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REPO-29 CNEA-NT 25/87

GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS AT SIERRA DEL MEDIO MASSIF-ARGENTINA

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GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS AT SIERRA DEL MEDIO MASSIF-ARGENTINA.

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ABSTRACT

Geological investigations were performed at Sierra del Medio (Cushamen County, Chubut Province in Central Patagonia), a mountainous massif of about 25 km by 8 km of migmatic origin, which emerges from a depressed tectonic trench or graben called Pampa de Gastre. The most ancient rocks belong to biotitic and anphibolic schist that passed almost entirely to tonalitoid migmatites with a second process producing granitic rocks. Boreholes were drilled on the basis of conclusions from Landsat satellites imagery and aerial pothographic sets, followed by field work on geological, petrographic, geophysical and hydrogeological features at surface, structural interpretation supported by geostatistical computations.

Two sets of boreholes were drilled to investigate subsurface rock behaviour at 300 m depth and 800 m depth respectively, beginning at peripheral places and ending at the central part or selected site. Basic purposes of boreholes were to define structural and petrographic features of the rock massif by a good comprehension of master joints and faulting distribution with its belts of alteration mylonitization or brecciation, mechanical properties of samples, chemical composition and variations, petrographic facies and mineralogy.

Boreholes provided data to investigate joints, faults and dikes as general discontinuities for hydraulic research like permeability or effective hydraulic conductivity, and their geoestatistical modelling.

Boreholes are also being prepared for geophysical logging from which logthermal ones have already been completed.

RESUME

Les recherches ont été faites à Sierra del Medio (Dep. Cushamen, province du Chubut) ce petit massif montaigneux migmatitique émerge comme un horst sur le nivel d'une dépression tectonique connue comme Pampa de Gastre.

Des schist biotitiques et amphibolitiques sont les roches plus anciennes lesquelles ont été transformées presque completement en migmatites tonalitoides et aprés granitisées jusqu'a granities migmatitiques. Les sous-sol a été investigué avec des sondages a carottage dont leur positions furent choisises en employant des études préalables sur images Landsat, photographies aériennes; et enfin sur le terrain en faisant des travaux

géologiques, pétrographiques, géophysiques et hidrogéologiques. Une interpretation structurelle a été obtennu par géoestatistique a l'aide d'un ordinateur.

Deux groups de sondages ont été faites: L'un jusqu'à 300 metre de profondeur, dans la périfheries et l'autre jusqu'à 800 metres dans le centre de l'air choissé.

Ces sondages ont permis de connaître les charactheristiques structurelles et pétrographiques du massif, principallement si elles que concernent les "Master joints", la distribution des failles avec les zones d'alteration, milonitization ou formation de brêche; les proprietés mechaniques des carottes, et leur composition chimique, pétrographique et minéralogique. De même, ceux-là, ont été utilisés pour l'investigation des joints, failles, et filons rocheux commes des discontinuités pour la recherche hidraulique (permeabilité, et conductivite hidraulique effective) et leur modellation géophysiques de lesquels on a fini déjà les sondages thérmiques.

1. INTRODUCTION

Sierrra del Medio, a gentle small range located in the Province of Chubut was, as first step, studied using vertical aerial photographs at a scale of about 1:40.000 with the control od field surveys. Taking this approach as decision base, a central sector having structural and petrographic characteristics with an adequate homogenity and appropriate conditions to work as geological barriers was selected.

Consequently, with the geometric support of good topographic and cartographic surveys, petrographical, structural, hydrological, geomorphological, geophysical and geochemical studies were carried on.

This paper presents some of these subjects emphasizing not only the geological and geophysical studies but also the data geostatistical processing obtained on surface and at depth carrying out drill diamond boreholes.

2. GEOLOGICAL ASPECTS.

In order to achieve the geological outcrop cartography and sections, common geology stages were followed beginning with stereographic photointerpretation at a scale of 1:40.000 with field surveys, detected unit sampling, planimetric plotting of the overall region, microscopical investigations of each petrographical facie and physico-chemical and chemical analysis.

Figure N°1 shows a summary with the most important Sierra del Medio geological features.

The ancient rocks are biotitic schists with sillimanite and amphibolic schists yielded by a regional metamorphism. They are supposed as being of the pre-Cambrian or Lower Paleozoic age. As an intense migmatization changed almost every former rock into tonalitoid migmatites, only small and space relicts are present nowadays in Sierra del Medio. The age of this migmatic process is still unknown, but it could be assumed as pre-Cambrian or Lower Paleozoic.

The neosom and paleosom relationship gives rise to a certain arrangement that constitute the rock structure. These structures have been described according to Mehnert's nomenclature (1969).

Tonalitoid migmatites were partially granitized and profusely intruded by aplite-pegmatites hydrothermall fluids yielding granodioritoide migmatites and migmatitc granites. They are considered as being also of pre-Cambrian to Lower Paleozoic age. Every migmatite and migmatitic granite underwent cataclasis. Subsequently, dacite dikes unaffected by cataclasis were intruded so they are either of the Upper Paleozoic or Lower Triassic period (K/Ar dating).

Once the above mentioned dacite dike intrusion took place, left-strike-slip displacement faults with a north-western/south-eastern trend were formed. They constitute a couple originating a tension-fracture system with a predominant north-eastern/south-western trend, partially filled with basic dikes probably of Triassic age.

For a long time Sierra del Medio underwent a strong erosion period giving rise to its present configuration. During the Upper Terciary fracturing processes have raised it as a "horst" in the central part of the Gastre great ditch graben.

The internal portions of this migmatitic massif were directly known by means of diamond drillholes cores. Two different groups of DDH were performed according to their objectives and length (Figure N°2). The former group was called "Intermediate Drillholes". They were disposed in a pattern so as to define the whole Sierra del Medio rocky massif structural and petrographic features. Different sets of main fractures and either their probable alteration or milonitization or breccia stripes were located and investigated. Rock mechanical features, their chemical composition, their petrographical facies and mineralogy were studied, as well.

According to the initial conclusion from surface geological research, structural photointerpretation and geophysical surveys (refraction seismic and resistivity), the various DDH were located taking into account some sites with the following behaviour:

a. Those where surface features showed significant geologic anomalies.

b. Those having pertrographic and tectonic phenomena that originated bad-quality outcrops.

c. Those where surface rocks outcrops were of an excellent mechanical quality.

There were nine intermediate drillholes covering in all 2,002 vertical metres with a mean core recovery of 90%.

The latter was called "Deep Drillholes" group. Four drillholes were performed in a selected area of Sierra del Medio and basic data for Engineering Preliminary Planning were obtained.

Geological criteria plus geostatistical estimation results defining the minor bi-dimensional fracturation area were considered so as to locate each drillhole.

From these numerous investigations a zone of 24 km^2 was taken into account because it looked as if it was, at first, the best one all over the Sierra due to its petrographical, structural and mechanical features.

A total of 2,272 m were drilled in three vertical and one inclined wells (Figure N°3).

3. SITE GEOSTATISTICS

Based on the methods employed by traditional geology, the study of the minor fracturation rocky volume in the central sector of Sierra del Medio was carried out.

A data geostatistical processing was also fulfilled. Applying geostatistics to the structure study it was possible to estimate not only the fracturation density variability characteristics but also the mistake made in the different estimations.

The N/L parameter behaviour was modelled on surface during the first stage of this work.

The universal krigeage applications allowed to obtain the N/L mean values and their corresponding krigeage typical deviations.

In this way a good correspondence between the estimated N/L model and the detailed geology survey was obtained.

Finally, a three-dimendional fracturation model arised complementing the geostatistical results with the geological studies.

4. GEOPHYSICAL INVESTIGATIONS

Geophysical investigation was aimed at knowing the behaviour of the massif limbs in order to define its extension beneath the modern overburden surrounding it since there were two possibilities: either gradual descent following the slope of the outcropping flank or sharp descent in fault blocks of subvertical walls. Results showed the behaviour of the hill as that of a fault block structure. This problem was treated using refraction seismic and resistivity

Geophysical methods were also used to define the thickness of the weathered layer at the center of the rock massif. For this purpose, an at-tempt was made to correlate seismic wave velocities with rock quality or RQD (rock quality desingnation) and frequency occurrence per unit length or N/L.

This correlation was good as later shown by cores from the wells.

Results obtanined mathematically and from geophysical sounding and logging were good as later show by support drilling.

The accuracy and detail of non available information could be substantially improved by pilot scale (tunnels and shafts) mining work, which is out of the reach of the research agreement for the time being.

In orden to obtain geothermal gradient information and correlate thermal anomalies with possible graoundwater flow, temperature log measurements were performed.

Seismic refraction surveys were done using an ABEM TRIO seismograph with 12 transistorized channels and a sensitive paper recorder. The west-east trending lines with a length of a 1.300 m and line spacing of about 400 m were shot at the central body of the massif. Explosive sources were located every 110 m.

Electrical vertical sounding on modern accumulations (outwash and downgoing fans) was carried out using Schlumberger symmetris 4-electrode arrays with a maximum AB spacing of about 1.000 m when working on the valleys around the Sierra.

Temperature logging was performed using a TI 51 S.E.A. probe, manufactuared in Argentina, for measuring within 0.5°C equipped with and 800 m coaxial wire and temperature/depth digital reading. From data obtained in the course of the above mentioned surveys, it was concluded that Sierra flanks deepen almost vertically to the sedimentary cover sorrounding it with no other blocks occuring down to 500 m depth. Thus, it can be concluded that the Sierra flanks are defined by dip throw fault planes.

When applying the above mentioned seismic refraction surveys on the granitic massif to the determination of the mechanical quality of the rock, it was noted that the low wave velocity (1.000 to 1.500 m/s) weathered layer was up to 150 m thick in sorrounding areas or downgoing flanks the Sierra, whereas at the central part, the thickness of the weathered horizon appeared very shallow with apparent velocities higher than 6.000 m/s fur sound rock from 20 m depth on.

The results obtained during the surveys satisfied the original requirements: seismic data match those fron drilling holes where rock quality (RQD) and number of fractures per meter (N/L) were measured on cores.

Because of this good correlation, shown by, the series of support diamond drilling holes performed on parameter sites, rock quality was extrapolated into areas with no drilling based uniquely on geophysical data.

From thermal loggings performed along the drillholes, a geothermal gradient of a 1°C per 40 m was found, the value being typical of tectonically stable areas. Comparing thermal logs with core geological structure logs, thermal anomalies resulting from graoundwater flow could be interpreted. Such anomalies occur in fracture rich areas. First, wells were allowed to settle for about 1 year and then temperature measurements were taken every 5 or 10 m, the sensor being left approximately for and hour at each measuring site.

Further research will involve regular logging aimed at comparing possible thermal anomaly fluctuations or variations as well as controlled electric and radioactive logging. In situ hydraulic conductivity surveys will also be executed.

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Fig. 3 Intermediate drillholes

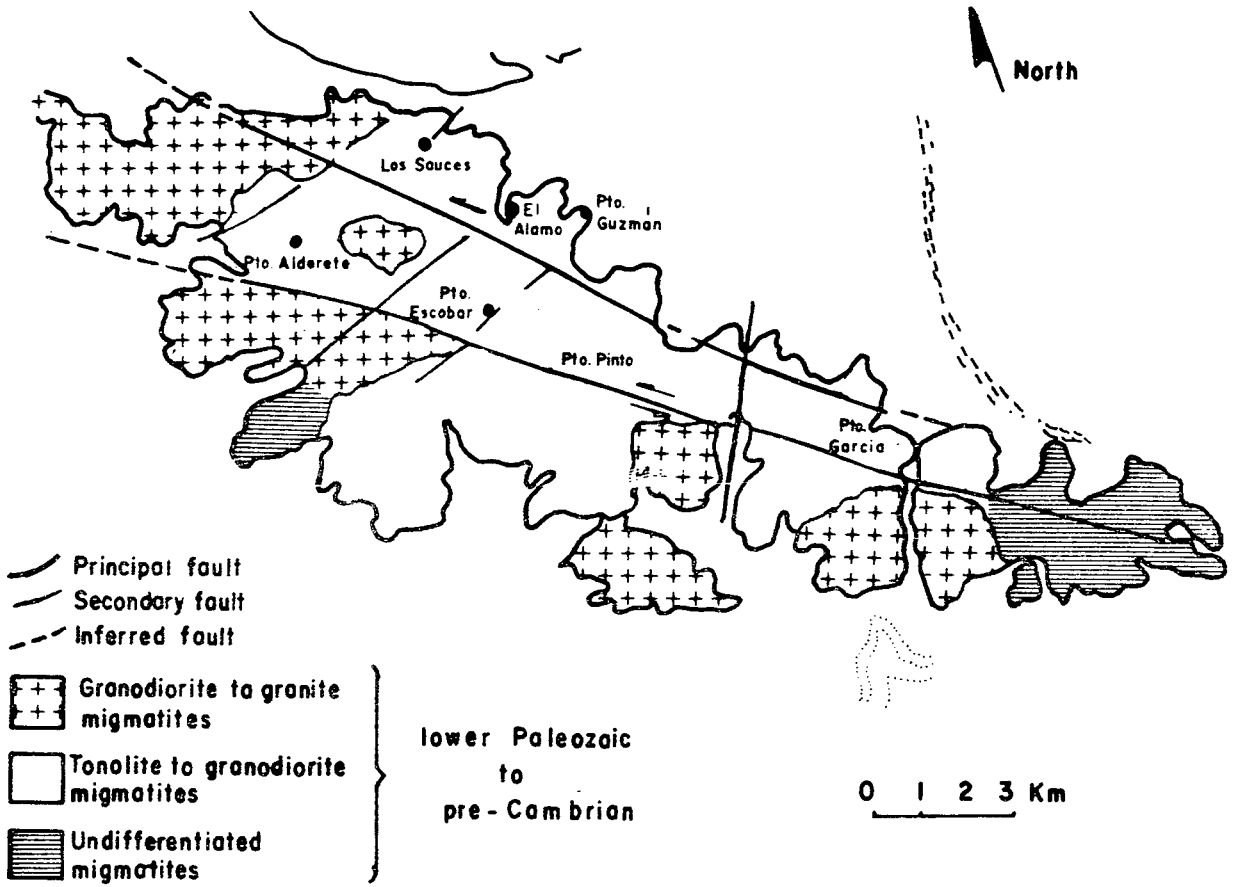


FIGURE N°1

SIERRA DEL MEDIO: GEOLOGICAL FEATURES

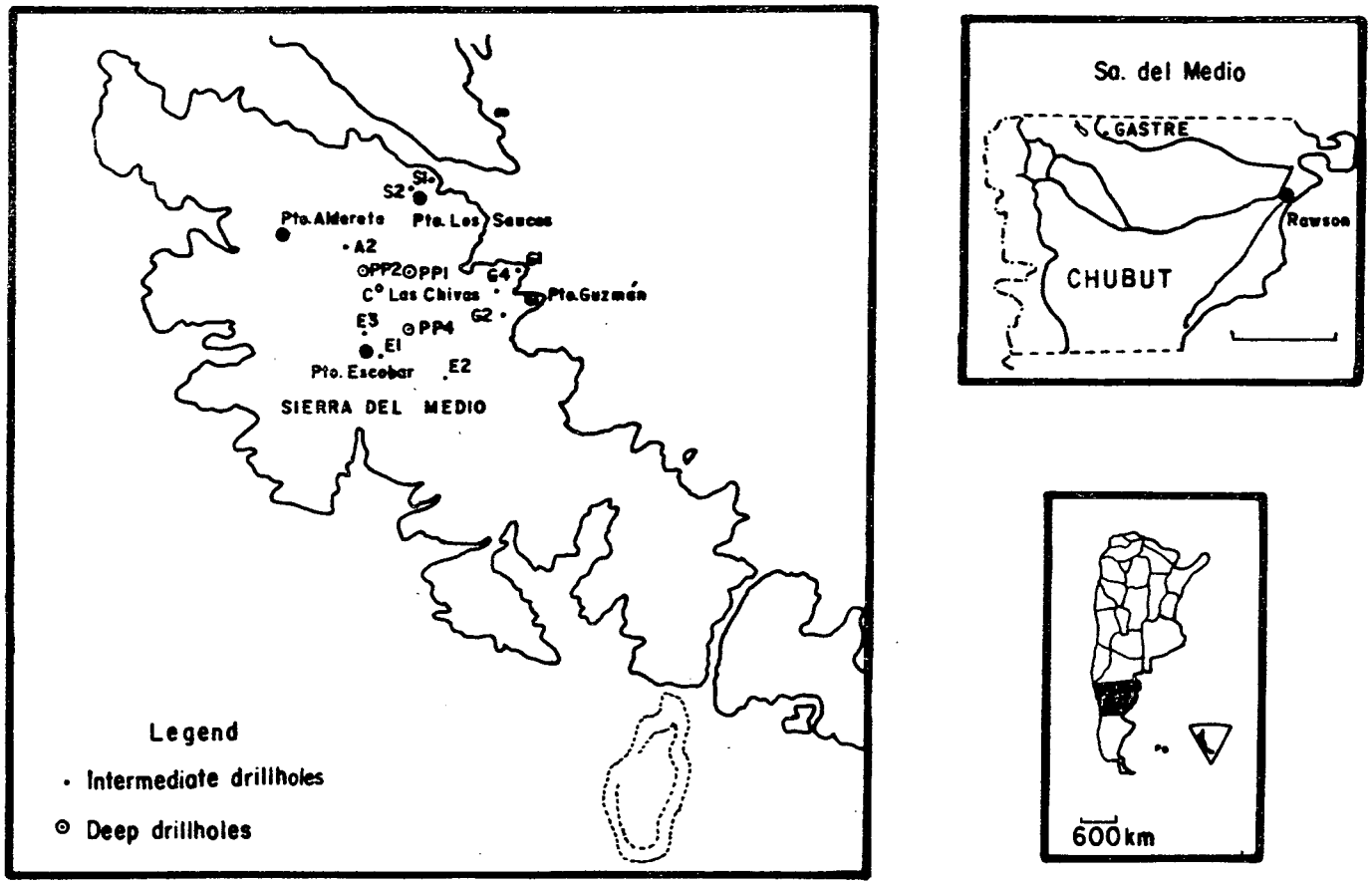
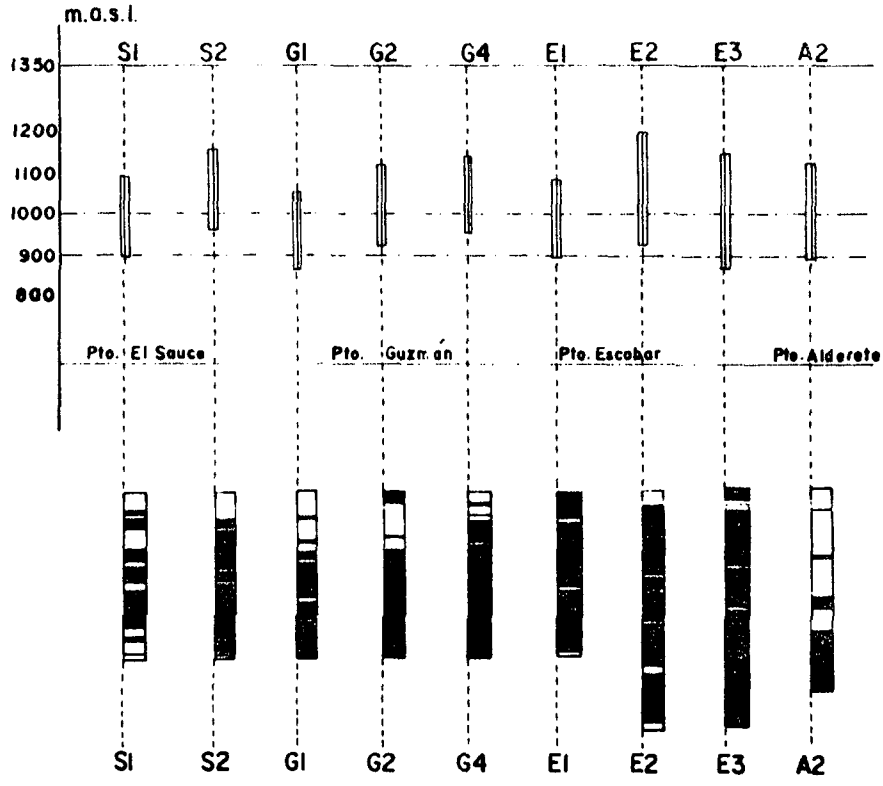


FIGURE N°2

INTERMEDIATE AND DEEP DRILLHOLES

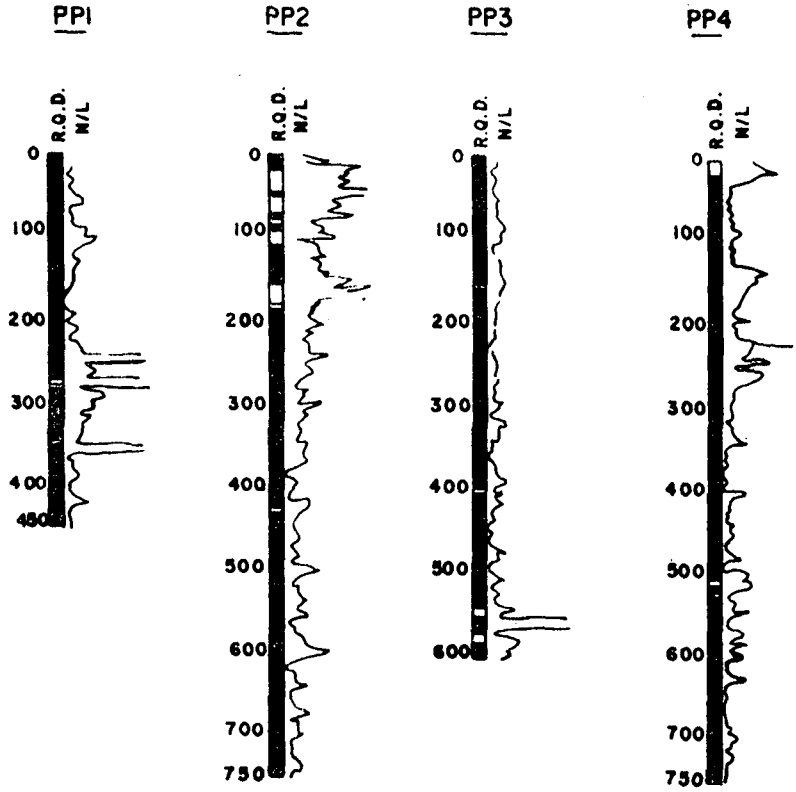
INTERMEDIATE DRILLHOLES



Legend

- R.Q.D > 60 %
- R.Q.D < 60 %
- N/L Fracture/m
- E Spacing

DEEP DRILLHOLES



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