Alamo" post, 4 km. in length and 6-8 m. thick. It has an almost vertical north 50° eastern trend. The different contacts with the host rock can be easily observed. Several rhyolitic dikes with an almost vertical east-western trend have been found. These dikes are more resistant to erosion but they have a high density set of fractures. They are considered as being of Lower Permian-Triassic age.
- c) Microdiorite dikes: Numerous microdiorite dikes are spread all over the Sierra, but most of them are in the central and north-western section. They have a vertical or subvertical position with predominant east-western and north-western trends. Their thickness does not exceed 2 m. They are quite densely jointed and show clear, well-cut contacts. As they cross acidic dikes, they are undoubtedly younger. Perhaps they belong to the Permian-Triassic period.

3.1. STRUCTURAL FEACTURES.

Sierra del Medio is a block limited by fractures subparallel to its main axis. Therefore it looks like a tectonic pillar. This block is crossed by two fracture systems (Figure N° 1) (5). The most important system has a north-western/south-eastern trend and it is represented by two parallel faults with a right strike-slip displacement called "El Alamo" and "Escobar". They have a rectilinear topography and an almost vertical position. "El Alamo" fault zone has a mean thickness of about 250 m. Rocks have undergone an intense cataclasis in this strip. "Escobar" fault covers a zone 150-200 m. thick and it also yields intense cataclasis. As it is a silicified fault it is more resistant to erosion and it is located in high topographic sites.

The secondary system with a north-eastern/south-western trend belongs to a tension fracture system represented by the "Portezuelo del Angelito" and "Quebrada Larga" faults. They have well-defined rectilinear plots which coincide with depressed areas that control peculiar long, straight, deep creeks.

Some evidence such as: slickensides, gouges, crackling, adjacent rock alteration and so on were recognized in order to carry on the faulted structure investigation.

Although no outcrop was found in some sites its presence was made evident by means of geophysical profiles.

Not only migmatites but also pegmatites and aplites are affected by cataclastic effects. On the other hand, dacitic and microdioritic dikes belonging to the latest generation are not affected. This fact shows that the most important tectonic events were previous to the basic (Permian-Triassic) dikes emplacement. Consequently, it can be seen that cataclastic-forming processes were very ancient, perhaps mid to upper Paleozoic (pre-Permian).

4. HYDROGEOLOGICAL FEATURES

From regional hydrogeological investigation it was determined that Sierra del Medio is an upward block (horst) situated in the central northwestern sector of an underground water basin. It was also established that this Sierra contributes the basin recharge partially transferring the surface and subsurface runoff derived from rainfalls over its area of about 170 km².

Its annual mean rainfall of 150 mm makes it possible to estimate that 25 hm³/y are distributed mainly between direct runoff and evapotranspiration. Groundwater flow and storage variations are unknown up to date, but several approaches have been planned for future research considering log testing and mathematical modelling with finite element techniques.

4.1. HYDROGEOLOGICAL UNITS

Some hydrogeological studies such as hydraulic conductivity measurements will be carried on in the near future in order to define with accuracy they hydrogeological behaviour of each rock unit and any geological structure involved in secondary permeability or hydraulic conductivity. A hydrogeological research unit classification is proposed as a guide and it is shown in Diagram N°1, Figure N°1.

| UNITS OF HYDROGEOLOGICAL INVESTIGATION | STRUCTURES | THICKNESS (m) | LENGTH (Km) | TYPE OF FRACTURE |
|--|--|---------------|-------------|-------------------|
| I | Rocky mass | | | |
| II | Regional faults Edges of the Sierra | + 300 | + 50 | |
| III | Escobar A | 140.230 | 25 | Trend emplacement |
| | El Alamo B | 240.310 | 25 | Trend emplacement |
| | Portezuelo del Angelito C | 120-240 | 8 | stress |
| | Oda. Larga D | 85-110 | 8 | " |
| | La Tapera E | 60-80 | 8 | - |
| | Chivas Norte F | 40-90 | 8 | Trend emplacement |
| | Chivas Sur G | 35 | 3 | Trend emplacement |
| | El Tornillo H-I | 5-10 | 0.250 | shear |
| | Jointed and fractured zones J | | | In drillholes |
| IV | Dikes | 2 | 0.600 | stress |
| V | Quaternary sediments and soils | | | |

UNIT I: Rocky mass

It is mainly formed by migmatites. These rocks are partially covered by a regolithic soil (Unit N°V). A portion of the water percolated from such a soil or directly is the recharge to the joint and fracture system.

UNIT II: Regional fractures

As very depressed groundwater levels and very important runoff were detected in the drillhole injection circuit SI and GI situated to the northern part of the Sierra, these regional fractures could be compared with those units that are more pervious than the rocky massif.

An important fact to be mentioned is that these fractures would partially be the hydrogeological link between the rocky massif and the Cainozoic and Mesozoic sediments bordering Sierra del Medio.

UNIT III: Local Fractures

The hydrogeological interpretation of the major fracture behaviour of the so-called main system determines that these fractures are associated with the most important springs in the Sierra.

Based on the silification observed in Escobar Fault (III A; Figure N°1) it is assumed that the correct hypothesis is that it is an almost impervious unit having a positive palaeoreleif and when the underground flow section decreases it makes the groundwater level increase until aligned springs crop out. Due to the fact that the underground flow moves in these spring surroundings partially as a result of the Quaternary filling it is rather difficult to define whether the water comes from the Quaternary or from the fractures or from both. Future studies may solve this problem.

UNIT IV: Dikes

The different kinds of dike behaviour has not been reached yet from the hydrogeological point of view. There can be no doubt that they form an element giving a distinct anisotropy to the rocky massif, in particular to those having a major length and, due to this fact, they may have a great influence on the direction of groundwater flow.

On the other hand, as their mechanical properties or resistance to weathering differ from the host rocks they always constitute either drainage paths or impervious screens (2).

UNIT V: Quaternary sediments and soils (Regolith)

Even though this unit has not been mapped in the hydrogeological study due to its poor area representation, it is an important element in Sierra del Medio because it has a high intergranular porosity, permeability and capacity of percolation (100-120 mm/h with Müntz method). It is also an important element in the local hydrological cycle development (reception and transference of shallow and underground runoff). These sediments fill almost every Sierra depression (water points and "mallines" which is the local name for ponds), have poor human settlements and are frequently filled with water working as big natural sponges. Based on points such as: water points, springs and wells present in this zone it was possible to make the preliminary isophreatic curve map.

5. GROUNDWATER LEVEL. SPRING DISCHARGE.

Taking the topographic curves and the highest levels of ground water measured at 50 water points as a guide, the different isophreatic curves were plotted with a contour line interval of 50 m (Fig. N°2).

No differentiated marks were observed when the 12 drillholes piezometric levels were compared with the levels suggested for these points by the isophreatic curves.

It was established that the distributed discharge is about 3 % and 27 % of the rainfall volume in order to find a relationship between the mean annual volume of water fallen over four small hydrographic basins of the massif and the mean annual volume of water distributed by the four springs discharged by these basins.

As they are the first measurements achieved, it is impossible to design either hydrogeological correlations or adjusted interpretations of the rocky massif hydrological performance.

6. SUBSOIL STUDY.

Twelve diamond drillholes were performed so as to know the rocky massif underground geology from 200 m. down to 750 m. depth and fairly good drill cores were obtained. A detailed study of the fractures, fracture minerals, rock formations, dike presence and so on. as achieved based on these DDH cores (4, 10, 11).

Certain parameters such as per centage core recovery, ROD, N/L (frequency of fractures per metre) and E (fracture spacing) were measured not only to locate and assess the fractured zones but also to correlate them with the surface geophysical and geological cross-sections. Furthermore, each fracture site was measured taking into account the drillhole axis, roughness, opening size, filling type, etc..

Moreover, temperature profiles (logging) using a thermal sensor made in San Juan (Argentina) with an accuracy of 0.5° C, digital depth gauge and an electronic display of point display were carried on at every vertical drillhole.

From the analysis of these logs negative and positive thermal anomalies were detected (Fig. N° 3). They show thermal anomalies that coincide with fractured zones (Unit III J). Another anomaly coincidental with a dike of basalt type (Unit IV) can also be observed. These thermal anomalous values may be considered as zones of groundwater flow in the rocky massif discontinuities (faults, joints, dike contacts).

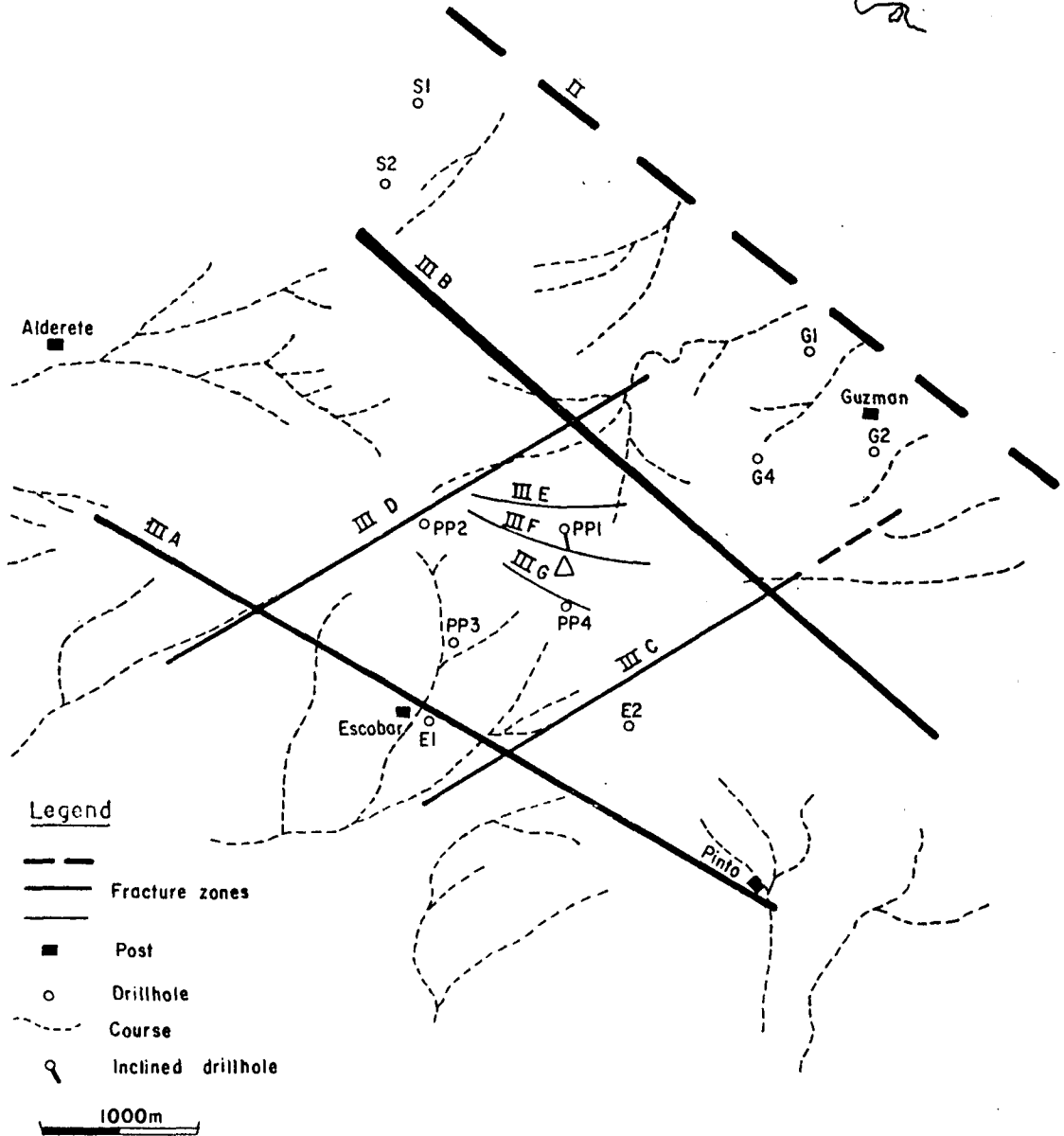
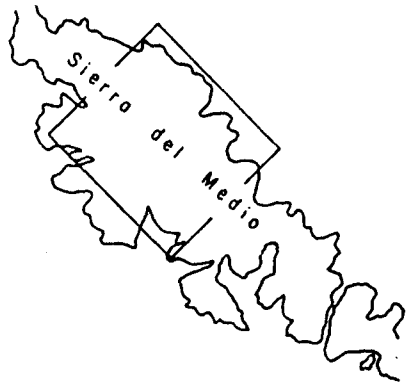
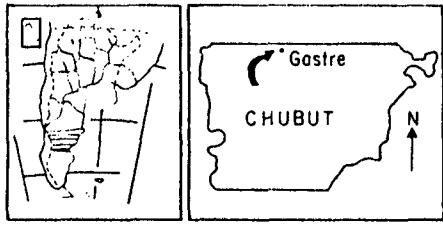
Figure N°4 shows drillhole groundwater level variation in time.

REFERENCES

- (1) Centro Regional de Aguas Subterráneas, San Juan (Argentina). "Estudio hidrogeológico preliminar de la zona de Gastre, Provincia de Chubut". San Juan, C.R.A.S., 1983. Publicación N° 256.
- (2) Custodio, G.E. y Llamas, M.M. "Hidrología subterránea. Tomos I y II". Barcelona, Editorial Omega, 1976.
- (3) Girardi, J.P. y Sarquis, M.A.M. "Estudio en el emplazamiento de un repositorio para los desechos nucleares argentinos. Aplicación de la geoestadística". San Juan, Argentina, Univ. Nac. de San Juan-Instituto de Investigaciones Mineras, 1985.
- (4) Grassi, I.; Perucca, J.C. y Salinas, L. "Estudio de las discontinuidades en el interior de un macizo migmatítico". IX Congreso Geológico Argentino. Bariloche, oct. 1984.
- (5) Llambias, E. et al. "Petrografía de la formación M. Choique de la Sierra del Medio, Depto. Cushamen, Pcia de Chubut". IX Congreso Geológico Argentino. Bariloche, oct. 1984.
- (6) Nullo, F. "Descripción geológica de la hoja 41 d. Lepetrén, Provincia de Río Negro". Buenos Aires, Servicio Geológico Nacional, 1978.
- (7) Perucca, J.C. et al. "Selección de un emplazamiento". Seminario Nacional sobre el Proyecto Gastre. San Juan, Argentina, jul. 2-4, 1984.
- (8) Proserpio, C. "Descripción geológica de la hoja 42 d. Gastre, Provincia de Chubut". Buenos Aires, Servicio Geológico Nacional, 1978.
- (9) Ravazzoli, J. y Sesana, F. "Descripción geológica de la hoja 41 c., Río Chico, Provincia de Río Negro". Buenos Aires, Servicio Geológico Nacional, 1977.
- (10) Grassi, J.I.; Perucca, J.C. y Salinas, L. "Control y ensayos perforaciones intermedias". San Juan, Argentina, Univ. Nac. de San Juan-Instituto de Investigaciones Mineras, 1984.
- (11) Grassi, J.I. y Salinas, L. "Control y ensayos perforaciones profundas". San Juan, Argentina, Univ. Nac. de San Juan-Instituto de Investigaciones Mineras, 1985.

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- Fig. 4. Groundwater level variations in drillholes.



STRUCTURAL OUTLINE

FIGURE N°1

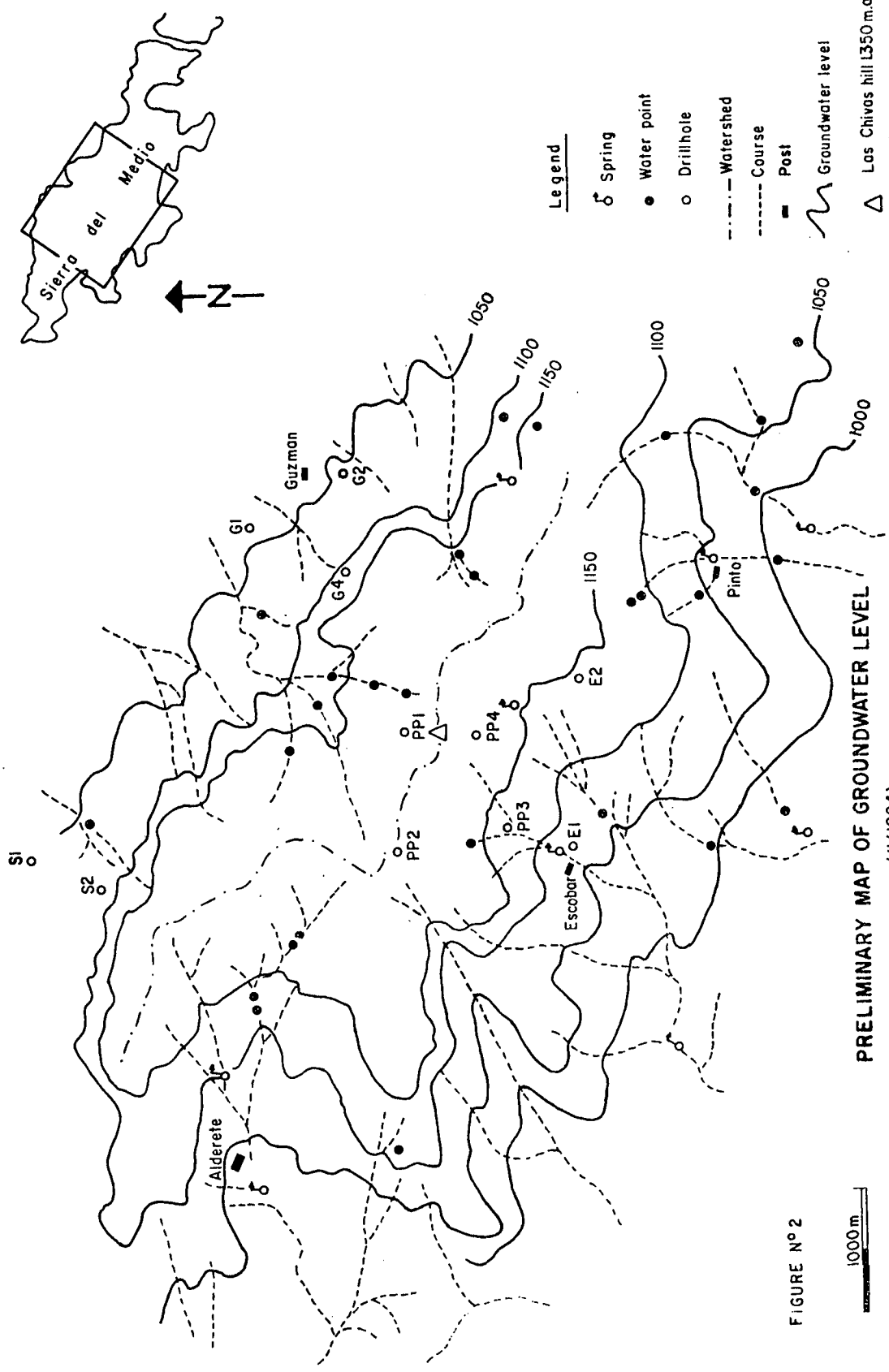


FIGURE N° 2

1000 m

PRELIMINARY MAP OF GROUNDWATER LEVEL

(11/1984)

△ Las Chivas hill 1350 m.a.s.l.

DRILLHOLES

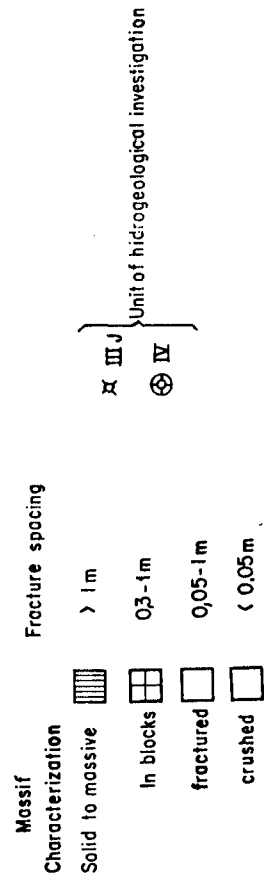
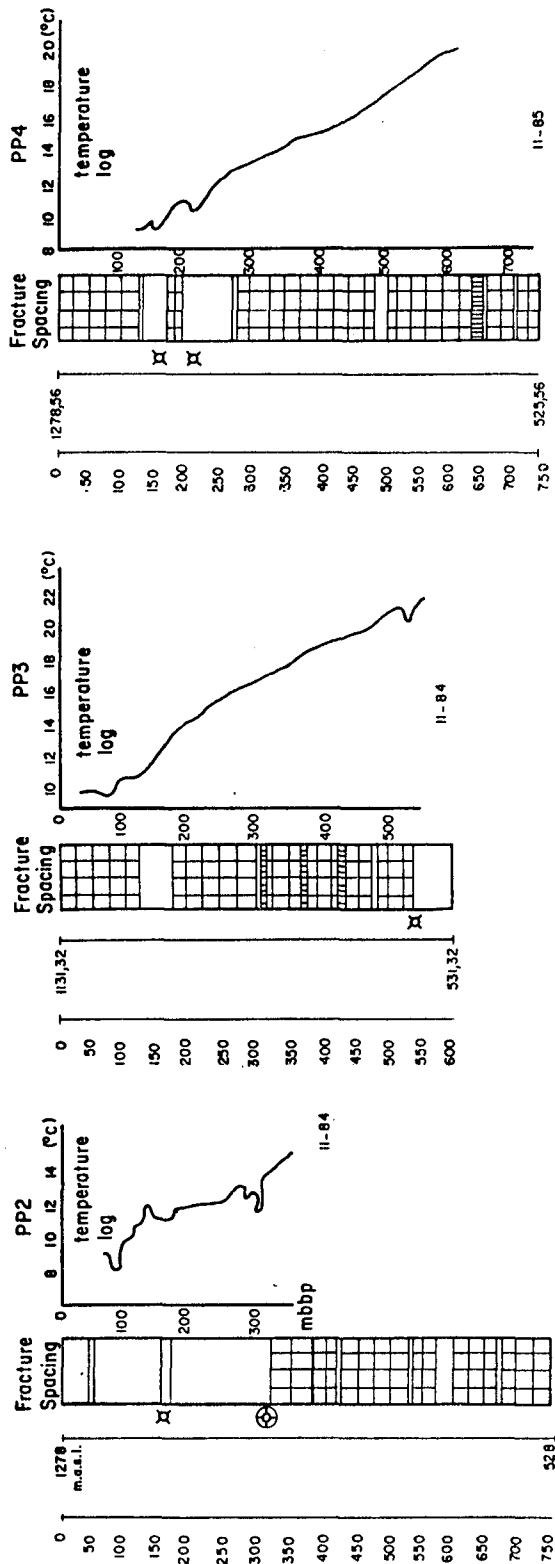


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