THE 1597 TSUNAMI IN THE RIVER VOLGA*

Irina I. Didenkulova[1] **and Efim N. Pelinovsky**[2]

[1] Nizhny Novgorod State University, Nizhny Novgorod, Russia,
[2] Institute of Applied Physics RAS, Nizhny Novgorod, Russia
E-mail: **dii@appl.sci-nnov.ru**

ANNOTATION

The fortunate find of a description of the 1597 tsunami in the River Volga determined that the tsunami was due to a collapse a cliff near the river, which caused a landslide. Data collected at the inspection of the site mentioned show evidence of a strong landslide probability to induce tsunami in the river. Evaluation of the event parameters has been made.

1. INTRODUCTION

It is now evident that landslides may generate major tsunamis. An underwater landslide caused the destructive Papua – New Guinea tsunami (July 17, 1998), which took more than 2000 lives (maximum runup of this tsunami was 15 m). An earthquake with magnitude 7.1 triggered this landslide [McSaveney *et al.*, 2000; Tappin *et al.*, 2001; Synolakis *et al.*, 2001]. In August 17, 1999 an earthquake with magnitude 7.4, occurred in the Bay of Izmit (Turkey); it caused a shore slump that generated a tsunami 2.5 m high [Altinok *et al.*, 2001]. The same year (September 13, 1999) the slump of a high cliff generated a 5 m tsunami near Fatu Island (French Polynesia) [Hébert *et al.*, 2002]. The maximum height (524 m) was recorded in Lituya Bay in Southeastern Alaska on July 10, 1958. This tsunami was due to a massive subaerial slide failure. All these events show the importance to study tsunamis of landslide origin. The NATO Advanced Research Workshop, Istanbul, 2001 was especially dedicated to this problem [Yalciner *et al.*, 2001].

Tsunami waves caused by landslides appear not merely in oceans and seas but also in rivers and water reservoirs. Soloviev [1978] evidently was the first to mention tsunami in rivers originated by slides. These events also have to be taken into account in order to improve the theory. The present work studies one such event: – the 1597 tsunami in the River Volga.

2. HISTORIC DATA

This event occurred in the 16th century, in the vicinity of Nizhny Novgorod. Nizhny Novgorod (it was founded in 1221 by the prince Yury Vsevolodovich) is one of first-rate Russian cities; it is situated 400 km from Moscow at the junction of two large Russian rivers: – the Volga and the Oka. Advantageous geographic position with respect to the main transport ways promoted the town's quick development and appearance of several monasteries in its vicinity. Monasteries were at that time cultural and written-language centers. Therefore, the event that demolished one of the monasteries in the vicinity of Nizhny Novgorod was mentioned in a chronicle, which described the tsunamigenic landslide on the coast of the Volga River.

* Translated by O. I. Yakovenko, edited by A. B. Rabinovich and W. Rapatz

The chronicle says the following (Fig. 1) [Gatsysky, 2001]:

«In 1597, on July 18, on the day of St Leonty, between 2 and 3 o'clock a.m. God's wrath burst out over Nizhny Novgorod. Being detached from the mainland, a hill in the Pechersky monastery went into the Volga with all the wood on it for 50 sazhen (107 m) or more here and there. Because of this, rough water occurred in the river, and boats moored in the river under the monastery were thrown inland by 20 sazhen (43 m). After the slide, many springs appeared in the hill. The slide destroyed many stone-worked monastery temples: Ascension Church, Protection of Our Lady Church, Apostle and Evangelist John the Baptist Church, Nicolas the Wonder-Worker Church, St Boris and Gleb Church and Serguey the Wonder-Worker Church. As well, Saint Gate, cells, hothouses, cellars, and other monastery service rooms were broken. The Protection of our Lady Church with the refectory became unsteady, the basements of the churches of Nicolas the Wonder-Worker and Euphimy Suzdalsky moved under the ground from their places by 2 sazhen (4 m), and the bell tower with all its bells was collapsed. The Sacred Image of Our Lady The Miracle Worker and other church utensils had been removed from the churches one week before the first signs of the slide near the monastery bridge. This distress occurred under archimandrite Triphon.


Лѣта 7105 ого Году, Июния въ 18 день: на
память святаго мученика Леонтия, въ
третиемъ часу нощи: Было потрясение
Господне въ нижнемъ новѣградѣ въ
печерскомъ монастырѣ; отпадъ Гора отъ
матерые степи, да пришла подъ ту Гору на
которой монастырь стоитъ и съ лѣсомъ, и
вышла в волгу Саженъ на 50, а инде и болши.
И стали въ волгѣ Бугры великие: Суды
которые стояли подъ монастыремъ на водѣ, и
тѣ суды стали на брегу на сухъ, Саженъ 20
отъ воды и болше. И послѣ того нанъ пенила
гора, пошли изъ Горы ключы великия.

Figure 1

After the destruction of the monastery, the archimandrite Triphon went to Moscow to ask Tsar Feodor Ioannovich to restore the monastery buildings. Tsar Feodor Ioannovich ordered a voevoda ("military commander") and a church clerk together with wise men from Nizhny Novgorod to examine if it were possible to erect the monastery and stone churches on the former site. The wise men told voevoda Leonty Ivanovich Aksakov and clerk Ivan that it would be impossible to put stone churches in the former site as the soil had become insecure due to the slide. The voevoda and the clerk reported this to Moscow, and Tsar Feodor Ioannovich ordered the erection of the Ascension and Our Lady churches one verst (about 1 km) from the destroyed monastery, upstream. There were seven hills, which were leveled due to the Tsar's command and at his expense. We petitioned for the other place, but our

Sovereign found the selected place to be the most suitable, as it was situated on the Volga. He ordered the building of a monastery and a wooden church on the former site to commemorate parents and deceased brothers.»

So, on July 18, 1597 the huge slide demolished completely the Pechersky monastery situated a few kilometers from the Kremlin of Nizhny Novgorod downstream of the Volga River (now this is one of the city districts). A part of a shore cliff slid down for about 100 m, carrying along the monastery buildings. The nature of this slide is not clear, though the chronicle noted certain shearing of the cliff at least a week before the event itself.

The monastery was located on the quite large territory (Fig. 2) [Dmitrievsky, 1997]. Later, in the former place of the monastery a wooden church was erected, which became parochial. In 1780 it was replaced by a stone building that exists up to now (Fig. 3). A memorial plate at its entrance tells us about the event of 1597 (Fig. 4).

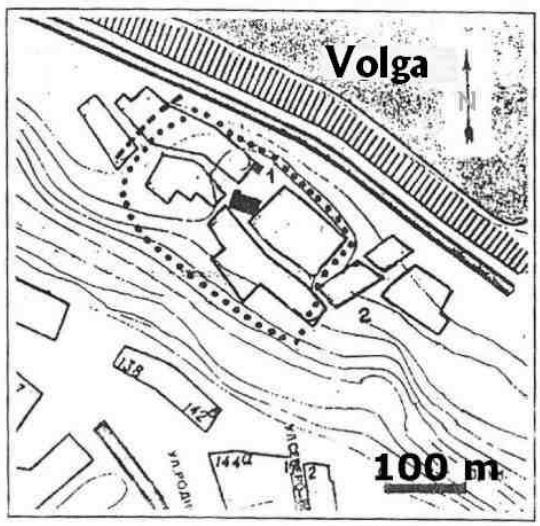

Figure 2

They rebuilt the monastery after the catastrophe two kilometers closer to the town center (Fig. 5). For a long time it had been deserted, but in recent years it began to be actively reconstructed. Now it is open and performs religious services.

Fig. 5 gives also a general idea about the Volga's cliffs inside the city boundary. They are quite steep and conducive to slide formation. The same chronicle mentions, "a big slide occurred over the so-called salt bams" in 1867. Even now there is a high risk of a slide. The Committee for Environmental Protection and Nature Management of the Nizhegorodsky Region informed that in the year 2000 alone, 3 new slides were formed and 33 old slides were activated in Nizhny Novgorod along the cliffs of the Oka and the Volga rivers [State of…, 2001]. Maximum sliding activity was observed in April 2000. The largest newly formed slide inside the city boundaries was the slide in the Pochainsky ravine. Its length was 45 m, the width 30 m, and the sheared depth 5 m. Main causes of slide formation are precipitation, high level of subsoil water, and shore erosion.

3. ANALYSIS AND ESTIMATIONS

To analyze possible tsunami waves we have to evaluate the scale of the slide itself – its volume, height, cliff angle and its speed as it slides into the river. Assuming that the characteristic of the cliff steepness of the right Volga shore in the vicinity of Nizhny Novgorod has not been changed much from the 16th century, we may take the mean angle of the modern slope equal to 40^{o} and the height h = 40 m. We can evaluate the slide mass from the archeological digging shown in Fig. 2 [Dmitrievsky, 1997]. The slide area was 200 m × 300 m. So, the slide volume and mass are W = 150000 m^3, and m = 4.1 10^8 kg respectively.

Figure 3.

Figure 4.

Figure 5.

We used here the typical density value for clay soils: ρ =2740 kg/m^3 [Babakov *and* Bezruk, 1986]. The slide velocity when the slide is falling into the river may be evaluated from the equations of motion. If we suppose that the slide moves as an entire body [cf. Pelinovsky *and* Poplavsky, 1997]:

$$m\frac{dv}{dt} = mg(\sin\alpha - \mu\cos\alpha), \qquad (1)$$

where g is the gravity acceleration, v is the slide velocity, α is the cliff slope angle, μ is Coulomb (sliding) friction coefficient. As it is known, the friction coefficient depends on dampness, decreasing with increase of the latter. Due to this fact, the right part of (1) becomes positive after the rise of the soil-water level or abundant precipitation, and the slide starts. For clay soils we can take μ = 0.27 [Babakov *and* Bezruk, 1986]. Then integrating (1) and assuming the initial velocity to be equal to zero, we can estimate its velocity when it enters the river: v = 13 m/s for the slope inclination of 40^o. For comparison, we would like to note that the velocity of the surface waves in the river is about 5 m/s if the river depth is 3 m; the velocities of currents are of order 1 m/s. So, the slide velocity is much greater than those of the surface waves and of the river currents. Taking into account this fact, in the first approximation, we can suppose that the impact of the slide upon the water occurs instantaneously. Naturally, this is a preliminary estimate. Based on these estimates we plan further to examine more specifically the generation of this tsunami and evaluate its height.

4. CONCLUSIONS

In this work we gave the description of a river tsunami known from historical documents. This phenomenon took place in 1597 on the coast of the Volga River near Nizhny Novgorod. A huge slide collapsed from a steep cliff of the right Volga bank, where the Pechersky monastery was situated, causing this tsunami. The destruction of the monastery was the main reason to mention the landslide in the chronicle. It seems that this is one of the most aged documentary descriptions of tsunamis in rivers.

The work was supported by the Russian Foundation for Basic Research (RFBR), Grant No 02-05-64107. ID is also grateful to RFBR for the support of her participation in the Kamchatka Workshop, 2002 (Grant No 02-05-74505).

REFERENCES

Altinok Y., Tinti S., Alpar B., Yalciner A.C., Ersoy S., Bortolucci E., and Armigliato A., 2001: The tsunami of August 17, 1999 in Izmit Bay, Turkey. *Natural Hazards*, 24, 133-146.

Babakov V. F., and Bezruk V. M., 1986: Bases of Soil Science and Mechanics of Soils. Moscow, High School (in Russian).

Dmitrievsky S. M., 1997: Archeological exploring in the area of the Pechersky monastery. Nizhny Novgorod Study of Local Lore and Archeology. Nizhny Novgorod, Nizhegorodsky Humanitarian Center, 56-60 (in Russian).

Gatsysky A., 2001: The Chronicles of Nizhny Novgorod. Nizhny Novgorod, Nizhegorodskaya Yarmarka (in Russian).

Hébert H., Schindelé F., Heinrich P., Piatanesi A., and Okal E.A. Local tsunami hazard in the Marquesas Islands (French Polinesia): Observations and numerical modeling of the 1999 Fatu Hiva landslide and tsunami. Abstract, Int. Workshop "Local Tsunami Warning and Mitigation", Petropavlovsk-Kamchatsky, p.57.

McSaveney M. J., Goff J. R., Darby D. J., Goldsmith P., Barnett A., Elliott S., and Nongkas M., 2000: The 17 July 1998 tsunami, Papua New Guinea: Evidence and initial interpretation. *Marine Geology*, 170, 81-92.

Pelinovsky E., and Poplavsky A., 1997: Simplified model of tsunami generation by submarine landslides. *Physics and Chemistry of the Earth*, .21 (1/2), 13-17.

Soloviev S. L., 1978: Tsunamis. "*Technics of the Youth*", No 8, 38-43 (in Russian).

State of the environment and natural resources for the region of Nizhny Novgorod in 2000. Nizhny Novgorod, 2001 (in Russian).

Synolakis C. E., Bardet J., Borrero J. C., Davies H. L., Okal E. A., Silver E. A., Sweet S., and Tappin D.R., 2002: The slump origin of the 1998 Papua New Guinea Tsunami. *Proc. R. Soc. Lond.*, A458, 763-789.

Tappin D. R., Watts P., McMurty G.M., Lafoy Y., and Matsumoto T., 2001: The Sissano, Papua New Guinea tsunami of July 1998 – offshore evidence on the source mechanism. *Marine Geology*, 175, 1-23.

Yalciner A. C., Pelinovsky E., Synolakis C., and Okal E. A., 2001: NATO Advanced Research Workshop "Underwater Ground Failures on Tsunami Generation, Modeling, Risk and Mitigation". Istanbul.