

Paraguay Seismicity during 2000

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Abstract

The work presents and analyses the recent earthquake activity in Paraguay, as detected by the Itaipu Binacional Seismograph Network during the year 2000. The discussion of Paraguay seismicity during 2000 is placed in the wider frame of the available historical seismicity of Paraguay based on all available data from various sources, as well. The main outcome of the presentation is to call attention on the April 28, 2000 event, $m_R = 3.9$ (Marza et al. 2000) and the subsequent smaller events occurring in the areas of Yacyreta and Ypacarai reservoirs. We find pretty compelling evidence that the events of the year 2000 associated with the Yacyreta reservoir were possibly triggered earthquakes, while the event close to Ypacarai natural lake, is associated with usual tectonic activity.

Introduction

The Itaipu Binacional Seismograph Network (ISN), composed by six remote stations, operating by radio telemetry has contributed to the monitoring of Paraguay seismicity, since its implantation, in 1981. The ISN was for a while (1981-1994) the sole current seismic system for regional monitoring of Paraguay detecting Paraguayan earthquakes with magnitudes between 2,5 and 5,6 m_b (Veloso et al., 1994). Recently, a seismograph station (CPUP) was installed in Paraguay, part of the GTSN (Global Telemetered Seismograph Network) Project, entered in operation only seven years ago (1994).

In April 28, 2000 an earthquake of magnitude 3.9 m_b was detected, having its epicenter relatively close to Yacyreta Reservoir, on the Paraná River, located in Paraguay-Argentina border region. This earthquake, reached an intensity of VI (MM), in the Itapuá and Misiones districts, frightening the local population. With that occasion, the Seismological Observatory (SIS) of the University of Brasilia (UnB), having working in the region for 22 years, in agreement with Itaipu Binacional company for monitoring the Itaipu Binacional reservoir, issued, a special report, where the event was analyzed (Marza et al., 2000). Later, in December 2000, other three smaller earthquakes were detected in the region, with magnitudes ranging between 2.5 and 2.8 m_D .

This work presents the basic source parameters of the four recent events that occurred during 2000 and of the previous seismicity based on data available in the Seismic Data Base of SIS-UnB.

Itaipu Binacional Seismograph Network (ISN)

The ISN is composed of six remote stations, three of them situated in Brazil and other three in Paraguay. Figure 1 shows the Itaipu Binacional reservoir map, indicating the location of the stations composing the ISN. The analog signals of these stations are sent by radio to a central station, located in the structure of the dam, elevation 214 m, where they are digitized and recorded. Time signals of a GPS clock together with a tri-axial accelerometer signals are recorded in the same acquisition and data recording system (Fig. 2).

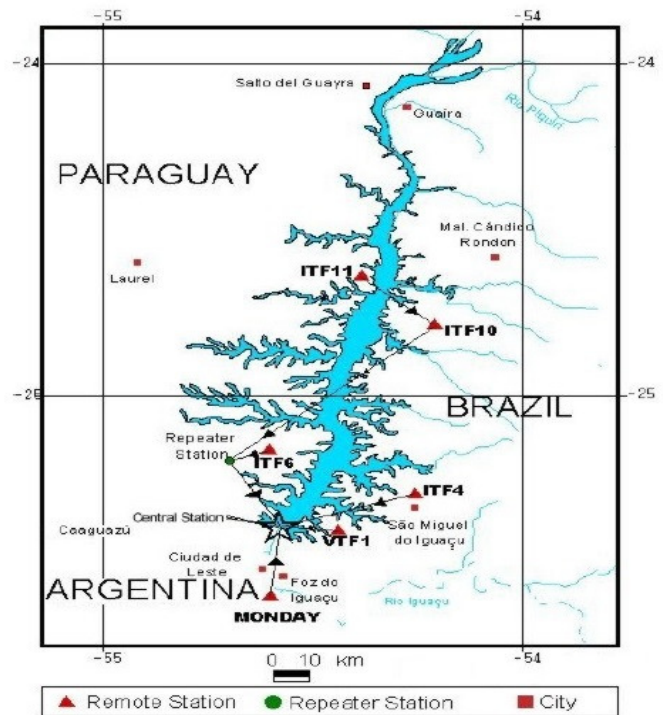


Fig. 1 - Itaipu Binacional Reservoir Local Seismographic Network.

Two seismic data acquisition, detection and analysis systems work in parallel, one operates with 24 bits resolution under a Windows operating system (ViSeis System) while the other operates within 12 bits resolution under a DOS operating System (PCQuake System).

The SIS/UnB can access this system, from Brasilia headquarters, using dial up line or Internet, for remote control or data retrieval. Figure 2 shows the block diagram of the reception and the Central Recording Station.



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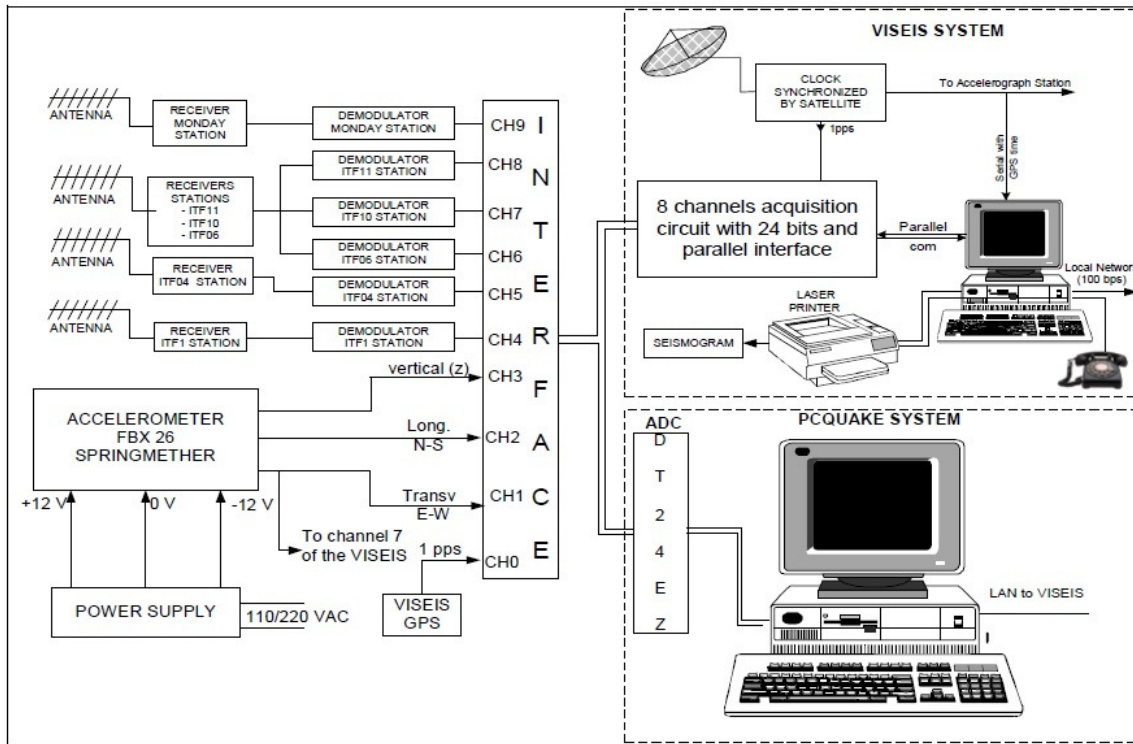


Figure 2 - Block diagram of the reception, acquisition and data recording systems (ViSeis and PCQuake) in the Central Station. Note the accelerometer signals being recorded together with the seismic signals.

Historical Seismicity of Paraguay

Paraguay, located in the central part of the South American Plate, between the Andean orogen and the Paraná Basin in South Brazil, is a region with very low seismicity compared with the Andean countries and related literature is very scarce (Velázquez, 2000).

The local instrumental monitoring of the Paraguay begun with the installation of the first station (ITA1) of the ISN, in January, 1979, and it was gradually upgraded with the deployment of the ISN network and GTSN/IMS station (CPUP). Table 1 summarizes the evolution of the completeness thresholds in Paraguay.

Table 1 - Detection threshold for Paraguay from 1950 to 1994 (updated after Assumpção, 1998)

Year	Magnitude	Commentary
1950	6.0	Summary of the International Seismological
1962	5.0	Deployment of the WWSSN Network
1968	4.0	Start operation of the SAAS (South American Array System) in Brasilia
1975	3.5	Start local seismographic Network of USP and UnB.
1979	2.5	Start of ITA1 Seismographic Station in Itaipu
1994	2.0	GTSN Station in Paraguay (CPUP)

Table 2 and the map in Fig. 3 show all Paraguay events present in the SIS-UnB and NEIS Database. As one can see, they are situated in two different regions divided by the Paraguay River: one in the western part in the Paraguay-Argentina boundary, whose seismicity in great part is associated with the Nazca plate subduction and another region in the central and southern part of the country with shallow earthquake as suggested by Assumpção (1992); Berrocal and Fernandes (1996).

Paraguay Seismicity (during 2000) as detected by ISN

The Itaipu Binacional Seismograph Network detected in the year of 2000, four regional events with epicenters in Paraguay, whose source parameters are listed in Table 2 and their epicenters are indicated in Fig. 3. The largest magnitude event (3.9 m_b), occurred in 2000/04/28, was located by the ISN and wide band three component GTSN station (CPUP). Figures 4 and 5 show the waveforms registered. Inherently, the instrumental locations of all earthquakes during 2000 are poor and certainly they are strongly scattered from their true locations, however the microseismic data can help to better place their origin close to Yacyreta reservoir or Ypacarai lake (cf. Velázquez J.C., 2001, personal communication).



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Ypacarai is a smaller lake, located some 30 km east of Asuncion City, and crossed by a known tectonic active fault.

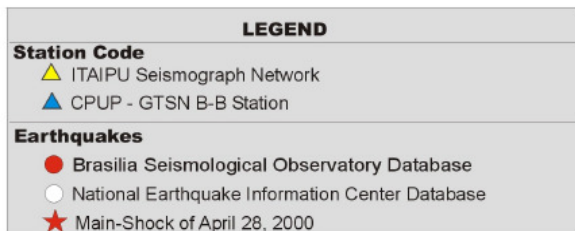
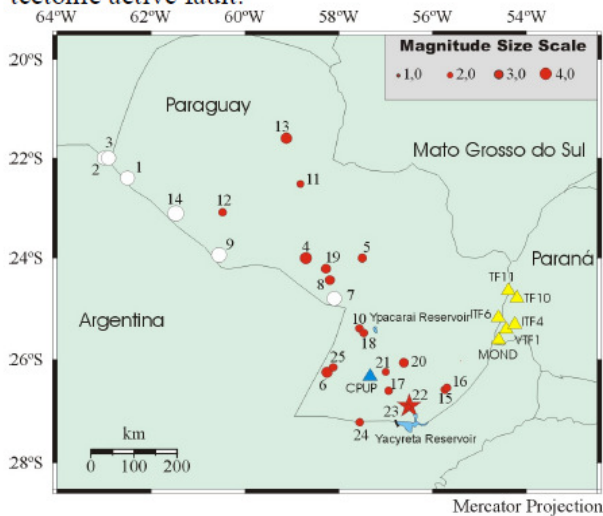


Fig. 3 - Map of Paraguay Seismicity according to Table 1. Events 22 to 25 belong to the seismicity of the year 2000.

however, no information was available in the Paraguay newspapers.

The probable RIS of the Yacyreta Reservoir

The Yacyreta Reservoir is a bi-national Paraguay-Argentina enterprise located in the boundary of these two countries, with a capacity of generating 3,200 MW of energy. The first turbine, of 160 MW, entered in operation in September, 02, 1994 and the last (twentieth) in July, 02, 1998. The barrage has a height of 83 m flooding an area of 1,600 km² with a volume of 21 x 10⁹ m³ (Yacyreta Bi-National Company, Online).

During December 2000 in the areas of both reservoirs was reported felt microearthquake activity (Velázquez J.C., 2001, personal communication). This is an indirect evidence that, in the ranges of location errors, the events #22,23 and #25 (in Table 2) occurred probably close to Yacyreta and Ypacarai reservoirs, respectively, the last one, however considered as natural manifestation of the tectonic activity of the area.

On the other hand, we must highlight, however, the low seismicity of the Paraná Basin, especially in its central part, considered one of Brazil's most aseismic areas. The Itaipu Binacional Reservoir with more than 22 years of uninterrupted Seismographic monitoring has never presented induced seismicity.

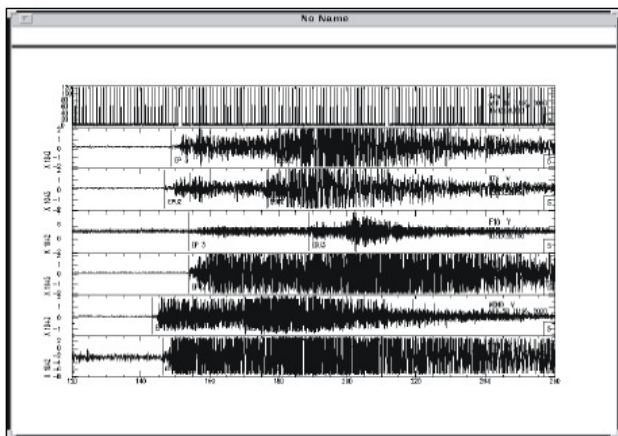


Figure 4 - Waveforms (vertical component) of the April, 28, 2000 Paraguay earthquake, registered by stations of ISN (Channel 1 - time code(IRIG); channel 2 - ITF4 Station; channel 3 - ITF6 Station; channel 4 - ITF10 Station; channel 5 - ITF11 Station; channel 6 - Monday Station and channel 7 - VTF1 Station).

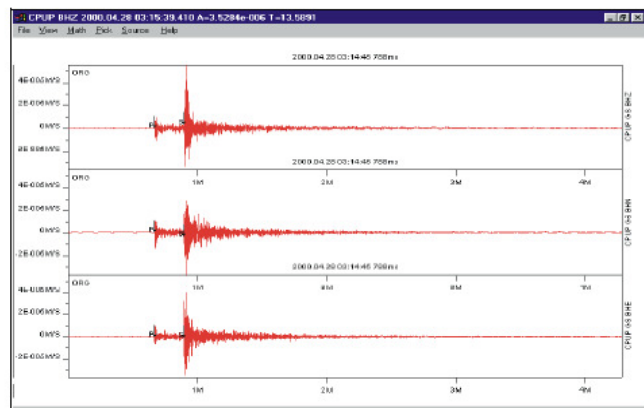


Figure 5 - Waveform registered by CPUP Station (GTSN), of the April, 28, 2000 Paraguay earthquake. The movement components (from up to bottom) are: vertical (Z), horizontal (N-S) and horizontal (E-W) with a high filter of 2 Hz and 4 polo. Phases P and S are marked in the seismograms. The vertical axis of the seismogram represents the ground velocity in m/s of each component and the horizontal axis indicates the time in minutes.

Macro seismic data based on newspapers information (Noticias del Paraguay and ABC, editions of 2000/04/29), indicate the boundary of Paraguay-Argentina as the area of biggest intensity. The event was probably also felt in Argentina,



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Table 2 - Source parameters of the events in Paraguay

	Data yyyy/mm/dd	Origin Time (UTC) hh:mm:ss			Depth (km)		
1	1947/08/31	06:17:29	-22.40°	-62.50°	223	5.2 m _b	NEIC-USGS
2	1959/05/30	03:07:03	-22.00°	-63.00°	500	4.9 m _b	NEIC-USGS
3	1961/04/28	08:40:26	-22.00°	-62.90°	82	5.1 m _b	NEIC-USGS
4	1979/01/16	05:38:24	-24.00°	-58.70°		4.0 m _b	SIS-UnB
5	1979/07/20	07:00:37	-24.00°	-57.50°		3.0 m _b	SIS-UnB
6	1980/11/20	22:29:07	-26.25°	-58.25°		3.8 m _R	SIS-UnB
7	1982/04/08	05:58:52	-24.80°	-58.10°	33	5.1 m _b	SIS-UnB/NEIC-USGS
8	1984/03/07	03:18:50	-24.44°	-58.19°		3.3 m _b	SIS-UnB
9	1985/04/12	14:34:54	-23.94°	-60.55°	24	5.3 m _b	SIS-UnB/NEIC-USGS
10	1986/12/11	05:27:10	-25.39°	-57.56°		2.8 m _R	SIS-UnB
11	1988/10/15	07:18:57	-22.52°	-58.82°		2.6 m _R	SIS-UnB
12	1988/10/17	06:27:47	-23.09°	-60.47°		2.8 m _R	SIS-UnB
13	1988/10/17	07:51:28	-21.60°	-59.12°		3.9 m _R	SIS-UnB
14	1989/02/28	13:01:58	-23.11°	-61.47°	569	5.6 m _b	SIS-UnB/NEIC-USGS
15	1989/09/21	02:59:19	-26.59°	-55.74°		2.7 m _R	SIS-UnB
16	1989/10/20	22:58:54	-26.55°	-55.70°		2.8 m _R	SIS-UnB
17	1990/09/20	20:54:27	-26.61°	-56.94°		2.8 m _R	SIS-UnB
18	1990/11/13	08:42:41	-25.48°	-57.47°		2.9 m _R	SIS-UnB
19	1994/02/09	12:14:05	-24.21°	-58.27°		3.4 m _R	SIS-UnB
20	1995/10/04	18:43:12	-26.06°	-56.62°		3.4 m _R	SIS-UnB
21	1998/05/06	04:27:41	-26.24°	-57.00°		2.6 m _R	SIS-UnB
22	2000/04/28	03:15:49	-26.90°	-56.50°	5	3.9 m _R	SIS-UnB
23	2000/12/01	00:28:42	-26.93°	-56.53°		2.5 m _D	SIS-UnB
24	2000/12/18	01:31:40	-27.22°	-57.55°		2.8 m _D	SIS-UnB
25	2000/12/21	04:43:34	-26.15°	-58.12°		2.8 m _D	SIS-UnB

Source: National Earthquake Information Center, USGC, and SISBRA Database, SIS/UnB.

Conclusions

The local seismographic monitoring of Paraguay begun after the deployment of the first station (ITA1) ISN, in 1979. Since then earthquake with magnitude above 2,5 has being detected in Paraguay. Before then only earthquake with magnitude over 5.0 m_b were detected by the Worldwide Seismographic Network.

The Paraguay seismicity clearly presents two seismogenic zones: one in the western and other in the eastern, both divided by the Paraguay River, as defined by Assumpção (1992) and Berrocal & Fernandes (1994).

In the year 2000 four regional events were detected by ISN, three of them probably could be associated with induced seismicity in the Yacyreta Reservoir, located in the Paraguay-Argentina boundary. To validate the case of RIS at Yacyreta, at least one seismographic station should be installed in the reservoir area.

References

- Assumpção, M. Seismicity and stresses in the Brazilian Passive Margin. *Bull. Seism. Soc. Am.*, **88**, 160-169, 1998.
- Assumpção, M. The regional intraplate stress field in South America. *J. Geophys. Res.* **97**, 11,889-11,903, 1992.
- Berrocal, L. Fernandes C. Seismicity in Paraguay and

Neighboring Regions, Alkaline Magmatism in Central-Eastern Paraguay. São Paulo, 1996.

Jornal Noticias del Paraguay, edition of 29/04/2000.

Jornal ABC del Paraguay, edition of 29/04/2000.

SIS-UnB Database of the Seismological Observatory University of Brasilia.

SIS/UnB - Reports (n°s 18- 23, 30-35, 40, 46, 50, 54, 55, 64, 68, 72, 74, 85, 95) Agreement FUB/Itaipu Binacional.

Marza, V. Barros, L. Soares, J. The Paraguayan earthquake of 2000/04/28, Special Report. Seism. Obs., Univ. of Brasilia, 12 pp., 2000 (in Port.).

Velázquez, R. J. F. - Earthquakes in Paraguay - An Appraisal, *Bull. Int. Inst. Seism. Earthq. Eng.* **34**, p. 75-77, 2000.

Veloso, J. A. V., Soares, J. E. P. & Velasquez, J. C. - Earthquake in Paraguay: An appraisal, Regional Seism. Ass. in South America, Brasilia, 1994.

Yacyreta Bi-National Comp. (La Entidad Binacional Yacyreta) (Online) <http://www.eby.org.ar/html>.

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