

Cases of RIS in the Brazilian Amazon area

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ABSTRACT: The first two hydroelectric powerplants that were constructed in the Brazilian Amazon area showed minor induced seismicity, through instrumental recording. Almost seven months after the impound of the Tucuruí and Balbina reservoirs a low activity appeared in both lakes. That activity was followed by a main seismicity that affected those reservoirs with tremors of magnitude 3.4 MD. The epicenters of Tucuruí reservoir are located inside of the lake area, almost 10km from the dam, and in Balbina reservoir they are almost 17km from the dam, but outside of the lake area. In both cases no correlation between seismicity and reservoir water level was observed.

1 INTRODUCTION

Brazil is situated far from the active boundaries of the South American Plate and it can be considered as an intraplate region. Thus the hazard posed by earthquakes in Brazil is very low. In terms of natural seismicity, data from Brazilian earthquakes were first showed by Branner (1912,1920). More recently, a compilation by Berrocal et al (1984) pointing out observations of tremors from 1560 to 1980. About induced seismicity the main event triggered by reservoir impound occurred in February 24,1979 around the area of the neighbor Porto Colombia (20.3 S; 48.5 W) and Volta Grande (19.9 S; 48.2 W) reservoirs.

It occurred in subsequent to the impound of the first lake, and just during the filling of the second. A mb 4.2 and VII MM affected an area of 8.6×10^3 km². No structural damage to the two dams was observed but the shock caused moderate damage to some locations around the reservoirs. After that, the main Brazilian hydroelectrical power companies started an important program to monitoring large reservoirs.

Several studies from 1970 point out cases of reservoir induced seismicity (RIS) at least in seven opportunities Mendiguren (1979), Veloso and Assumpcao (1986), Veloso et al (1987, 1989 and 1991).

RIS studies have been carried out by the Seismological Observatory of the University of Brasilia from 1975, and actually, it control the data from 15 different reservoirs. In this paper we present results of local seismic activity that was observed at the Tucuruí and Balbina reservoirs.

2 THE AMAZON REGIONAL SEISMICITY

The Amazon area is situated in the Northern region of Brazil and represents almost 45% of the Brazilian territory. The main geological feature in this region is represented by the Amazon craton divided in the Guiana shield, at the North of the Amazon river, and the Central Brazil shield, at the south of the same river. Over this stable platform lies sedimentary and volcanic rocks of the great Amazon basin, that covers 1.200.000 km², 60% of these being Paleozoic sediments.

The first earthquake catalogue of the Amazon area was compiled by Sternber (1953). Now it is known that several of those events were, in fact, large Andean earthquakes that were felt in some part of the Amazon area. Few seismic historical data are available due to the extreme low density population in that Brazilian region. Only in the beginning of the 80's, a set of portable seismographs was installed, at five different sites surrounding the future reservoirs. These equipments represented the first seismograph stations operating in all the Brazilian Amazon area.

Figure 1 shows the epicenter locations of earthquakes that occurred in the Amazon region. Almost all these events are small (< 4.5 mb) and shallow tremors (<25km). The largest event in this area occurred on August 8, 1983 with 5.5 mb in the middle of the Amazon sedimentary basin where no previous significant event had been recorded. A focal-plane solution suggests a predominantly thrust fault with about NNE-SSW horizontal compressive axis (Assumpcao et al,1983). Based on epicenters map it is

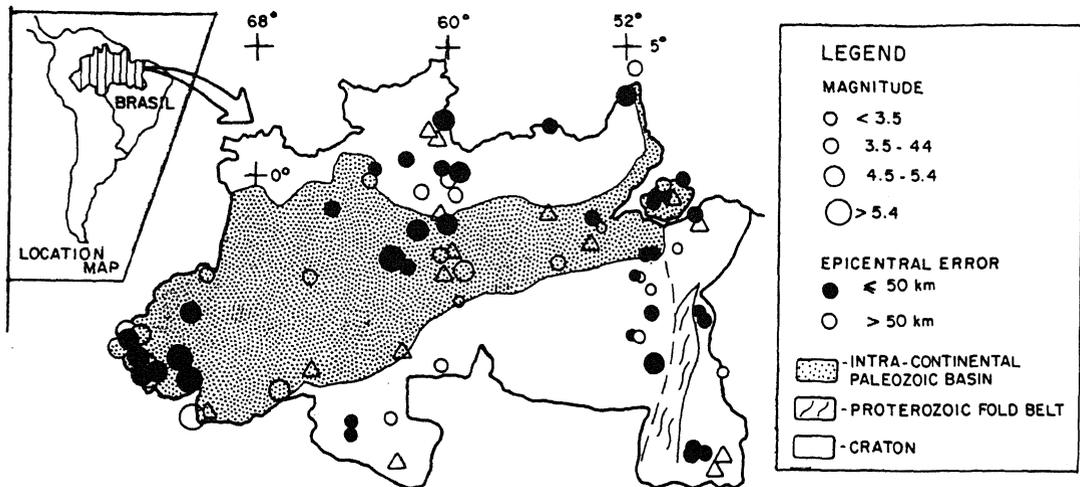


FIGURE 1 - SEISMICTY IN THE NOTHERN REGION OF BRAZIL AND THE ITS MAJOR GEOLOGIC FEATURES.

possible to point out three main seismic zones: the cluster of earthquakes in the western border that represented almost deep focus events due to the subduction of Nazca Plate; the central belt cutting the middle part of the Amazon basin and the extreme eastern North-South belt. These last two epicenters' distribution do not show apparent relation with the main geologic features present in this area.

3 THE TUCURUI RESERVOIR

3.1 Main features

The Tucuruí dam was the first large hydroelectrical power plant that was built in the Amazon area. The dam (03,83S; 46,62W) on the Tocantins river has 100m height, 7 km length and a storage capacity of 45.8×10^9 m³. The lake covers an area of 2200 km² and shows a maximum depth of 90 m. The Tocantins river, in the reservoir area, carved its bed just in a transition zone between the basement and the metamorphic rocks. So, different rocks appear in both sides of the river: granite and gneiss on the left bank and schist and quartzite on the right border. A long and sinuous thrust fault, with a general North-South direction and dip of 10 - 20 to East, represents the major tectonics feature in all reservoir area.

3.2 Seismological data

The pre-impound seismic program started six years before the completion of the Tucuruí lake. During this period a single vertical seismometer L4C with a MEQ-800

record did not detect any type of seismic event less than 120km from the site. The nearest major site event riched magnitude 4.5 and occurred 300km from the future dam.

3.3 Local seismicity

A low-magnitude activity was observed seven months of the initial filling of the lake. The main activity period, showing tremors with magnitude between 3.2 to 3.4 MD, occurred almost one year after the completion of the lake. During this phase the epicenters were located inside the lake about 10km from the dam and exhibited a general trend of NE-SW, that is contrary to the regional pattern of faults in the reservoir area. After this main activity period a small number of shocks was detected in the left side of the lake (Figure 2). Probably, the tremors with magnitude 3.4 MD produces shaking less than 1cm/s² on the dam structure.

Now, the seismic activity at Tucuruí reservoir is very low and the major portion of the accumulated strains in the region has probably already been released. The evolution of the local seismicity compared with the fluctuation of the water in the lake do not show clear correlation.

4 THE BALBINA RESERVOIR

4.1 Main features

The Balbina earth/rockfill/gravity dam type (1.92 S; 59.47 W) on the Uatuma river, has 41.8m high, a 2.9km length and the lake has a maximum depth of 35m with a storage

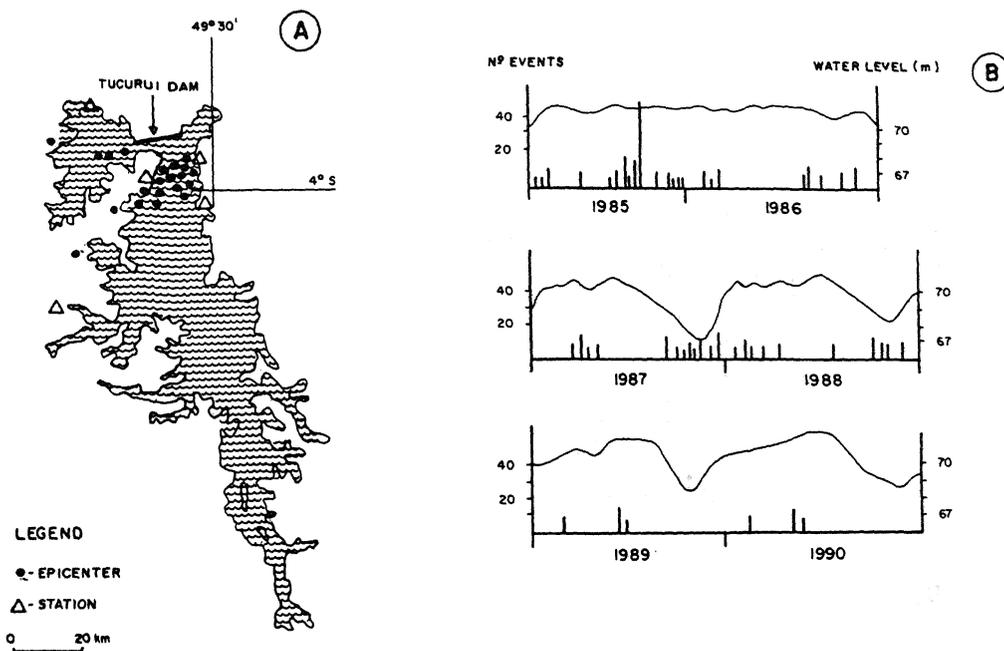


FIGURE 2 - EPICENTER IN TUCURUÍ RESERVOIR (A) AND THE EVOLUTION OF SEISMICITY VERSUS FLUCTUATION OF WATER LEVEL (B).

capacity of 17.5×10^6 m³.

The reservoir extends almost 150km along the Amazon forest, covering an area of 2.875 km². The dam is located close to the contact of Guiana shield and the Amazon basin, but the reservoir lies on a predominant Precambrian terrains having a variety of rocks changing from Precambrian basement to the Cenozoic cover. The Balbina regional tectonics environment shows several faults represented by two orthogonal NE-NW directions.

4.2 Seismological data

The first seismograph station, using a single vertical component seismometer and a MEQ-800 recorder, start operating in the beginning of 1980, almost seven years before the construction of the dam. During this time several events with magnitude <3.0 were detected but not located due to the small number of stations in the Amazon area. The nearest major site event occurred almost 120km SW of the dam and reached magnitude 5.1.

4.3 Local seismicity

The Balbina reservoir began filling early in October 1987 and minor seismic activity

near the lake was first observed few months ago. That seismicity has been monitored by two stations and the epicentral location could not be exactly defined. In July 1990 a three weeks field survey was developed and the microearthquakes in the region were monitored by a network of five stations. The spatial distribution of these stations was not ideal due to the extreme difficulty to operate seismographs inside the forest. Because of the decrease of local activity during the special field survey only few epicentral locations could be obtained. However, the S-P time for good events, that were recorded for the first local seismograph station during three years, showed a range remaining between 2.7 to 3.2 seconds (22 to 26 km) which corresponds to the same distance for the epicentral determination obtained during the July 1990 field survey. Thus, it is reasonable to say that the main activity of Balbina reservoir is located in the right border of the lake, almost 17 km western of the dam axis (Figure 3a). The local seismic activity was more intense during the phase of March to July of 1990 (Figure 3b). The average size of these tremors is very small and only four shocks reached magnitude 3.0 to 3.4 MD, according to the logarithmic duration formula developed by the Seismological Observatory. The focal coordinates were calculated using S-P times (Lee and Lahr, 1955), a P-wave

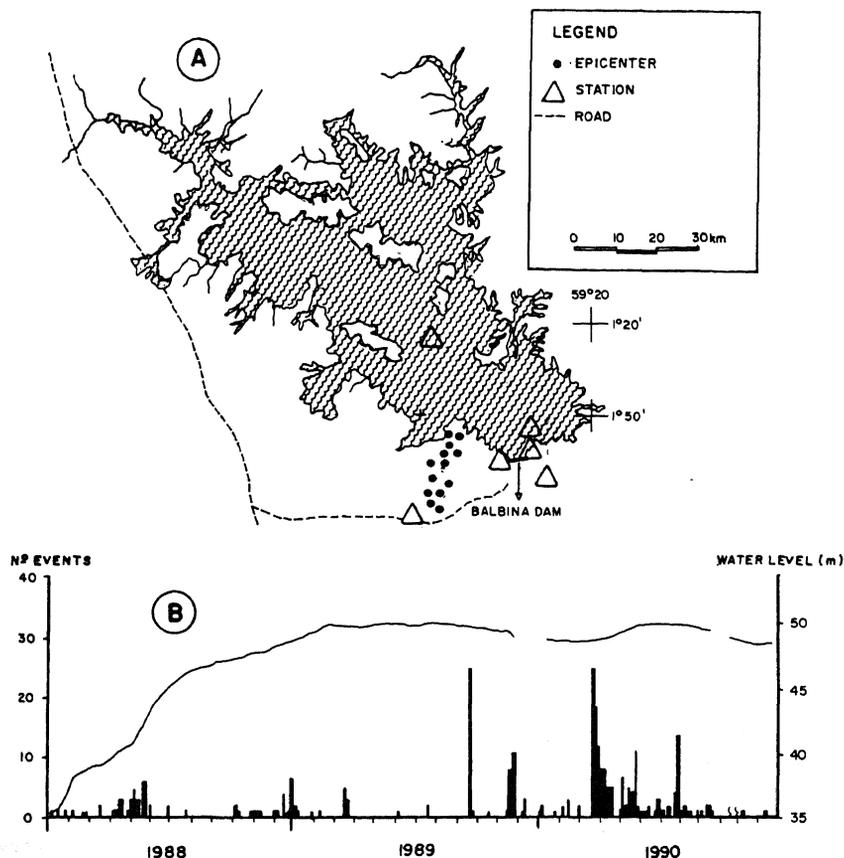


FIGURE 3 - EPICENTER LOCATION (A) AND THE EVOLUTION OF SEISMICITY COMPARED WITH THE CHANGES OF WATER LEVEL (B)

velocity of 5.8 km/sec for a half-space model and P and S velocity ratio of 1.73 were used. The average of foci depth was 1.5km. The data analysis of the reservoir water level and the seismic events do not support clear correlation of the water level changes against seismic activity.

5 CONCLUSIONS

The Tucuruí and Balbina reservoirs located in the Amazon forest exhibit expressive differences in size, geometric shape, epicenter location and geological setting but, in other hand, show some similar seismological results.

In both cases sufficient pre-impound instrumentation data were available to show that, for more than six years before the construction of the dams, no significant earthquakes had occurred near the lakes. So, there is no doubt that the post-impound seismicity represents examples of induced seismicity associated with reservoir loading.

In the two cases, low activity has started soon after impound and the level of the activity has increased about seven months after the water reached the reservoir maximum operating level.

The evolution of the local seismicity does not appear to be related to the water level of the lakes. The seismic activity has been observed on the microearthquake level and the main shocks reached only 3.4 MD and never caused any structural damage to the dams.

The detection of local seismicity around the Tucuruí and the Balbina lakes denotes that the phenomenon of reservoir-induced seismicity must be considered where major dams are to be built in the future in the Amazon area.

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