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ABSTRACT - Morro do Ferro is an isolated hill, 140 m. high, in the center of the Poços de Caldas geological intrusive, in the Brazilian State of Minas Gerais. Two dikes of magnetite show secondary fractures with rare earth oxides, thorium and traces of uranium. An Area greater than 71,000 m^2 shows external levels higher than 0.6 mR/hr while 10,200 m^2 have levels above 1.5 mR/hr. Soils have been tested according to agronomers methods for physical properties, pH factors, exchangeable ions. The ^{224}Ra content varies from 120 to 2,100 pCi/g. Grass sample on the slope show values of 30 - 1,270 pCi/g of ^{224}Ra. In holes in the forest concentrations of ^{220}Rn of up to 50,000 pCi/l have been found. Studies have been made of the exposure to rats, and a cytogenetic study on scorpions has been made.

INTRODUCTION

During the past two decades a considerable amount of information has been collected in the Brazilian regions of high natural radioactivity (Eisenbud et al, 1964, Roser and Cullen, 1964). While the main thrust has been in the populated area of Guarapari (Cullen and Penna Franca, 1976), the purpose of the present communication is to draw attention to another area, an uninhabited hill in the State of Minas Gerais.

Morro do Ferro (Iron Hill) has been regarded as a natural laboratory for radioecology. Here teams of scientists from different institutions have work together: Universidade Federal do Rio de Janeiro, Departamento de Produção Mineral, Museu Nacional, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, and New York University. Geologists, physicists, radiochemists, geneticists, botanists have all contributed their skills.

It seems timely that a review should be made of the progress made to date, with an invitation for the future.

GEOLOGY

The central granite-gneissic plateau that forms what is called the Brazilian shield, is of precambrian formation. The remnant sial blocks that came from the archeozoic continent that paleographers call the Sudatlantis, pressed together to form the Gondwana continental complex. Later this spit apart, with Africa and South America drifting apart (Roser et al. 1964).

Where three rounded blocks had merged, the triengular region of coalescence was left as an area with a thin crust. Through this crust the submagmatic alkaline materials could thrust their way upward.

An outstanding example of the non-explosive volcanic intrusive is found in the region of Poços de Caldas. An alkaline plug, 35 km in diameter, thrust its way 400 meters above the surrounding terrain. Weathering and erosion have lowered the central part of the plug, and an intricate pattern of secondary fractures is revealed that permitted further mineralization.

Morro do Ferro is in the center. Here two well developed dikes of magnetites are found, with admixtures of titanium and residual manganese. These are accompanied by secondary fractures yielding rare earth oxides, a strong percentage of thorium oxide, with traces of uranium.

It is a steeply rising hill, 140 meters high. On the face of this hard slope, seemingly impervious to chemical or physical change, only poor quality grazing grass grows. Tropical rains, though, have slashed gulleys down its face, and at the foot a forest area is found. Here we find rich vegetation, with an interesting array of rats and insects.

RADIOMETRIC MAPPING

The external radiation levels were mapped, using a combination of ionization chamber-vibrating reed electrometer together with portable scintillometers. The ionization chamber was a flat one, 30 x 30 x 8.8 cm, designed by Victor Hess and co-workers at Fordham (Hess and O'Donnell, 1951).

Four horizontal traverses were made with the ionization chamber. Forty bench marks were established and marked with wooden posts. This was followed by the more detailed study with the portable scintillometer, a Victoreen Thyac II. Thirty four traverses were made this time, 10 meters apart, with readings written every 5 meters. Every traverse, the portable meter was calibrated in terms of the ionization chamber bench marks.

A portable meter will only give a good mR/hr reading if the quality of the radiation measured is the same as that of the calibrating source. In general, the direct probe reading and the chamber reading for a post were not equal, but a linear relation was clear. Later, spectra taken at these 40 positions with a 2" NaI crystal and a 256 channel analyzer were studied by Wayne Lowder of HASL, and the dose rate computed. They confirmed the chamber readings within 10%. It is interesting that the portable meter gave the same reading only where the prominent 860 KeV peak showed a strong surface contamination.

In Fig. 1 the map of the central area is shown.

An area of more than 10,000 m^2 shows a radiation level above 1.5 mR/hr, while more than 30,000 shows a level above 1.0 mR/hr. In Fig. 2, the radiometric map of the forest area, at the foot of the hill, is given.

SOIL AND PLANT STUDIES

In the first attempt to study the soil concentrations and plant uptake, an alpha spectrometer was used, essentially a pulse ionization chamber, modeled on that of Osborne (Osborne and Hill, 1964). The sample preparation followed the method of Hill (Hill, 1961). In Fig. 3 two alpha spectra are presented, one of soil and the other of plant. The ^{232}Th peak is dramatically absent from the plant spectrum, while being present in that of the soil. The ^{228}Th peak that appears in the plant spectrum can be readily attributed to the decay of ^{228}Ra. This assumes that the plant can take up radium, a congener of calcium, but not thorium.

The first systematic soil-plant study was begun by Harry Gomes and Neyla Leal da Costa. Across the face of the mountain they set a grid of 41 posts. At each they selected soil samples at three depths and samples of grass (Andropopogon tener and Trachypogon canescens).

The soils were analyzed at the Botanical Garden, according to the 30 agronomers' soil parameters. These include physical and chemical properties, pH factors and the available cations. From this wealth of data is was hoped that a multiregression technique would reveal the factors that enhance or impede the uptake of radionuclides from soil. This was not successful, for there was not sufficient variation of the parameters within the set of samples.

A histogram of the occurence of ^{224}Ra concentrations as percentage of concentration in soils and grass is given in Fig. 4.

The soil and grass samples were measured for ^{224}Ra by gamma spectroscopy. The soil samples ranged from 120 to 2,010 pCi/g, with a mean of 570. The mean activity ratio of ^{224}Ra in the grass (pCi/g. wet grass/ pCi/g. soil) for 36 samples of Andropopogon tener is 1,4%, with a range from 0.6% to 6.9%. These results show that approximately 1% of the radium in the soil is absorbed by the grass. Leaching experiments indicated that 1.4% of the ^{224}Ra in the soil is available.

The soil-plant study was extended to the forest area. The quality of the soil seems to change abruptly at the forest edge. Here is found humus, while there is none on the slope. The grass on the slope is burned every year, and any decayed material is probably washed down by the rains. There are also certain plant families, Melastometacea and Rubiaceae, that tend to concentrate radium nuclides. In concentrating these elements, do they render them in a more suitable form for absorption by other plants?

The two areas selected in the forest are shown on the map in Fig. 2. Area I has 196 m^2 and levels from 0.5 to 0.6 mR/hr. From this area 28 plant samples were taken, and identified by Miss Margaret Emmerich of the Museu Nacional. From the second area 19 samples were taken and identified. At each spot 5 kg soil samples were taken.

The results of this study are summarized in Fig. 5.

Eduardo Penna Franca (Penna Franca, 1967) have also studied the radionuclide concentrations in plants at the foot of the hill. He has also developed the technique of radiographs for these plants.

Johann Becker and Margaret Emmerich (Penna Franca, 1967) have catalogued the flora and fauna of the mountain. If new species and even families are found it is probably due to the insufficient cataloguing to date in this region of Brazil.

DOSE TO RODENTS

Robert T. Drew (Drew, 1967) studied the exposure received by rats in the environment of the forest area.

Early measurements of thoron by filters measured over the ionization chamber showed high values. Assuming 0.005 pCi/l to be a normal concentration, concentrations of 2000 times normal were found over open cuts, and 5×10^5 times normal were found in the mine shaft.

Drew used 1/4 liter flasks covered on the inner surface with zinc sulfide. Air was drawn from an enclosure into the flask. The flask was then placed on a photomultiplier tube and alpha counted. In rat holes and termite mounds he found thoron concentrations ranging from 3 to 115 nCi/l, with an average of 27. This would be 5×10^6 times normal values. Radon values ranged from 0.05 to 4.8 nCi/l with an average of 1 nCi/l. The ^{212}Pb concentrations ranged from 2 to 140 pCi/l with an average of 23.

A number of animals were trapped, had glass rod dosimeters injected and let free. After an interval they were recaptured and the whole body dose could be measured.

In the laboratory he simulated the thoron environment and exposed 5 rats. These were then sacrificed, the several organs were measured for ^{212}Pb. Finally the dose was computed for the organs. The range of doses is given in Table 1.

The highest dose is that received by the surface of the trachea and bronchi, 310 rads/yr. Ten animals trapped on Morro do Ferro were sacrificed, and the lungs dissected and preserved. Later histological examinations revealed no abnormalities.

CYTOGENETIC STUDY OF SCORPIONS

The final study we should like to review is the cytogenetic study of scorpions by Miss Catarina Satie Takahashi in her D.Sc thesis for the Faculty in Ribeirão

Preto in the State of São Paulo (Takahashi, 1972).

The scorpion studied was the Tytyus Bahiensis, the common one that lives from Bahia down to southern Brazil. A study was made of the mobility of the females in this region. It was found that they travel at a rate of 1.58 ± 0.58 meters/month. The single male studied showed essentially the same stability.

Males were collected from under the rocks on the face of Morro do Ferro where the external levels range from 0.8 to 1.5 mR/hr. The scorpion sacrificed was anesthetized in ether, dissected under running waters. The testicles were removed and sliced with blades that were cooled to liquid nitrogen temperature. The sample was then studied under an optical microscope and scored.

The number of cells showing single and double breaks in the chromosomes is given in Table 2. An interesting relationship between the rate of break occurence and distance from Morro do Ferro is shown in Fig. 6.

Morro do Ferro, perhaps the largest thorium deposit in the world, will continue to be a natural laboratory. There is still valuable information hidden, waiting only for an intelligent questioner. So the invitation is open ended.

Table 1: Summary of Dose Estimates to Rodents on Morro do Ferro (Drew, 1967).

SOURCE	TISSUE	ANNUAL DOSE (RADS) Mean	Range
External Gamma	Whole Body	2.6	1 - 6.7
Tn + daughters	Average to Trachea and Bronchi	200	20 - 800
Tn + daughters	Surface of Trachea and Bronchi	310	31 - 1240
Tn + daughters	Alveoli	50	5 - 200
Tn daughters	Kidney	10	1 - 40

Table 2: Resume of Cytogenetic Study of Scorpions, Morro do Ferro (Takahashi, 1972).

	Number of Cells with Chromosome Breaks Single Break	Double Break	Without Break
Control	73	1	16,299
Morro do Ferro	224	13	13,731

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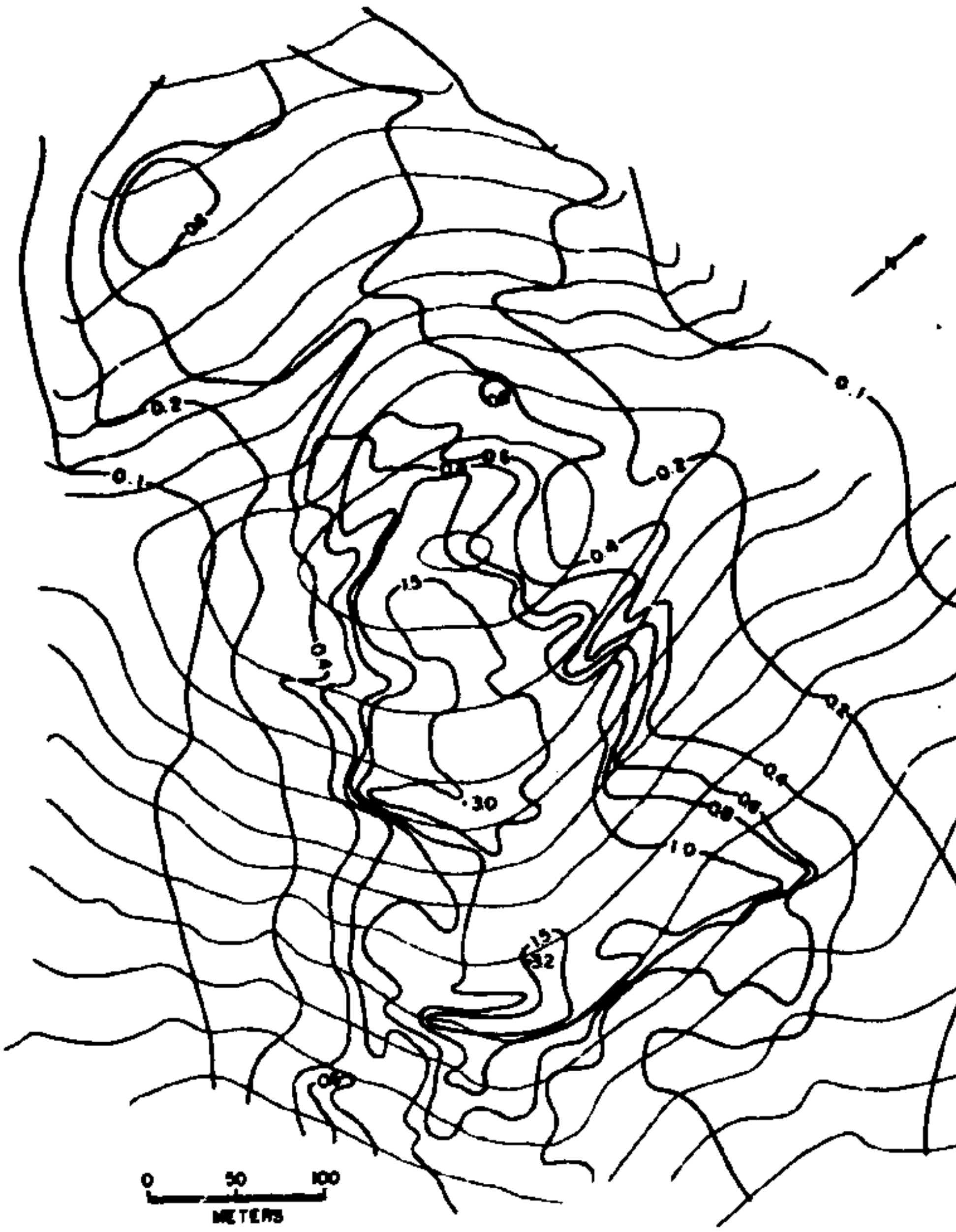

ISODOSE LINES IN mr/hr
ALTITUDE LINES - 10 M

Figure 1 MORRO DO FERRO CENTRAL AREA

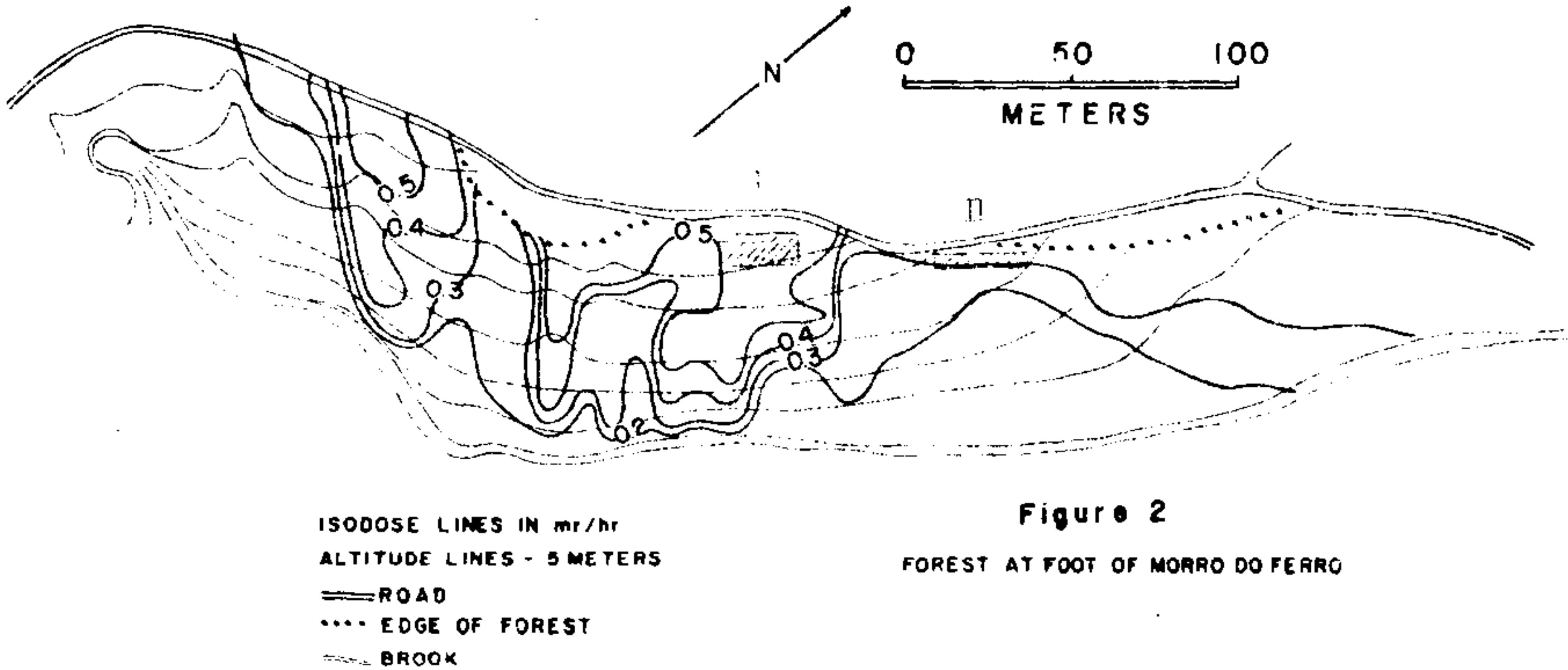

Figure 2

FOREST AT FOOT OF MORRO DO FERRO

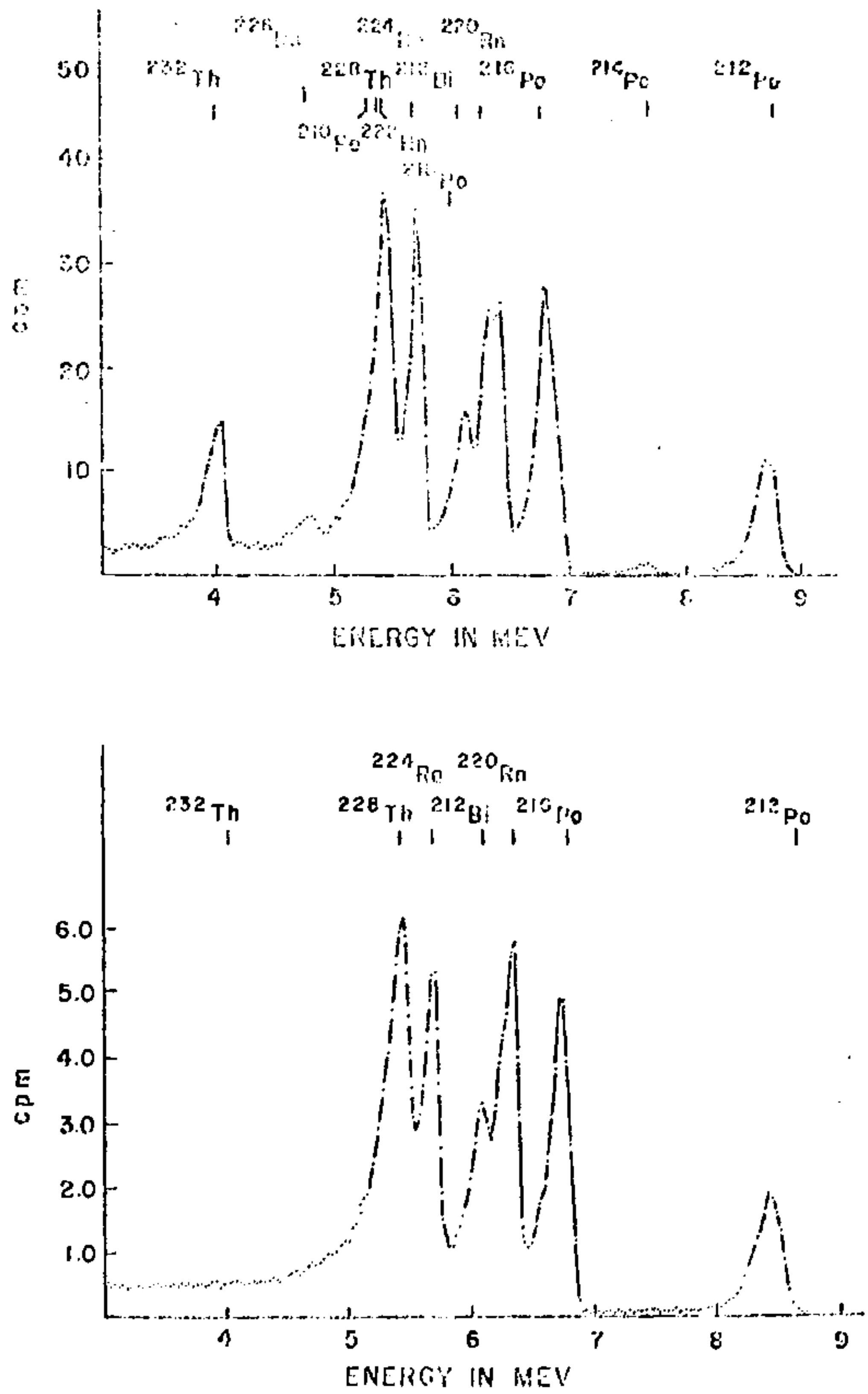

Figure 3 - Alpha Spectra of Soil (top) and plant (bottom), Morro do Ferro.

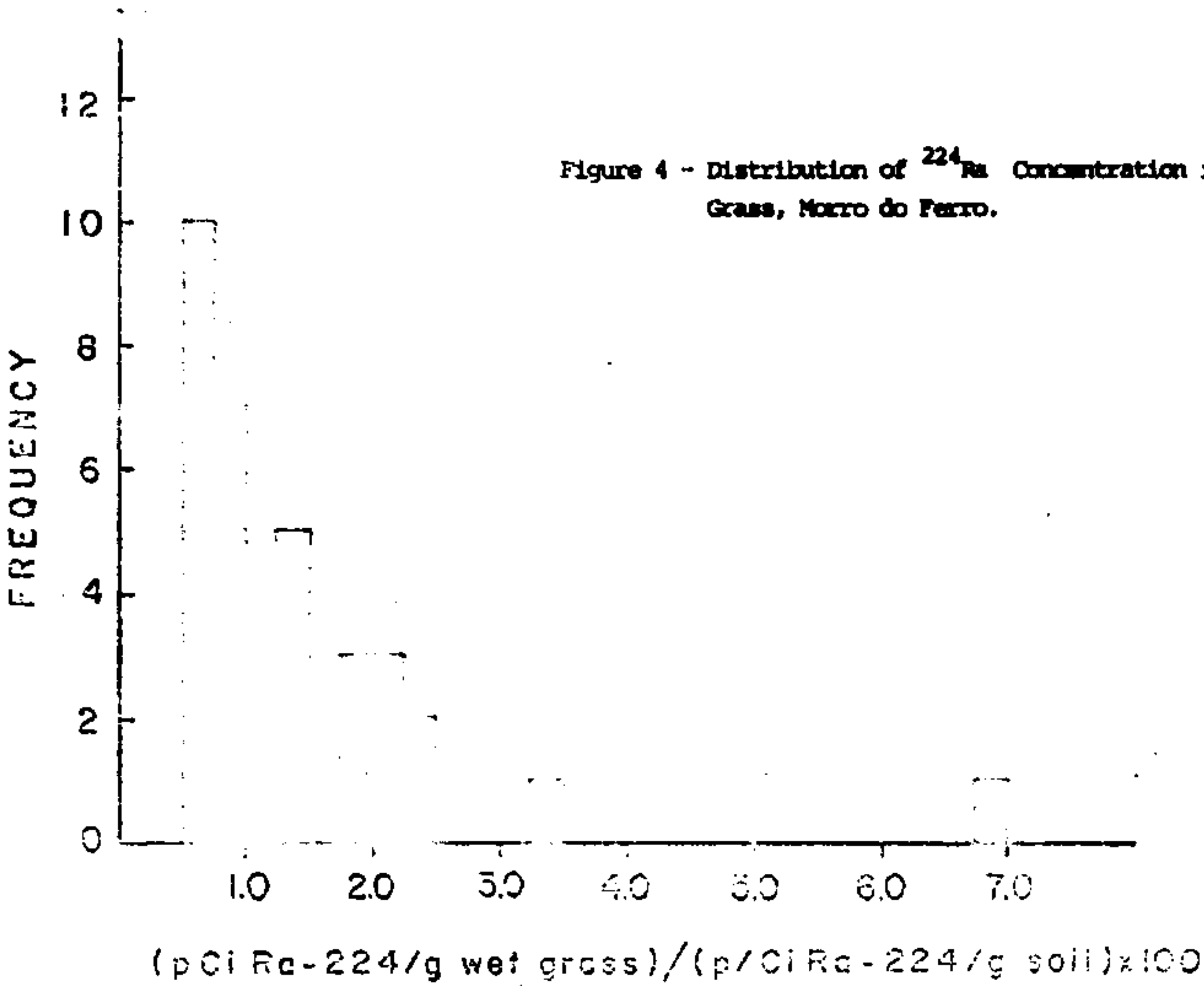

Figure 4 - Distribution of ^{224}Ra Concentration in Grass, Morro do Ferro.

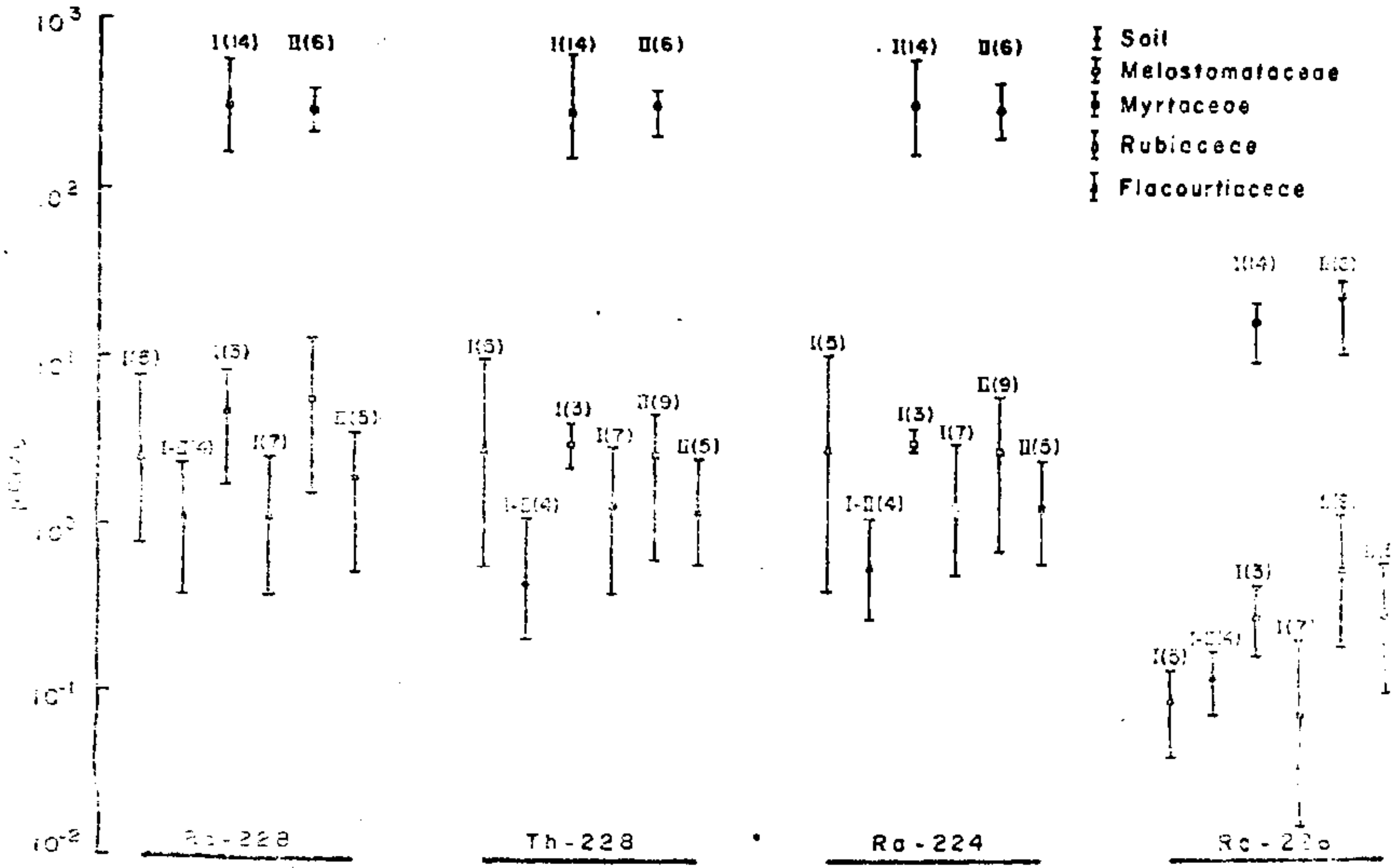

Figure 5 - Range of Radiosotope Concentration in Families of Plants, Morro do Ferro.

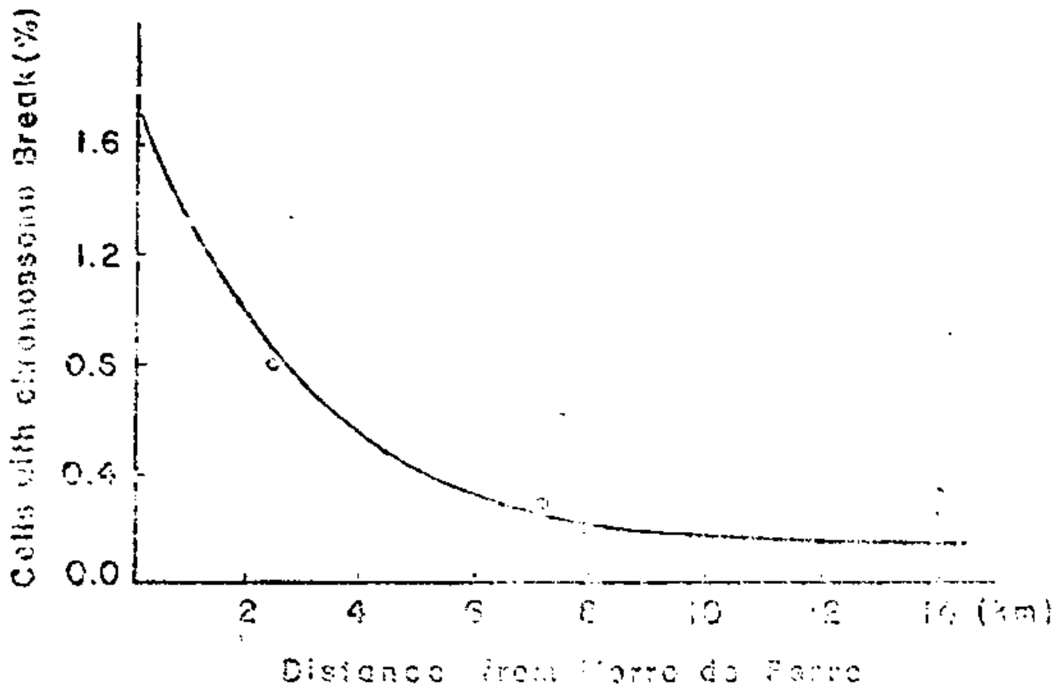

Figure 6 - Incidence of Chromosome break in Scorpions as function of distance from Morro do Ferro.