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STUDY OF HYDROLOGICAL INTERCONNECTIONS OF STREAMS AROUND CAVES IN THE REGION OF AREADO GRANDE - CAPÃO BONITO, SÃO PAULO.

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ABSTRACT

In the region near Areado, São Paulo, many caves and openings have been discovered by Clube Alpino Paulista. There are innumerable springs, streams and rivers which are discontinuous and resurgent. The area is represented by Precambrian rocks belonging to the Açungui group. The relief is typically karst in nature with total masking of the original structure of the carbonate rocks. In the region many faults and fractures have been found to exist. In the present work, a study of origin of the local springs, streams and their interconnections has been studied by carrying out stable isotope (oxygen-18) and conductivity measurements on samples of local waters. The study ruled out existence of any artesian or deep circulating water in the region. The springs/streams are superficial and are resulting from infiltration of rain water through various cracks and fissures in the local geological formations.

RESUMO

Na região próxima à cidade de Areado, São Paulo, muitas cavernas e grutas foram descobertas pelo Clube Alpino Paulista. Nela ocorrem inúmeras fontes, riachos e rios que apresentam descontinuidades ao longo do trecho e ressurgem em diferentes locais. A área está representada por rochas do Pré-Cambriano pertencentes ao Grupo Açungui. O relevo é tipicamente cárstico com total mascaramento das estruturas originais das rochas carbonáticas. Observa-se a presença de inúmeras falhas e fraturas na região. O presente trabalho estuda a origem das fontes e riachos e as interconexões hidrológicas entre eles, através das análises de Oxigenio-18 e medidas de condutividade. Os resultados obtidos concluem que não existem condições artesianas para as fontes. Todas as fontes e riachos são superficiais e resultam da infiltração da água da chuva por meio das fraturas e fissuras presentes nas formações geológicas do local.

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INTRODUCTION

The vicinity of Areado near Capão Bonito, São Paulo, is characterized by the presence of many caves of large and small dimensions. The population of the caves is particularly more in the region of Areado where local rivers Areado and Temimina are flowing. Many of the caves in the region have been discovered by CLUBE ALPINO PAULISTA and are still being investigated by the members of the club.

The vicinity of some of the caves is characterized by intermitent surface streams which disappear into ground only to appear again at some distances away. Some streams are small to be neglected while others are big enough not to be ignored. Even the medium size river Temimina at a locality, (near Point 7, Fig. 1) from distance, appears to be vanishing into local geological formations and emerging again from an opening in a vertical rocky mountain . On approaching the region of apparent discontinuity of the river, it was found to be flowing inside a big cave of rare coincidence of nature.

There is yet another cave almost 1 km long (see Point 8, Fig.1) which was discovered by CLUBE ALPINO PAULISTA. There are surface streams in and around this cave which are emerging from and disappearing into, the local formations.

These streams make an interesting case of hydrological interconnections. Existence of some deep artesian springs could not be ruled out in the region and hence it was interesting to study if these streams had different origin. It was also interesting to find out if these streams were finally joining the river Temimina or are leading to different directions.

To study some aspects of the hydrology of surface streams of the region ie. interconnections and origin, use was made of stable isotope analysis of sample of waters collected from points of interests.

Deuterium and oxygen-18 are stable isotopes which form part of water molecule and are present in natural waters in trace concentrations (about 300 and 2000 ppm respectively). Variations of deuterium and oxygen-18 concentrations in surface and ground waters offer an efficient tool for studying origin of water bodies or for identifying different water bodies and their interconnections. A description of the use of these environmental isotopes has been made by PYANE (1971). Detailed discussions on the the subject are contained in International Atomic Energy Agency guide book (IAEA, 1968).

Because of its occurrence in very low concentrations , the oxygen-18 composition of a water sample is expressed in δ units, ie. as difference in per mille of the ratio ($^{18}O/^{16}O$) in the sample with respect to the same ratio in the standard mean ocean water SMOW as defined by CRAIG, 1971.

$$\delta\,^{18}O = \frac{(\,^{18}O/\,^{16}O)_{sample} - (\,^{18}O/\,^{16}O)_{standard}}{(\,^{18}O/\,^{16}O)_{standard}} \times 1000$$

In a given location, seasonal variations in the stable isotope composition of precipitation are common. Thus, ground water bodies would have an oxygen-18 composition similar to that of precipitation recharging them, depending on the area and time of recharge. It is possible to differentiate between directly infiltrated precipitation and infiltration from surface water bodies that have been subjected to evaporations.

Quality of water ie. dissolved ions or electrical conductivity of ground or surface waters also serves as a tracer for identifying intermixing of two different waters. Waters having same origin but passing through or emerging from two different geological formations would have different values of conductivity. Such formations then can be studied to

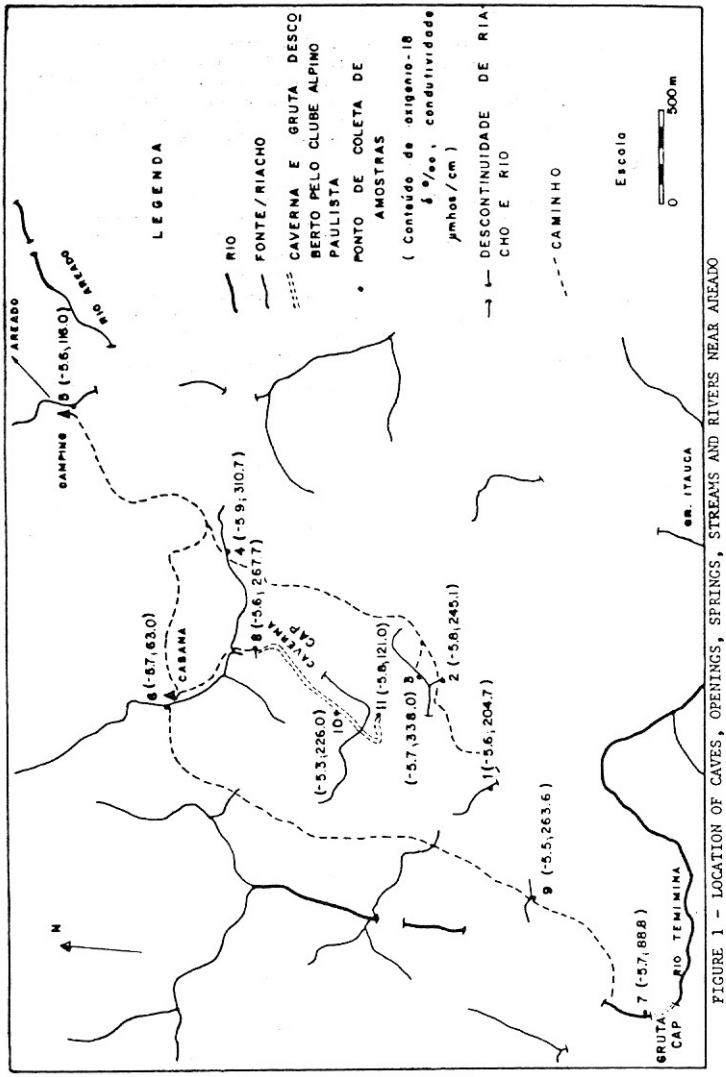

FIGURE 1 - LOCATION OF CAVES, OPENINGS, SPRINGS, STREAMS AND RIVERS NEAR AREADO

determine the flow paths of springs or sub-surface or surface streams.

DETAILS OF THE AREA OF INVESTIGATIONS

The area of investigations (Fig.2) is situated in the extreme SW direction of the state of São Paulo near the small city called Areado. The region of caves, intermitent streams and the rivers Areado and Temimina lie in the SSW direction of the Areado city. The city Areado is situated 28 km SSW of Guapiara. The city of Guapiara itself is situated about 30 km south of the city Capão Bonito. The caves and the streams/

springs situated within 3-4 km distance from Areado are shown in Fig.1.

The region is characterized with undulating topography and trellis drainage patterns as shown in Figure 3. The relief is typically karst in nature with total masking of the original structure of carbonate rocks. In addition to big openings there are innumerable streams and rivers which are discontinuous and resurgent. The vegetation of the region consists of natural forest which to a large extent has been destroyed by human activity.

The area under study is represented by Precambrian rocks belonging to the Açungui group. The lithology of the region (Fig.4) consists of predominantly phyllite, schists and intercalations of silty and carbonate meta-sediments. According to the findings of CPRM (1972) the bodies of phyllite and schists regionally follow NE direction which corresponds to predominant direction of schistosity. The local rocks show intensive plastic tectonism which consequently results in the trellis type drainage. The investigation carried out by CPRM (1972) show that the basic dykes have sub-parallel and interfingering relationship with these rocks. According to Bittencourt (1971), there are lenticular bodies of calcite and dolomite exhibiting a banded nature. In the region many faults and fractures have been found to exist with principal direction of N 409-609 E and secondary direction of N 409-609 W.

The rainfall data obtained at the nearest station of city of Ribeirão Branco, indicate an annual precipitation between 1100 to 1600 mm. The average relative humidity in the region varies between 75 to 85%. The data of rainfall representative of the area from 1971 to 1975 are shown in Table 1 (DAEE, 1971 to 1975).

SAMPING PROGRAMME

The intermittent streams in the vicinity of the caves, openings and the rivers Areado and Temimina are shown in Fig. 1. In all eleven

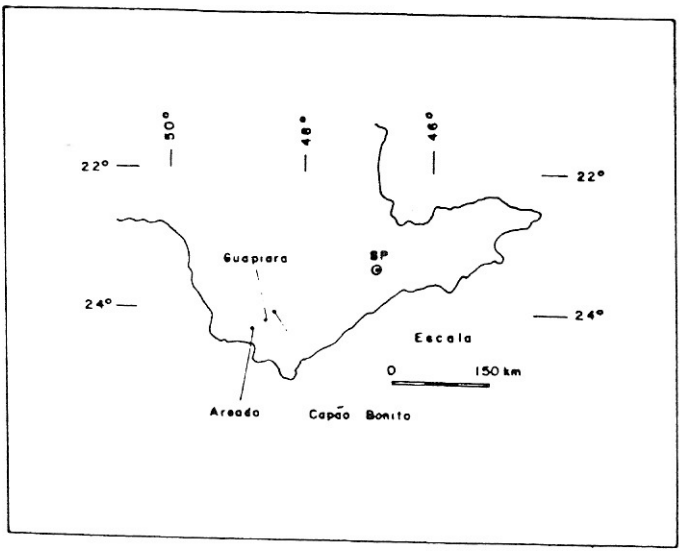

FIGURE 2 - LOCATION MAP OF AREADO, GUAPIARA AND CAPÃO BONITO

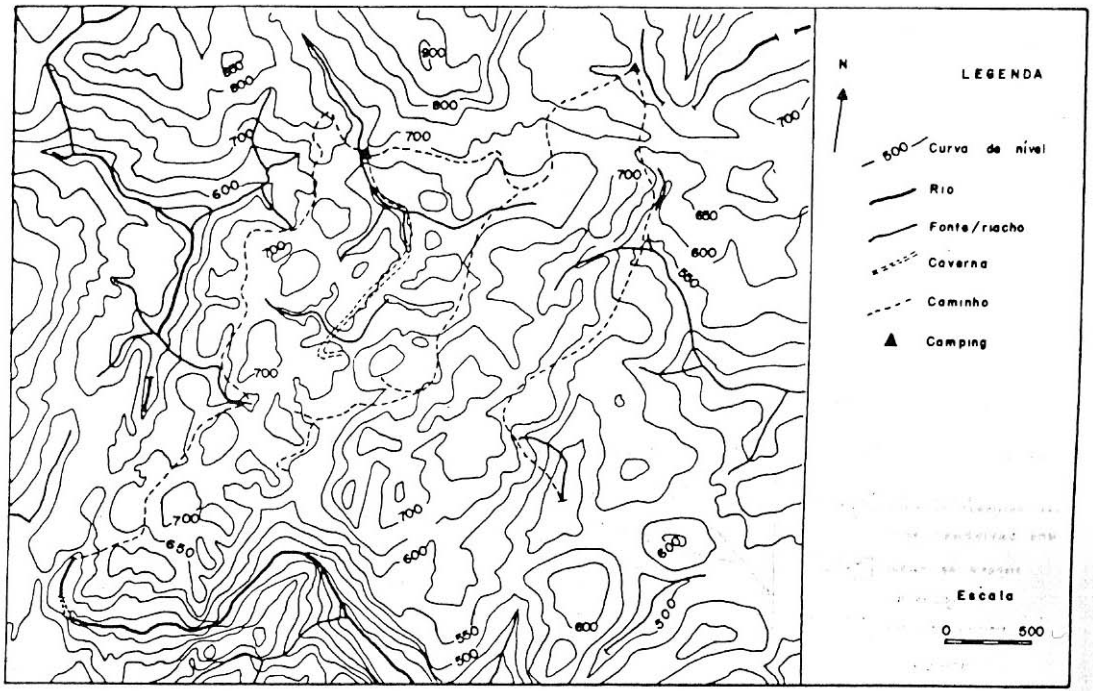

FIGURE 3 - TOPOGRAPHICAL FEATURES AROUND AREADO

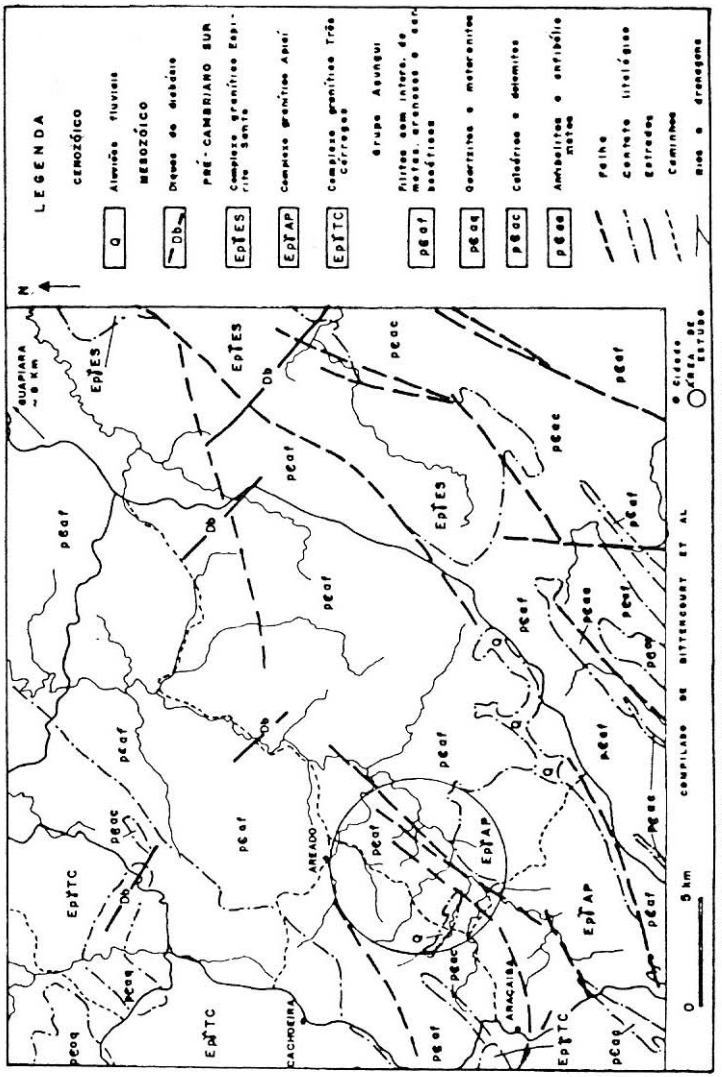

FIGURE 4 - GEOLOGICAL CLASSIFICATION OF THE REGION AROUND AREADO

samples of water were collected. The sample number and its location are indicated in the figure. Of special interest are samples 4, 6, 8 which are near the entrance of the cave. Sample 10 is from the middle of the inside of the cave and sample 11 is the sample of stream coming out at the end of the cave. Sample 7 is the water of river Temimina inside a big opening in the local rocks.

MEASUREMENT OF OXYGEN-18 AND CONDUCTIVITY

The analysis of oxygen-18 was carried out on gas carbon dioxide equilibrated with water sample using Variant-Mat mass spectrometer model MAT-230. The analytic error in measuring $\delta\ ^{18}O$ value with respect to SMOW was 0.2 °/oo.

The measurement of conductivity in water samples was carried out in laboratory using a conductivity meter. The values of $\delta\ ^{18}O$ and conductivity in micromhos/cm of each water sample are indicated Table 2 and Fig. 1.

RESULTS AND DISCUSSION

The data of oxygen-18 and conductivity of water (Table 2 and Fig. 1) indicate that there is hardly any difference in the isotopic composition of stream and spring waters in the region. The range of variation of $\delta\ ^{18}O$ values is -5.9 to -5.3 °/oo. This shows all water have the same origin and are resulting from run-off of the precipitation and its infiltration through the local terrain. The slightly positive value (-5.3 °/oo) corresponds to sampling point Nº 10 collected from middle of the cave. This water was virtually dripping from the roof of the cave and indicates partial enrichment due to evaporation.

Water from points 1,2,3,8,9,10 seem to have infiltrated through loose sediments/overburden before emerging in the region and thus have picked up dissolved ions. The waters show higher value of conductivity, ranging from 204 to 388 micromhos/cm. On the contrary waters from points 5, 6,7 do not seem to have seeped through local soil but seem to be resulting from direct run-off through less leachable rocky interfaces. These waters show much lower values of conductivity ranging from 63 to 120 micromhos/cm.

Sampling points 8,10,11 are located at the entrance, middle and end of the big cave discovered by CLUBE ALPINO PAULISTA. Water at point 8 appears to be mixture of saline water from point 4 and fresh waters coming from the direction of point 6. Water at point 10 appears to be connected with water from point 8, but it is also getting diluted by fresh water seepages which seem to join it. Water at point 11 is the discharge from point 10 and from other unidentified channels in the cave. These unidentified flows are waters of lower conductivity and seem to be seeping through the rocks from the western direction. Thus, waters from beginning to end of the cave are being joined and diluted by seepages inside the caves.

It is demonstrated that geochemical data of ground or surface waters serve as good tracer for hydrological studies. Such data when used with environmental isotope data often yield useful information regarding hydrological interconnection and origin of waters.

TABLE 1 - DATA OF RAINFALL NEAR THE AREA OF INVESTIGATION (STATION RIBEIRÃO BRANCO)
1971-1975 (DAEE)

Year	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL
1971	249.7	219.9	123.4	42.8	103.3	178.9	26.0	101.2	135.1	63.7	74.2	238.4	1556.6
1972	109.8	102.6	181.4	79.8	70.6	99.3	102.8	15.1	61.5	99.3	78.1	134.1	1134.3
1973	164.8	251.0	100.7	56.5	87.5	84.2	89.5	177.7	115.0	127.5	159.8	254.2	1665.0
1 974	245.5	109.3	277.4	24.1	70.9	183.4	24.2	56.3	23.8	134.2	80.8	171.1	1401.0
1 975	62.3	200.4	74.5	13.3	67.3	51.8	83.3	46.6	77.4	138.4	203.0	164.4	1182.7

TABLE 2 - ^{18}O AND CONDUCTIVITY DATA OF WATER SAMPLES FROM AREADO REGION

SAMPLE Nº	$\delta\ ^{18}O$ °/oo	CONDUCTIVITY µmhos/cm
1	- 5.6	204.7
2	- 5.8	245.1
3	- 5.7	338.0
4	- 5.9	310.7
5	- 5.6	116.0
6	- 5.7	63.0
7	- 5.7	88.8
8	- 5.6	267.7
9	- 5.5	263.6
10	- 5.3	256.0
11	- 5.8	121.0

CONCLUSIONS

Oxygen-18 contents of the waters sampled in Areado region near Capão Bonito do not indicate different origin. All waters are resulting from local precipitation. The study rules out existence of any artesian or deep circulating water in the region. The springs/streams are resulting from passage of rain water through various cracks and fissures and form part of the trellis drainage pattern which is characteristics of the region.

Based on conductivity data of the local waters is appears that water at point 8 at the entrance of the cave is connected to point 10 and water at point 11 is being joined by fresh water seepages from yet unidentified channels inside the cave.

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