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REMOTE SENSING APPLIED TO PROSPECTING OF THERMOMINERAL
WATER IN THE COUNTY OF CALDAS NOVAS-GOIAS

P. Veneziani and C. Eustaquio dos Anjos

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16. Summary/Notes

The utilization of remote sensing for natural resources prospecting, integrated or not with conventional methods, has been shown to be of much value, especially when time and cost are considered. The Caldas Novas thermomineral water region has been known for a long time. The authors have studied this region with the purpose of locating additional thermomineral water sources. One objective of this work is to show the effectiveness of the method employed. LANDSAT imagery of the region were studied allowing the placement of the area of study in the regional geological context. A geological mapping of the 1:60.000 scale was done. A methodology was developed which consisted in a regional temperature mapping using trend surface analysis. Through the correlation of all these data, four different areas were localized with a high potential as thermomineral sources.

17. Observations

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*Translator's note. Illegible in foreign text.

REMOTE SENSING APPLIED TO PROSPECTING OF THERMOMINERAL
WATER IN THE COUNTY OF CALDAS NOVAS-GOIAS

Paulo Veneziani* and
Celio Estaquio dos Anjos*

1. Introduction

The existence of a contract between INPE and GOIASTUR, signed in 1975, to implement prospecting for thermomineral water, made it possible to develop a methodology — a first, in certain aspects — which led to the detection of thermal anomalies.

/3**

The area of study is limited on the west by the Piracanjuba River and on the east by the Corumba River and the latitudes 17°58'08" and 17°41'40" south. It encompasses approximately ...*** km². The existence of thermomineral water was already known in the areas of Caldas Novas, Pousada do Rio Quente, and Lagoa Pirapetinga.

The importance of the measurements, data processing and interpretation of geological parameters stems from the fact that one can delineate anomalous areas where the probability of encountering thermomineral water through drilling is greater.

/4

* Institute of Space Research - INPE, National Council of Scientific and Technological Development - CNPq.

** Numbers in margin indicate pagination in original foreign text.

*** Translator's note. Illegible in foreign text.

Besides, it has been demonstrated that the chances of obtaining the same results, and (actually) with greater accuracy, using an airborne thermal image is far greater.

The authors wish to thank Dr. Gilberto Amaral, the geologists Athos Ribeiro dos Santos (M.S.), Marx Prestes Barbosa (M.S.), Raimundo Almeida Filho (M.S.), and Mr. Jose Onofre Carvalho for the support given throughout the various phases of the research.

2. Experimental Methodology

The surface temperature on the air/ground boundary depends basically on the solar energy. According to Sellers (1965) and Hase (1971), 99.97% of the caloric energy at that boundary is supplied by solar radiation. In order to obtain significant data from a thermally anomalous area where one assumes the existence of a geothermal flux, it is necessary to consider, in addition to the aforementioned factor (solar radiation), the minimizing effects of the daily (circadian) and annual variations to solar heating, the heterogeneity of the materials being evaluated, the depth necessary for measurements, and logically, the adequacy of the equipment being used.

With the use of a 50 cm R. Fuess soil thermometer and a PRT-5 radiometric thermometer which measures surface temperatures, both giving direct readings in degrees Celsius, a comparative test was conducted, with positive results, between an area containing thermomineral water and an area known to be sterile.

Figure 1 shows a chart made by Hase (1971) of a test area in Mono Lake, California. In that work, the basis for defining the main topics of the procedure to be used was sought. Thus, the time between 5:00 and 6:30 for the 50 cm depth measurements for ground thermometers was selected. The sand/clay soil, formed by decomposition of schists which are predominant in that region, can be considered homogeneous.

From that point, two phases of work were established in the field. The first one, with the purpose of studying regional temperature behavior encompassing all the area of interest, was accomplished through conducting radial profiles of the Caldas structure. The data was submitted to a mathematical-statistical processing through a program of analysis of the Area of Tendency. After the analysis of the residual curves which matched surface measurements and ground measurements, four anomalous areas were outlined: Caldas Novas, Pousado do Rio Quente, Lagoa Pirapetinga and Corrego Tucum. In the second phase, the same procedures were applied to those areas.

At the same time, a geological map, scale 1:1,000,000 was made based on the interpretations of LANDSAT images. Another map, scale 1:60,000 was also made, based on aerophotography and ground truth. Finally, a verification of the new wells* drilled in the Caldas Novas area was made.

3. Geological Features

The main purpose of presenting the regional geological map was to show that the structure of Calcas Novas lies on a strip with a NW-SE orientation between the Parana River basin and the Sao Francisco River basin. In this strip, important intrusions, such as Araxa, Salitre, Catalao, and others, are encountered.

The geological region located between parallels 17° and 20° (south) and meridians 46° and 49° (west) is represented in general, and from the base to the top, by a complex granite-gneissic of the Pre-Cambrian Inferior period mica sediments** of the Pre-Cambrian Superior period of the group Araxa, Canastra, and rocks from the group Bambui and mesozoic sediments of the basins of the Parana River and Sao Francisco River and, finally, ultrabasic and alkaline intrusions of the Cretaceous period.

/5

*Translator's note. The word in the text is "precos" which means prices. I think the intended word was "pocos" which means wells.

**The term is almost illegible in the foreign text.

The geology of the area of study is constituted by a sequence of micaceous quartzite and muscovite-quartz-schist-feldspathic conglomerates with intercalations of limestone and amphibolites of lesser importance, correlated to the Araxa group. Covering these two lithologic units, one will find a biotite-muscovite-quartz-schist conglomerate with intercalations of quartzite correlated with rocks of the Canastra group.

As the crystalline group is predominant in that area, the skimpy tertiary-quaternary coverings become negligible as to being aquiferous. Thus, it is evident that the structures play a very important role. A detailed study would be very interesting to better understand the aquiferous network of the prospected area.

Large synclinals (like the one of Calcas Novas) and anticlinals with a general direction of NNW-SSE were registered on a map. A major feature is the Caldas Novas mountain, with its brachy-anticlinal form. The type of bending is asymmetric and the axial planes dip toward ENE.

There are two systems of faults bearing the directions NW-SE and NE-SW around 60° . The first is more important and it suffered dextral occurrences and vertical upheavals during the Mesozoic reactivation.

The rocks in the area are badly fractured. The fractures are distributed through the four quadrants, and they are generally vertical.

4. Results and Discussion

The geological parameters, obtained with remote sensors and field work, which were later integrated with thermometric data, supplied the basis to achieve the desired goals.

As a result of the analysis of the Area of Tendencies, the regional temperature behavior was obtained. The first interesting

result was the visualization of a subtle tendency of temperature increase in the direction of the Caldas Mountain. The local effects are represented by the difference between the computed values and the observed values, that is, the residual values. Through the interpretation of curves drawn from these values, four thermally anomalous areas were pinpointed. Figure 2 shows a geological sketch of the prospected region and the placement of those areas.

As was mentioned in section 2, "Experimental Methodology", the same procedures were repeated for each one of the thermally anomalous areas. In May 1978, Caldas Novas was visited when it became known that 14 new wells had been drilled. Figure 3 shows the map obtained from plotting the residual values and the localization of the 14 new wells.

The interval between curves is 0.5° Celsius. The shaded areas beginning from $+0.5^{\circ}$ C were considered positive anomalies.

Direct local measurements and information obtained in the area show significant aspects concerning the validity of the prospecting.

Of the 14 wells, nine present the following general characteristics:

- a - yields between 10,000 and 20,000 liters/hour. All wells are somewhat artesian, but the above yields were obtained by pumping;
- b - well depths varied from 80 meters to 250 meters, depending on when the area of fracture (rock bottom) was reached for each well;
- c - temperature varied from 33°C to 41°C .

[These nine wells are indicated on the map with the symbol "q"].

Two wells drilled to a depth of 400 meters ("l") yielded hot mud, according to verbal information.

On the east side of the map there is an artesian well indicated by the symbol "s", which presents the following characteristics:

- a - approximate yield of 40,000 liters of sulfurous water per hour;
- b - depth: 280 meters;
- c - temperature: 29° C.

Finally, of the last two wells, indicated by the symbol "e", the one to the north is still in the process of being drilled and the other, to the south, is sterile.

Because all of the thermomineral water of the area is exploited for tourist purposes, there are no hydrological data that would be necessary for better control and rationalization of the exploitation, and also to better understand the quantitative and qualitative behavior of the aquiferous network. Some of these elaborations are the result of observations and are more inclined toward the realm of hypothesis.

Systems of faults and/or fractures constitute the networks of thermal waters. The area has a normal water table (phreatic layer) near the surface, but this water is "cold". In areas where the crystalline forms are more clearly exposed (defined), it is possible to venture which structural directions are more promising, as long as they agree with the thermometric data. This is not the case of Caldas Novas, because the increasing human occupation, the alluvial coverings, and the colluvial coverings disguise the features of interest.

Finally, emphasis is placed on the positive aspect of prospecting such as, from the 14 wells drilled only one was sterile, if we consider that hot mud is not by itself a discrediting fact.

In addition, going back to the first phase of the work when the surface temperatures were measured, one verifies in the first attempt the coincidence of the anomalous areas and the surface

temperatures. Also, considering that the difference between the maximum temperature (25° C) and the minimum temperature (17° C) is sufficient to be detected by an airborne thermal imager, one concludes that such technique is perfectly feasible.

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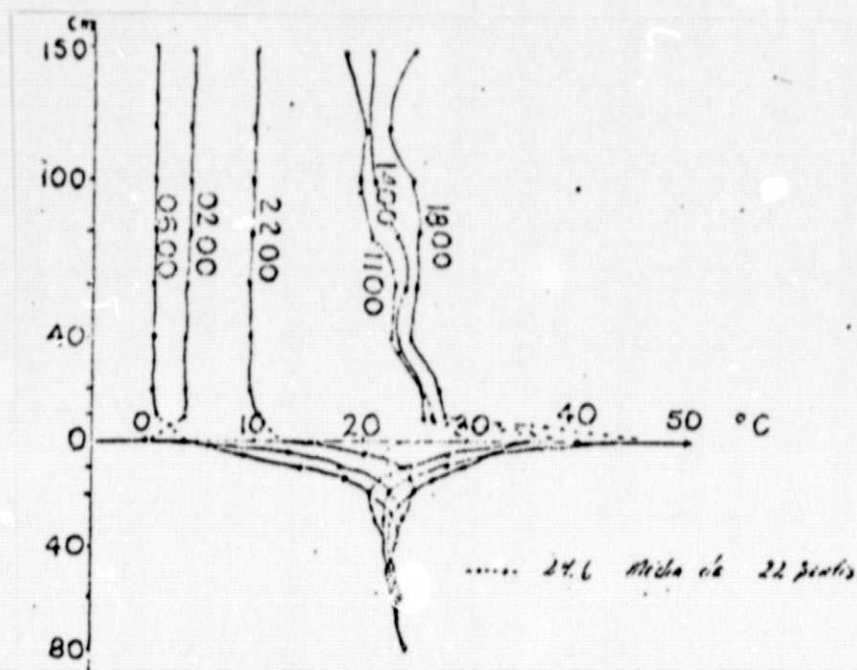


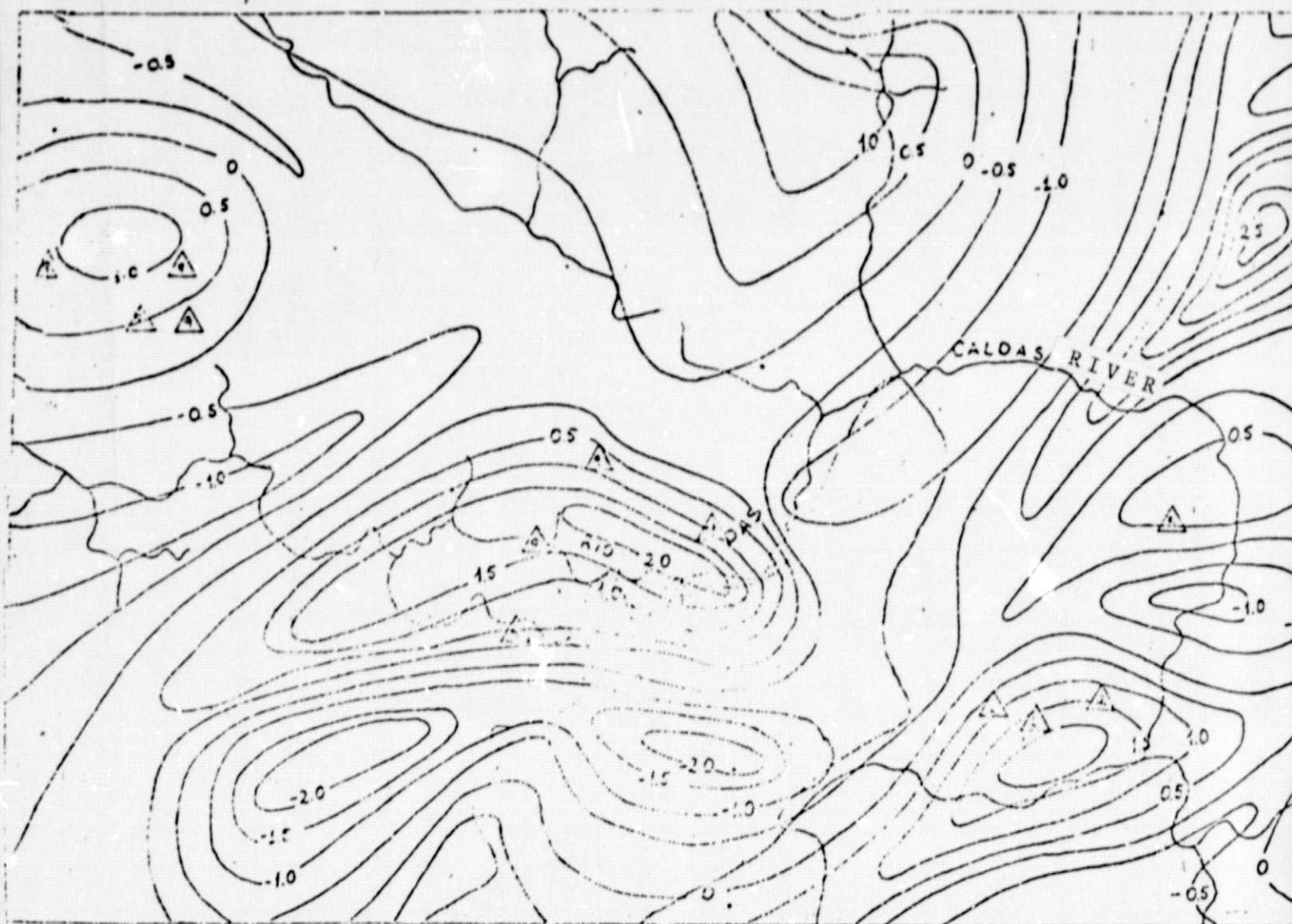
Figure 1. Chart showing temperature measurements taken in sandy soil of medium and fine granulation. These measurements were taken on May 27 and 28 under unclouded skies and in the time between 5:41 and 19:46 hours in the Mono Lake, California area by H. Hase (1971). As one can observe on the chart, temperature variations below the depth of 30 cm are not significantly affected by solar heating.

18

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600m

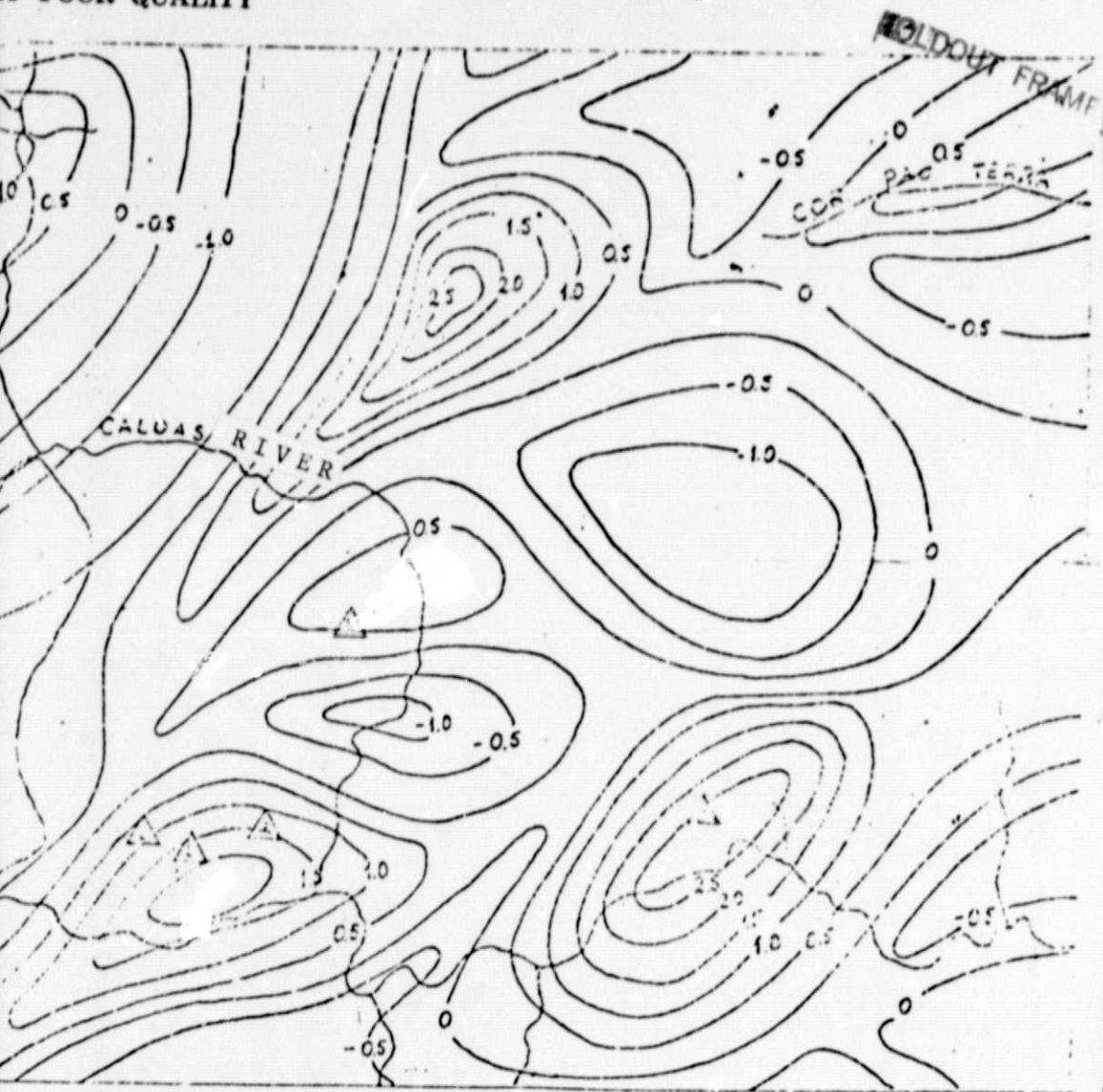
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Figure 2. Area of Caldas Novas

Positive anomaly 0,5°C
Thermomineral water wells
Temp. - 33° - 41°C
Hot mud
Sterile well



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positive anomaly 0.5°C
thermomineral water wells
Temp. - 33° - 41°C
hot mud
Sterile well

Sulfurous water well
- Temp. - 29°C
City
Drainage

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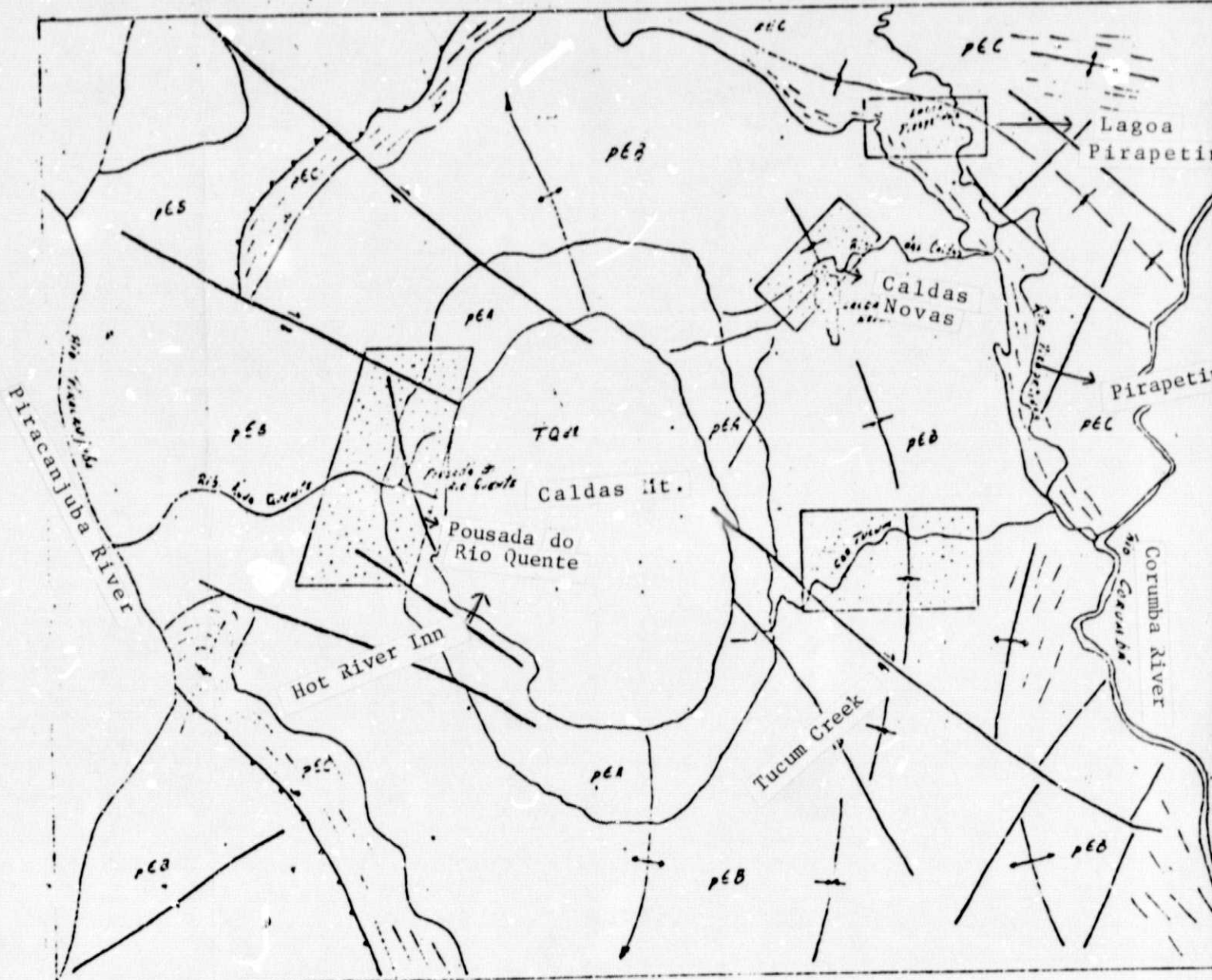
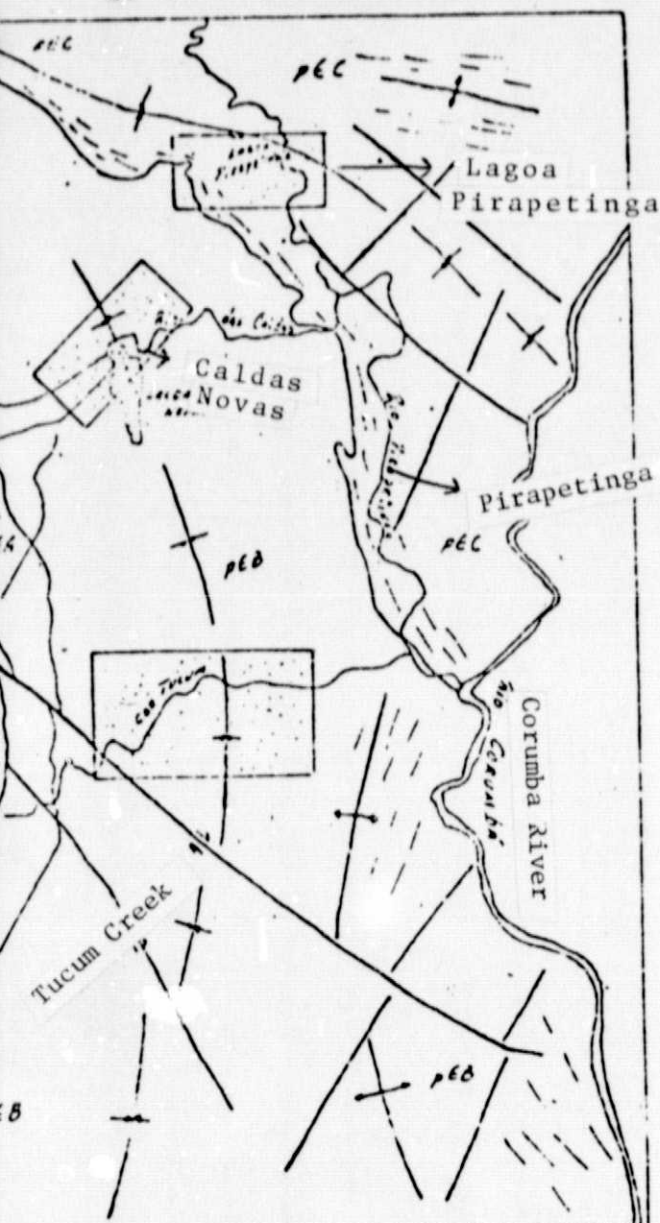


Figure 3. Approximate scale 1:180,000

7.3 km

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GEOLOGICAL SKETCH OF CLADAS NOVAS
AREA AND LOCALIZATION OF AREAS
THERMALLY ANOMALOUS

- TQC Tertiary-Quaternary
- PEC Canastra group
- PEB Bambui group
- PAA Araxa Group
- Anticlinal with dip
- Sinclinal with dip
- Brachy-anticlinal
- Random Fault
- Opposite slippage fault
- Pushing fault
- Structural layering
- Contacting surface between rock systems
- Drainage

