Geofísica Internacional (2002), Vol. 41, Num. 4, pp. 393-398

Correlation of heating index with production zones in Cerro Prieto, area IV, Mexico

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Received: September 6, 2001; accepted: February 27, 2002.

RESUMEN

Se presenta la aplicación de los índices de calentamiento como una metodología en ingeniería de yacimientos geotérmicos para identificar zonas de interés en un yacimiento geotérmico. En este trabajo se calcularon los índices de calentamiento de 16 pozos ubicados en el área de Cerro Prieto IV del campo geotérmico de Cerro Prieto, México. Se presentan gráficas que incluyen para cada pozo: Terminación del pozo, índice de calentamiento, litología y registros térmicos. En estas gráficas se observa la zona donde los fluidos entran al sistema, así como el flujo de calor se mueve de las rocas al pozo. Esta zona permeable se conoce como la zona de sílica-epídota.

Los índices de calentamiento para cada pozo se calcularon como función del tiempo y del perfil térmico del pozo. También se considera el enfriamiento debido a la perforación. Los índices de calentamiento deben correlacionarse con otros parámetros para obtener una evaluación completa de la formación.

PALABRAS CLAVE: Campo geotérmico de Cerro Prieto, índices de calentamiento, ingeniería de yacimientos.

ABSTRACT

We apply a methodology used in geothermal reservoir engineering in order to look for features related to the production zones of the area. Heating index was calculated for 16 wells located in the area of Cerro Prieto IV in the Cerro Prieto Geothermal Field, Mexico. Graphs including heating index, lithology, thermal logs and well completion were prepared for each well. They show the layer where water enters the reservoir and heat flows from the rock to the well. This permeable zone is known as the silica-epidote zone.

The heating index for each well was calculated as a function of time and temperature gradient along the well profile. Cooling due to drilling was also considered to determine heating indices. The heating indices are useful, but they also need to be correlated with other parameters to obtain a complete evaluation of the formation.

KEY WORDS: Cerro Prieto geothermal field, heating index, reservoir engineering.

INTRODUCTION

Marx and Langenheim (1959) and Ramey (1964) have analyzed the thermal transfer process by injection of cold fluid into the reservoir, as well as the effects that are present in formation properties from the changes in reservoir temperature.

The continuous fluid circulation during drilling of a geothermal well causes thermal disturbances in the reservoir. The magnitude of these changes is related to lithological characteristics. Grant *et al*., (1982) applied heat balances into the well and the inverse proportionality between temperature gradient and the injection flow to identify feed zones along the well.

Reservoir engineering uses the productivity index (*J*) or the injectivity index (*I*) to characterize the initial reservoir power (Aragón *et al*., 2000). Also, in order to determine reservoir depletion rate, it is possible to determine such indices at different periods of operative well life.

From an analogy of productivity and injectivity indices, Aragón *et al*. (2000) formulated the heating index (*IC*) using the temperature derivative respect to the stability time. Correlation of heating indices with fluid lost circulation during well drilling as well as with mineralogy, lithology and temperature-pressure profiles has been observed in wells of the Los Humeros Geothermal Field (Arellano *et al*., 1999).

The heating index is calculated as a function of time from the temperature gradient along the well profile. A low heating index value is related to low or none heat flow from the rocks to the well. It is common to find it where low permeability occurs. On the other hand, high heating index is an indication of heat entrance to the well (from the rocks to the well). Heating indices by their own are useful, however they need to be correlated to others parameters to obtain a complete evaluation of the surrounding rocks (Aragón *et al*., 2000). The method requires a set of temperature logs for different stability times.

THE CERRO PRIETO GEOTHERMAL FIELD

The Cerro Prieto Geothermal Field (CPGF) in Baja California is located in the southern part of the Salton Trough about 20 miles south of the United States-Mexico border (Figure 1). It is contained mostly in sandstones and shales of the Colorado River delta.

For administrative purposes the geothermal field was initially divided into three areas (Lippmann *et al*., 1991). At present, four areas have been recognized in the field (Gutiérrez and Helio, 2000). These are CP-I (Cerro Prieto I) to the west of the railroad, CP-II (Cerro Prieto II) in the southeast area, CP-III (Cerro Prieto III) in the northeast area and CP IV northeast from CP-III. At the moment total installed capacity is 720 MW.

There are three reservoirs developed in sandstone and sandy shale units that are fed from depth by fluids rising from fractures (Lippmann *et al*., 1991). The alpha reservoir in the west part of the field is the shallowest and was the first to be exploited. It is found at depths between 1000 and 1500 m. The deeper Beta reservoir extends underneath the entire area of the Cerro Prieto (about 15 km^2) at depths between 1500 and 2700 m with temperatures higher than those in Alfa reservoir. The deep Gamma reservoir is not yet exploited.

GEOLOGIC SETTING

Tectonically, the Salton Trough-Gulf of California area is a zone of transition between the divergent boundary of the East Pacific Rise and the transform boundary of the San Andreas fault system.

The sediments at Cerro Prieto were deposited mainly in alluvial, deltaic, estuarine and shallow-marine environments during Pliocene to middle Pleistocene times (Halfman *et al*., 1984).

The sediments are classified into two units A or B, both overlying a granodioritic basement. Unit A consists of clay, silt, sand and gravel, considered as unaltered unindurated sediments.

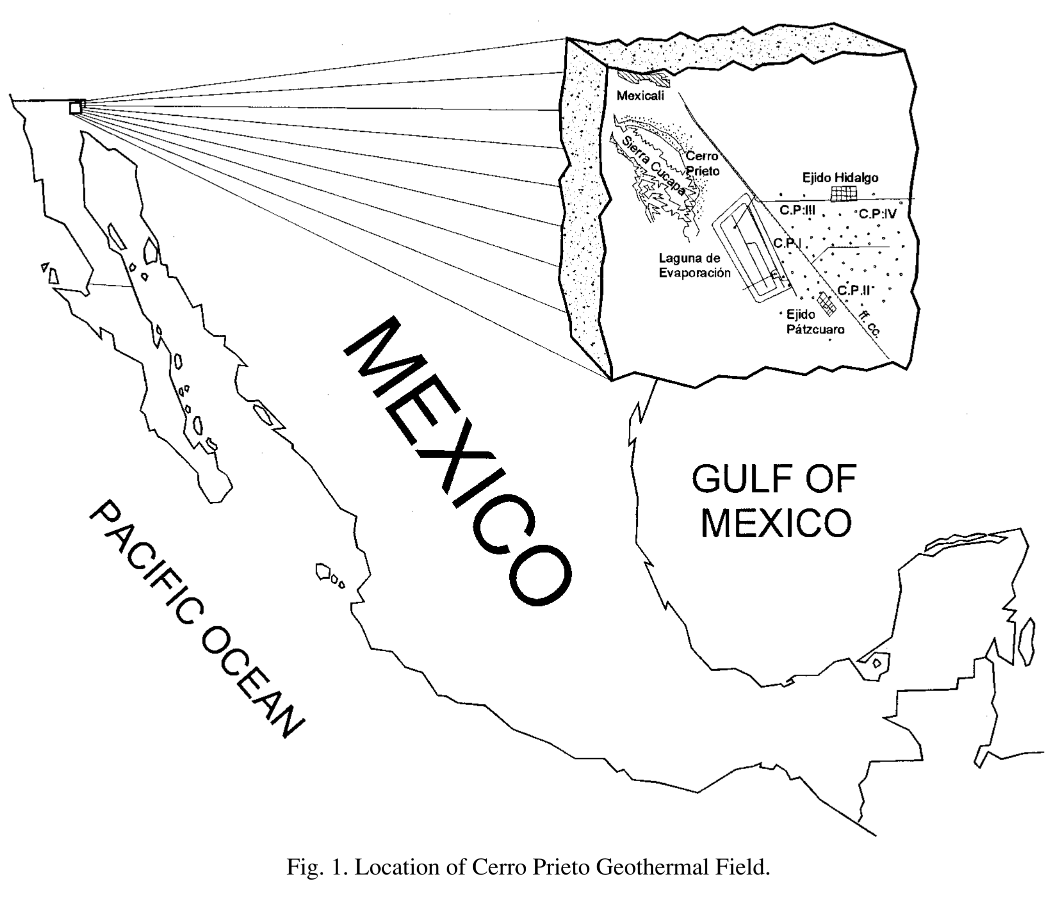

Fig. 1. Location of Cerro Prieto Geothermal Field.

Unit B, below unit A, consists of shale, siltstone and sandstone. Sediments of unit B are considered become indurated by compaction, cementation and metamorphic reactions. The contact between the A and B units approximately corresponds to the first occurrence of hydrothermal minerals.

RESULTS AND DISCUSSION

Heating indices were calculated using data from 16 wells located in the Cerro Prieto IV area.

To record the thermodynamic conditions of the wells temperature and pressure logs were measured in wells at different stabilization times during breaks under drilling. In order to calculate the heating index, two temperature measurements were used, both taken at the same depth, but at different time along each well.

In this work, the behavior of heating indices (*dT/dt*) along the well profile has been analyzed and it is shown for several wells from Figure 2 to Figure 5.

Plots include apart from the heating index profile, well completion, circulation loss profile, lithology and temperature logs. From the four plots it is clear that the heating index profile follows the same trend showing a maximum of (dT/dt) at a depth that is coincident with the silica-epidote zone. As far as the exploitation policies are concerned, it is considered as the production zone. It is the most permeable zone where the main alteration mineralogy appears and the highest temperatures have been recorded.

Figure 6 is a north-south cross section including some wells from the area of Cerro Prieto IV. It is quite clear the relation of the maximum values of heating index with the zone in which hot fluids enter into the system. On the other hand the heating index maximum also corresponds to the maximum temperature recorded at different stabilization periods.

The exception is well E48, where the maximum values of the heating index were found in the gray shale. By geochemistry and isotopical interpretation (Izquiero *et al.*, 2000 and Izquierdo *et al.*, 2001) for fluids from wells close to E48 (E49, E25, 329) it has been assumed that infiltration

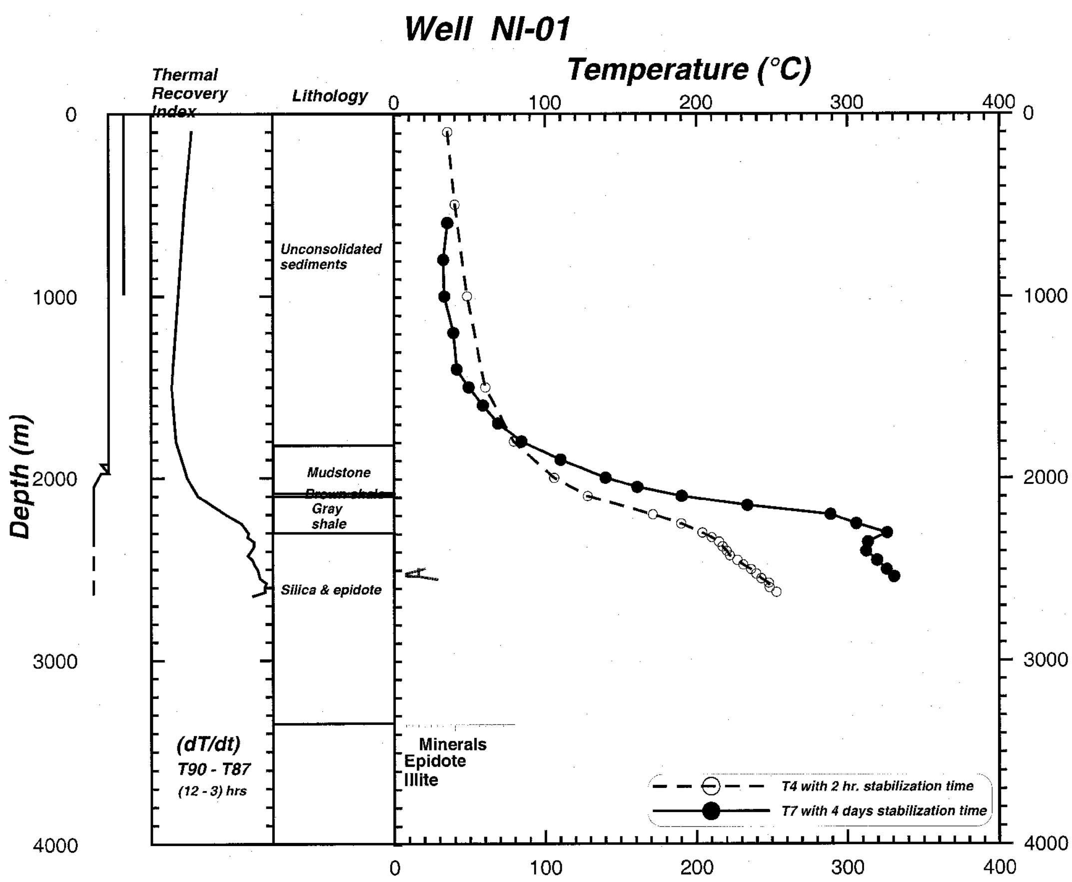

Fig. 2. Heating index profile, well completion, circulation loss profile, lithology and temperature logs for well NL-01.

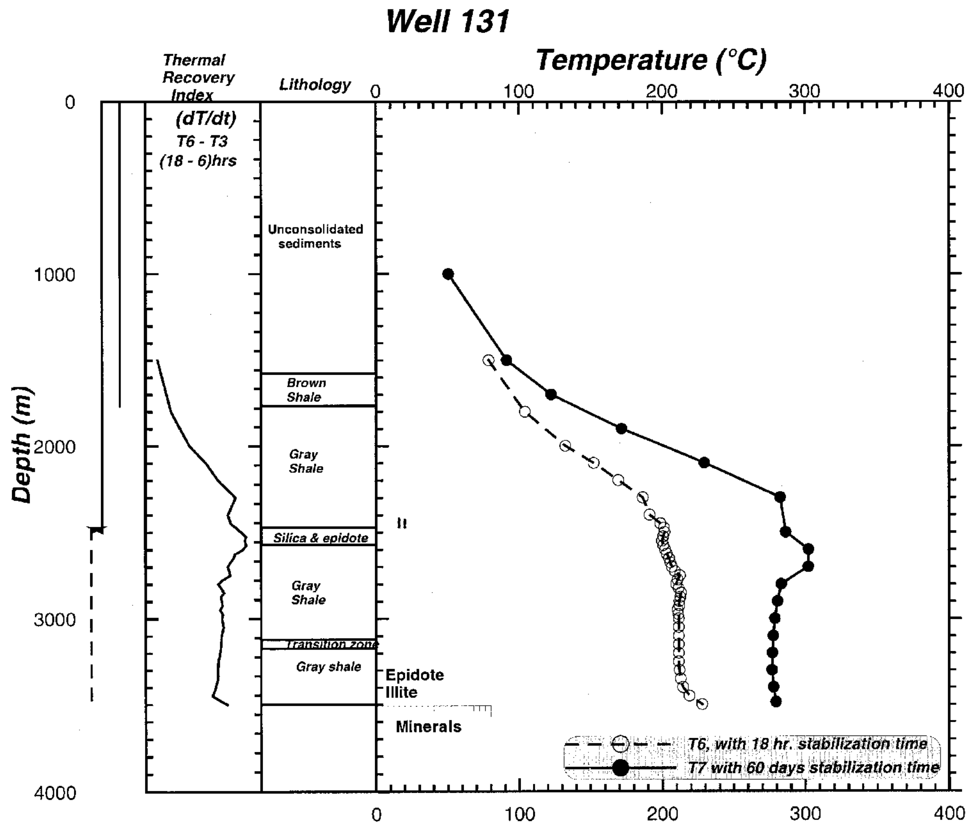

Fig. 3. Heating index profile, well completion, circulation loss profile, lithology and temperature logs for well 131.

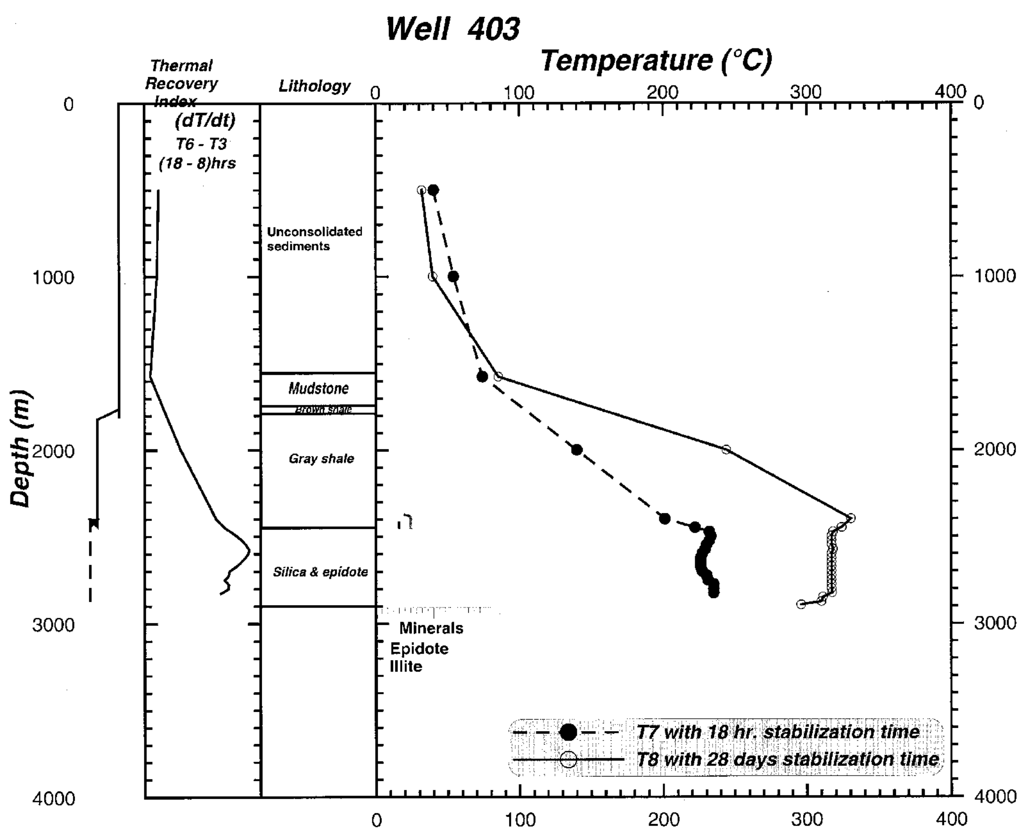

Fig. 4. Heating index profile, well completion, circulation loss profile, lithology and temperature logs for well 403.

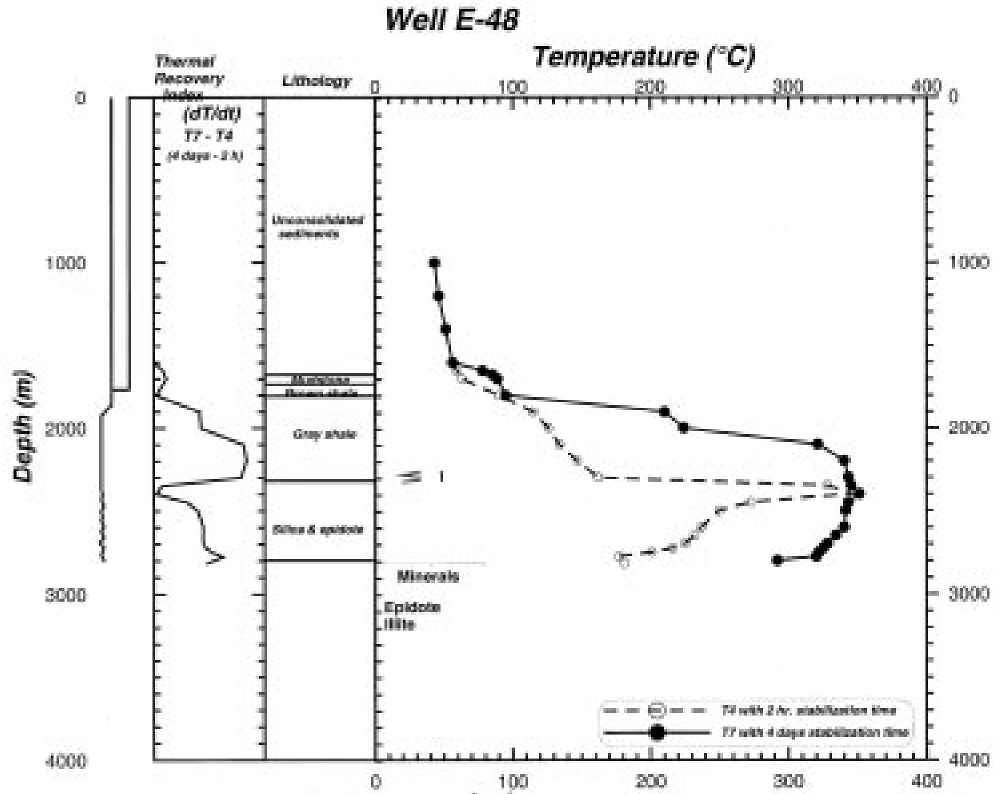

Fig. 5. Heating index profile, well completion, circulation loss profile, lithology and temperature logs for well E-48.

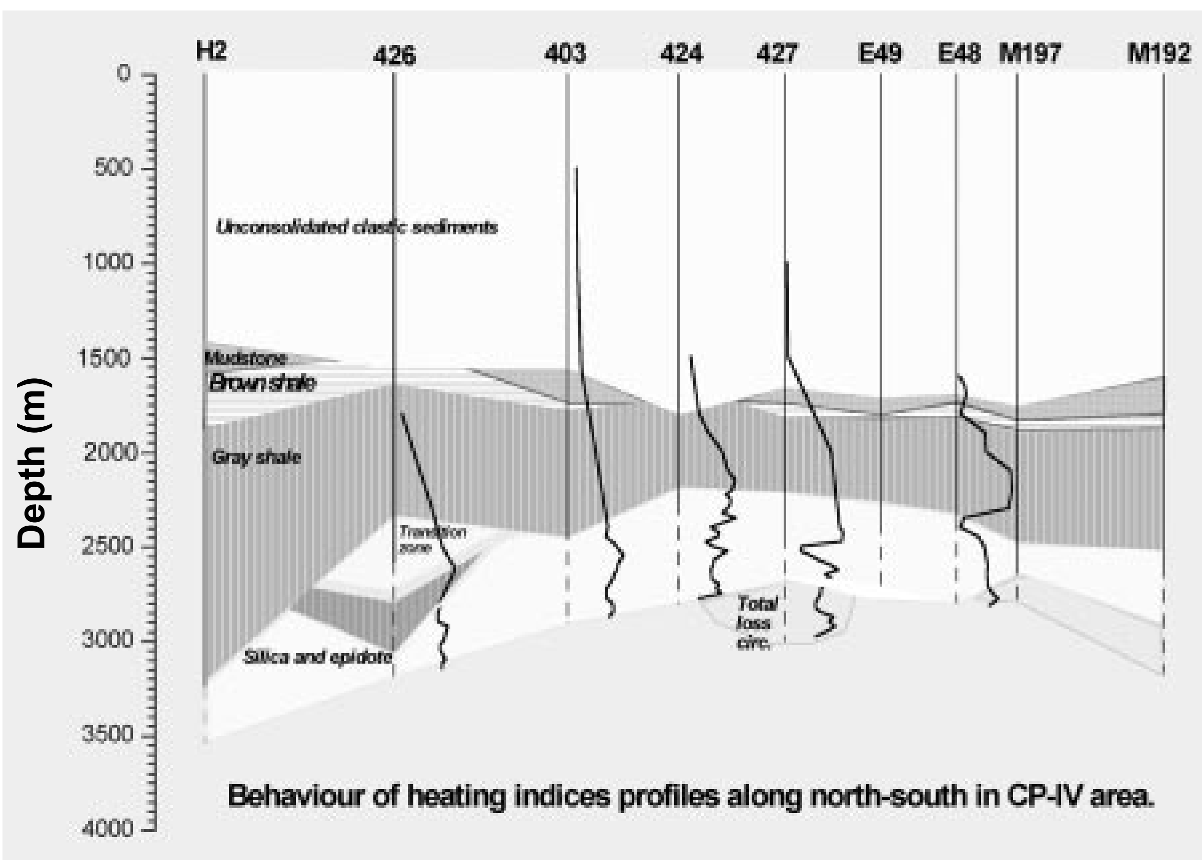

Fig. 6. North-South cross section including some wells from Cerro Prieto IV.

of groundwater has reached the production zone of such wells. That is the reason why E48 show low heating indices values in the silica epidote zone.

CONCLUSIONS

Heating indices have been calculated for 16 wells from the area of Cerro Prieto IV. Plots of heating index show a straight correlation to the productive strata in the geothermal system.

One main advantage on calculating heating indices is that only two temperature logs are required even the recorded conditions are different.

It has been shown that the heating index profile keeps the same tendency during all drilling stages.

ACKNOWLEDGEMENTS

The authors wish to thank to the authorities of the Residencia General de Cerro Prieto of the Comisión Federal de Electricidad for giving us all the information required in this work and to Ing. Héctor Gutiérrez Puente for his support, comments and permission to publish this work.

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