



# A Precursory Seismicity Pattern Associated to the Nova Ponte (MG) Reservoir Induced Mainshock of 1998 May 22 ( $m_R = 4.0$ )

MARZA, V. I., BARROS, L. V., SOARES, J. E. P., CARVALHO, J. M. CHIMPLIGANOND, C. N. & CAIXETA, D. F.

Seismological Observatory, University of Brasilia, CP 04598, Brasilia-DF, Brazil

## ABSTRACT

The reservoir induced seismicity (RIS) at Nova Ponte/MG has a well a documented history due to the adequate seismographic monitoring network operating there since the emergence of RIS and the conspicuous RIS related to this reservoir which in turns sparked off the interest of both seismologists and engineers. The RIS at Nova Ponte belong to the "initial seismicity" category and has manifested until now by two main reservoir induced earthquakes (RIEq), one in 1995 April 21 ( $m_R = 3.5$ ,  $l_0 = IV - V$  MM) and the other on 1998 May 22 ( $m_R = 4.0$ ,  $l_0 = VI$  MM) making the RIS at Nova Ponte as a case of "repetitive cycle" as well. The present work is investigating a salient time-space precursory seismicity pattern associated to 1998 Nova Ponte main RIEq displaying the following generic stages: background activity - early foreshocks - seismic quiescence - immediate foreshocks - mainshock - aftershocks together with a nonrandom spatial configuration of the event population.

## INTRODUCTION

The Nova Ponte (MG) reservoir is a thoroughly investigated case of reservoir induced seismicity (RIS) in Brazil (e. g., Veloso et al., 1994, 1995; Veloso & Marza, 1996; Assumpção et al., 1997; Marza et al., 1997; Marza & Barros, 1998 etc) being classified as "initial seismicity" and "repetitive cycle" (cf. Marza et al., 1999). The two principal reservoir induced earthquakes (RIEQs) occurred on 1995 April 21 ( $m_R = 3.5$ ,  $l_0 = IV - V$  MM) and on 1998 May 22 ( $m_R = 4.0$ ,  $l_0 = VI$  MM). Other significant events happened on 1994 April 21 ( $m_R = 2.8$ ,  $l_0 = VII$  MM) 1998 Jul 21 ( $m_R = 2.6$ ,  $l_0 = II - III$  MM) etc. The RIS at Nova Ponte started shortly after beginning (1994 OCT 14) of the impoundment. It is worthy to mention that during the 8 years of pre-impounding seismographic monitoring no local event was detected. The seismic activity came out quasi simultaneously in two separate areas of the reservoir (see Fig. 1), one more further from dam on the left branch (denominated A1, around the coordinates 19.4S and 47.6N) and the other closer to the dam and the new town of Nova Ponte (denominated A2, around 19.2S and 47.7W, more dispersed and elongated in the NEE - SWW direction. The principal RIEQs, listed above, occurred in area A2 and were amply felt by local population. The current and past seismographic station distribution is mentioned in Fig. 1, as well.

## THE MAINSHOCK OF 1998 MAY 22

The main RIEq event of 1998 MAY 22 occurred at 17<sup>h</sup>35<sup>m</sup>43.4<sup>s</sup> (UTC) and was largely felt (the macroseismic survey found a maximum epicenter intensity of VI degrees on MM scale). The location of the seismic events was done using the local 4-5 seismic station network and the regional velocity model of the area. The focal parameters of the mainshock are:

Date: 1998 MAY 22  
Origin Time: 17:35:43.4 (UTC)  
Epicenter: 19.17°S; 47.68°W; Depth: 3 km (fixed)  
Magnitude: 4.0 ( $m_R$  - regional magnitude scale)

The adapted magnitude  $m_R = 4.0$  is based on the average of individual values from various seismographic stations and conversions from other magnitude scales to regional magnitude scale. This value put the RIEq at Nova Ponte on 1998 MAY 22 as the second largest RIEq ever observed in Brazil [after the RIEq of Porto Colômbia - Volta Grande (MG/SP) on 1974 FEB 24, which had  $m_b(\equiv m_R) = 4.2$ ].

It is noteworthy to observe that the RIEq of 1998 followed the peak of water level at Nova Ponte caused by the rainy season 1997-1998 with a time lag of approximately 3 months.

## THE PRECURSORY SEISMICITY PATTERN RELATED TO THE NOVA PONTE 1998 RIEq

Due to an improved resolution of seismicity at Nova Ponte (the location threshold is around magnitude  $m_D \approx 1$ ; N.B., the  $m_D$  scale is calibrated in respect with  $m_R$  scale), the recent seismicity at Nova Ponte is well mapped up to microearthquake level.

Plotting spatially and temporally the seismicity before and after 1998 main RIEq it was possible to infer a conspicuous seismicity pattern (Fig. 1 and 2) which exhibit a clear precursory feature.

This precursory seismicity pattern associated to the Nova Ponte 1998 mainshock resembles with the time-space seismicity patterns discussed and reported elsewhere (see for example Kanamori, 1981 or Mogi, 1985).

The time-space-rate behavior of the seismicity pattern discussed here exhibit the following features (see also Figures 1 & 2):

- 1) Activity concentrated mainly in area A2 (lacking completely, at least up to detection level, in area A1);
- 2) The mainshock is located off the area of intense pre-seismic and post-seismic activity (secondary/dependent events);
- 3) The dependent events (foreshocks and aftershocks) are distributed in two clusters C1 and C2, separated by the parallels 19.19°S and 19.20°S;
- 4) The rate of foreshocks is much higher than that of aftershocks;
- 5) The inferred (precursory) seismicity pattern is as it follows: *background activity - early foreshocks - seismic quiescence - immediate foreshocks - mainshock - aftershocks*;
- 6) The spatial distribution of foreshocks follows a nonrandom pattern as well, i. e., the early foreshocks befell in cluster C2, the immediate ones in cluster C1, which the aftershocks took place both in C1 and C2.

Obviously, the *time-space-seismic rate* features of this sequence related to 1998 Nova Ponte main RIEq evolved according to a more less general pattern of precursory seismicity (for a taxonomic framework see, for example, Marza, 1991).

## CONCLUSION AND DISCUSSION

The paper presents a salient precursory seismicity patterns associated to the Nova Ponte main RIEq at 1998. Moreover, the obvious lull (12 days) in seismic activity and the subsequent burst of immediate foreshocks (at a rate of 21 events/day, comparing with the background rate of 1-2 events/day) can be obviously interpreted as a clear-cut precursory behavior prior to the main RIEq of 1998.

The result of this work proves both the suitability investigation of RIS as a "laboratory" for seismicity studies and the potential usefulness of real-time monitoring of seismicity for forecasting of larger shocks.

## REFERENCES

- Assumpção, M., Barbosa, J. R., Berrocal, J., Bassini, A. M., Veloso J. A. V., Marza, V. I., Huelsen, M. G. & Ribotta, L. C., 1997, *Seismicity patterns and focal mechanisms in SE Brazil*, *Rev. Bras. Geof.* 15: 119-132.
- Kanamori, H., 1981, *The Nature of Seismicity Patterns before Large Earthquakes*, in SIMPSON D. W. & RICHARDS P. G. (Eds), "Earthquake Prediction. An International Review", Maurice Ewing Series 4, AGU, Washington DC, p. 1-19.
- Marza, V.I. 1991, *Precursory Seismicity Patterns in Vrancea (Romania) Region : a general account*, *International Conference on "Earthquake Prediction : State-of-the-Art"*, 15-18 October 1991, *Scientific-Technical Contributions (Pre-prints)*, CSEM/EMSC, Strasbourg, France, p. 73-84.
- Marza, V.I. & Barros L. V., 1998, *Considerações sobre o sismo principal de Nova Ponte de 22.05.98*, *Relatório Especial*, Observatório Sismológico, FUB, 18pp.
- Marza, V. I.; Veloso J. A. V.; Carvalho J. M.; Barros L.V. & Gomide L.C., 1997, *Reservoir induced seismicity at Nova Ponte (MG): Revisited*, *Anais do 5º Congresso Internacional da SBGF*, p.968- 971.
- Marza, V.I. Barros, L. V., Soares, J. E. P., Carvalho, J. M., Fontenele, D. P., Chimpliganond, C. N., Caixeta D. F., Gomes, I. P., Furtado, G. O., Carim, A. L., Souza, I. F., Caliman, E. H. & Barros, J. B., 1999, *Aspectos da sismicidade induzida por reservatórios no Brasil*, *Anais do XXIII Sem. Nacional de Grandes Barragens*, Belo Horizonte, MG, 22-26 de março de 1999, Vol. I, p. 199-211.
- Mogi, K., 1985, *Earthquake Prediction*, Academic Press Japan, Tokyo, 355 pp.
- Veloso, J. A. V. & Marza, V. I., 1996, *Estimativa da aceleração máxima ocorrida na barragem de Nova Ponte devida ao sismo de 21/04/95*, *Relatório Especial*, Observatório Sismológico, Fundação Universidade de Brasília, 15pp.
- Veloso, J. A. V.; Carvalho, J. M.; Huelsen, M. G. V.; Gomide, L. C. & Chimpliganond, C. N., 1994, *Recent Seismic Activity in the Nova Ponte Reservoir Area, Brazil*, *Abstract SSR. 12*, *Reg. Seismological Assembly in S. America, Brasília, Brazil*, p.22.
- Veloso, J. A. V.; Barros, L. V. & Carvalho, J. M., 1995, *Progress in reservoir monitoring technology for induced seismicity in Brasil*, *Proc. ISORIS'95*, Nov. 1-5, 1995, Beijing, p. 304-312.