Application of the radar interferometry for the landslide detection in Slovenia

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Introduction

Many areas in the world are known to be affected by slow gravitational soil movements, called soil creep and several are situated in Slovenia. As creeping is one of the pre-failure processes in landsliding, monitoring and analysis of creeping slopes is crucial when planning any remediation measures or even detecting more obscure slope movements. Although soil creep causes steadily increasing damage to buildings and infrastructure in the long term, it receives less attention from the media and decision makers than landsliding and is also harder to detect. Among the remote sensing monitoring techniques radar interferometry is one of the most promising tools that provide valuable data for mapping, monitoring and updating regional landslide inventories. Various upgrades of radar interferometry technique, including Persistent Scattering radar Interferometry (PSI, Figure 1), enable monitoring and in particular identifying slope instability worldwide. PSI allows us to detect the stability/instability for very large areas with a millimetre precision and the possibility of reviewing historical events dating back to 1992 when interferometry data acquisition began. This method provides high value data in areas where other techniques (e.g. optical remote sensing techniques) for monitoring the instability fail. PSI is often used complementary with other techniques (e.g. ground control points). In the field of engineering geology the use of radar interferometry method also has great potential, especially as its ability to accurately measure the movements in range of mm opens new domains of effective expertise implementation. In Slovenia, PSI campaigns have been used to detect slope mass movements in the Škofjeloško-Cerkljansko area, the area surrounding Maribor and Ljubljana and in Potoška planina (Figure 3). Displacement rates over the first three areas have been obtained by natural point targets, referred to as persistent scatterers (PSs, Figure 6), such as buildings, antennas, bridges, urban structures or stable natural outcrops, while deformation rates in Potoška planina have been monitored by artificial scatterers in a form of compact active transponders (CATs, Figure 7). Historical SAR images were acquired from ESA, ERS-1, ERS-2 and Envisat that operated in C-band with a wavelength of 5.6 cm.

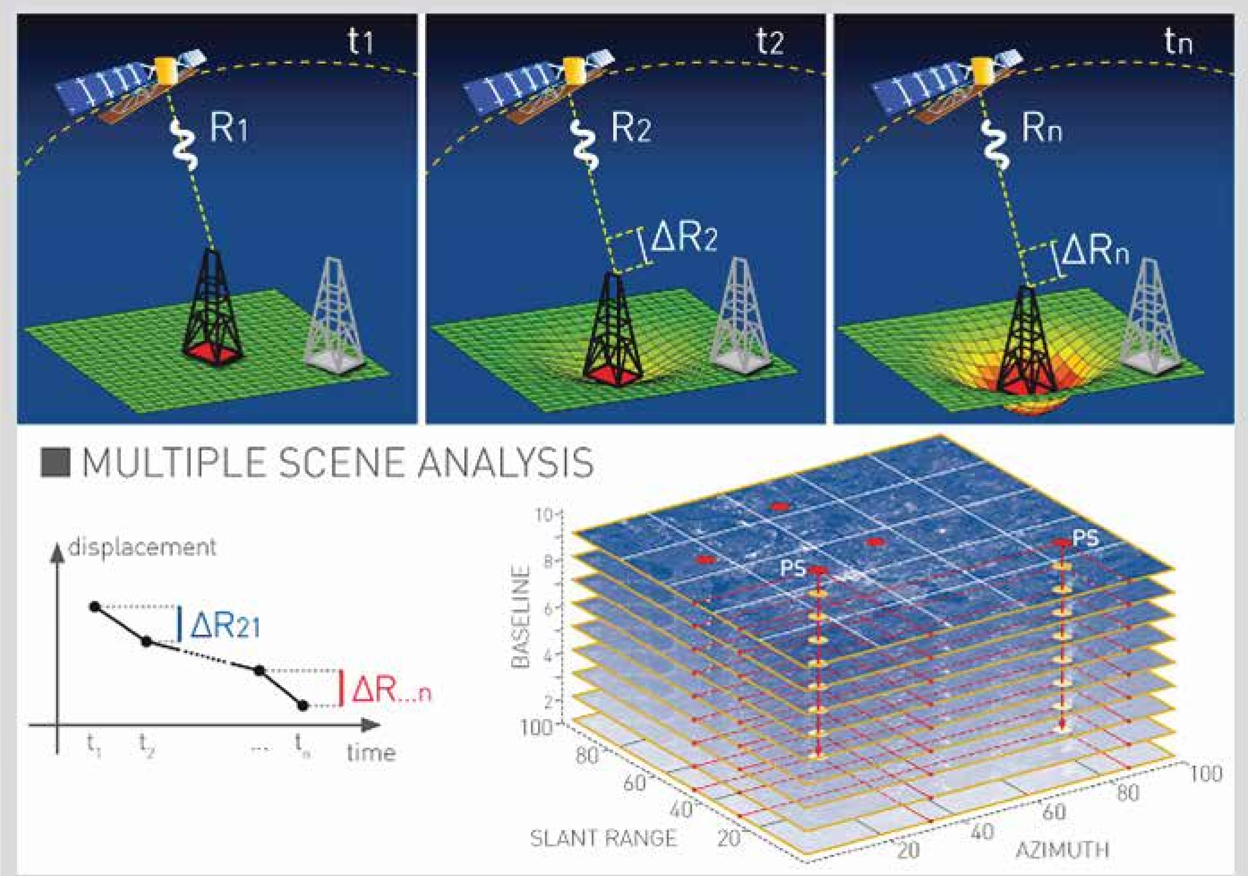

Figure 1: PSInSAR processing schematic

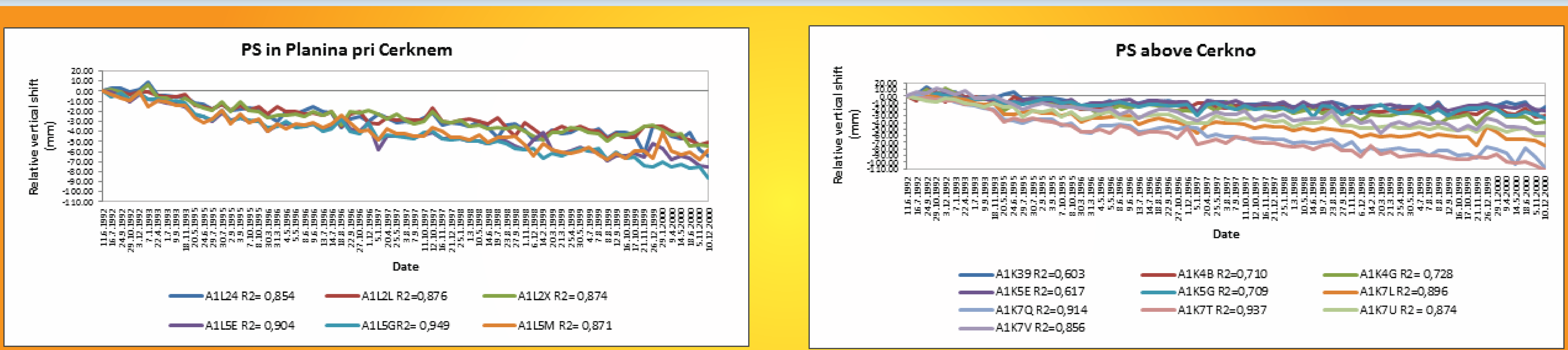

Figure 2: PS movements in locations Planina pri Cerknem and Cerkno area

Škofjeloško-Cerkljansko area

The results of the PSI survey in the Škofjeloško-Cerkljansko area show that the PSI method is suitable for assessing the temporal evolution of slow and extremely slow landslides with constant deformation velocities, hereafter called the soil creep. Due to the high PS density in some smaller areas within the broader study area it was possible to identify three areas with a constant deformation (area above Cerkno, Planina (Figure 2) and Čeplez (Figure 4)). In those areas, the analysis of average annual creeping rates revealed that lithology and slope inclination are among the key precondition factors for the occurrence of the slope creeping process.

Ljubljana and Maribor areas

The PSI revealed unstable slopes in the vicinity of Maribor and Ljubljana as well, but to smaller extents. Due to the ability of PSI methods to monitor the deformations in time, the assessment was made regarding possible climatic triggering factors, especially rainfall events. The results show that soil creep is induced not only by heavy precipitation events (>100 mm/day), but also by less intense precipitation (>20 mm/day), or cummulative 50 mm of rainfall over a period of three days. First event produced 0.4-0.76 mm of elevation change, and events with higher precipitation the average elevation decrease of -1.2 mm.

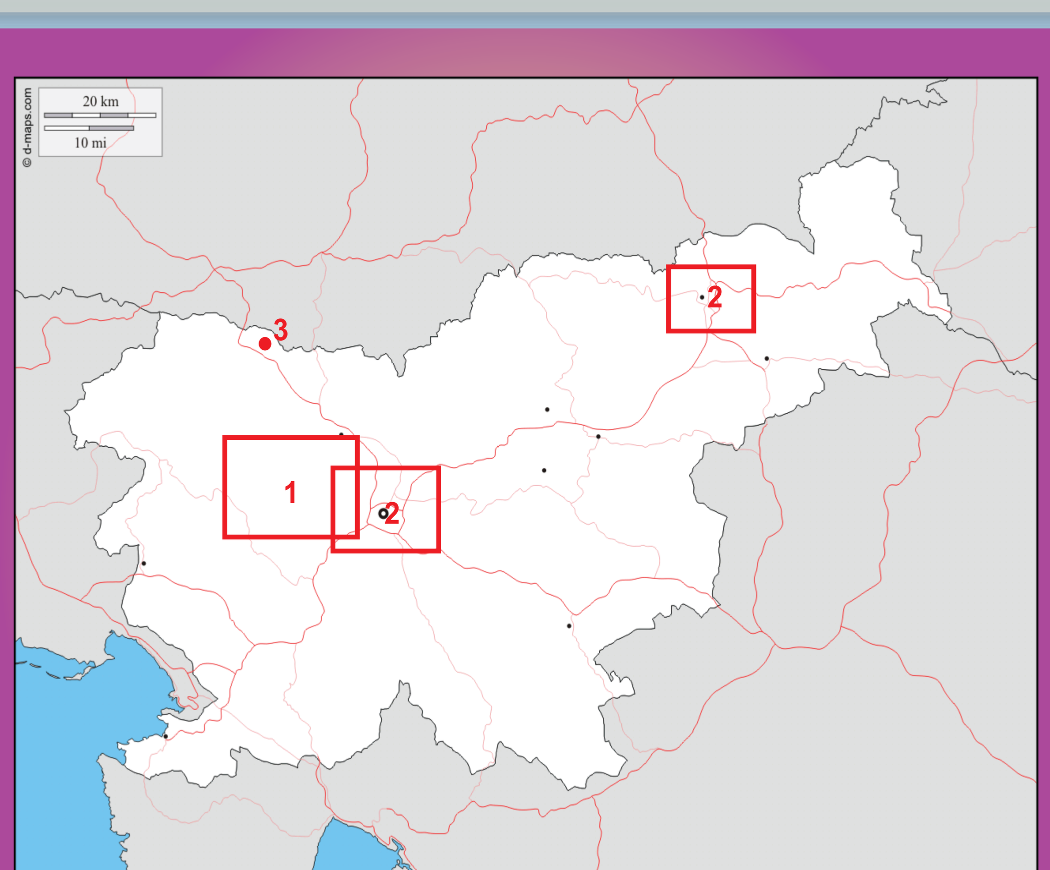

Figure 3: Locations of the study areas 1: Škofjeloško-Cerkljansko area; 2: Ljubljana and Maribor areas; 3: Potoška planina

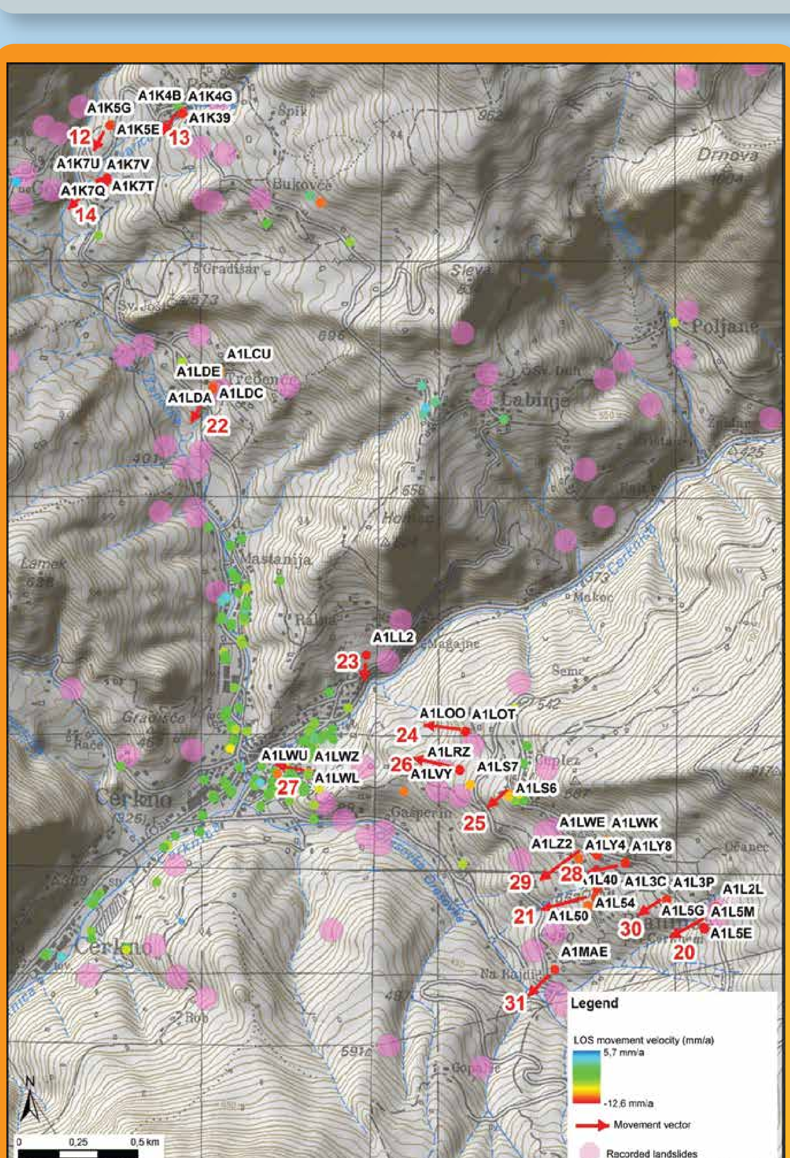

Figure 4: Landslide inventory and PS locations in Čeplez area

Potoška planina

In the case of Potoška planina (Figure 8) a field trial was set up to test a novel device that was developed in the frame of European Union funded project "Integrated Interferometry and GNSS for Precision Survey (I2GPS)" found by Seventh Framework programme (FP7-GALILEO-2008-GSA-1). The device (Figure 7) combines a Compact Active Transponder (CAT) and a Global Navigation Satellite System (GNSS) antenna and therefore integrates InSAR with global navigation satellite system (GNSS). This approach provided 3D displacement assessments of the monitored locations on the landslide and its vicinity. InSAR and GNSS results for the monitoring period (02/2011 – 08/2011) showed relatively large (up to 32 mm horizontal and up to 15 mm) vertical displacements, indicating a displacements of the central-upper and south-eastern parts of the landslide body.

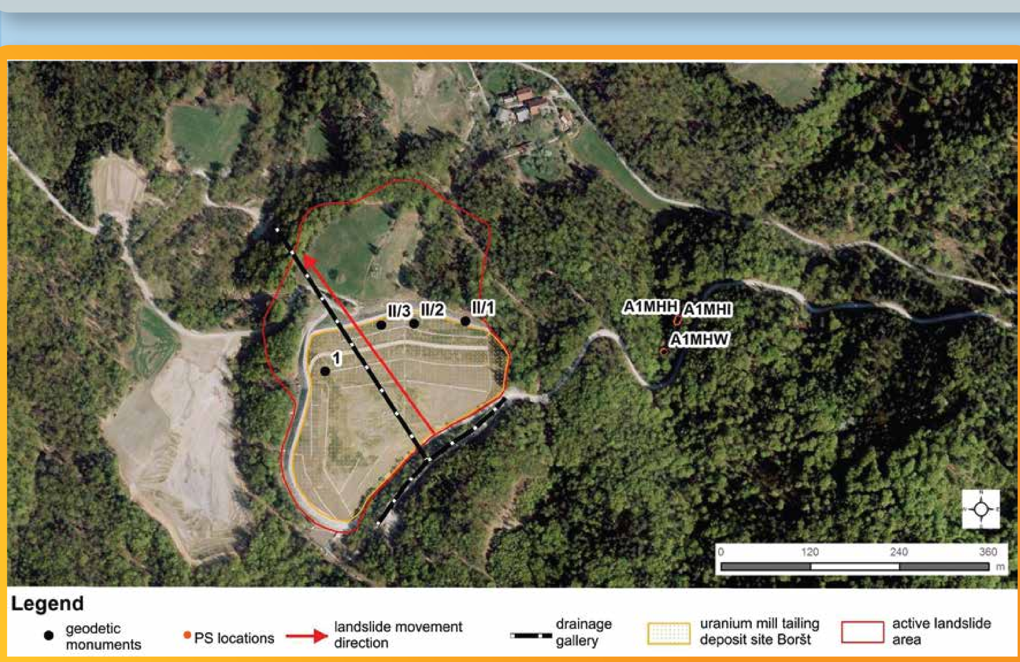

Figure 5: Landslide at uranium mill tailing deposit site Boršt

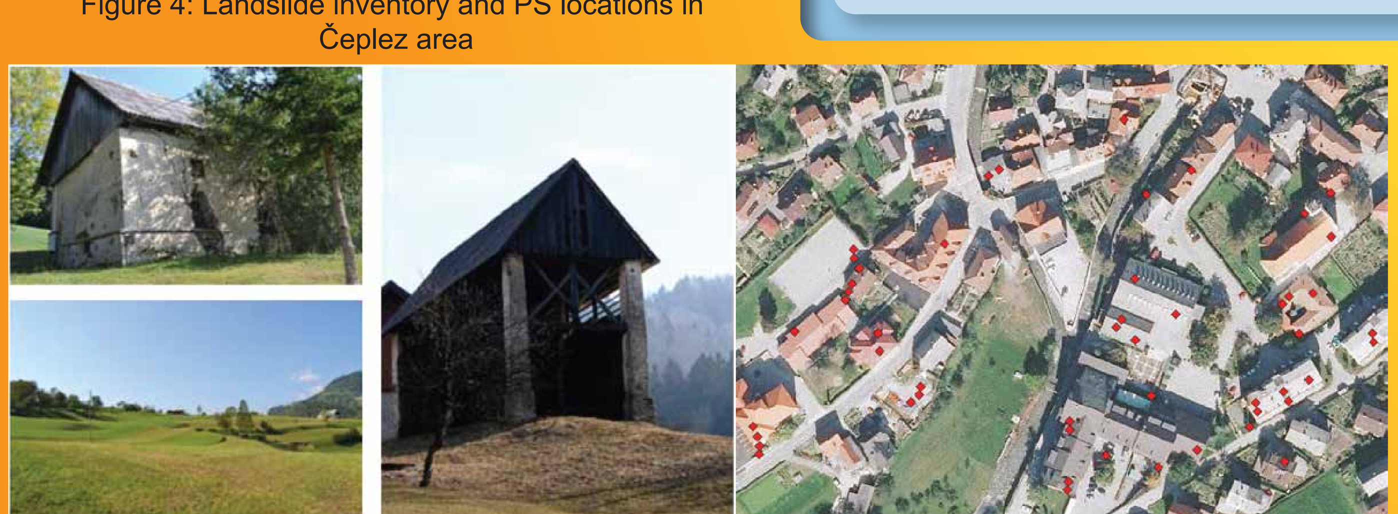

Figure 6: PS location examples in the Škofjeloško-Cerkljansko area

Figure 7: I2GPS instrument, a combination of GPS and CAT, installed on Potoška planina

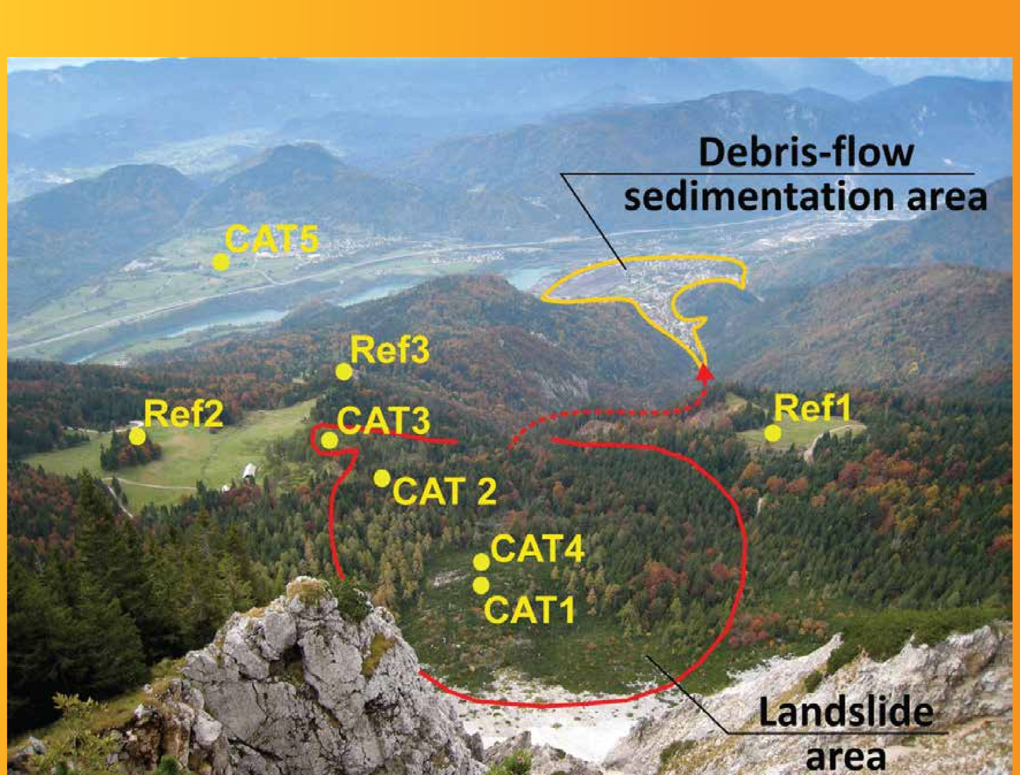

Figure 8: Potoška planina landslide and CAT instrument locations

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