GEOFISICA INTERNACIONAL

RADIOACTIVITY AND HEAT SOURCES IN THE CENTRAL DEPRESSION OF CHIAPAS STATE, MEXICO

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RESUMEN

Se midieron los contenidos de Uranio, Torio y Potasio usando espectrometría de rayos – γ en algunas rocas así como también en aguas termales de la depresión central del Estado de Chiapas. Los resultados de estas mediciones demuestran que las muestras no tienen altos contenidos de radiactividad, implicando posiblemente que los elementos radiactivos no son responsables de la presencia de manantiales termales en el área. Además, los cálculos de balance térmico de un modelo geológico que mejor representa un cuerpo extrusivo ígneo emplazado en dicha depresión central, indican que éste y otros cuerpos pueden ser las posibles fuentes de calor para las aguas termales en el área.

ABSTRACT

Contents of Uranium, Thorium and Potassium were measured by γ –ray spectrometry in some rocks as well as thermal waters from the central depression of the state of Chiapas. The results of these measurements show that the samples do not have high radioactive contents, possibly implying that radioactive elements are not responsible for the presence of hot-springs in the area. Further, heat-balance calculations of a geological model representing an extrusive igneous body emplaced in the above-mentioned central depression show that such bodies might be the possible heat-sources for the thermal waters in this area.

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INTRODUCTION

Anomalous radioactive contents associated with mineral and hot spring systems have been recognized in many areas. Thus, Belin (1959) reported the occurrence of radon in New Zealand geothermal regions; Mazor (1962) related radium and radon in Israeli water sources with oil, gas and brine reservoirs of the Rift Valley; Pohl-Rüling and Scheminzky (1972) found high radium and radon contents in air, water and muds of Badgastein, Austria and Wollenburg (1974) described high radioactivity of Nevada hot spring systems. In Japan also, the association of radioelements and hot and mineral spring systems has been reported (e.g., Kimura, 1949 and Kikkawa, 1954).

The area studied in the present work is part of the state of Chiapas. Last series of earthquakes that affected "Chiapa de Corzo" village towards the end of 1975, motivated the State Government and the Institute of Geophysics to organize inter-disciplinary geophysical study in the area. This report is an effort to investigate a possible correlation of radioactivity with hot-springs in the central depression of Chiapas.

GEOLOGY OF THE AREA

Exposed rocks in this area are both extrusive and intrusive igneous rocks as well as sedimentary rocks of marine and continental origin. Granites and diorites of Paleozoic age are the oldest rocks in this area and form its basement. Upper Triassic to Lower Jurassic Formations are not exposed in this area (Hernández, 1968). During Middle and Upper Jurassic, Todos Santos Formation was deposited under a continental environment which is characterized by sandstones, conglomerates and red-beds, with a total thickness of about 400 to 700 meters and this is overlain by approximately 400 m of Lower Cretaceous San Ricardo Formation consisting of sandstones and limestones of marine origin (PEMEX, 1974). During Middle and Upper Cretaceous, Sierra Madre limestones (1000 to 1900 m thick) and Méndez Formation (approximately 1000 m thick) were deposited (Pacheco, 1976).

These are overlain by Paleocene sediments, Eocene-Oligocene shales and sandstones and Miocene conglomerates. From Upper Pliocene to Pleistocene, the central depression of Chiapas has seen an intense volcanic activity mainly andesites and rhyolites (Montesinos, 1976). It is precisely one of these andesitic and dacitic flows that is probably responsible as a heat-source for the thermal waters of this area.

RESULTS AND DISCUSSION

A number of rock and water samples were collected from this area so as to measure their radioactive contents in the laboratory. A map showing sample locations is given in Fig. 1.

γ –ray scintillation spectrometry was used to obtain γ–ray spectra of the samples and to compute their equivalent U, Th and K contents. Details of the method have been described elsewhere (Terrell and Pal, 1977; García *et al.*, 1976), with the only difference that the calculations were done using the well-known method of least-square fit of the standard and sample spectra. Results of these measurements are given in Table 1. One typical γ –ray spectrum obtained for sample 76008 is given in Fig. 2.

Radioactive contents of rocks from this area are rather low as compared to those of similar rocks from other areas (Rogers and Adams, 1969, a; b). Water samples did not show any significant peaks in their γ –ray spectra (Fig. 3) obtained with our high-efficiency and low-background γ –ray scintillation detector system. It employs a 4″ dia. x 4″ height NaI (T1) crystal. The entire system is installed in an underground laboratory which resulted in a significant decrease in its background (an integrated value of $\sim$ 160 cpm for energies up to 3 Mev). In conventional peaks used for the determination of U, Th and K contents (1.76, 2.76 and 1.46 Mev γ –rays) the background count-rates of 2.75 ± 0.05, 1.74 ± 0.04 and 10.5 ± 0.1 cpm respectively were obtained with this system which are quite low when compared with those obtained by others. For example, Rao (1974) obtained values of

11.8, 6.9 and 23.1 cpm respectively in a 6″ thick mild steel shield with a γ –ray scintillation system employing a smaller 4″ dia. x 2″ height NaI (T1) crystal. By employing a bigger shield (6″ thick mild steel + 3″ thick lead), however, he could reduce the background down to 5.7, 3.0 and 8.4 respectively.

Equivalent U, Th and K contents for water samples are not given because of the absence of secular equilibrium in U and Th series. However, low radioactivity of these samples can be assessed, for example, by comparing 1.76 Mev ^{214}Bi peak of their γ –ray spectra with that of hot springs of some other area. In our samples, this peak is quite low (∿ 0.001 counts/min. gm) even with our high efficiency system as compared to the radioactivity of several Nevada hot-spring waters (0.003-0.036 counts/min. gm) obtained by Wollenberg (1974) who used 10 cm³ Ge(Li) high-resolution system for obtaining their spectra. No spring deposits were analyzed in the present study. However very low radioactive contents of spring waters tend to indicate that radioactivity is probably not responsible for heat production in these springs.

Springs of this area are not really hot-springs but are only moderate (∿ 35°C) to cold (∿ 25°C). Springs with temperature above 35°C are practically absent (unpublished data from C.F.E., Mexico). Further, springs near Santo Domingo river (Fig. 1) which originate in granitic terranes are all cold-springs while Grijalva river has "hot" springs near which a number of Quaternary extrusive bodies can be found. "Agua azufrada" spring (∿ 35°C) lies near one such body. One radiometric K/Ar date available on this body is 800 000 years (Montesino, 1976). Assuming some reasonable parameters for the physical dimensions of the body (deduced from the lithology of the surrounding limestones) and starting from an initial temperature of ∿ 1200°C of the flow, actual temperature of the body can be estimated by simple equations for heat conduction of a plate under certain boundary conditions (García, 1976). Estimated heat capacity of this body is perhaps so large that it may supply sufficient heat to thermal waters for some 15,000 years before its temperature reduces by $\sim$ 1°C. As there might have been a series of lava flows spaced in time, the problem is rather complex. However, these arguments can be extended to explain the origin of heat for these "hot" springs.

Isotopic analysis of water samples shows their origin to be largely meteoric (Durazo *et al.*, 1976). Seismic activity in this area indicates its rather shallow origin with depths between about 1 and a maximum of 3 km (Ponce, 1977).

Existence of dispersion centers and transform faults has been postulated in this area (e.g., Moore and Del Castillo, 1974; Del Castillo, 1976). However, no complex mechanism is really necessary to explain heat sources for "hot" springs. Cold springs are found very near hot-springs (less than 10 Km apart). No global mechanism can therefore be put forth to explain their co-existence.

CONCLUSIONS AND RECOMMENDATIONS

Base on this study, the following conclusions can be drawn.

1. Water samples from springs of this area have very low radioactive contents.
2. Radioactivity can not possibly account for the existence of hot-springs in this area.
3. Quaternary and probably Recent extrusive igneous activity possibly supplies the necessary heat to these hot-springs.
4. Co-existence of hot and cold springs suggests that probably no global phenomenon can be called for as an explanation.

It should however be pointed out that interesting correlation of radioactivity with geothermal fields encountered in other areas makes such investigations necessary in other existing or potential geothermal areas in Mexico. Perhaps, the study can be extended to several other chemical elements to evaluate the geothermal potentiality of an area and look for possible environmental implications (Tongiorgi, 1963; Bowman *et al.*, 1974; Chowdhury *et al.*, 1974).

TABLE 1. RADIOACTIVE CONTENTS OF THE SAMPLES OF CHIAPAS, MEXICO

Sample No.	Rock type	Location: Distance (Km)	Location: from	Location: to	U ppm	Th ppm	K %	Th/U
76001	Andesite	63.8	Tuxtla Gutiérrez	San Cristóbal las Casas	2.41	6.07	1.61	2.51
76002	Limestone	61.8	Tuxtla Gutiérrez	San Cristóbal las Casas	3.36	0.52	<0.02	0.15
76003	Limestone	10.8	Tuxtla Gutiérrez	San Cristóbal las Casas	1.08	0.34	0.01	0.31
76004	Andesite	9.0	Flores Magón	Nicolás Ruiz	2.48	9.32	1.44	3.75
76005	Pegmatite	79.6	Tuxtla Gutiérrez	Villa Flores	0.82	2.26	3.58	2.75
76006	Granite	79.6	Tuxtla Gutiérrez	Villa Flores	0.71	3.66	3.41	5.15
76007	Granite	79.6	Tuxtla Gutiérrez	Villa Flores	0.81	4.06	2.47	5.01
76008	Granite	73.2	Tuxtla Gutiérrez	Revolución Mexicana	1.33	6.18	2.22	4.64
76009	Shale	46.7	Tuxtla Gutiérrez	Revolución Mexicana	1.90	10.68	1.77	5.62
76010	Coal	48.0	Tuxtla Gutiérrez	Revolución Mexicana	0.22	0.28	<0.01	1.27
76011	Sandstone	48.0	Tuxtla Gutiérrez	Revolución Mexicana	1.15	7.58	2.19	6.59
76012	Shale	20.3	Tuxtla Gutiérrez	"La Angostura" Dam	0.95	3.89	1.17	4.09
76013	Marble	15.5	"El Parral" Ranch	Yerba Santa	1.39	0.35	<0.01	0.25

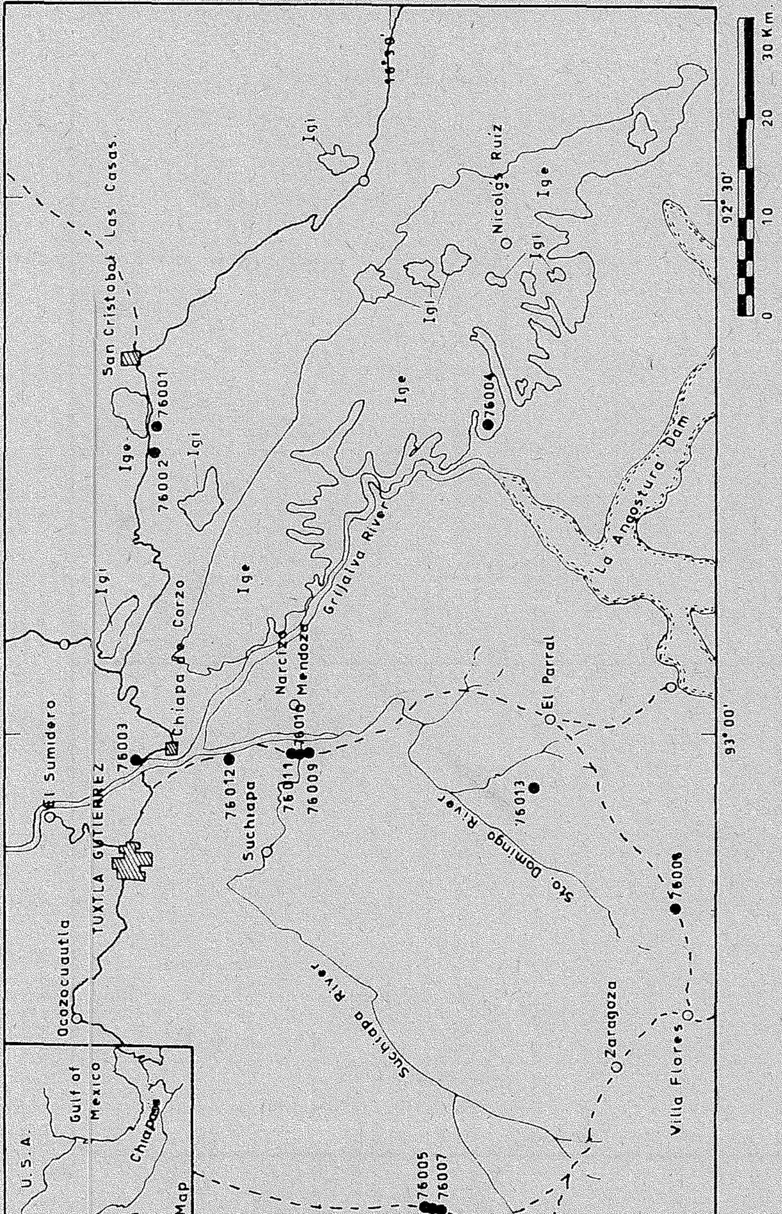

Fig. 1. A simplified map showing sample locations (after C.R.N.N.R., 1976).

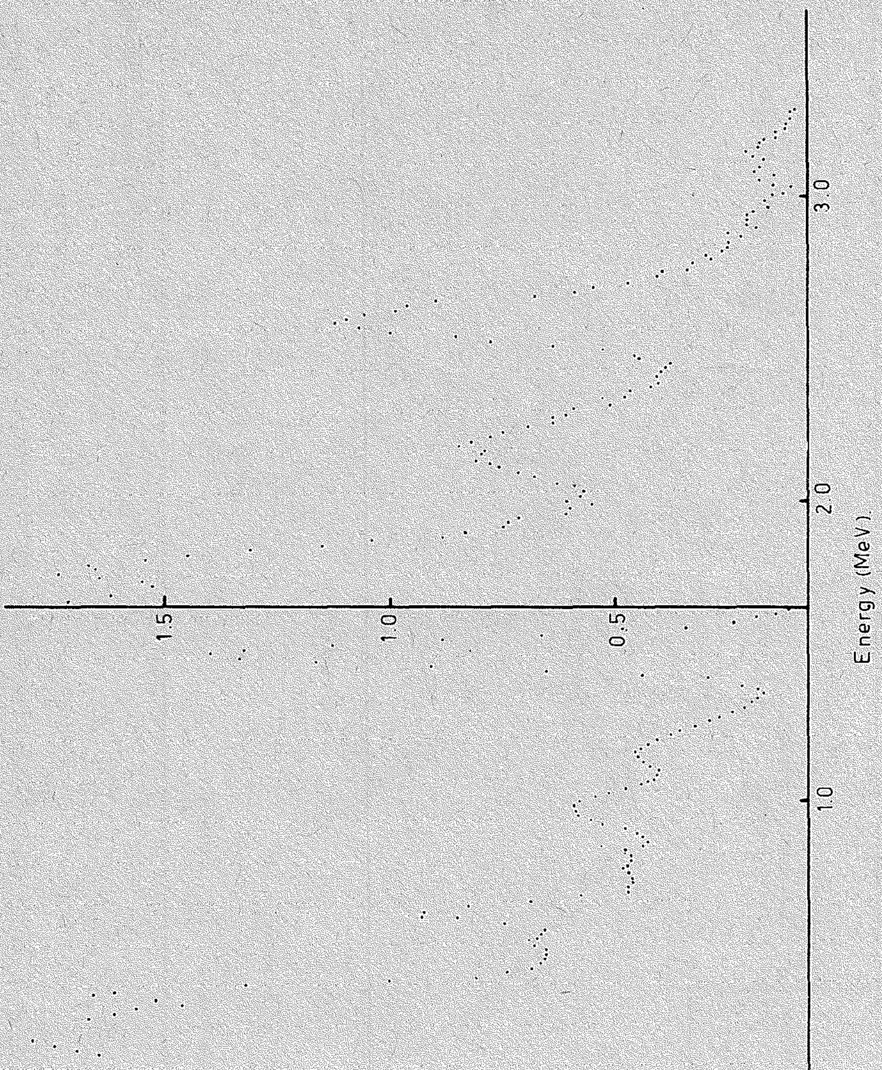

Fig.2. A typical γ-ray spectrum for 76008 (a granite sample).

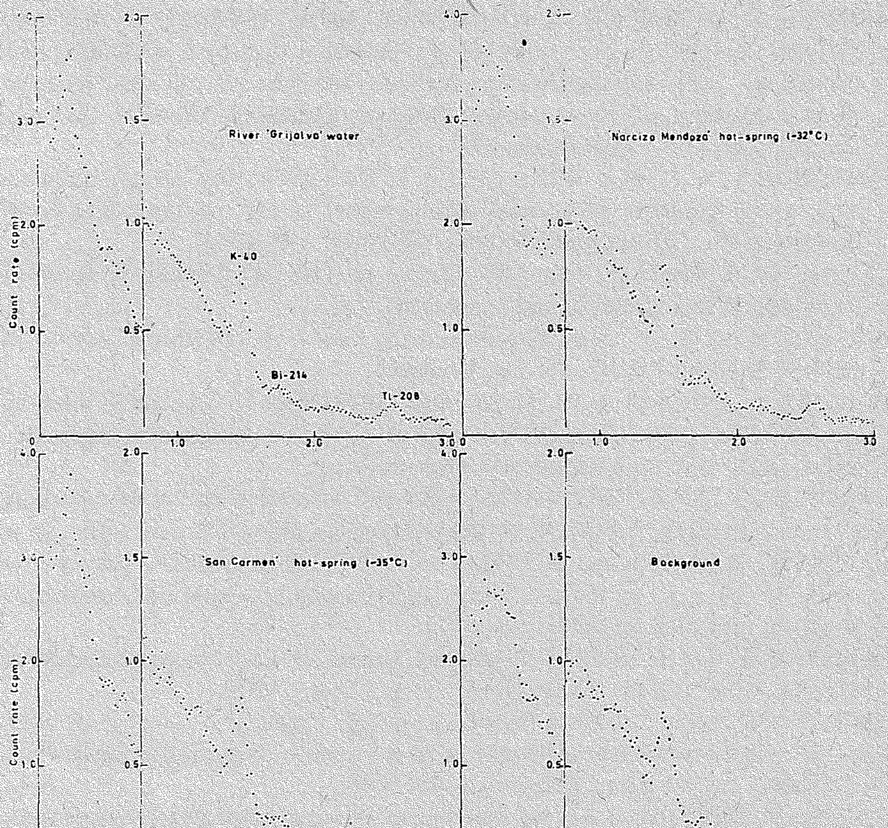

Fig. 3 Some γ-ray spectra of water samples. (A background spectrum is also included for comparison).

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