PRACE GEOGRAFICZNE, zeszyt 116

Instytut Geografii i Gospodarki Przestrzennej UJ
Kraków 2006

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CATASTROPHIC EARTHQUAKES IN THE ALTAI MTS, THEIR AFTERMATH AND IMPACT ON SLOPE AND FLUVIAL PROCESSES

Abstract: The paper presents a study into a catastrophic seismic event rating 9-10 on the international scale MRS-64. The event took place on 27 September 2003 in the Altai Republic of the Russian Federation. Immediately after the event, the authors studied its impact on slope and fluvial processes.

Key words: catastrophic earthquakes, palaeoseismogenic structure, epicentre, palsas (bugors), permafrost.

1. Introduction

On 27 September 2003, the Upper Altai (Russia) near the border with Mongolia, China and Kazakhstan, experienced one of the strongest earthquakes over the previous 300 years. This catastrophic event has been rated 7.3 in force and 9-10 in intensity of tremors on the international MSR-64 scale. Aftershocks continued for several months, but with progressively reduced power

An earlier earthquake of the same strength was recorded in the Great Altai Mountains on 9 December 1761 in Mongolia, when the unloading of tension at the epicentre was roughly estimated at eight units and the intensity of shocks was rated 11 at degrees. This earthquake was linked with the Palaeoseismogenic structure of Ar-Khutel on the north-eastern slopes of the Mongolian Altai Mountains (Luzgin et al. 2003). A number of researchers regard Ar-Khutel as the largest discovered palaeoseismogenic structure on Earth.

The earthquake reverberated causing shocks in the towns of Ust'-Kamenogorsk and Biysk rating six degrees in intensity and at Barnaul and Semipalatynsk rating ca. five degrees (Solonenko et al. 1960). Other sources in the literature (Rogozhin, Platonova 2002) propose different views on the significance of this epicentre, but they are not sufficiently supported by facts.

There were multiple earthquakes in the area during the 20th century. One of the strongest was the Gobi-Altai of 4 December 1957 (Florentsev, Solonenko 1963, Grachev 2000). It reached a magnitude of 8.2-8.6 and the intensity at the epicentre rated 11-12. The epicentre of the latest earthquake in the Altai Republic was located in the Chuyska Basin and the Kurayska Basin. These sparsely populated areas avoided any fatalities, but individual buildings were completely destroyed in the village of Beltir situated closest to the epicentre (Photo 1).

2. Geological conditions of the earthquakes

The earthquake concerned took place in one of the most structurally stressed areas in the south-eastern part of the Russian Altai. Here, geological structures of very differing ages come together: the Proterozoic-Salairian, Caledonian-Hercynian, Hercynian and Alpine (Mezozoic-Cenozoic). The main folded structures and rifts change direction from north western (diagonal) into the longitudinal that dominates in the south. This is also an area of intensified development of fault zones, including old tectonic junctures and also rejuvenated shifts.

Most of the epicentres of earthquakes that took place within more than a month after the initial episode of the latest event (80-90% of the number) follow a belt 85 kilometres long and 20 kilometres wide on average (Figure 1). The axis of that belt roughly approximates with the location of the south western zone of contact between metamorphic limestone of Proterozoic age and Cambrian formations (in NW) and Devonian formations (in SW). Half of the most intensive shocks (over 5-6 units), especially the early ones, had epicentres located outside of the zone to the north west and north east of its maximum reach. Another three were located in the north western part of the zone near Aktash village.

Probably, just as in the case of the Gobi-Altai earthquakes, there was also a concurrent ripping/splitting movement, and a development of various types of shifts, from faults to overthrusts, depending on the individual conditions of the unloading of tensions built up in rock masses.

3. Geomorphological and hydrogeological effects of the earthquake

The authors carried out field studies at the epicentre, a few kilometres west of the village Beltir on the right-bank slopes of the valley of the River Taltura, a left-bank tributary of the River Chagan-Uzun. They found that the main shock triggered a seismic landslide (Photo 2) involving moraine formations aged by Okishev (1982) and Okishev and Borodavko (2001) as mid- or early Pleistocene. Boulders and smaller pieces of rock cemented with loam with lenses of pure ice and ice filling were found at the site uncovered by the tremor. Practically the entire layer of moraine formations remains frozen, with just the top layers down to 2.0-2.5 metres being unfrozen in early October 2003. The occurrence of ice lenses in the moraine formations and their resting directly on bedrock probably contributed to the development of the landslide.

Crevices in the colluvial mass of the landslide run up to 200-250 metres long and 8-10 metres wide. The crevices are often parallel to each other and the morphology

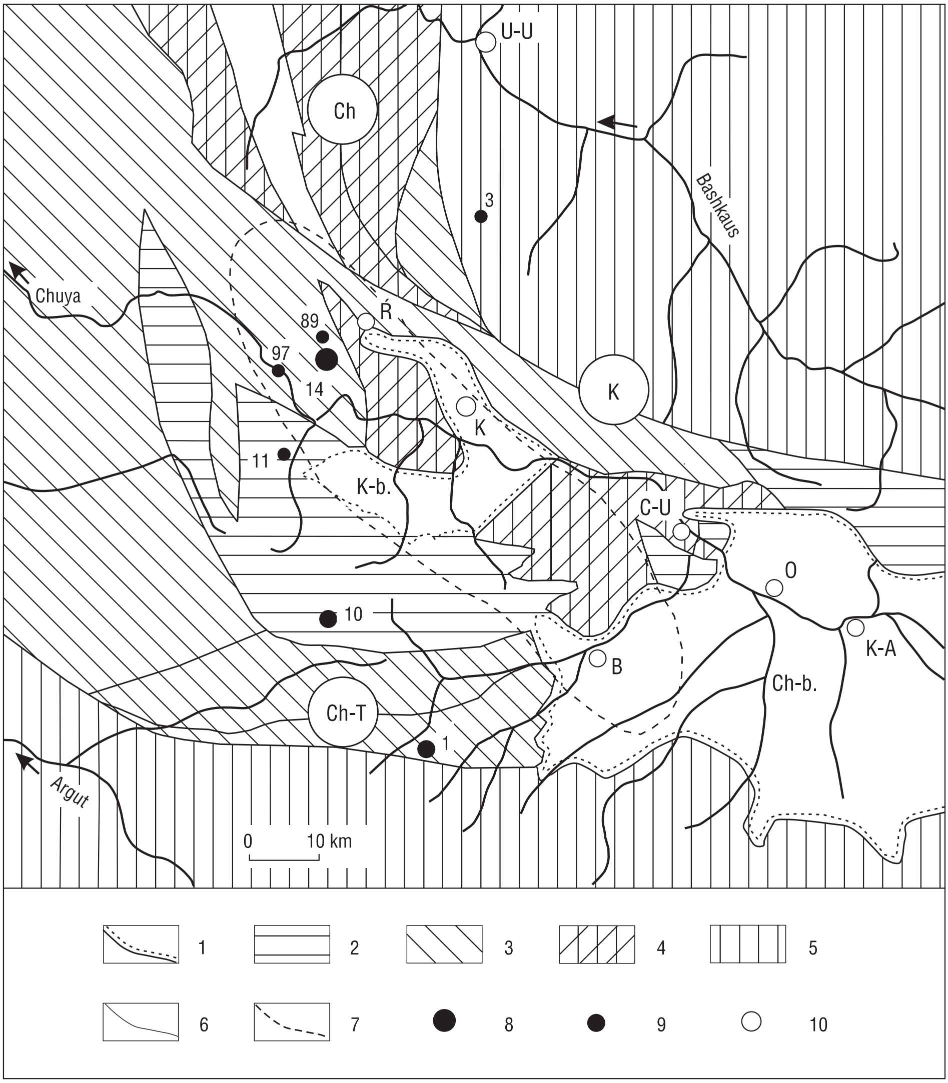

Figure 1. Geological and structural situation of the earthquakes in the Southern Russian Altai

Explanations: 1 – mid-mountain basins (K-b. – Kurayskaya, Ch-b. – Chuyskaya; 2-5 – structural formation zones, including: 2 – Hercynian; 3 – Caledonian-Hercynian; 4 – early Proterozoic Carbonaceous; 5 – Proterozoic crystalline slates; 6 – rifts mostly defining structural formation zones, including: K – Kurayskiy, Ch – Choktakskiy, Ch-T – Charyshsko-Terektinskiy; 7 – areas with the greatest concentration of earthquake epicentres; 8 – epicentres with a magnitude greater than 6; 9 – epicentres with a magnitude greater than 5; 10 – localities: A – Aktash, B – Beltir, K – Kuray, K-A – Kosh-Agach, O – Ortolyk, U-U – Ust'-Ulagan, C-U – Chagan-Uzun.

of the crevices indicates brittle deformations within the colluvial mass caused by its frozen state and a sudden, almost instantaneous, application of force.

It is worth highlighting that, among the microeffects of the earthquake studied, was the development of multiple crevices running north westerly along the surface of the second dry terrace of the River Chagan-Uzun and investigated in the village of Beltir. There are small-scale landslides along these crevices, sometimes engulfing built structures.

Despite the high frequency of earthquakes in the area, the local population was rather shaken by these natural phenomena. Accounts were received of large amounts of warm water spewing from underground and flooding a low-lying sports stadium. Some frightening reports also referred to "magma flows" that followed the water. This sort of report was not only heard from the local populace, but also from various levels of local authority. Indeed, Beltir is located both on top of a terrace and on the slopes of palsas (bugors locally known as *tebelery*). The opening of the crevices in these landforms released confined ground water that was also warmer than the ambient air temperature (12-16°C).

Baryshnikov (1988) studied the palsas (bugors) by drilling at the village of Tebeler in the same area. One of the boreholes was located at the top of an ice mound, while another lay at its foot (Figure 2). While the samples from the palsas revealed numerous thin ice lenses, no ice core was found like that present in similar mounds known from Yakutia (bulgunniakhs, pingos), or in North America (pingos). It is well known that segregating ice does not cause the emergence of landforms such as long-term palsas more than five metres high. The swelling of the rock formation was caused by the growing volume of the water-saturated, slowly freezing, thinly-dispersed, debris mass (silt, loam and silt-sand). This explanation of a mechanism for the development of long-term palsas is similar to that for the seasonal palsas that are widespread throughout the Chuguyska Basin and the Upper Altai.

Hydrogenic features of a seismogenic nature are tightly linked with lithogenic features. They were mentioned after the Gobi-Altai earthquake but received little attention. Particularly interesting among these were griffons (sinks) that developed at an initial stage of the earthquake in the Southern Russian Altai in 2003. They have the form of quite regular conical sinks with the diameter of 1.0-1.5 metres and a depth in excess of 1.5 metres (Photo 3). Typically located along straight lines and much less often in isolation, they follow a pattern of activity featuring sudden water eruptions from a group of griffons located nearby and an equally sudden cut off. The appearance and subsequent disappearance of the outflows is probably caused by the opening and closing of tectonic fissures in the loose waste mantles in the River Chuya valley. These processes take place in permafrost deposits with confined ground water activated seismically. In these circumstances destructive geo-deforming wave processes occur that destroy the gas-water absorption in the fluid phase. The abrupt ending of the water eruptions from the griffon channels is difficult to explain without considering the instantaneous destruction of the water conducting medium, which may be happening as a result of new seismic shocks.

The rolling of a flexible wave may reduce the ground strength several times and relatively strong seismic activity may cause certain water-permeated terrain to become fluid. The fluidised ground may be violently ejected upwards leading to the development of sandy craters on the surface (Voskresiensky 1993). The volume of water involved

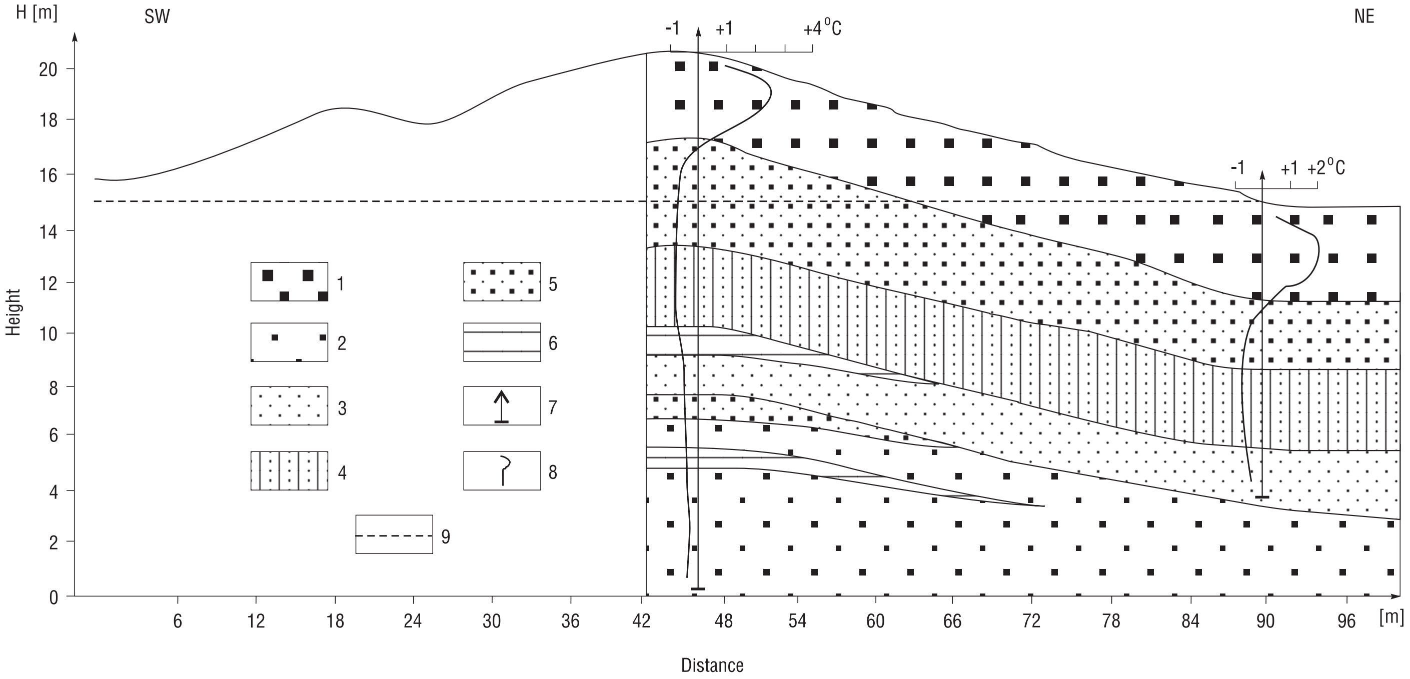

Figure 2. Geological cross-section of palsas in the village of Tebeler, Kosh-Agachski region, Altai Republic, Russia

Explanations: 1 – gravel, 2 – medium-grained sand, 3 – fine-grained sand, 4 – sandy/dusty loam, 5 – sandy loam with fine gravel, 6 – fine-layered sand loam, 7 – crevice, 8 – crevice temperature chart, 9 – a daily swelling line from the feet of the *palsas.*

in the creation of the landforms studied in the area of Beltir was estimated at 1000 m^3. After the initial earthquake episode, according to the authors, a considerable outflow of ground water was likely to have caused the eruption of water from the griffons. This opinion is substantiated by the hydrogeology of the Chuyska Basin with its growing prominence of artesian water towards the west and, consequently, the increasingly confined nature of ground waters in the same direction. In such circumstances strong seismic activity leads to a vibration differentiation of waste mantles, including the water-permeated poorly consolidated sand and silt subsoil layers. Geodeformation wave processes, accompanying the seismic activity, make a considerable contribution to the destruction of the absorbed material with a water/gas composition. This expands the capillaries in the waste mantle and leads to the discharge of fluids into the atmosphere. Similar processes had been studied in many oil exploration areas.

The ending of the griffon activity as the seismic shocks weaken is explained by the reduced pressure of the confined ground water. Certain analogies with geysers can be drawn where water eruptions also cease with the reduction of underground water pressure.

4. Other earthquake effects

Earthquakes are accompanied by atmospheric phenomena, such as dust emissions. They were particularly spectacular during the Gobi-Altai earthquakes and much less evident at the time of the earthquake in the Southern Russian Altai. Some observers only reported a specific pattern of clouds, which cannot be ruled out even though the authors did not observe it. It is worth noting here that South American Indians believe that long awaited rain falls after earthquakes (Vavilov 1987). According to another view the order of these processes may be the reverse, i.e. changes in the atmospheric circulation may cause earthquakes (Bokov 2003).

In that connection there is an interesting view of Morozova (2003) on the relationship between the lithospheric and atmospheric processes. Her analysis of strong earthquakes on the Kamchatka Peninsula and the Japanese Island of Honshu showed that large numbers of linear cloud anomalies occurred along tectonic rifts close to the epicentre shortly (several hours) before an upcoming earthquake. Similar anomalies were recorded near the North Chuyski mountain range at 15:00 hrs local time on 10 October 2003, i.e. before the seismic tremors of the 15 October. The anomalies looked like a “layered cake” (Photo 4) along the tectonic rift that would experience the strong seismic shocks.

Earthquakes also involve interesting acoustic phenomena in the form of noise. They were reported in the Southern Russian Altai and the noise intensity was correlated with the energy of the shocks.

During earthquakes, there is undoubtedly a mass-scale energy connection between geospheres. This is why particular attention should be paid to the rhythm and dynamics of transformations during earthquakes. Based on the data collected so far a conclusion may be drawn that the issue of the energy connection between geospheres during earthquakes is key to understanding the direction in which seismic events are about to develop. Vartanyan (1999) expressed this view most explicitly in his studies on hydrogeodynamic fields that underwent specific deformations immediately before earthquakes. Statements by Rudakov and Voytov (1999) on regrouping of radon emanations stand very close to the view of Vartanyan.

It is time to move from conventional earthquake research methods dealing mostly with lithogenic phenomena to an integrated approach to research of complex impacts on various systems of nature.

5. Conclusions

The study provided new and original results on a rare phenomenon of a natural disaster involving tremors of the Earth's crust producing an earthquake with an intensity of 9-10 degrees. The impacts of this earthquake on the surface morphology were identified and other effects were documented, such as underground water eruptions from palsas with accompanying noise and dust emissions, as well as the development of cloud patterns that might be used to forecast catastrophic seismic events.

Acknowledgements

The study was carried out with financial support from the Russian Universities Programme (grant UR 08.01.001).

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