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UPDATED INFORMATION ON TEMPERATURE DISTRIBUTION IN THE GEOTHERMAL FIELD OF CERRO PRIETO II AND III

LOCATION

The Cerro Prieto geothermal field is located in northwestern México 30 km. from the city of Mexicali in Baja California on the alluvial plain of the Colorado River where the only elevated point is the Cerro Prieto Volcano, which rises 225 meters above sea level (Fig. 1).

INTRODUCTION

This paper to provide updated information on temperature distribution studies in Cerro Prieto II and Cerro Prieto III is based on the wells drilled in 1980-1981 and on recent field studies.

Temperature plays an extremely significant role in locating new areas for exploitation in a geothermal field and for constructing wells in zones where studies have indicated geothermal potential, since it serves as a parameter for thermal conduction and is an essential aid in gaining knowledge of flow distribution because it provides an idea of flow movement.

Not all geothermal reservoirs present the same behavior because of factors such as: their thermodynamic state, the physical and chemical properties of the rock and geological subsoil alterations. Thus, reservoirs may have completely different production behavior and hot water may be extracted from one and dry steam or a mixture of water and steam may be extracted from another. Each reservoir has a certain content of gases and other components, in addition to thermal manifestations that show similar behavior.

GEOLOGY

In the work previously carried out and presented at the Second Symposium on the Cerro Prieto Geothermal Field (1), three main lithologic units were defined: the first is a caprock formed by deltaic sediments that lie from 200 m to 2,800 m deep; the second layer is also formed of consolidated and metamorphized deltaic sediments composed of lutites, limotites and sandstone, and the third layer is formed by a granitic basement.

The second geological layer, composed of consolidated deltaic sediments (lutites, limolites, sandstone, and so forth), is the zone of most interest, since geothermal fluids are extracted from it. This layer is uneven and has been altered by tectonic movements just as the basement has.

The top of this zone has the shape of an oblong dome running from east to west with a steep slope to the north and a gradual slope to the south. An analysis of the cores taken during drilling indicated the presence of microfaults, fractures and sinking structures (2), alterations in the rock that play a significant role in the storage and flow of fluids depending on their degree of permeability. It could also be stated that there are "active" faults that serve as conductors of fluids and "inactive" faults that block such flow, since they may not be in constant movement.

ISOTHERMS

As temperature data were gathered on recently constructed wells, modifications have been made in the isotherms presented at the third Symposium on the Cerro Prieto Geothermal Field and Figs. 2-4 show the migration of temperatures toward the center of the field, although this does not mean that the greatest supply of fluids come from this same direction, as will be seen further on.

Isotherms at 1,500 m (Fig. 2).

As indicated in Fig. 2, the highest temperature in these isotherms is found toward the center of the present exploitation field and, as may be observed, includes wells E-1, E-2, E-3, E-4 and M-47, which are the most recently constructed wells in this area and are slightly deeper than the rest of the wells, with enthalpy between 350 and 450 Kcal/Kg, although the evaluation of well M-47, which is currently in a period of warming up, is still pending.

Isotherms at 2,000 m (Fig. 3).

As may be seen in Fig. 3, the area with the highest temperatures (325-350°C), consecuently the best enthalpy, continues to be the central part of the field, but now shifted slightly to the east where the current division between Cerro Prieto II and Cerro Prieto III lies.

Is should be noted that temperature at this depth range from 200°C to 350°C in the three areas, with the exception of some wells located on the southeastern side.

Isotherms at 2,500 m (Fig. 4).

In these isotherms, it may be observed that the area with temperatures from 200°C to 350°C is greater at this depth and includes all the wells constructed for exploitation in the near future to feed the units in Cerro Prieto II and Cerro Prieto III.

THERMAL CORRELATIONS

In Fig. 5A, line A-A', and Fig. 5, a cross section of the reservoir between wells M-189, T-364, T-348, T-328, M-109, M-139 and H-2 shows a maximum temperature between wells M-109 and M-139, which indicates the presence of temperature toward the eastern side of the field, a little to the south of H-2 to T-348. In Figs. 6 and 7, lines B-B' and C-C', temperatures above 350° may be seen for wells M-117, M-139 and M-157, which are the maximum temperatures obtained to date.

Line D-D' in Fig. 8 shows that wells M-169, M-149 and M-109 cut through a formation with an aquifer of lower temperature at a depth between 1,600 m and 1,800 m, which affects other wells in that area, such as M-129 and T-328.

The grading or difference in levels between wells T-328 - M-129 (Fig. 9) and T-328 - M-109 (Fig. 10), lines E-E' and F-F', and the stratigraphic low of the first well suggests that there is a fault between them through which fluids of a lower temperature flow into the wells, causing convective currents of great intensity in a large part of the reservoir, and affect the temperature of T-328 at depths between 1,800 m. and 2,200 m as may be seen in the same figures.

In the analysis of the cores of T-328, no calcite was observed since it was replaced by silica and hydrothermally altered minerals such as chlorite and epidote. The dissolving of calcite caused an increase in permeability because of increased porosity (3).

PATZCUARO FAULT

At the Second Symposium on the Cerro Prieto Geothermal Field, the location of the Pátzcuaro Fault was situated to the south of T-328 (Bermejo, 1979), but current observations and evidence seem to indicate otherwise and the location was modified and reconfirmed at the second exchange meeting in San Felipe, Baja California, in January, 1982 as being situated to the north of well T-328 (Fig. II).

An evaluation of the wells in Cerro Prieto II and Cer Prieto III shows that the wells that were completed with total mud losses, due to interception with or proximity to a fracture, presented very good steam production and thus good thermodynamic properties, as in the specific cases of wells M-104, M-102, M-103, M-147, T-328 and others (Fig. 5).

In the temperature logs in Figs. 12 and 13, lines G-G' and H-H', it may be seen that the maximum temperatures in wells 94, 172 and 132 are 215°C, 280°C and 295°C, the lowest temperatures currently being obtained in the Cerro Prieto III area. When these wells were being drilled, the lithologic components of the second layer (lodolites, limolites, sandstone, etc.) appeared at a fairly deep level and observations indicate that the wells are somewhat distant from the thermal anomaly with the heat coming from a greater depth than in the rest of the wells in Cerro Prieto II.

Since wells M-132 and M-172 are near the Hidalgo Fault and wells with good enthalpy, and good sandstone content was found in the layers cut through when they were drilled, they were expected to show good steam production, but such was not the case. On the contrary, fluids with low calorific power were obtained and the maximum flow rate during their assessment was less than that of any other well in these two areas. During the warming up and output evaluation of these wells and well M-94, samples of their water content were analyzed and compared with analysis of water from wells M-120, M-169 and T-348 (Fig. 5). A lower content of chlorides and salts (4) led to the conclusion that the wells being constructed to the north of M-110, M-53 and M-133 were possibly being feed by different aquifers than those that feed Cerro Prieto II.

When the temperature of well M-110 is related to its lithologic column (Fig. 14) obtained from drilling data, we find a reduction in temperature at a depth of

1,750 m. This reduction in temperature is not frecuently found in the wells in these two areas and thus led to an investigation of its cause in order to provide a logical interpretation.

When the lithologic column was analyzed, a certain amount of quartz was found between a depth of 1,860 m and the bottom and almost no calcite was found in the highest temperature zone, which is between depths of 1,550 m and 1,860 m, since it had previously decomposed and had been replaced by hydrothermally altered minerals such as epidote and chlorite.

The inflow of water at a temperature below 300°C into a hot rock area, known as geothermal "discharge", may cause the precipitation of quartz and feldspar and form a solution of calcite and anhydrite (5).

Fig. 15 shows the temperature and pressure logs before flow and during the heating of this well, in which a reduction in both temperature and pressure may be seen at a depth of 1,750 m. A change is the slope of the straight line may be noted, which is caused by the pressure drop resulting from the inflow of cold water. On the basis of temperature and pressure logs during warming up, it was decided that this well would present good thermodynamic properties, since it is located at a strategic exploitation point, which was subsequently confirmed during its assessment because the mass flow rate obtained was 490 tons/h and steam enthalpy was 345 Kcal/Kg. The thermodynamic properties found, together with the mass flow rate, seemed to indicate that part of the hot fluids come from the eastern side of the field, since there was a discharge of fluids with temperatures below 300°C at the bottom of the well.

CONCLUSIONS

Bearing in mind the well isotherms at different depths, the mineralogic analysis during well completion, the analysis of water separated during development and the primary assessments made to evaluate the potential of each well, it may be seen that temperature logs play a significant role as an essential aid in selecting the best areas for targeting new wells.

Correlating several wells with the above mentioned parameters,some wells in the Cerro Prieto I and II area have been completed with satisfactory results, that is, contact with lutites, CO_3Ca cementing materials, expected downhole temperature depth required and other factors were able to be predicted prior to drilling.

It should also be noted that the isotherms at 2,250 m could serve as reference data for the completion of wells constructed in areas not yet expropriated on the eastern side of the field.

Since the Cerro Prieto Fault is, in a sense, "united" to the Imperial Fault at the altitude of the present exploitation field and this connection is a spreading center (6), geophysical and geological studies, in addition to temperature logs, all firmly indicate that fluid distribution in the Cerro Prieto II and Cerro Prieto III area (Fig. 16) includes the migration of fluids from the deepest zones located on the northeast and southeast sides of the field toward the surface on the west side of the field.

If the subsoil geology of this zone east of the field shows good permeability at a depth that is feasible from an investment standpoint, it may be unequivocally stated that the volume contained under this area where the depth of the basement is 5,000 m (7) will include fluids with good thermodynamic properties that may be taken advantage of in the future, either as wells to back up Cerro Prieto II and Cerro Prieto III or within expansion for new plants.

FIGURES

Fig.1. Location of the Cerro Prieto Geothermal Field in Baja California Norte.

Fig.2. Cerro Prieto Geothermal Field Isotherms at a depth of 1,500 m.

Fig.3. Cerro Prieto Geothermal Field Isotherms at a depth of 2,000 m.

Fig.4. Cerro Prieto Geothermal Field Isotherms at a depth of 2,500 m.

Fig.5. Cerro Prieto Geothermal Field Correlation of Temperatures.

Fig.5A. Thermal Correlations Line A-A'

Fig.6. Thermal Correlations Line B-B'

Fig.7. Thermal Correlations Line C-C'

Fig.8. Thermal Correlations Line D-D'

Fig.9. Thermal Correlations Line E-E'

Fig.10. Thermal Correlations Line F-F'

Fig.11. Tectonic Map of the Cerro Prieto Geothermal Field.

Fig.12. Thermal Correlations Line G-G'

Fig.13. Thermal Correlations Line H-H'

Fig.14. Temperature Log and Lithologic Column for Well M-110.

LOCALIZACION DEL CAMPO GEOTERMICO DE CERRO PRIETO B.C.N.

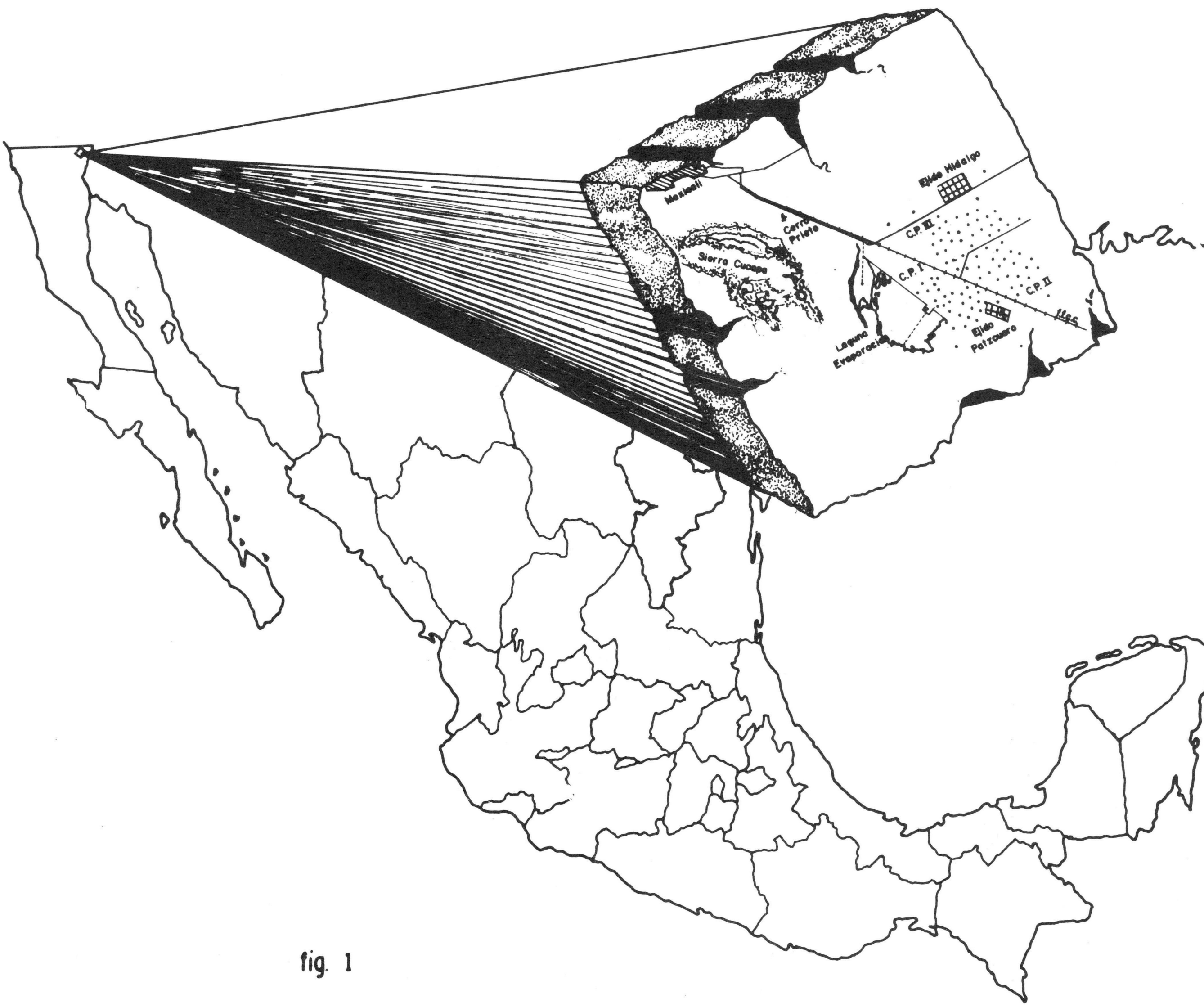


fig. 1

CAMPO GEOTERMICO CERRO PRIETO

ISOTERMAS A 1500 m. DE PROFUNDIDAD

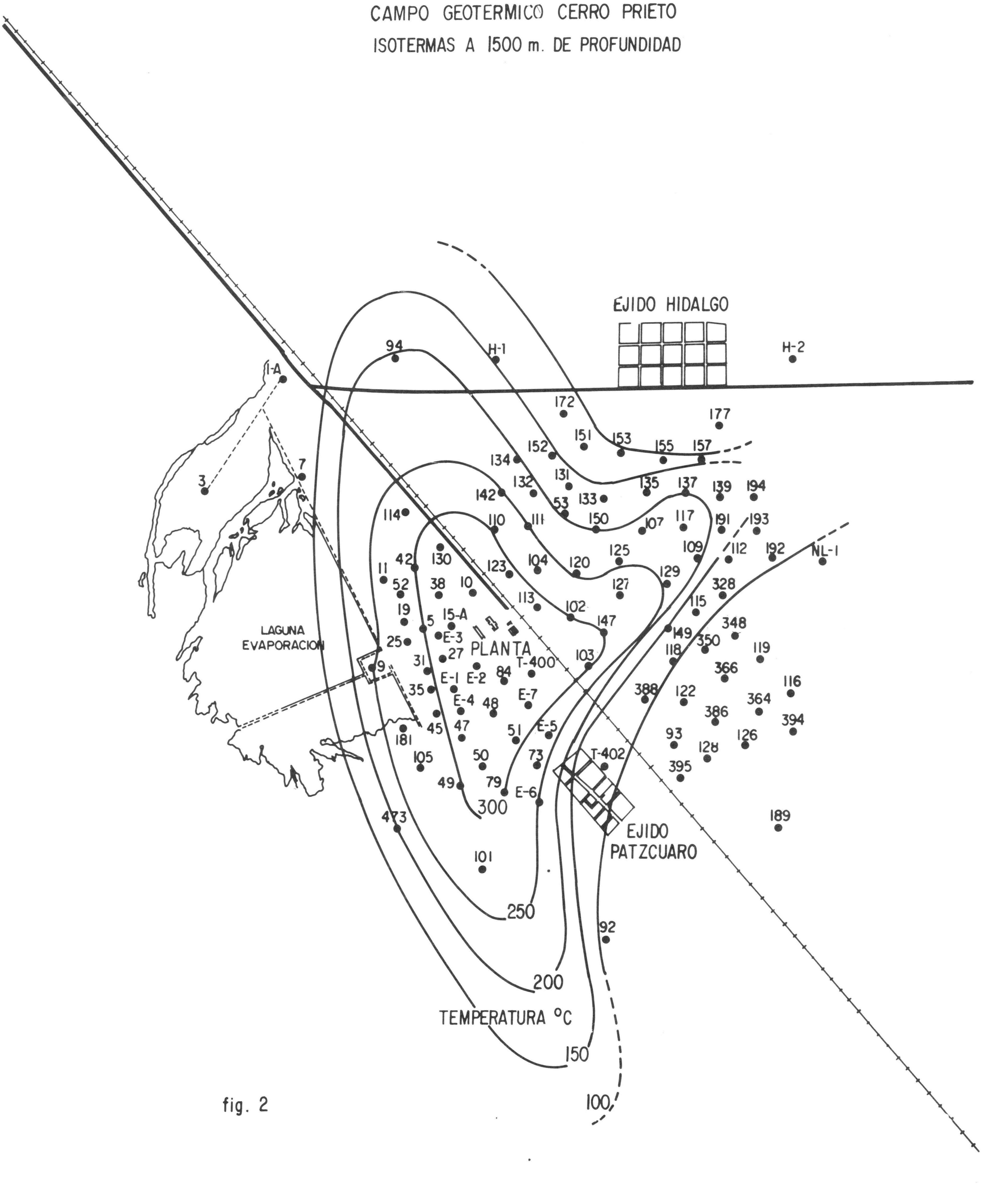


fig. 2

CAMPO GEOTERMICO CERRO PRIETO

ISOTERMAS A 2000 m. DE PROFUNDIDAD

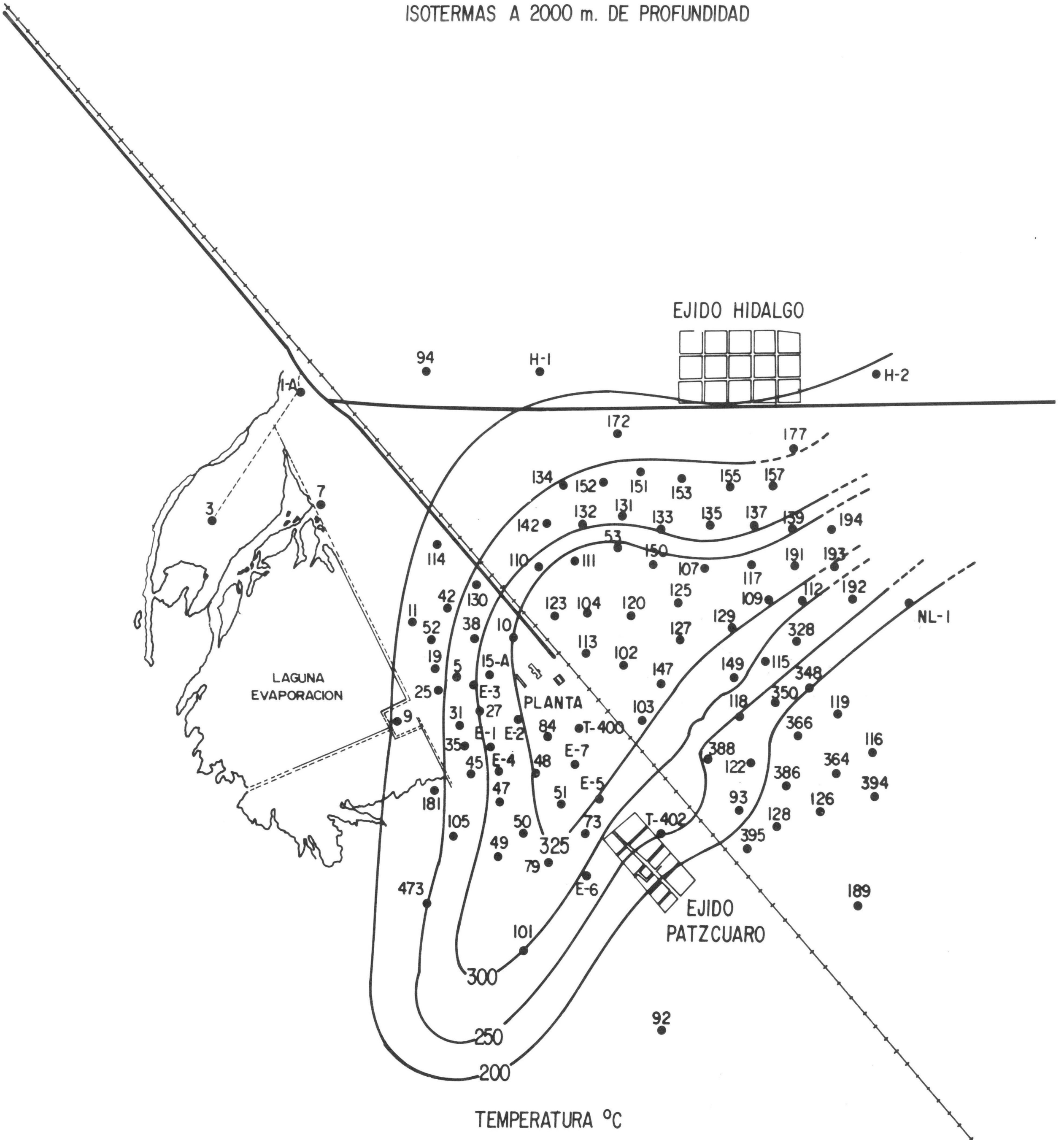
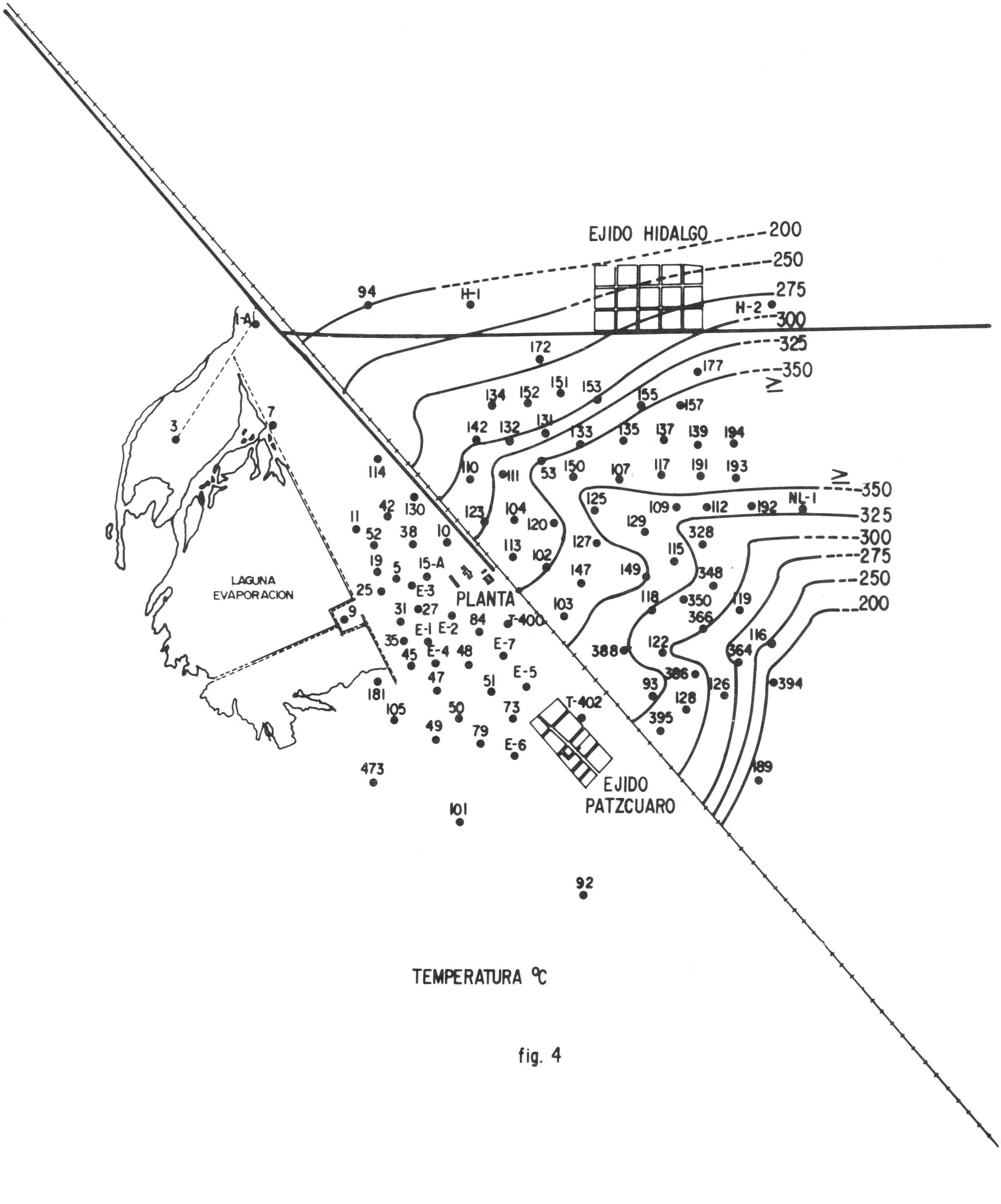


fig. 3

CAMPO GEOTERMICO CERRO PRIETO
ISOTERMAS A 2500 m. DE PROFUNDIDAD



TEMPERATURA °C

fig. 4

CAMPO GEOTERMICO CERRO PRIETO
CORRELACION DE TEMPERATURAS

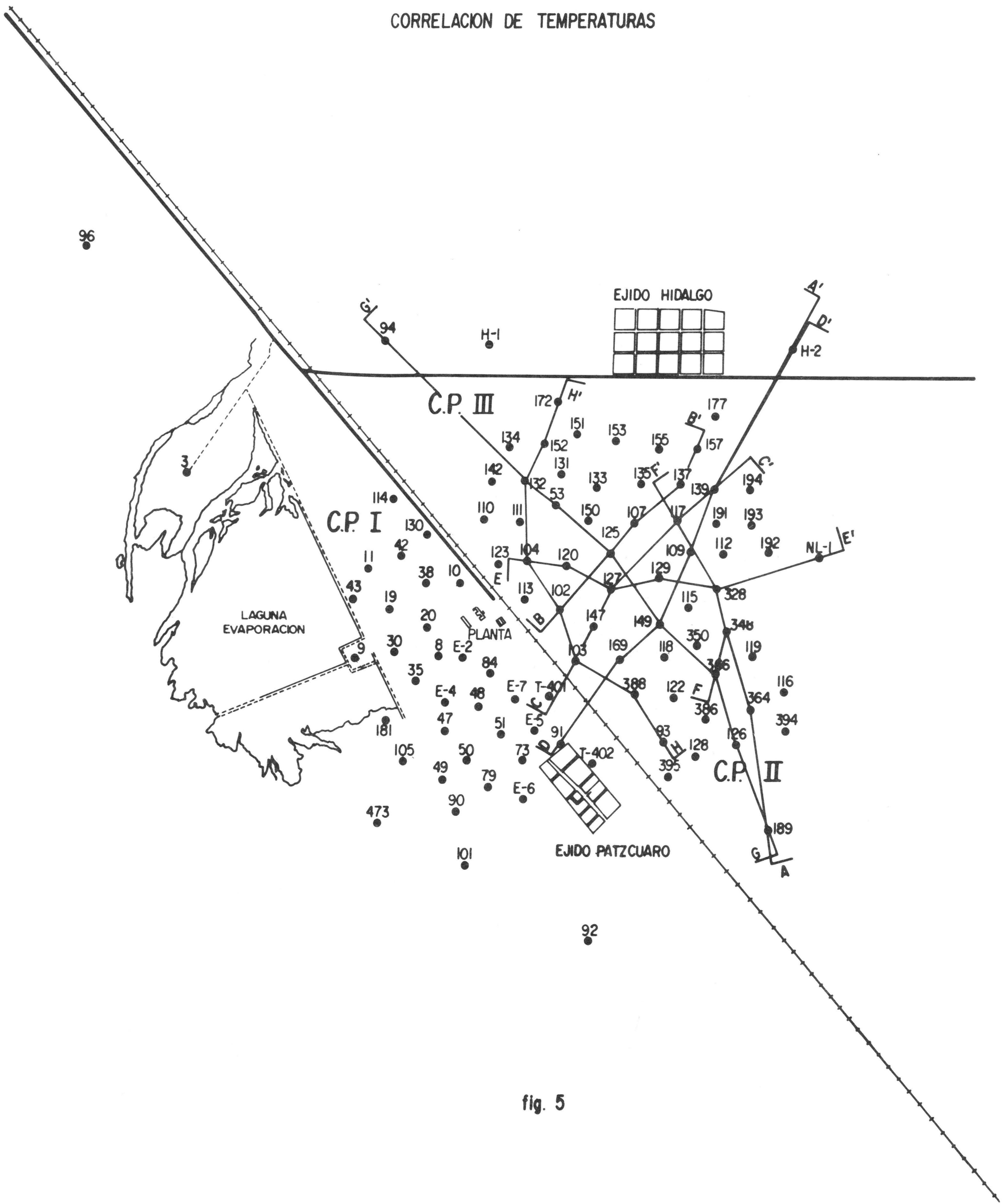


fig. 5

CORRELACIONES TERMICAS

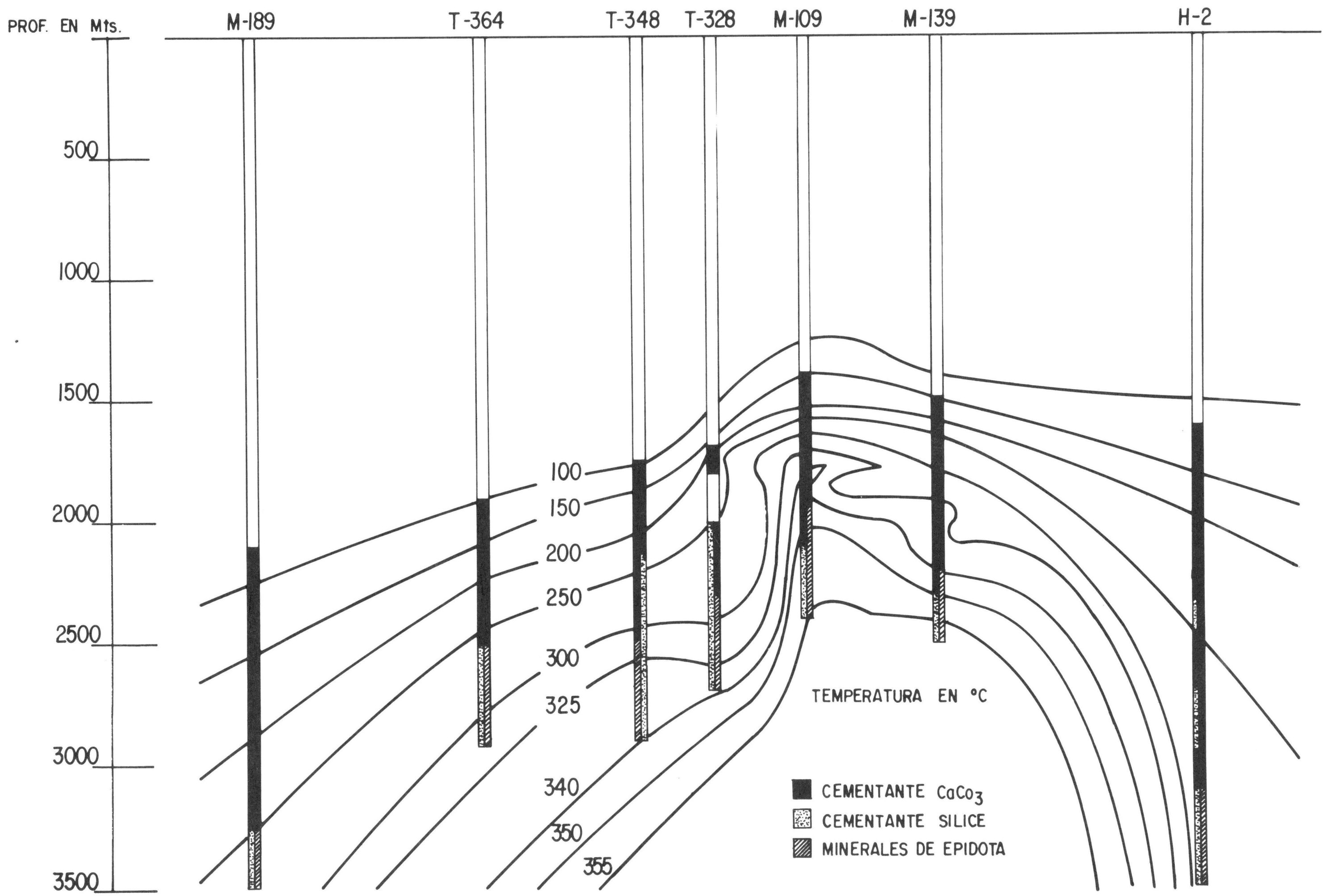


fig. 5A

CORRELACIONES TERMICAS LINEA B — B'

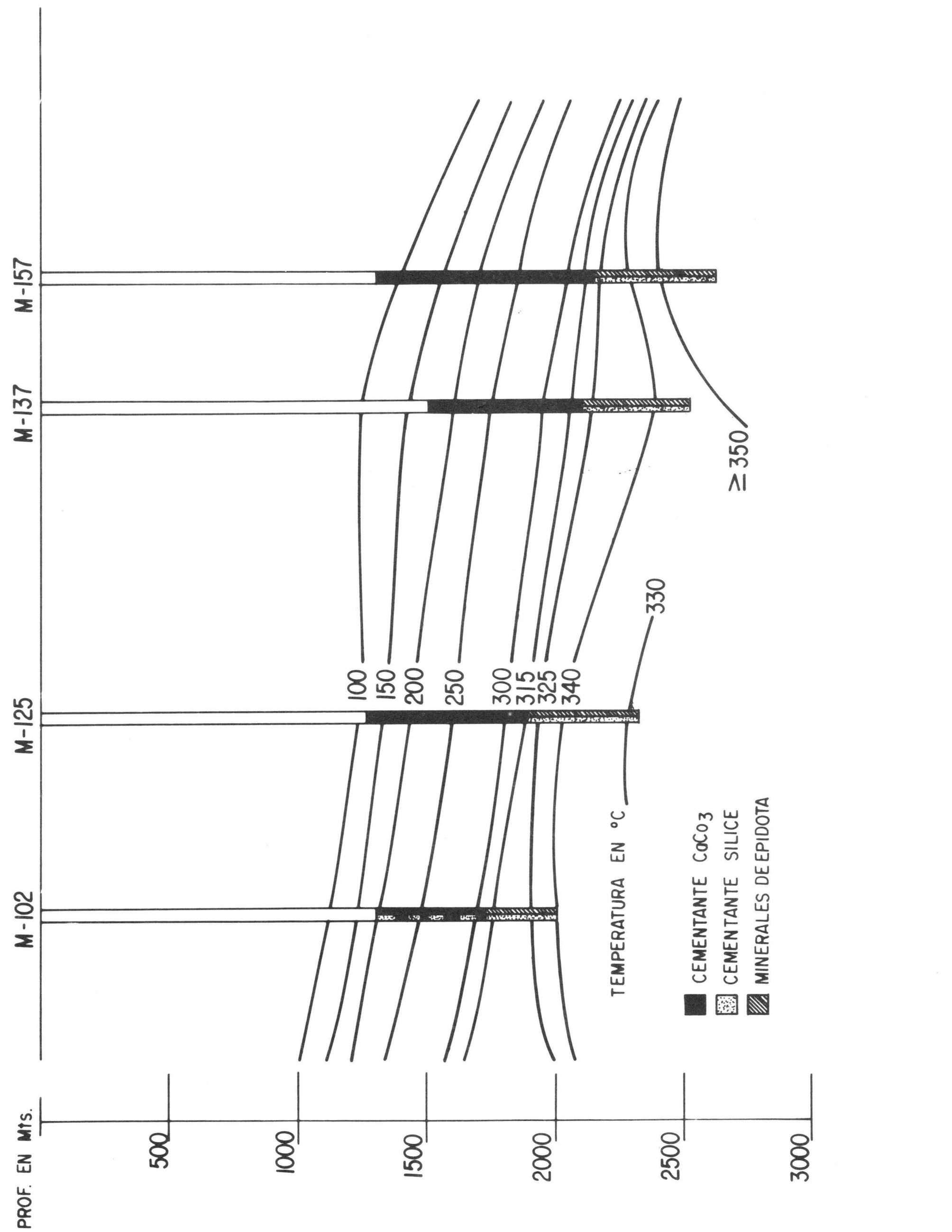


fig. 6

CORRELACIONES TERMICAS LINEA C — C'

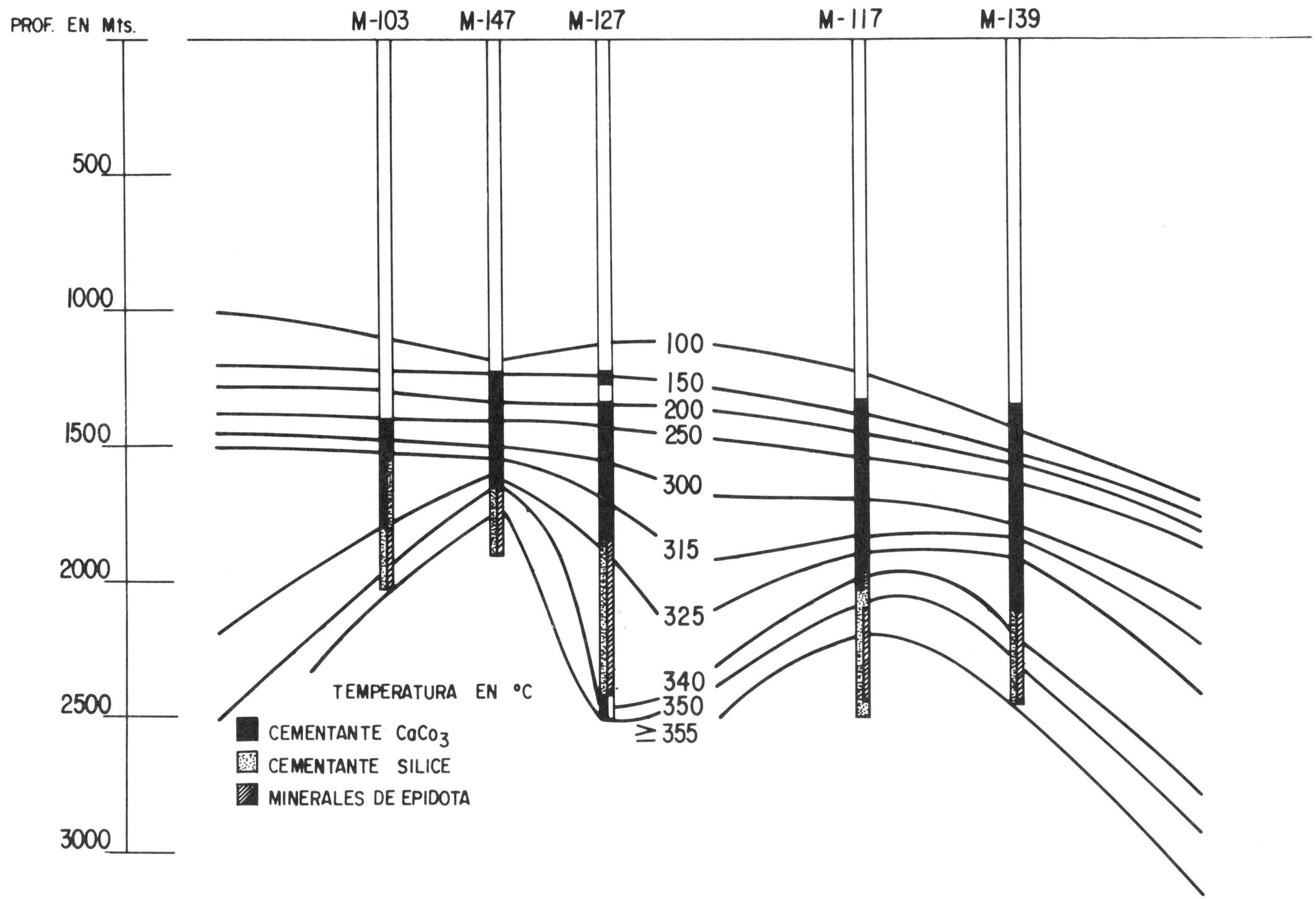


fig. 7

CORRELACIONES TERMICAS LINEA D - D'

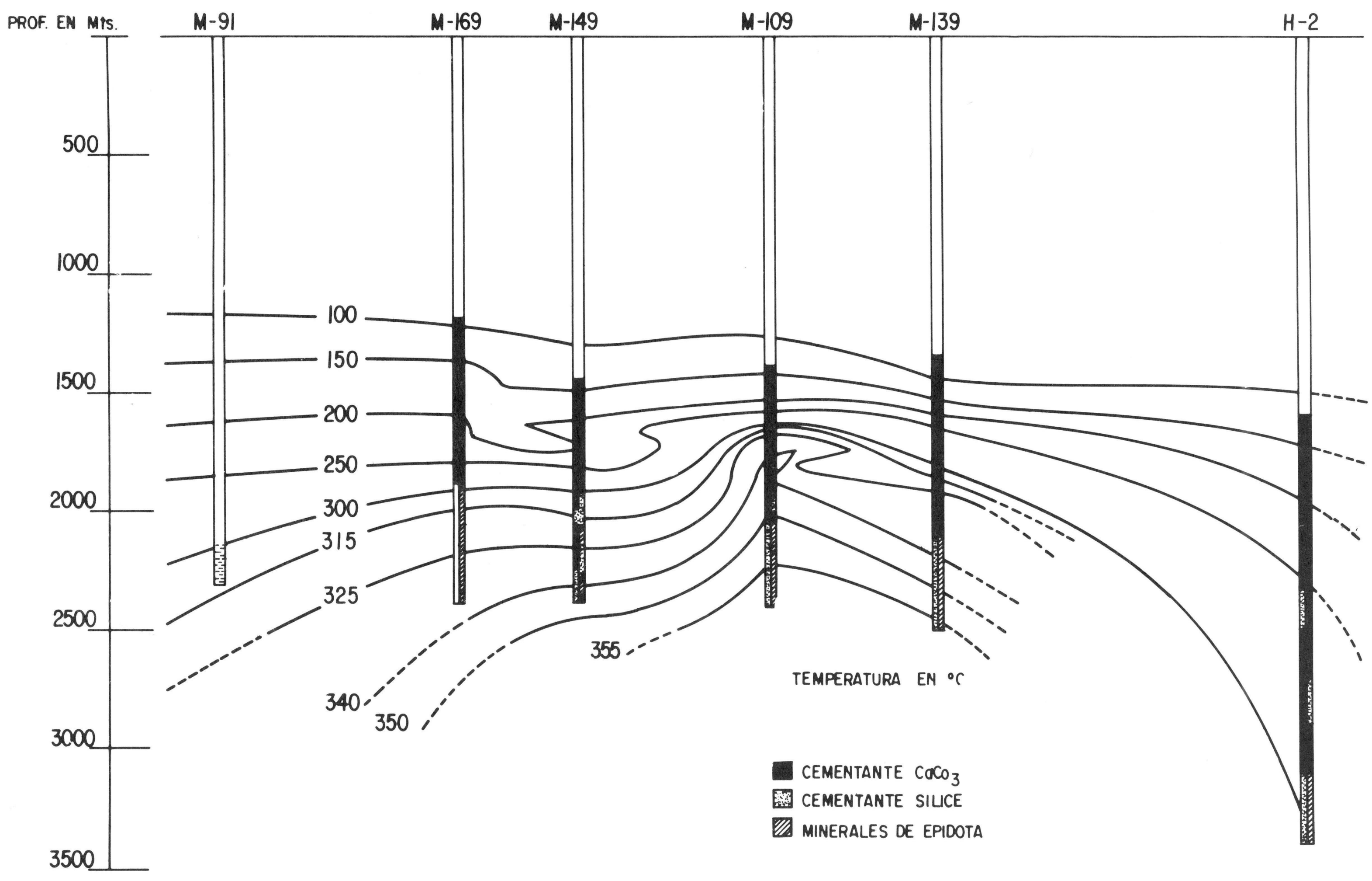


fig. 8

CORRELACIONES TERMICAS LINEA E — E'

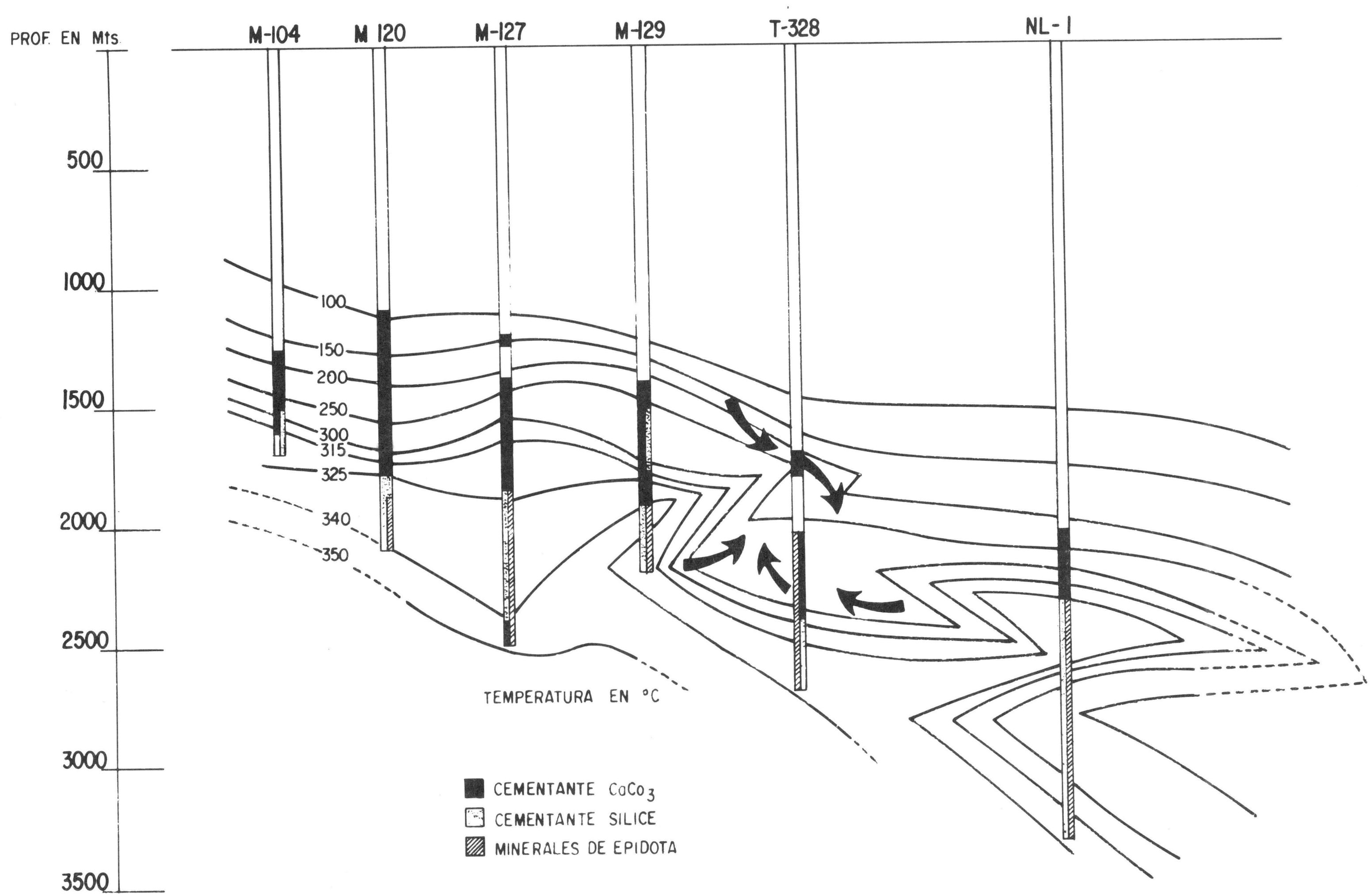


fig. 9

CORRELACIONES TERMICAS LINEA F — F'

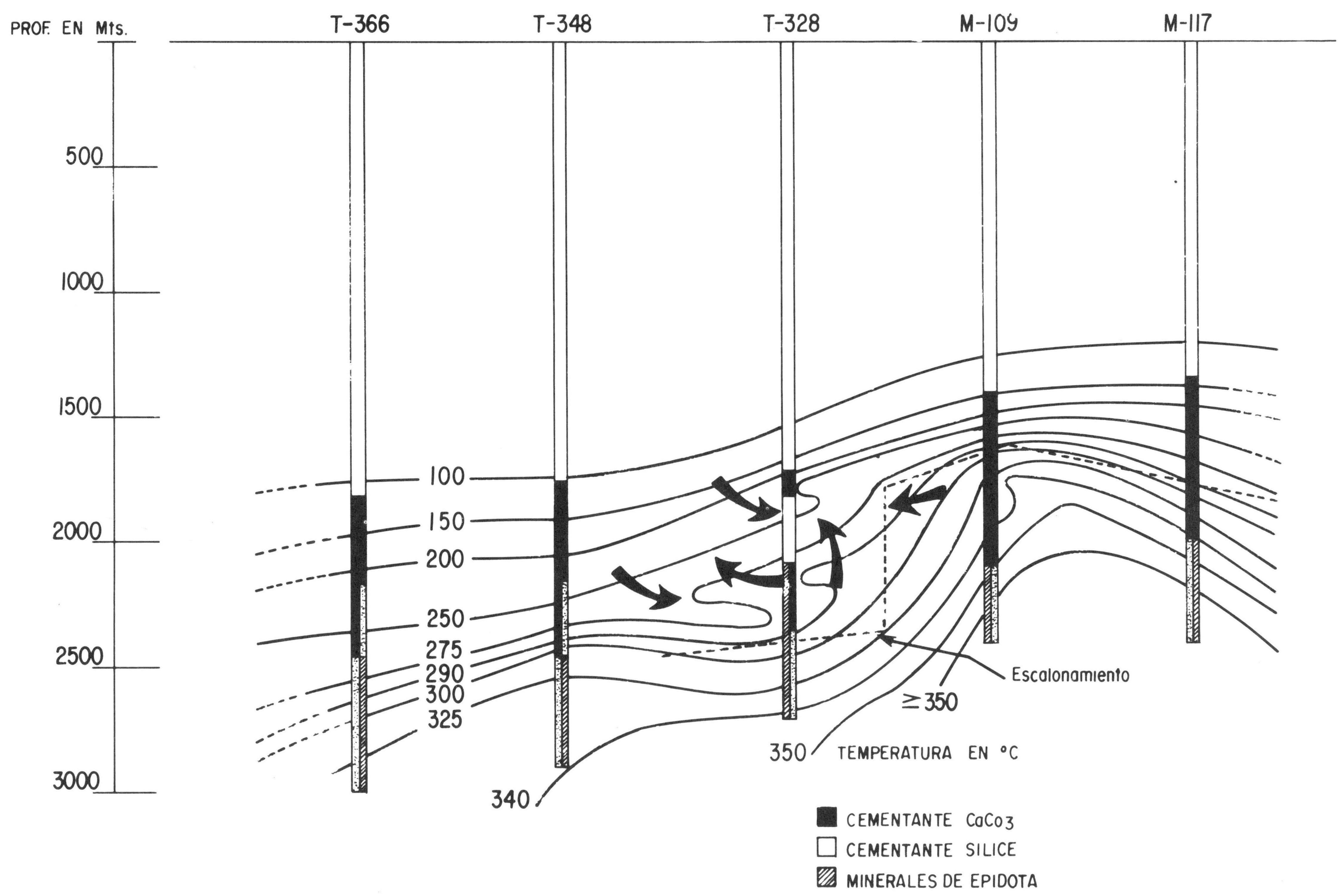


fig 10

PLANO TECTONICO DEL CAMPO GEOTERMICO CERRO PRIETO

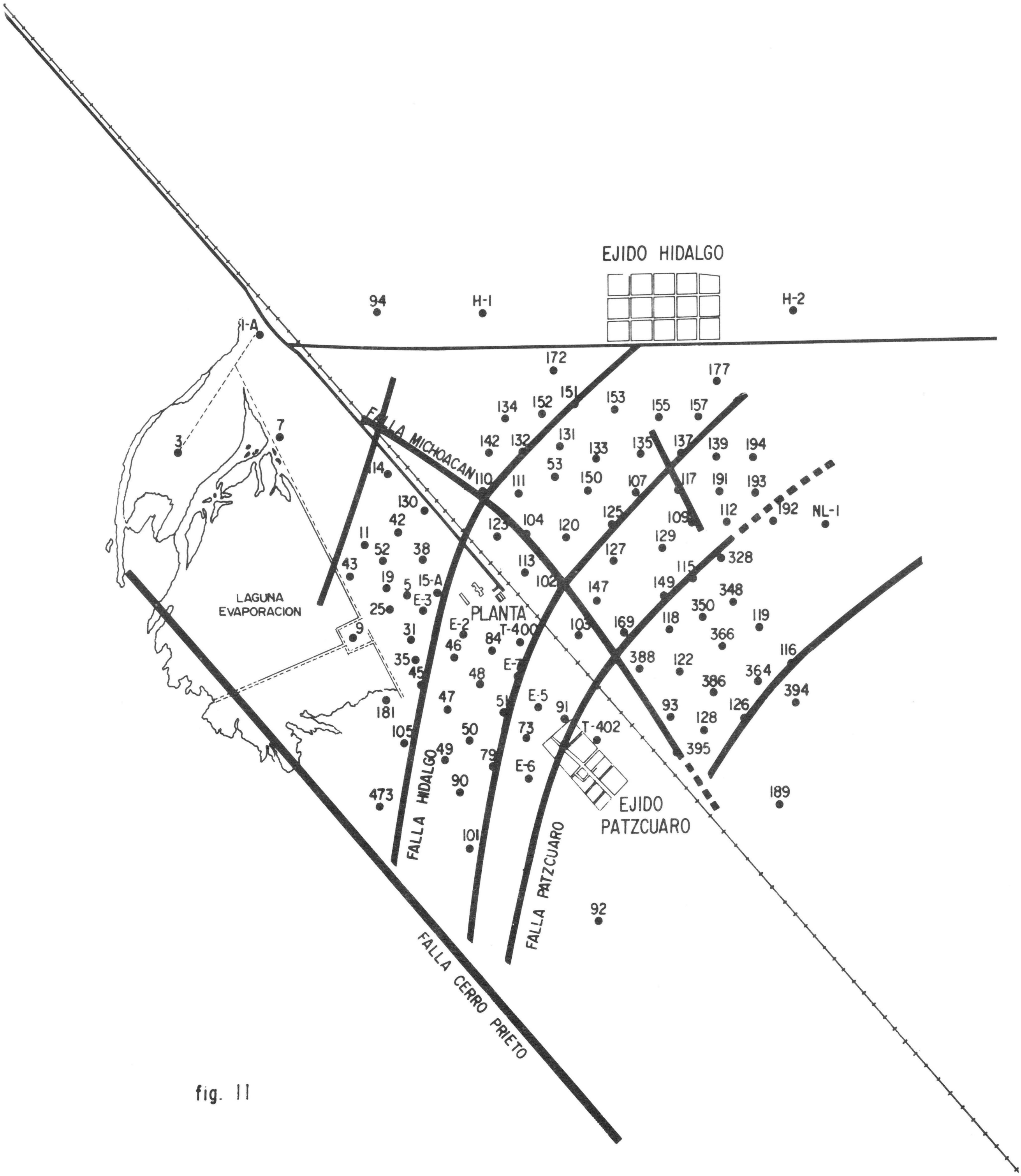


fig. 11

CORRELACIONES TERMICAS LINEA G — G'

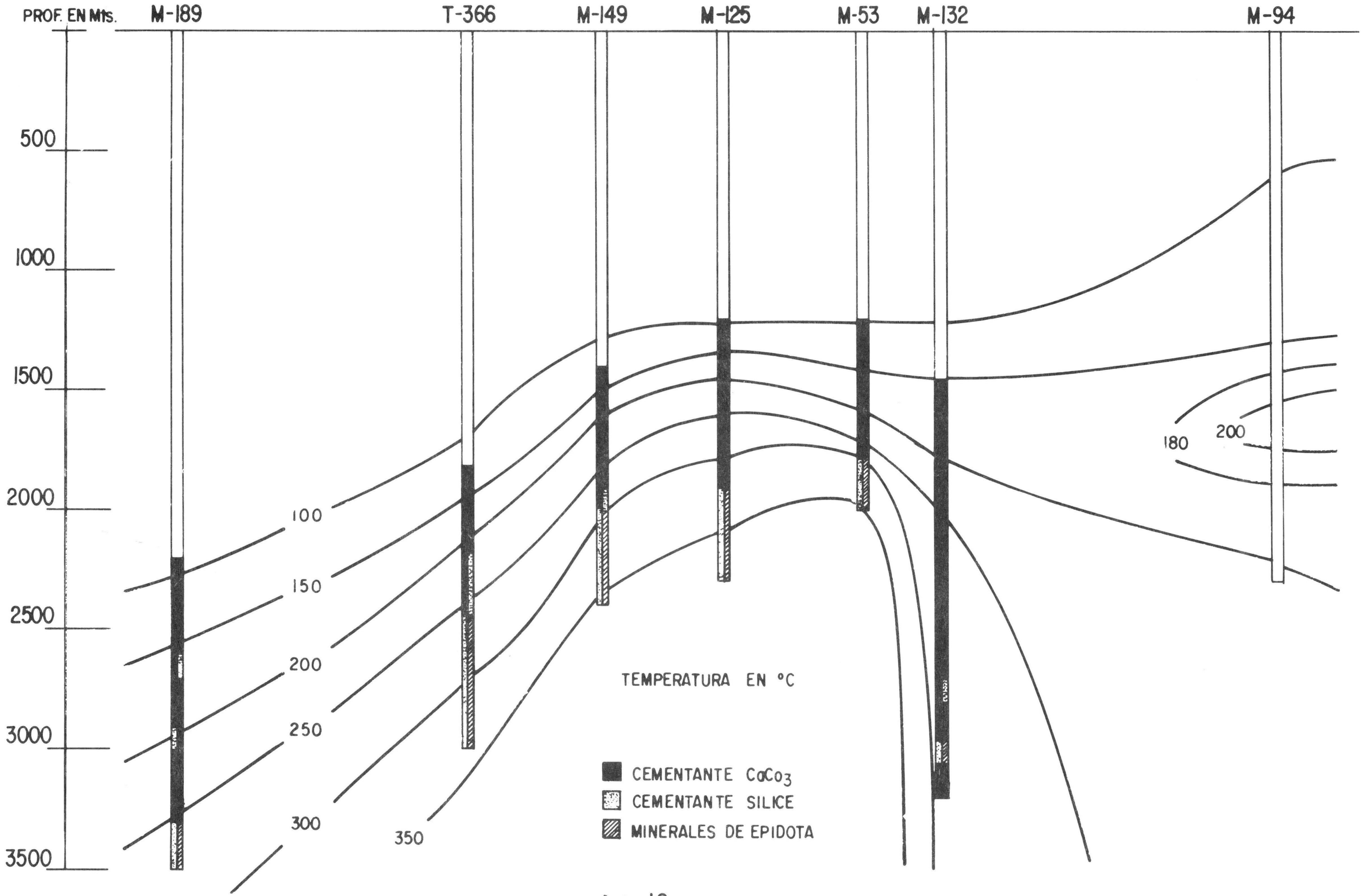
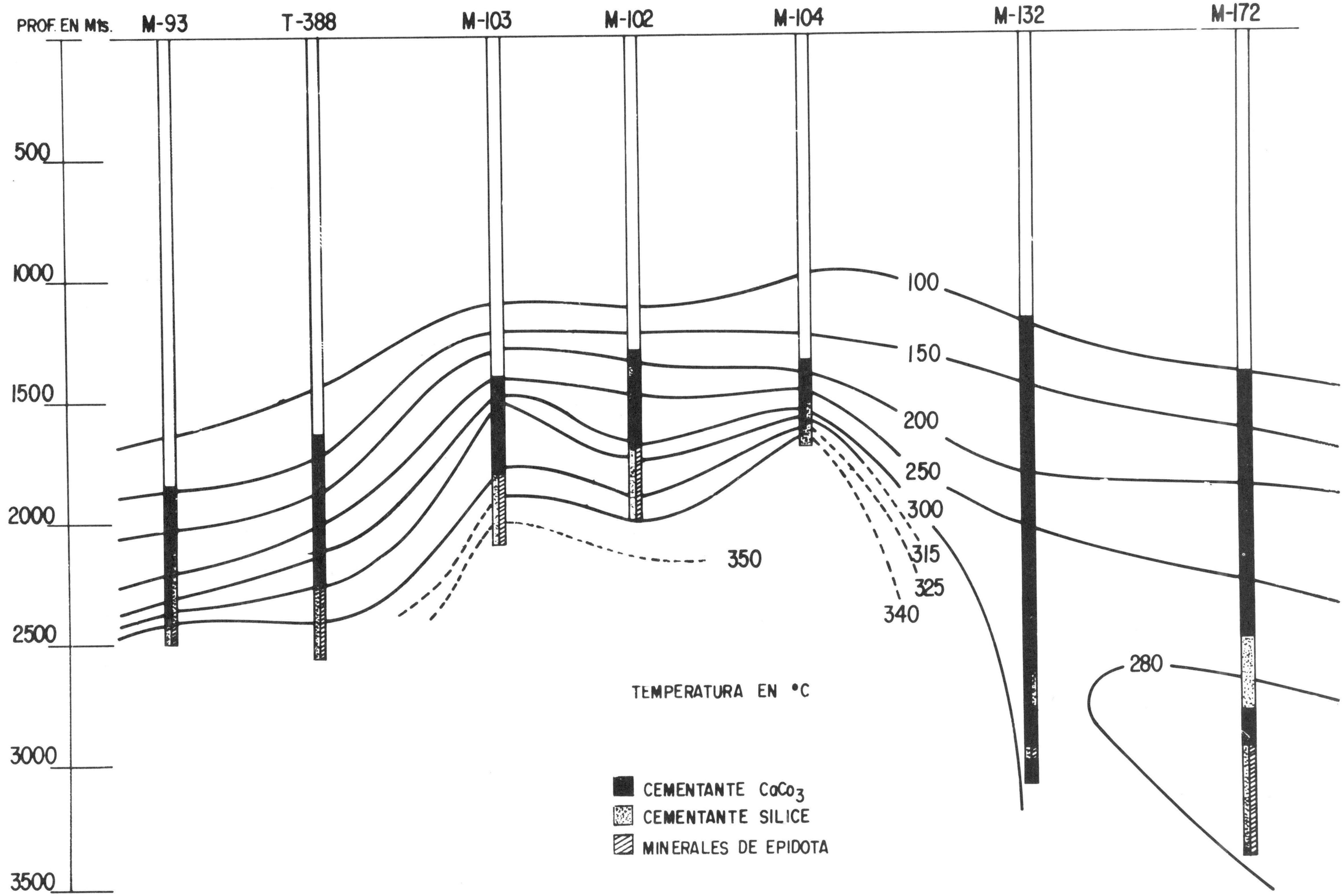


fig. 12

CORRELACIONES TERMICAS LINEA H — H'



TEMPERATURA EN °C

- CEMENTANTE $CaCO_3$
- CEMENTANTE SILICE
- MINERALES DE EPIDOTA

fig. 13

REGISTRO DE TEMPERATURA Y COLUMNA LITOLOGICA
POZO M-110

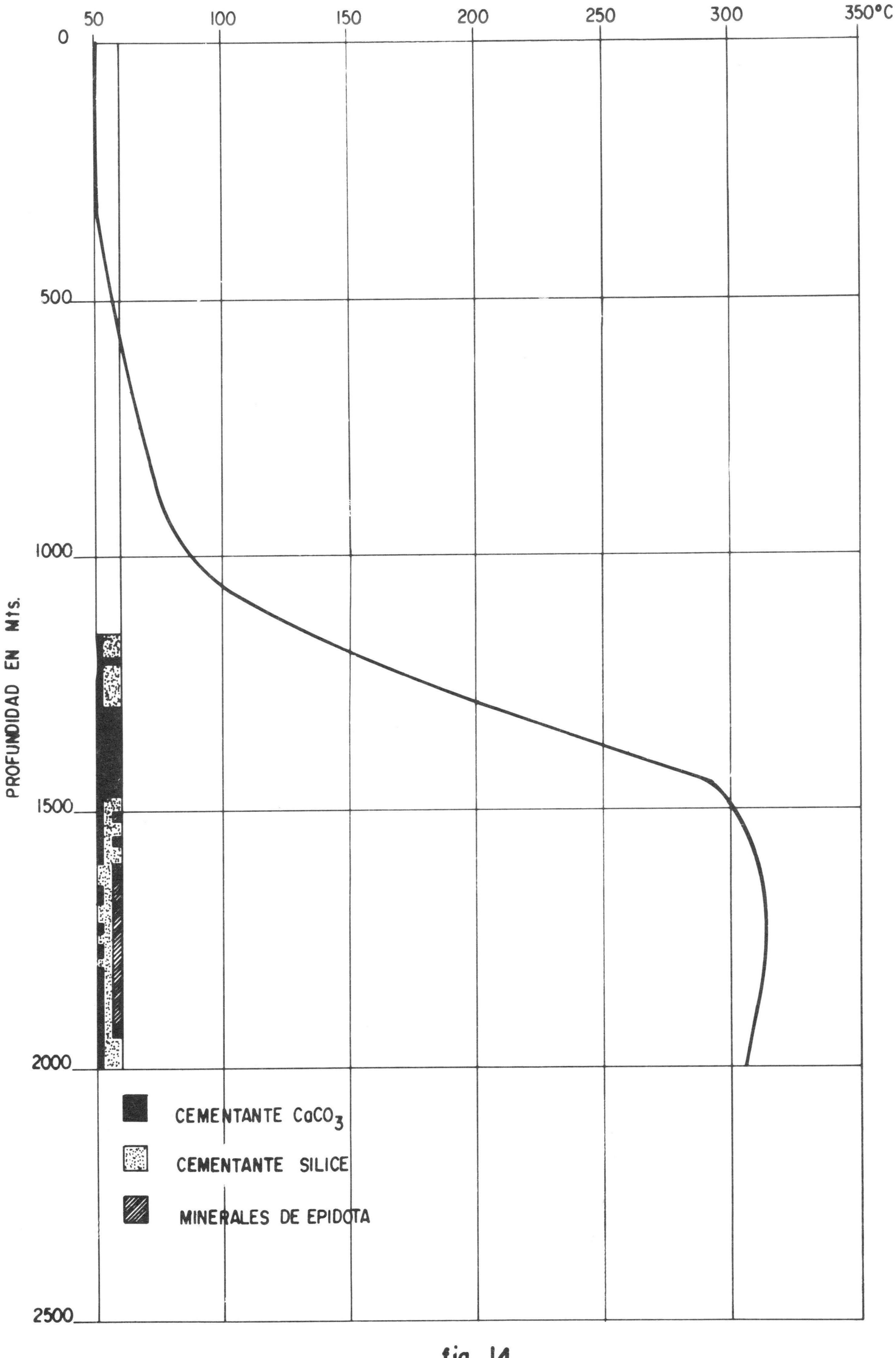


fig 14

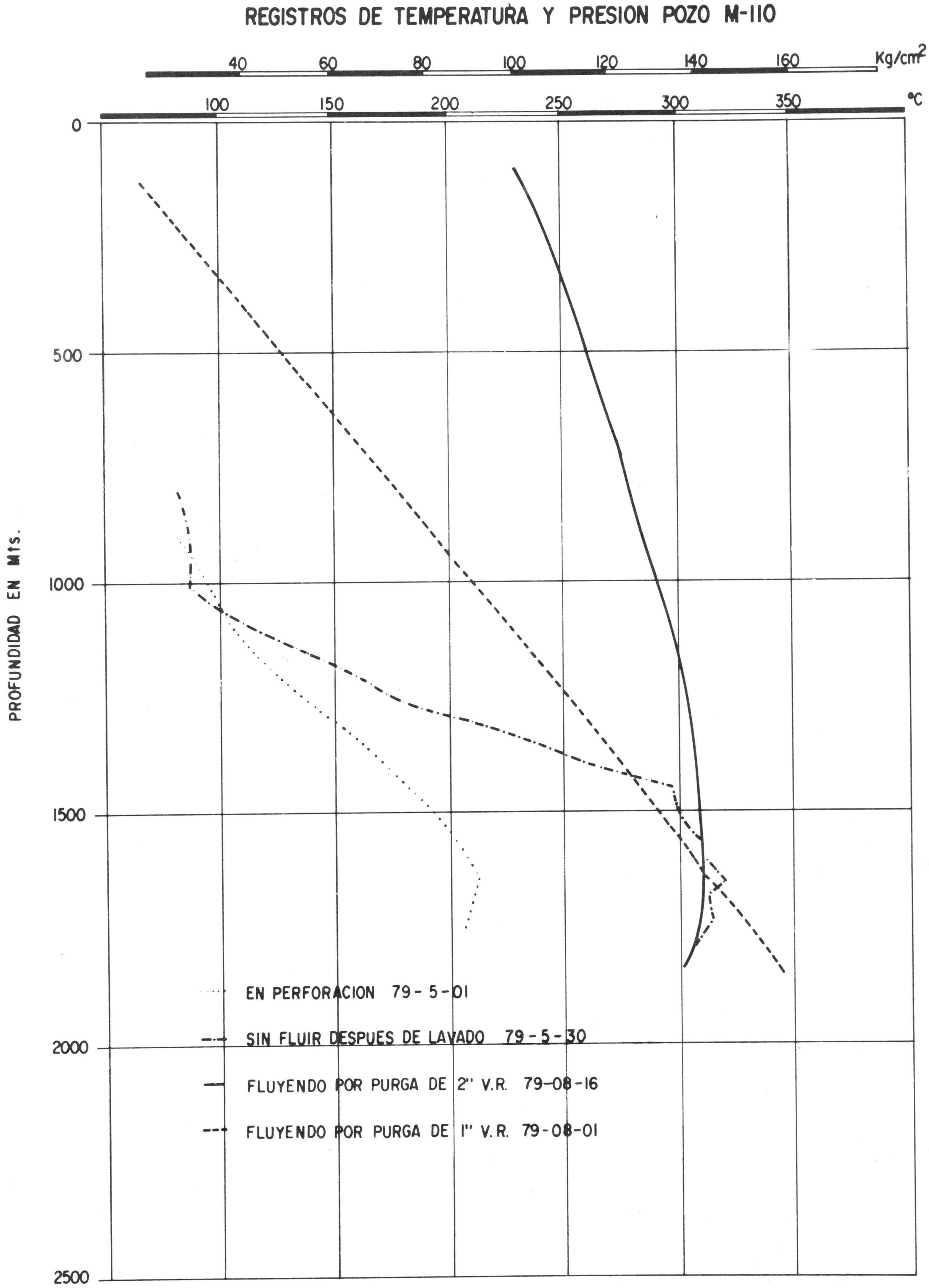

REGISTROS DE TEMPERATURA Y PRESION POZO M-110
40
60
80
100
120
140
160
Kg/cm²
100
150
200
250
300
350
°C
0
500
1000
1500
2000
2500
PROFUNDIDAD EN Mts.
EN PERFORACION 79-5-01
SIN FLUIR DESPUES DE LAVADO 79-5-30
FLUYENDO POR PURGA DE 2" V.R. 79-08-16
FLUYENDO POR PURGA DE 1" V.R. 79-08-01

fig. 15

CAMPO GEOTERMICO CERRO PRIETO

DIRECCION DE LOS FLUIDOS

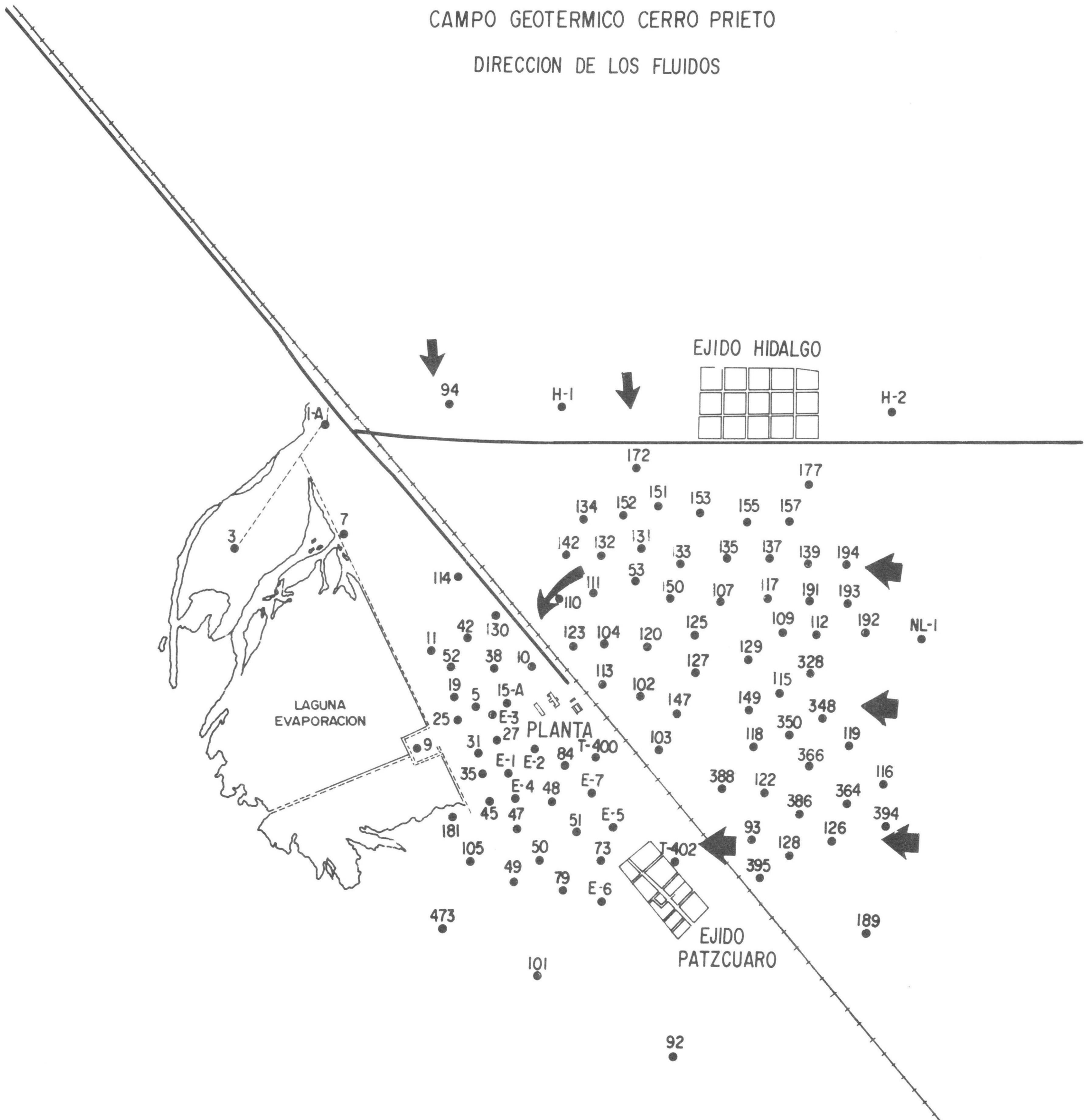


fig. 16