RECENT MASS MOVEMENTS IN SLOVENIA

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Since 1998, Slovenia has witnessed major mass movements caused by extreme precipitation (landslides, debris flows) and earthquakes (rockfalls).

Around 8,000 landslides are active (0.4/km^2) in Slovenia, which is more than the number of settlements in Slovenia. However, barely a quarter of these landslides present a threat to infrastructure and buildings.

The largest known mass movement is the prehistoric Kuntri rockfall on the south slope of Mount Polovnik in the Julian Alps, which totals almost 200,000,000 m^3 (Zorn 2002).

In the past, settlements were built on »safe« areas and potentially »dangerous« areas were only used for extensive activities, but as man's relationship with nature changed, his knowledge of mass movements was mostly lost. Due to human encroachments in higher areas, mass movements and man's interests often collide (Komac and Zorn 2002a).

Table 1: Potential landslide and rockfall source areas in Slovenia.

	Area [km^2]	Percentage of total surface
Potential landslide source areas	1,214.2	6.0
Potential rockfall source areas	699.9	3.5

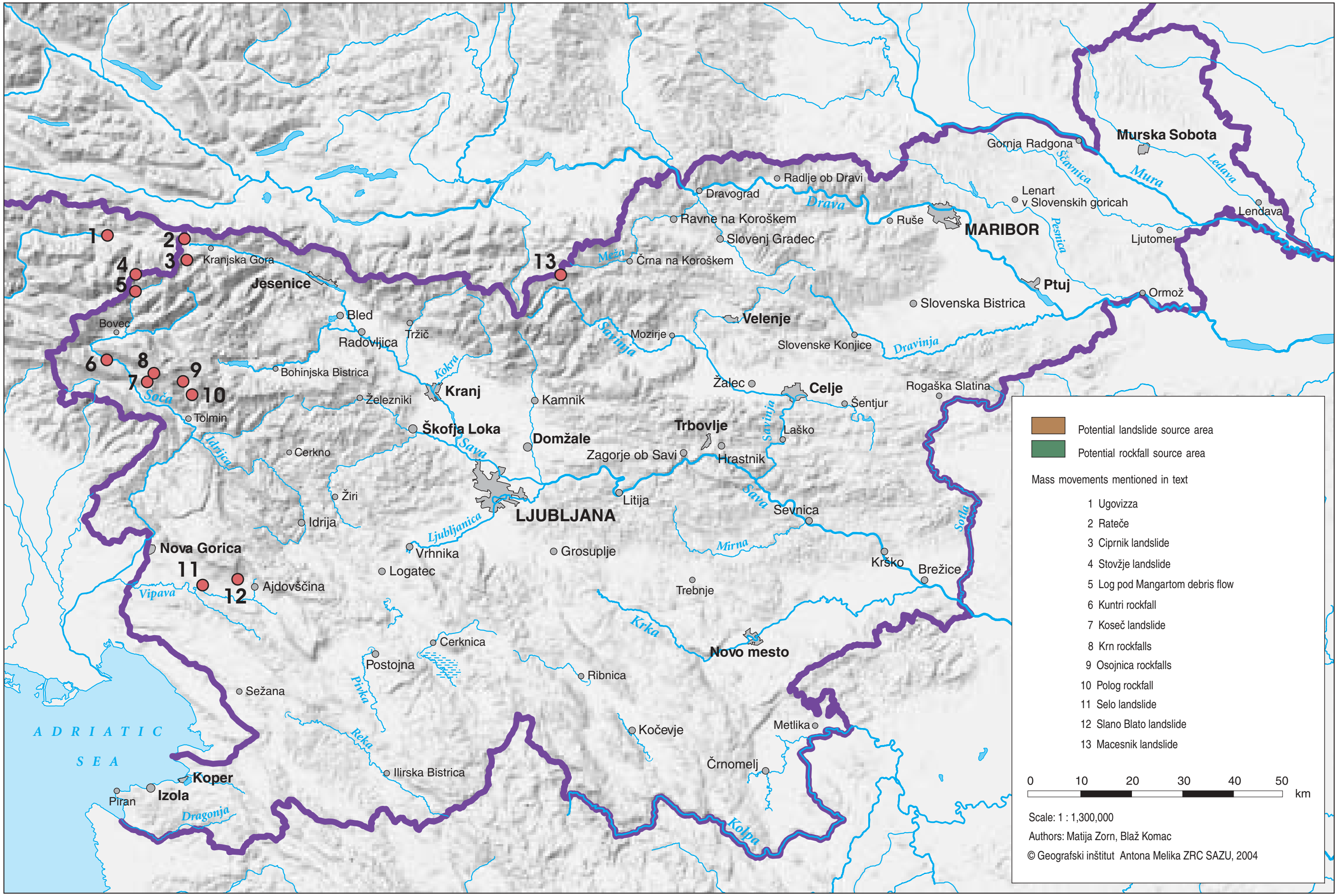
Recent mass movements

Macesnik landslide in the upper Savinja Valley

After extremely heavy rains, many landslides were triggered in the upper Savinja Valley in 1990. Due to the rise of the groundwater and the intensive clearing of forest thirty years earlier, the 2,200-meter long and 100-meter wide Macesnik landslide (2,000,000 m^3) occurred at the contact of limestone and dolomite with the slate claystone lying beneath. Between 1994 and 2000, the landslide moved 850 meters (0.3 meters/day) and then an outcropping of limestone stopped its progress. After it overcomes this rock barrier, its movement could accelerate and the landslide could reach the hamlet below which the valley narrows into a torrent. The houses beneath the landslide and the village of Solčava with its 241 inhabitants are under threat. Protection measures have not been successful because the landslide occurred on the area of a 350-meter wide and 30-meter deep fossil landslide (Pečnik 2002).

Rockfalls in the upper Soča Valley

Earthquakes at higher elevations ground often trigger mass movements. Many such phenomena are known in Slovenia and the neighbouring regions. Extensive rockfalls and landslides were triggered by the Villach earthquake in Austria on January 25, 1348; the Idrija earthquake on March 26, 1551; the Ljubljana earthquake on April 14, 1895; the Litija earthquake on May 19, 1963; earthquakes in


Potential landslide source area
Potential rockfall source area
Mass movements mentioned in text
1 Ugovizza
2 Rateče
3 Ciprnik landslide
4 Stovžje landslide
5 Log pod Mangartom debris flow
6 Kuntri rockfall
7 Koseč landslide
8 Krn rockfalls
9 Osojnica rockfalls
10 Polog rockfall
11 Selo landslide
12 Slano Blato landslide
13 Macesnik landslide
0 10 20 30 40 50 km
Scale: 1 : 1,300,000
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Murska Sobota
Gornja Radgona
Lenart v Slovenskih goricah
Lendava
Ljutomer
MARIBOR
Ruše
Radlje ob Dravi
Dravograd
Ravne na Koroškem
Slovenj Gradec
Črna na Koroškem
Ptuj
Ormož
Slovenska Bistrica
Velenje
Slovenske Konjice
Mozirje
Žalec
Celje
Šentjur
Rogaška Slatina
Laško
Trbovlje
Hrastnik
Zagorje ob Savi
Sevnica
Krško
Brežice
Litija
LJUBLJANA
Domžale
Kamnik
Kranj
Škofja Loka
Tržič
Bled
Radovljica
Jesenice
Kranjska Gora
Bovec
Bohinjska Bistrica
Železniki
Tolmin
Cerkno
Žiri
Idrija
Nova Gorica
Ajdovščina
Vrhnika
Logatec
Grosuplje
Trebnje
Novo mesto
Cerknica
Postojna
Ribnica
Sežana
Kočevje
Metlika
Črnomelj
Ilirska Bistrica
Koper
Izola
Piran
ADRIATIC SEA
Mura
Ščavnica
Ledava
Drava
Pesnica
Dravinja
Meža
Savinja
Sava
Kokra
Soča
Idrijca
Ljubljanica
Mirna
Sotla
Krka
Vipava
Pivka
Reka
Dragonja
Kolpa

◄ *Figure 1: Potential landslide and rockfall source areas in Slovenia.*

Kozjansko on June 20, 1974; and the Friuli earthquake in Italy on May 6, 1976. The appearance of the landscape was also changed by the earthquake in the upper Soča Valley on April 12, 1998 (M: 5.8; I: VII–VIII EMS), which had its hypocenter at a depth of eight kilometers and triggered more than one hundred rockfalls of various sizes. Several million cubic meters of material were moved (Ribičič and Vidrih 1998).

The rockfalls occurred in uninhabited and hard to reach areas several hundred meters above the bottoms of valleys. Their number increased with their relative altitude because the horizontal acceleration and amplitude of seismic waves increase with altitude. The rockfalls did not affect people but only caused some damage to mountain pastures and mountain trails. The largest rockfalls occurred in the southwestern wall of Mount Krn (2,244 m), where rockfall material was deposited over fifteen hectares, and on Mount Osojnica above the valley of the Tolminka River (30 hectares; Natek et al. 2003).

Stovžje and Ciprnik landslides, and the debris flow in Log pod Mangartom

A landslide (2,500,000 m^3) was triggered west of Mount Mangart (2,679 m) on November 15, 2000, between 1,340 and 1,580 meters above sea level that stopped in the valley of the Mangartski potok stream. Due to the abundance of water it carried with it, a debris flow occurred on November 17, 2000, that took seven lives and destroyed several houses and outbuildings in Log pod Mangartom. New houses were built for the stricken inhabitants, and the construction of safety barriers above the village is planned because the material remaining in the slide area is not stable.

Figure 2: Rockfalls on Mount Krn (photography Matija Zorn).

Figure 3: Fan of the debris flow in Log pod Mangartom (photography Blaž Komac).

Figure 4: The Stovžje landslide on the left and the alluvial fan of the debris flow in Log pod Mangartom on the right with Mount Mangart in the middle (photography Matija Zorn).

On the night of November 18, 2000, a landslide (60,000 m^3) was triggered on the west slope of Mount Ciprnik (1,745 m) that partially changed into a debris flow and destroyed the forest and part of the road through the Planica Valley lying 600 meters lower.

In both cases, the main cause of sliding was the Tamar rock formation (alternating layers of sandstone, claystone, limestone, and dolomite) or its weathered debris (clay minerals) that swells when soaked. The parallel incidence of the rock layers also contributed to the movement.

Heavy precipitation triggered both slides. In November 2000, 1,234 mm of rain (50% of the annual average) fell in Log pod Mangartom. Debris flows of larger dimensions occurred in the vicinity of Bovec and in the Planica Valley in the Pleistocene. In the historical period, place names and historical sources mentioning similar events 300 and 110 years ago also reveal their occurrence (Zorn and Komac 2002).

Slano Blato landslide in the Vipava Valley

A landslide caused by abundant precipitation occurred in the valley of the Grajšček stream above the village of Lokavec near Ajdovščina on November 18, 2000. The kilometer long and 280-meter wide landslide at 330–630 meters above sea level affected twenty-five hectares of flysch rock and slope rubble covered with forest and meadow vegetation. The highest velocity of the slide was 90 meters/day.

The landslide lies below the thrust of carbonate rock of Trnovski gozd on the flysch of the Vipava Valley. Along the thrust, the rock is damaged and broken and therefore subject to weathering. On the slopes, a several dozen meter deep talus of slope rubble developed that is additionally labile due to the numerous abundant springs at the thrust contact. Landslides occurred here 200 and 100 years ago, and in the immediate vicinity near Selo there is an enormous (100,000,000 m^3) Pleistocene landslide (Kovač and Kočevar 2001; Popit and Košir 2003).

Mass movements above the village of Koseč in the upper Soča Valley

Above the village of Koseč, fissures developed on the slope during the earthquake on April 12, 1998, into which water flowed. Later, steps up to one meter high formed, alongside which one-decimeter horizontal shifts occurred until one of the larger landslides in Slovenia (675,000 m^3) was triggered on December 22, 2001. It lies 130 meters above the village and moves at 1.2 meters per month. Rockfalls occur on the steep slope above the landslide, and after heavier precipitation, smaller debris flows (1,000 m^3) travel down the course of the Brsnik and Ročica streams to the valley (Komac and Zorn 2002c).

The main causes are the fractured and unstable rock and the water that seeps out at the contact between Lower Cretaceous flysch and *scaglia* (plate limestone and marl) during rains.

Mass movements endanger Koseč and its 61 residents and Ladra and its 153 residents. Moving the inhabitants of six houses in the endangered area is foreseen. A map of the influence area of the Koseč landslide and a map of the potential threat from major mass movements for the wider area of Kobarid have been elaborated. In the vicinity of Koseč, more sliding occurred on April 18, 1994, when a 50-meter long landslide covered a road (Pavšek 1994; Natek et al. 2003; Ribičič and Hočevar 2003).

Torrential alluvia in Rateče and Ugovizza

At the end of August in 2003, the tri-border area between Italy, Austria, and Slovenia was struck by a major storm. In the last three days of August, 274 mm of precipitation fell in Rateče, considerably more than the August average (158 mm). Due to the large water discharge (0.7 m^3/km^2/s), the Trebiža brook threatened to destroy houses in Rateče and deposited debris and mud beneath the village. A similar occurrence in 1885 covered twelve hectares of cultivated fields and meadows.

In August of 2003, torrential alluvia blocked traffic on the Vršič and Predel passes and covered the road between Jesenice and Rateče. Austrian Carinthia and Italy's Valcanale Valley were affected as more than 400 millimeters of precipitation fell, destroying the road in thirteen places and cutting the Udine–Villach railway line. Fourteen days before the 100th anniversary of a similar event that is remembered by the street name »*Via 13. Settembre 1903 alluvione*,« the Ugovizza stream covered the western part of the town of Ugovizza. Two people died, and more than three hundred fled their homes. Sources from the end of the 18th century also describe the dangerous nature of the Ugovizza stream.

Rockfall near Polog in the Tolminka River valley

After abundant April precipitation, a rockfall composed of Cretaceous flysch with alternating layers of marl, sandstone, calcarenite, and limestone breccia was triggered on May 5, 2004, near Polog in the valley of the Tolminka River.

The rockfall source and influence area is 600 meters wide and 450 meters long. The rockfall swept away twenty hectares of forest but does not present a direct threat to settlements or infrastructure. In two places, it filled the Tolminka stream, which rose by ten meters in two 200-meter-long lakes behind the dams.

Conclusion

The mass movements described above are very large ones. The four large landslides together total six million cubic meters, about 1.5 tons of material for each resident of Slovenia.

Other landslides are smaller. The average volume of 225 landslides of known size is 28,000 m^3 and their average area is 0.7 hectare. Together these landslides total 3.2 m^3 of material per capita and their surface is 0.8 m^2 per capita.

Figure 5: Wedge-shaped rockslide in the Lepena Valley triggered by the earthquake on April 12, 1998 (photography Matija Zorn).

Table 2: Most important parameters of major landslides in Slovenia.

Landslide	Koseč	Slano Blato	Stovžje	Macesnik
Area [ha]	10	20	25	19
Thickness [m]	10	10	10	10–14
Length [m]	600	1,100	900	2,200
Width [m]	to 150	to 200	to 400	to 100
Altitude [m]	730–1,200	360–660	1,340–1,580	800–1,350
Volume [m^3]	675,000	1,000,000	2,500,000	2,000,000
Volume per resident of Slovenia [m^3/capita]	0.3	0.5	1.3	1.5
Beginning of processes	22. 12. 2001	18. 11. 2000	15. 11. 2000	November 1990
Current state	active	active	temporarily stable	active

Table 3: Basic characteristics of 225 landslides of known size in Slovenia.

parameters	average
length (m)	128
width (m)	55
depth (m)	4
area (ha)	0.7
volume (m^3)	28,160

The geomorphic processes described here are natural processes that cannot be stopped, and therefore appropriate adaptation is often the major limiting factor for urban and economic development. In higher regions, usable space is limited to just the edges of the valleys because other areas are threatened. From the perspective of geomorphic events, the phenomena we have witnessed in Slovenia in recent years are neither rare nor special. While alluvial fans, for example, seem to be »most suitable« places for building, we keep forgetting that they originated from the same exceptional geomorphic phenomena as those described above (Natek 2003).

Not taking acquired experience or the actual threat to individual areas into account can have devastating consequences, and therefore the inclusion of potentially threatened areas in the Strategy of Spatial Development of Slovenia (2003) was necessary. With the implementation of legislation and regulations, we can hope for better spatial planning in the future, but we still need a detailed analysis of the potential threat from mass movements to built-up and populated areas.

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