WLF4 Poster Proceedings

P1. The erosive power of rainfall

Neil Bar, Mark Reynolds

Abstract: The erosive power of rainfall has shaped our planet for millions of years. In Papua New Guinea, it is possible to see such changes in a relatively short timeframe. High volumes of rainfall in different environments induce numerous landslides across the country in both natural and constructed slopes.

P2. The updated scenario in Europe of Landslide susceptibility Vs UNESCO Cultural heritage: the PROTHEGO project

Carla Iadanza, Gabriele Leoni, Claudio Margottini, Daniele Spizzichino, Alessandro Trigila

Abstract: The present paper describes a specific research performed in the framework of the PROTHEGO project "PROTection of European Cultural HEritage from GeO-hazards" a collaborative research project funded in the framework of the Joint Programming Initiative on Cultural Heritage and Global Change (JPICH) in the Seventh Framework Programme (FP7) of the European Commission. The project (www.prothego.eu) will make an innovative contribution towards the analysis of geo-hazards in areas of cultural heritage in Europe. The aim of the project is to develop and validate an innovative multi-scale methodology for the detection and monitoring of European Cultural Heritages exposed to natural hazards, namely monuments and sites potentially unstable due to landslides, subsidence, ground settlement, as well as monument deformation. By applying this methodology to the UNESCO world heritage sites in geographical Europe (399 sites), and by integrating these data with existing landslide databases, PROTHEGO project will identify and rank the most critical cultural heritage sites over the entirety of Europe. A clear and update picture of the most endangered WHL sites at European level is carried out as useful tools for any kind of conservation and management plans as well as future conservation policies.

P3. A new method evaluating the 3D roughness of discontinuity surface in rock mass (Forun Theme 3)

Yi Cai, Huiming Tang, Tao Wen

Abstract: The surface roughness of rock mass discontinuity (RMD) has a strong influence on the mechanical properties and behaviour of rock mass, which can affect the rocky landslide stability. In order to obtain the evaluation index with a clear geometric meaning, the PAP (Projection Area Percent) was put forward as a new evaluation index, which was associated with the shear failure mechanism of the RMD. Based on the 3D laser scanning technology and the Matlab programming, the 3D geometric model of the RMD was built and PAP was calculated. Via an engineering example, the process and effect of PAP computation were presented and studied.

P4. Rockfall hazard mitigation using ditch charts modeled with CRSP-3D (part of session 3.3)

Jorge Yepes, Candida Garcia-Gonzalez, Miguel A. Franesqui

Abstract: Rockfalls on roadways are a serious hazard to users. Many resources are invested in rock slope maintenance and measures of stabilization and protection to mitigate the risk.

Catchment areas (ditches) are one of the least expensive and most effective protective measures to contain and restrict rockfall onto roadways. While their effectiveness depends directly on their design criteria, previous studies have mainly been limited and based on empirical studies. Ritchie (1963) drew up the first design charts and tables, establishing the impact distance of a rockfall as a function of the slope height and steepness. Though his work is still accepted, it has some significant limitations: his design relies on such a deep, steeply sloped ditch that it reduces road safety, restricts the slope geometry and complicates the maintenance of these catchment areas. Pierson et al. (2001) created new graphic charts based on real rockfall tests carried out on different slope-ditch arrangements, but their research presents certain drawbacks: the examined situations are limited to a specific type of material, shape and possible rock size, the dimensions proposed to obtain certain percentages of rockfall retention are very large and, in most cases, the costs are unreasonably high.

This present research complements previous studies by using a CRSP 3D computer simulation model (Colorado DoT, USA) and analyzing a wider number of slope-ditch arrangements and input parameters: (A) 5 talus heights, 5 slope gradients and V-ditches with 3 foreslopes. The highest slopes (≥18m) have an intermediate 1 m bench at 12 m height. (B) Different kinds of materials are handled: 4 bedrock lithologies, two of them for the slope (hard rock and soft rock), one for the ditch (concrete) and the other for the road pavement (asphalt). The properties of these materials (density, elasticity, roughness) have been established according to the CRSP 3D methodology and adapted to previous empirical knowledge of each material. (C) A wide array of blocks was studied considering various possible combinations of geometries (cube, cylinder, sphere) and sizes (0.31, 0.62 and 0.94 m). A total number of 270 different cases for hard rock and 180 for soft rock have been evaluated. (D) Rocks are released randomly (along the whole slope) and the initial velocity is zero.

As a result of the numerical analysis, a set of practitioner-friendly charts were drawn up, not only for infrastructure planning and design tasks, but also to evaluate existing catchment area effectiveness and to reduce rockfall hazard. The proposed design charts offer an estimation of the dimensions required for the ditch, depending on the relation between the optimal stop distance and the cumulative percentage retained along the trajectory, satisfying specific retention requirements (95%).

P5. Analysis of the rockfall stop-distance factors with CRSP-3D in volcanic talus (part of session 3.3)

Jorge Yepes, Candida Garcia-Gonzalez, Miguel A. Franesqui

Abstract: The costs associated with rockfall risk are high. Many resources are invested in rock slope maintenance and stabilization, and protection measures to reduce rockfall hazards on transport infrastructures. However, few studies aim to evaluate the relative influence of the different factors (geometrical and material properties) affecting falling rock trajectories and the efficiency (retention capacity) of catchment areas. Numerous factors influence both the characteristics of rockfall motion, and their impact and stop-distance. Ritchie's empirical research (1963) was the first to identify these characteristics and determine the expected impact distance of rockfalls depending on slope geometry. Later studies showed that Ritchie's results were not as conservative as previously thought, and also that it was hard to apply his ditches on roadways due to their excessive depth (dangerous for vehicles) and width (expensive construction and maintenance). The Ritchie ditch has therefore been improved by computer simulation programs, and the proposed use of concrete walls or fences at the edge of the road. Optimization of the catchment area geometry requires systematic and quantitative analysis of the effect of each factor on rock stop-distance through application of a simulation model. With this aim, this study applies a CRSP 3D computer simulation model (Colorado DoT, USA) considering 75 different configurations of slope-ditch geometries, 4 types of materials and 9 size and shape combinations of falling rocks. In all we examined 270 different cases for hard rock and 180 for soft rock. A statistical analysis was performed with the simulated rock stop-distances to assess the different variables affecting rockfall motion.

P6. Risk analysis of debris flow on public expressway in Korea using GIS

Beom-Jun Kim, Kyung-Suk Kim, Chan-Young Yune, Sang-Don Lee

Abstract: The prediction of debris flow hazard is difficult because of complicated triggering and flowing mechanism of debris flow. Especially, debris flows occurring around expressway should be treated with extra caution because it can produce severe damage to high-speed cars and drivers inside. Also the blocking of expressway for several hours can additionally cause substantial indirect cost. For the effective prevention of debris flow hazard on expressway, potential basin areas vulnerable to debris flow need to be selected and a quantitative risk assessment should be conducted for those basin areas beforehand. In this study, the risk assessment of debris flow on 3,062 sites (2,454km) of public expressway was conducted by the risk evaluation method suggested by Korea Expressway Corporation. Based on the risk assessment, basin characteristics of high and low risk areas around expressway were analyzed. Analysis results showed that the basin area at 958 sites (31%) out of total 3,062 sites were at high risk for debris flow. And they have a higher inclination than low risk area for both basin and stream channel.

P7. LANDSLIDE STABILIZATION BY INNOVATIVE ELECTROPNEUMATIC DRAIN® SYSTEM (Forum Theme 3)

Youssef Chahid, Sebastien Bomont, Alessio de Melas

Abstract: The Electropneumatic Drain® is an annotative technique in deep drainage developed by our company TPGEO, mainly to stabilize landslides by pumping the underground water within vertical wells reaching all the aquifer to treat. The system manages ground water lowering up to 40 m, at flows of 0 – 1.0 l/s per well and permeability of 10-5 – 10-7 m/s.

P8. Landslide displacement prediction using the GA-LSSVM model and time series analysis: a case study of Three Gorges Reservoir, China (Forum Theme 4)

Tao Wen, Huiming Tang, Yi Cai

Abstract: Predicting landslide displacement is challenging, but accurate predictions can prevent casualties and economic losses. Many factors can affect the deformation of a landslide, including the geological conditions, rainfall, and reservoir water level. Time series analysis was used to decompose the cumulative displacement of landslide into a trend component and a periodic component. Then the least squares support vector machine (LSSVM) model and genetic algorithm (GA) were used to predict landslide displacement, and we selected a representative landslide with step-like deformation as a case study. The trend component displacement, which is associated with the geological conditions, was predicted using a polynomial function, and the periodic component displacement which is associated with external environmental factors, was predicted using the GA-LSSVM model. Furthermore, based on a comparison of the results of the GA-LSSVM model and those of other models, the GA-LSSVM model was superior to other models in predicting landslide displacement, with the smallest root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE). The results of the case study suggest that the model can provide good consistency between measured displacement and predicted displacement, and periodic displacement exhibited good agreement with trends in the major influencing factors.

P9. Debris flow in Vrátna dolina Valley: field investigation and the causes of a recent disaster

Róbert Jelínek, Pavel Liščák, Andrej Žilka, Mário Olšavský, Michal Sentpetery, Ivana Pešková

Abstract: On July 21, 2014, after extremely intense rain-storm, an enormous debris flow evolved, fed by tens of small landslides in the uppermost parts of a cirque-shaped valley in Vrátna.

In addition to the field research, airborne laser scanning and photogrammetry were used in order to generate a very precise DMR of the territory with an area of about 4 km^2 affected by this event. The DMR has enabled to elaborate very precise landslide and debris flow map of the area on the updated geological map.

In the geological setting of the area Tatricum and Fatricum rocks are present. The greater part of landslides and their head scarps land were located mainly in the youngest rocks of the Fatricum sequence (Tithonian - Neocomian marly limestone of the Mráznica Fm.) with inclination 25 °- 35 °; in general to the W up to N.

Quaternary sediments are represented by colluvial sediments of varied lithological composition of rocky debris through loamy stone rubble up to deluvial loams. In fact colluvial sediments cover the major part of the area; their thicknesses, however, generally do not exceed 2 m.

Engineering geological conditions of the territory are derived from the geological setting. Formerly it had been postulated that the northern slopes of Chleb represent glacier cirque of fan-shaped form. Baliak et al. (1981) recognized that the northern flank of Chleb Peak is a slope deformation in a form of a rock slide along predisposed stratification planes. The maximum length of rock accumulation is 1400 m (NS), the maximum width of 700 m (EW), the maximum thickness is about 30-50 m.

Altitude difference between the head scarp and toe of the slide is 600 m. In the head scarp two main horseshoe-shaped escarpments have formed. One of them reaches to the Chleb summit and strongly violates its original dome shape. The maximum height of escarpment rock walls is 50 m. Sliding, or collapse of Jurassic limestone rock masses took place along the shale strata of the Carpathian Keuper (Upper Triassic). As in dozens of cases in Mesozoic mountains of Slovakia, the rigid, tectonically broken blocks of Jurassic limestone, lying on a plastic Keuper shale strata, have induced the formation of slow creep deformation, which over time transformed into a large-scale rockslide.

Colluvial deposits are characterized by large lithological variability depending on the basement rock. On marly sediments of the Mráznica Fm. loamy-stony and clayey deluvia are developed. In these deluvial sediments below the ridge of about 1600-1500 m a.s.l. activated debris flows.

The slope movements along the planar slip surface were conditioned by the favourable inclination of bedding/foliation. Within the detachment areas of these landslides of rather small thickness broke away quite small, but numerous "plates" of sliding material (with an area of several hundred m^2), which were generally moving at a speed of several meters per second, preferentially down avalanche chutes, often above strongly wetted vegetation cover (grass, blueberries).

Approximately 800 meters from the lower lift station Vrátna the thickness of a rolling mass of water-rock-earth-trees was measured on upright trees. It seems that the thickness of the flow here achieved up to 2m - at the time of inspection (July 28, 2014) the creek reached a depth of mere 20 cm. A flow of a mixture composed of water-clay-stones continued down the narrow valley. It absorbed also bottom fills, which had accumulated in the previous period. From the tributaries joined similar, although smaller, debris flows. Most of them eroded valleys down to the bedrock. Approximately at a distance of 560 m from the cable car station 2 main debris flows joined together (funnel-like confluence). Moreover from the surrounding slopes there was a mobilization of rocky debris that contributed to the material of the debris flows. In these parts of the area rock falls of fragments and blocks likely occurred. In many trees that remained intact stand are registered fresh incisions on the bark, no doubt due to the impacts of fragments and blocks (at a height of up to 2 m above surface), which also contributed to the material of debris flows.

The total cubic capacity of the displaced material is estimated at a minimum of 100 000 m^3. The toe of the debris flow reached the cable line terminal, which indeed experienced property damage, but without any serious static damage to buildings and poles line.

P10. The difficulty of obtaining field data for landslides, due to its diversification in tropical humid environment, the case of the coast of São Paulo, Brazil

Carolina Perdomo, Estefano Gobbi, Francisco Ladeira

Abstract: Brazil has observed an increase in both frequency and intensity of landslide events. Brazil is a country of great extension, and is divided in 5 regions, South, Southeast, Center-West, North and Northeast, the Southeast region suffers most from the events of landslides, in addition to being the most densely occupied. The study area is located on the coast of the State of São Paulo, which is cut by the Tropic of Capricorn, covering two different municipalities, but which have the same geomorphological and climatic characteristics. The work aims to show how a place that presents the same characteristics of the environment, the soils can be so different. Both in relation to the municipality itself and in relation to the other, the granulometric difference found in the studied profiles is quite significant, showing the difficulty of using data from pedological charts in tropical humid environments with geological diversity, such as the studied area.

P11. Land-cover of landslides in rural commune; the Outer Carpathians, Łososina Dolna commune, Poland

Pawel Kroh

Abstract: Land use of landslides is still a poorly investigated problem. Landslides cannot be regarded as areas unsuitable for use since they occupy a significantly large surface. The Łososina Dolna municipality in the Outer Carpathians is characterized by a very large number of landslides (16% of the total area, about 500 landslides). Land-cover analysis of this agricultural and forest municipality showed a relatively similar structure of land-cover types on areas affected and unaffected by landslides. Six categories of land cover: forest, woodland, agricultural fields, meadows, orchards and built-up areas occupy in total 98% of landslides and 89% of the municipality. On landslides forests had an 11% higher and agricultural fields a 3% lower share in land cover compared to the whole municipality area. The shares of other types of land cover, such as built-up areas, orchards, and shrubs, were very similar, with not more than a 1% difference. This indicates that despite the occurrence of landslides, these areas can still be used for economic purposes, and on sites under extensive management (e.g. meadows and pastures) landslides may cause no land-use changes.

P12. FLOW-LIKE LANDSLIDES VS DEBRIS FLOOD: CASE STUDIES FROM CAMPANIA (SOUTHERN ITALY) (Forum Theme 4)

Antonio Santo, Nicoletta Santangelo, Luciano Picarelli, Melania de Falco, Giovanni Forte

Abstract: The study focused on two peculiar phenomena occurring in the carbonate ridge context, represented by flow-like landslides (namely debris flow, debris avalanche and flowslides sensuHungr et al., 2014) and debris flood events (sensu Hungr et al., 2014).This study is a first attempt to identify and quantify the similarities and the differences for both phenomena, considering the main events occurred in Campania in the last decades (Di Crescenzo & Santo, 2005; Santangelo et al., 2012). Our goal is to point out the main differences in terms of triggering, propagation and depositional phase and more importantly in terms of velocities, impact forces and associated damage. As a consequence, these differences have to be accordingly accounted for the definition of the most appropriate risk mitigation strategies.

P13. Rock avalanche and a rock glacier: a compound landform study from Svalbard

Filip Hartvich, Jan Blahut, Josef Stemberk

Abstract: A study of rock block accumulations situated at the foot of Rotjesfjellet ridge on the northern side of the Hornsund fjord showed that the block accumulations are not always only the widely known post-glaciation period rock glaciers, but that there are other influences on their formation. Detailed study of one particularly unusually shaped block accumulation employed morphometric profiling and terrain analyses, lichenometry, Schmidt hammer measurements, geophysical measurements using electric resisitivity tomography and geodetic measurements using terrestrial LiDAR. While the morphometric analysis of detailed (0,5 m) DEM and relief profiles showed distinctly unusual morphology and suggested possible explanation of the sequence of events. The electric tomography revealed ice core in the accumulation and the Schmidt hammer we were able to establish younger age of the lobe-like left part of accumulation and finally, the lichenometry helped us to place the event on the approximate position on the timescale. In conclusion, we have explained the unusual block accumulation as a result of two consequent processes, as after formation of the rock glacier a large rockfall occured, adding material and deforming the NW part of the accumulation. We estimate the rockfall event to be 250 +/- 50 years old.

P14. Predictive performance of rainfall thresholds for shallow landslides in Switzerland (Forum Theme 3)

Elena Leonarduzzi, Peter Molnar, Brian W. McArdell

Abstract: In Switzerland floods are responsible for most of the damage caused by rainfall-triggered natural hazards (89%), followed by landslides (6%, ca. 520 M Euros) as reported in Hilker et al. (2009) for the period 1972-2007. The prediction of landslide occurrence is particularly challenging because of their wide distribution in space and the complex interdependence of predisposing and triggering factors. The overall goal of our research is to develop an Early Warning System for landsliding in Switzerland based on hydrological modelling and rainfall forecasts. In order to achieve this, we first analyzed rainfall triggering thresholds for landslides from a new gridded daily precipitation dataset (RhiresD, MeteoSwiss) for Switzerland combined with landslide events recorded in the Swiss Damage Database (Hilker et al.,2009). The high-resolution gridded precipitation dataset allows us to collocate rainfall and landslides accurately in space, which is an advantage over many previous studies.

Each of the 1670 landslides in the database in the period 1972-2012 was assigned to the corresponding 2x2 km precipitation cell. For each of these cells, precipitation events were defined as series of consecutive rainy days and the following event parameters were computed: duration (day), maximum and mean daily intensity (mm/day), total rainfall depth (mm) and maximum daily intensity divided by Mean Daily Precipitation (MDP). The events were classified as triggering or non-triggering depending on whether a landslide was recorded in the cell during the event. This classification of observations was compared to predictions based on a threshold for each of the parameters or a combination of them such as in the intensity-duration curve. The predictive power of each parameter and the best threshold value were quantified by ROC analysis and statistics such as AUC and the True Skill Statistic (TSS).

By applying the method to define an intensity duration power law threshold, a maximum TSS of 0.67 was obtained for: intensity = 18.3*duration-0.21.

The analysis was repeated for sub-regions of the country based on erosivity and climate, using MDP and erodibility (Kuehni and Pfiffner, 2001), or a combination thereof, in the classification. While the performance improved only slightly compared to the country-wide analysis, the regional maximum daily intensity thresholds varied greatly among classes, with differences of up to 43 mm/day, showing some clear trends: the amount of precipitation required to initiate a landslide is higher in region with higher MDP and/or lower erodibility.

In order to demonstrate the quality and robustness of the results, we also show reference cases obtained by randomization of landslides in space and time, and resampling the data to equal sample size between triggering and non-triggering events (prevalence).

P15. Dynamic analysis of a landslide in Caucasus

Kai Kang, Oleg Zerkal, Andrey Ponomarev

Abstract: The area of cableway Karusel-1 in western Caucasus is always subjected to landslide hazard. For safety of cableway facilities, stability assessment of the slope at mountain foot was conducted. In addition, the seismic hazard for the studied area is earthquakes with Mmax=7.0 and intensities of up to 9 on the MSK-64 scale. Therefore, the dynamic analysis of the slope is necessary to perform in order to ensure the safety of cableway facilities.

P16. Geological condition of landslides occurrence in the Bardzkie Mountains and adjacent areas (Sudetes, SW Poland)

Rafał Sikora, Tomasz Wojciechowski, Marta Tomaszczyk, Andrzej Piotrowski

Abstract: The Sudetes are a mountain range situated on NE margin of the Bohemian Massif. They form natural border between Poland and Czech Republic. The Sudetes Mountains are poorly recognized in terms of mass movements, however our latest research shows that landslides occur often in this area. One of terrains with large number of landslides is the Bardzkie Mountains and adjacent areas. About 118 landslides were identified based on analyses of LIDAR data and cartographic field works. Geological conditionof landslides susceptibility was determined based on comparison of landslides occurrence and geo-environmental factors of the slopes. The Weight of Evidence (WoE) method was used to analyse the impact of lithology, tectonics, gradient of slopes, exposure of slopes, distance from water courses and flow accumulation. The result of the analysis is a landslide susceptibility map of the Bardzkie Mountains and adjacent areas. Landsides are concentrated in the areasof the prevalence of the Pleistocene sediments and the Upper Devonian and the Lower Carboniferous flysch rocks. Especially fault zones in the basement rocks were an important, structural factor in the landslides development. Mass movements most frequently occur on slopes of the southwestern, western and southeastern exposure and inclined in the range of 9 to 24 degrees. Also vulnerable are areas with significant flow accumulation.Larges landslides susceptibility was found in the major rivers and streams valleys (eg. Nysa Kłodzka, Ścinawka, Wilcza, Jaśnica).Geological and geomorphological factors determined the formation of different types of landslides as confirmed by field observation. All indicators show good relevant to present knowledge relation to landslide susceptibility. The only exception is the factor that describe the distance between faults and landslide scarps. Our calculation shows that the susceptibility increase with the distance from faults which is diffrent from our field study and lineaments analisys. We suppose that this difference is connected with incoherence between archival maps we used in presented study.

P17. Daily to seasonal movement patterns of a large, slow-moving landslide, central North Island, New Zealand

Charlotte Holdsworth, Samuel McColl, Ian Fuller

Abstract: New Zealand has thousands of large (> 2 ha) landslides, most of which occur in the Neogene marine sedimentary cover rocks, and many of which are active. Active landslides in New Zealand damage lifeline infrastructure, entire suburbs, agricultural land, and they deliver large but little-quantified sediment load to rivers. Previous research has indicated that both river incision over decadal to millennial timescales and seasonal rainfall patterns play a role in the initiation, movement, and long-term evolution of large landslides in New Zealand's soft-rock terrain. This research assesses how toe cutting and rainfall on daily to seasonal timescales can drive movement of a large (50 hectare) slow-moving, reactivated, translational rockslide that is severely damaging a farm in central North Island, New Zealand. Geomorphological mapping, informed by field observations and high-resolution topographic data produced by photogrammetry, was undertaken to define the landslide boundary, drainage lines and to assess zones of movements. Since July 2015, 3-monthly RTK GPS-occupations of a network of 29 survey marks, and hourly time-lapse photography of the toe of the landslide have been used to identify the distribution and patterns of landslide movement. Pixel-tracking of time-lapse photos is allowing movement to be measured at a sub-daily frequency. Movement data are being compared with river flow data (i.e. toe cutting potential) and local rainfall. Results so far reveal that block sliding occurs in the upper part of landslide (with graben development, and annual movement < 1 cm), and this transitions to more

mobile earth flow-slide behaviour towards the toe (where annual movements are > 10 m). The failure surface is exposed at the toe, which is being actively cut by a major river, and reveals a highly remoulded landslide body 1-3 metres thick, overlaying intact sandstone. Based on existing structural data and the landslide surface morphology it is assumed that the landslide thickens to about 60 m towards the head. The geomorphology suggests the entire landslide is undergoing extension (with no evidence of toe compression), suggesting near-continuous toe-unloading is facilitating movement. Movement is fastest in the winter-spring months when water tables are high due to reduced evapotranspiration and slightly greater rainfall. However, this period also coincides with a period of higher river flow and flood events (i.e. toe cutting), and the landslide appears to be particularly sensitive (i.e. surges forward) following high river flow events that cut the toe. This observation suggests that movement is driven by both local and catchment-scale rainfall events, with rainfall and toe cutting driving movement, at daily to seasonal time-scales.

P18. The Influence of Hydrological Events and Check Dams upon the Geomorphic Changes of the Meng-Gu Waterfall

Su-Chin Chen, Cheng-Wei Kuo, Feng-Jyi Chang

Abstract: Most studies of waterfalls and focused on erosion process and recession rate. The influences of depositional process upon the form of waterfalls are seldom discussed. Abundant sediment could be the tools and covers to reshape the morphology of waterfalls. The Meng-Gu Waterfall, located in the Central Taiwan, was a beautiful waterfall with two steps. After serious debris flow events, the waterfall experienced huge morphological changes. This study explored the relation between waterfall evolution and sediment disasters.

P19. Field monitoring to measure deformation of a mine waste-dump slope (part of session 3.1)

Young-Suk Song, Yong-Chan Cho

Abstract: This study surveyed and investigated the deformation of the coal waste dump slope and the natural ground slope under the waste dump at Dogye village in Samcheock city, Gangwon Province, Korea. Multiple sets of south-north tension cracks were observed at the crest of the coal waste dump slope. The size of these cracks was greater than 100 m in length, and the resulting drop head averaged 1.0-1.5 m. To investigate the behaviors of the waste dump slope and the natural slope under the waste dump, wire sensors and a rain gauge were installed at the crest of the waste dump slope, and inclinometers were installed in the natural slope of the ground under the waste dump. According to the monitoring results, the deformation at the crest of the waste dump slope steadily increased and then converged over time due to the effect of the infiltration of rain into the ground after rainfall. In addition, the horizontal deformation of the natural slope under the waste dump was affected by the accumulated precipitation. The basis of this effect is that the rate of increase of the maximum horizontal deformation tends to show increasing or convergent behavior according to the precipitation.

P20. Silk Road Disaster Risk Reduction (SiDRR)

Peng Cui, Yu Lei

Abstract: Belt and Road Initiative (BRI) is a Chinese national strategy which calls for cooperative economic, political and cultural exchange at the global level along the ancient Silkroad. The overwhelming natural hazards located along the belt and road bring great challenges to the success of BRI. In this framework, a 5-year international program was launched to address issues related to hazards assessment and disaster risk reduction (DRR). The first workshop of this program was held in Beijing with international experts from over 15 countries. Risk conditions on Belt and Road Countries (BRCs) have been shared and science and technology advancements on DRR have been disseminated during the workshop. Under this program, six task forces have been setup to carry out collaborative research works and three prioritized study areas have been established. This workshop kicked start this program which involved partners from different countries including Pakistan, Nepal, Russian, Italy, UK, Sri Lank and Tajikistan. The program adopted the objectives of Sendai Framework for Disaster Risk Reduction and Sustainable Development Goals and was implemented to assess disaster risk in BRCs and to propose suitable measures for disaster control which can be appropriate both for the individual country and for specific sites.This poster points out current progress and opportunities for the near future international cooperation on this matter.

P21. Stability Analysis of Potential Rock Slides in El Rincón Cliff (GC-2 Highway, Gran Canaria, Spain) (part of session 2.2)

Martín J Rodríguez-Peces, Jorge Yepes, Moises Martin-Betancor

Abstract: In this work we have found landslides that may be developed in El Rincón cliff (Gran Canaria) and its impact on the GC-2 highway, at the base of the cliff. The stability analysis performed for the current conditions indicates that the slope is stable. The long-term analysis considers the water-saturated rock mass and defines the presence of two rocky blocks that are most likely to experience sliding, one along the mid-slope and another in the head. The mid-slope landslide would be favored by failure through the Formación Detrítica de Las Palmas, while the landslide located on the head of slope would have a more superficial

character and would be favored by the failure through the pyroclastics of the Post-Roque Nublo Group. The landslide of the block of the top seems more likely since it only requires the saturation of the pyroclasts and is favored by the reduction of strength related to the progressive opening of the sub-vertical cracks.

P22. Evolution of the Pajonales Landslide (Tirajana Depression, Gran Canaria): a Case of Advancing Landslide (part of session 2.2)

Martín J Rodríguez-Peces, Jorge Yepes, Cristina Fonollá, Alejandro Lomoschitz, Meaza Tsige

Abstract: We studied the evolution of different stages of the Pajonales landslide (Tirajana Depression, Gran Canaria), based on geotechnical research on both in situ and mobilized volcanic matter. The deposit extends over 560 ha and has been reactivated on several occasions, some during the 20th century. The landslide comprises four large bodies that have successively broken away from a single initial rock mass. The main scarp affects the lava flows with intercalations of pyroclastic matter of the Roque Nublo Group and later volcanic activity (5.5 Ma to present-day). The basal surface of the landslide developed in old rocks of the Mogán Group (14.0-13.3 Ma), which are rhyolitic and trachytic ignimbrites with hydrothermal alteration related to the infilling of the Tejeda caldera. This alteration caused silty-clay layers with a low friction angle, high plasticity and expansive behavior. We collected representative samples of pyroclasts and soils from landslides and performed laboratory tests to identify them and to determine unit weight, grain-size, plasticity, and shear strength. We reconstructed the morphology of the slope prior to sliding taking into consideration the location of first and second generation failure surfaces and scarps. We used limit equilibrium analysis software to identify failure surfaces for each stage of sliding. These surfaces developed through clayey-silt levels resulting from the alteration of pyroclastic materials, showing the most unfavorable geotechnical parameters (minimal or residual values). Moreover, the presence of water is a triggering factor, since total or partial saturation of the materials is required. Finally, the landslide is of the advancing type: as successive reactivations occur, the sliding masses are broken down into smaller ones moving towards the Tirajana ravine.

P23. Evolution of Landslide Susceptibility Patterns in Areas of Rapid Urban Development. Case Study Lanzhou City, Northwest China

Jewgenij Torizin, Lichao Wang, Michael Fuchs, Bin Tong, Dirk Balzer, Tingshan Tian, Dirk Kuhn, Liqin Wan, Ang Li, Liang Chen

Abstract: Lanzhou is a city with 3.5 million inhabitants, situated at the western margin of the central Loess Plateau. Since 2001, the city is under rapid urban development by cut and fill activity of the loess mountains and greening, associated with enormous impact on the environment. The current study investigates the evolution of the landslide susceptibility patterns from the early 1990's up to the year 2016 in the light of the anthropogenic influence. Evolution of the landslide susceptibility patterns was assessed using data-driven generative Bayesian approach. To catch the dynamic changes of the landslide-controlling conditions, multi-temporal landslide inventory, multi-temporal DEMs, morphological change detection, and historical and recent land use data were utilized. As result, three states of the landslide susceptibility pattern for the years 2000, 2012, and 2016 were estimated.

Understanding the causal relations between human activity and landslide susceptibility will allow to create scenarios and strategies for spatial panning of the new city development areas.

P24. POST EVENT LANDSLIDE MAPPING USING C– AND X– BAND INSAR DATA (Forum Theme 2)

Lorenzo Solari, Matteo Del Soldato, Federico Raspini, Nicola Casagli

Abstract: In this work we exploited the potentialities of a multi-temporal and multi-band interferometric analysis to derive the pre and post event deformations in an area affected by a large complex landslide, mobilized the 12 February 2017, in the Abruzzo Region (Ponzano hamlet). C- and X-band SAR (Synthetic Aperture Radar) data, analyzed by means of the SqueeSAR algorithm, have been used to reconstruct the development of the movement starting from 2003. The satellite data were finally compared with in situ evidences, derived from ground surveys and from a helicopter reconnaissance, to derive a post event map of the landslide. This output represents a fast way to obtain the area affected and damaged by an event, ideally suited for Civil Protection practices.

P25. Testing the awareness of landslide risk in some schools in Tuscany (Italy) (Forum Theme 5)

Laura Pastonchi, Veronica Pazzi, Stefano Morelli, Federico Marini, Luca Valori, Luca Gambacciani, Nicola Casagli

Abstract: It is sadly known that calamities related to geological hazards occur frequently all over the world, causing destruction, victims and economic losses. These phenomena, unfortunately, also affect schools. In Italy there are 51,113 school buildings (latest ministerial survey, February 2017). According to a recent report on the state of the Italian territory and school buildings (2014) approximately the 10% of these schools is located in areas subject to landslide and flood risk. Investing in activities aimed

at preventing these natural disasters is a necessity no longer negligible, even because the cost of such activity is lower than the economic effort needed to repair the damages.

This project developed a multi-hazard risk assessment in public school buildings, i.e., the evaluation of landslide, hydraulic and seismic risk. Twenty-five schools in Tuscany (central Italy) were selected as representative sample of different geo-morphological contexts, structural typologies, number and age of occupants. Six of these schools were chosen on the basis of the high landslide hazard prone area, according to the national landslide inventory (IFFI project-http://www.progettoiffi.isprambiente.it/cartanetiffi/), the landslide risk mapping of the "Piano Stralcio di Assetto Idrogeologico" (PAI), and the movements detected by satellite SAR (Synthetic Aperture Radar) data for the unstable areas.

The multi-hazard method is based on the definition of the GSC (Geohazard Safety Classification) that is obtained weighting the maximum specific risk with the resilience ($GSC=1-\max(Hi*Vi)/\rho$). The maximum specific risk of a school could be quantified on the basis of a) data collection (ancillary data and thematic maps), b) processing field data (seismic noise measures according to the H/V technique, thermographic immages and GPS surveys). The resilience is the ability of each community to resist and recover from the effects of a hazard to which it is exposed. Therefore, resilience could be a damper ($\rho>1$), an invariant ($\rho=1$) or an amplifier ($\rho<1$) of the maximum specific risk. For the aims of this work this parameter is obtained through the analysis of a questionnaire filled in by the school-population, and the quality and completeness of the school Emergency Plan and Risk Assessment Document (DVR, Italian acronym) with respect to the abovementioned geological risks. The illustrated methodology turns out to be straightforward, non-invasive and economic.

The results of this work are: i) no one of the selected school has a very low specific risk (class A of the GSC), ii) three schools have high specific risk (class D), and iii) the remaining three have very high (class E), low (class B), and medium specific risk (class C), respectively. In half of these schools the landslide risk was found to be the highest and therefore influenced the GSC value. The resilience turned out to be a risk amplifier ($\rho<1$), but only in one school the GSC is worst than the considered specific risk. The negative resilience is here due to both the lack of consideration of the landslide risk into the DVR/Emergencies Plan and the poor perception of the school personnel concerning this risk. This work also shows how the GSC can be affected by landslide risk and resilience. It is therefore evident that the knowledge of geological criticalities involving school buildings, coupled with the awareness of the community about the landslide risk, should become a common practice for minimizing the interaction of a landslide with school life and avoiding potential socio-economic losses.

P26 and P27. NEW GX GEORADAR GENERATION IN LANDSLIDE MONITORING

Željka Sladović, Zoran Mikić, Damir Halužan

Abstract: During the winter 2016/2017 geophyisical surveying with georadar MALÅ GX 80 MHz rough terrain antenna was performed in Samoborsko Gorje hills. During processing few historical landslide were noticed and analysed. Georadar signal processing workflow included data sorting, profile summation, velocities calculating based on hyperbolas, correction for elevation and interpretation. Measuring with GPR is an high frequency electromagnetic method, but data processing is very similar to reflexive seismic processing. Further analyses were performed in Opendect software that is designed for reflection seismic data analyses and interpretation. Multi-attribute analyses improved visibility of cross sections and enabled detecting timing and extension of landslides. The signal detection is up to 800 ns. After the processing the visibility of signal reached detection depth level and enable recognition of surface of rupture,main landslide body,landslide foot,scarps, ridges and faulting . GPR surveying, is a non-invasive and up to 100 m penetrating geophysical method could reduce the risks of the earthslide in the future.

P28. A landslide susceptibility map for Africa (Forum theme 2, session 4 Landslide Hazard, Risk Assessment & Prediction)

Jente Broeckx, Matthias Vanmaercke, Jean Poesen

Abstract: Understanding regional variations in landslide susceptibility is vital from a societal but also from an environmental and geomorphic point of view. Therefore, numerous local and regional studies on landslide susceptibility have been made over the past decades. However, relatively few studies focus on the continental or global scale. In addition, most of these studies for larger areas are based on relatively limited data of mapped landslides and the effect of seismic activity is often not taken into account. This is especially the case for Africa. Given that landslides form one of the deadliest natural geohazards in Africa and the fact that population growth in Africa is projected to be the highest in the world for this century, a better insight into the patterns of landslide susceptibility across the African continent is required. Therefore, this study aims at developing a first continent-wide landslide susceptibility map for Africa, that is calibrated by available landslide data that are well-distributed over the continent, and that is also tested for the effects of seismic activity. Such a map can be used as a tool to confront susceptible areas with inhabited areas to identify current areas at risk. Given the continent-wide uniform assessment of landslide susceptibility, this map allows for interregional susceptibility comparison across Africa.

As a first step, we compiled all available landslide inventories in Africa, in order to improve the robustness of our analyses, these mapped landslides were supplemented by additional landslide mapping in data-poor regions, using Google Earth. This resulted in ca. fifty different landslide inventories for more than twenty African countries, comprising a total of more than 6000 landslides. Several variables, such as slope, lithology, soil, land use, precipitation and seismic activity, were tested for their explanatory

power with respect to landsliding. As a result, a multiple logistic regression model was obtained, which was applied to construct a continent-wide landslide susceptibility map for Africa. We applied Monte Carlo simulations to calibrate this model. Further validation was carried out, with independent landslide data, not used for the Monte Carlo simulations. The results show that topography, seismic activity (peak ground acceleration) and precipitation are the most significant variables, explaining the spatial distribution of landslides all over the African continent. Interestingly, our analyses showed that also seismic activity is a highly relevant factor in simulating spatial patterns of landslides across Africa. This is surprising, given the overall low degree of seismic activity and the limited occurrence of strong earthquakes, directly triggering landslides. These observations concur with several other recent studies, indicating that earthquakes may not only trigger landslides, but can also increase landslide susceptibility (e.g. by weakening surface lithologies).

P29. Influence of diatoms content in relation to the slope deformations and soil behavior in the cuts of line constructions (Forum Theme 5)

Pavlína Frýbová, Radka Drápalová, Věra Glisníková, Alexandra Erbenová

Abstract: Within the field of geotechnics, diatom clay soils are considered as one of the risk groups of soils because of their specific mechanical behaviour. Clay properties have been investigated depending on the content of diatoms. To investigate the effects of diatom microfossil content on the index properties of clay soils, measuring tests were performed on cohesive soils with different diatom microfossils content. Based on the observed nature of the soil's behaviour, it was possible to design a simulation of the mixture's behaviour for an established amount of diatoms in the mixture.

P30. LANDSLIDE DAMMING IN A HIGH RISK AREA

Guido Paliaga, Fabio Luino, Francesco Faccini, Laura Turconi, Peter Bobrowsky

Abstract: The landslide dam of Prato Casarile, in the Bisagno valley (Genoa metropolitan area) is a classic case study illustrating the interactions between degradation processes and structural stabilization interventions aimed to reduce the risk level in a densely-populated area. The stabilization structures realized after the 1953 and 1970 disastrous events have been highly damaged by the recent ones, in particoulr in 2014. Actually the structures need important maintenance interventions and wider prevention actions are needed in order to control and mitigate the risk level in the highly populated area downstream from the landslide dam.

P31. LANDSLIDES AT ANGANGUEO (MEXICO): Shallow and deep reactivation from 2010 rainfall (Forum Theme 4)

Cecilia Irene Villaseñor Reyes, Víctor Manuel Hernández Madrigal, Sócrates Figueroa Miranda

Abstract: The 4th of February of 2010 the town of Angangueo, as all the Eastern part of Michoacán, was affected by climatological phenomena that produced heavy and prolonged rain in which the accumulated precipitation was of 300mm/48 hrs (33% of the annual precipitation in two days). These caused floods, debris flows, landslides, human losses, loss of crops, damage in infrastructure and economic loss. The investigations obtained by this investigation team allowed the elaboration of landslide inventory map of Angangueo and the numerical modelling of debris flow deposit (FLO-2D). Also, posteriori works of cartography-inventory and GPS monitoring have allow us to found the correlation of the extraordinary rainfall of 2010 with the reactivation of Deep Slides in Las Pilas and Jungapeo. Additionally, it was established that this rainfall event was the primary triggering factor in both kind of mass wasting, however, other factors as the lithology (slightly resistant, highly permeable and weathered) and the land use (especially perennial crops and its flood irrigation system) had the same importance.

P32. Landslide monitoring at the Cala Rossa sea cliff (Favignana Island, Sicily) (part of session 2.1)

Luca Falconi, Roberto Iannucci, Salvatore Martino, Antonella Paciello, Augusto Screpanti, Vladimiro Verrubbi

Abstract: Favignana Island is a historical and environmental attraction site frequented by tourists especially during the long warm season of the year. Over several centuries the sea cliffs have been exploited for the production of building stone. Currently, the quarries used for the rock extraction as well as the natural cliffs are undergoing extensive erosional and gravitational processes. Besides putting at risk the safety of the people attending the area, the widespread rock falls are likely to threaten sites of great historical and anthropological value that, once destroyed, can no longer be reconstructed. The rock mass quality assessment and slope displacement monitoring of cliffs were carried on to identify the most unstable areas providing a support to the local authorities in the implementation of effective and sustainable mitigation measures. If adequate measures will be taken in future, operators and users of the tourist circuit will have the opportunity to enjoy these amazing sites with a reduced risk.

P33. Onshore record of ancient landslides in Taganana (Tenerife, Canary Islands) (part of session 2.2)

Jorge Yepes, Martin J. Rodriguez-Peces, Candida Garcia-Gonzalez

Abstract: This study presents a geomorphologic review of the northern sector of Anaga Massif in order to establish a relative sequence of geomorphic processes. The present-day relief shows a polygenic nature, combining fluvial erosion with other prior erosive processes. The analysis of slopes and watersheds suggests the existence of an active instability process during the Quaternary. However, the anomalies of the drainage system are related with the differential strength which shows basic dykes against erosion. Some geomorphologic features suggest the occurrence of an old great landslide affecting the slopes of Taganana village. This instability will be a stage of the retreatment of the slopes which occurs in a volcanic island along time, in both emerged and submerged flanks.

P34. Modelling the onset of Valles Marineris landslides in Mars

Giovabattista Crosta, Stefano Utili

Abstract: Several questions arise as to the acting forces and rock strength in the stability of the walls of Valles Marineris (VM) of Mars. This work is an attempt: to set the analysis of landslides in VM on the basis of sound geomechanical principles; to understand the root causes of the slope instabilities occurred in VM; to explore what type of events and rock conditions must be invoked to explain the observed massive landslides

P35. EFFECT OF SEISMIC ACTION ON FISSURED SLOPES

Akram Abd, Stefano Utili

Abstract: Aset of analytical solutions applying the upper bound theorem and the pseudo-static approach was derived for the assessment of the stability of homogeneous c, φ slopes manifesting vertical cracks and subject to seismic action.

P36. MECHANICALLY STABILIZED EARTH TECHNOLOGY FOR PASSIVE PROTECTION OF AREAS PRONE TO LANDSLIDES

Robert Lozano, Anne-Cécile Gass

Abstract: Mechanically Stabilized Earth (MSE) technology is a flexible, well understood technology that allows the use of soil by adding discrete inclusions. MSE technology, also called reinforced soil is being in use for over 50 years for applications ranging from walls, reinforced slopes, protection bunds, back to back walls incorporating steepened fascia with different possible facing finishes, a relative wide array of soils for backfill including lightened backfills, in-situ soils and even incorporating the use of modified soils or recycled materials.

P37. Čeřeniště natural laboratory: a longterm monitoring of the active landslide

Petr Tábořík, Filip Hartvich, Jan Blahůt, Jan Klimeš, Tomáš Belov, Lukáš Vlček, Jan Balek

Abstract: The contribution aims at present progress in application of a complex geophysical and geotechnical monitoring of the active slope deformation Čeřeniště (České Středohoří Mts.). Čeřeniště landslide is situated in the České středohoří middle-mountains (Czech massif) and belongs to the Czech Tertiary Neovolcanites. The main scarp of the studied landslide as well as toppled ridges, forming the upper part of the complex slope deformation, are - according to our geophysical survey - predisposed by tectonic structures and further affected by deep-seated gravitational processes (spreading, toppling). Central part is formed by a large platform which is followed by an active flowlike landslide composed of weathered colluvium. The main goals of the long term monitoring of the Čeřeniště landslide are (i) to describe dynamics of the complex slope deformation, and (ii) to reveal a connection among predispositions (tectonics, lithology), triggering factors (extreme precipitations, soil humidity changes, long-term climatic oscillations) and landslide activity. For a description of a long-term landslide activity the geotechnical, measurements of displacements by means of 3-D spatial dilatometers (TM-71 3-D optical-mechanical crack gauge) have been performed at the Čeřeniště landslide since 1998. Since August 2013, it has been successively complemented by (i) extensometric measurements, (ii) geodetic measurements and (iii) repeated laser scanning. In order to identify relations between triggering factors and landslide activity, the following techniques were established (in 2013) on the landslide: (i) time-lapse resistivity measurements, (ii) hydroclimatic monitoring (precipitation, air moisture and temperature) and (iii) pore-water pressure measurements. Variations in resistivity distribution are measured by means of electrical resistivity tomography (ERT). The time-lapse resistivity survey would serve as an effective tool which can yield information on subsurface water saturation and its

changes and, also, it could help to reveal relations within the system „precipitation subsurface saturation - mass movement activation". Furthermore, using the monitoring of movement velocity based on repeated geodetic measurements we shall be able to determine the causal connection among precipitations, soil saturation and (re)activation of mass movements. Last but not least, the studied locality serves also as a testing site for the repeated resistivity measurements in terms of (i) measuring parameters

optimization, (ii) different electrode configurations testing, (iii) data processing optimization. For the following period 2017-2018 we are planning to realize hydrogeological well with inclinometric measurements and, also, to establish an automated resistivity monitoring system with 1-day period of the measurements. Research was supported by following grant projects: IRSM internal project no. 2015/505, GAUK 862213 and CzechGeo LM2010008.

P38. GIS-based deterministic and statistical modelling of rainfall-induced landslides: a comparative study

Carlotta Bartelletti, Jorge Pedro Galve Arnedo, Michele Barsanti, Roberto Giannecchini, Giacomo D'Amato Avanzi, Yuri Galanti, Andrea Cevasco, José Miguel Azañón and Rosa Maria Mateos

Abstract: Researches dealing with the forecast performance of rainfall-induced landslide susceptibility maps produced by both deterministic and statistical methods are abundant. However, comparisons between GIS-based deterministic and statistical/probabilistic modelling are less common. In this work we have compared the prediction capability of three different models: SHALSTAB, Likelihood ratio (LR) and Generalized Additive Models (GAM). These methods represent three different approaches for producing landslide susceptibility maps: (1) SHALSTAB is a deterministic model that integrates steady-state hydrological conditions of the slope with a infinite-slope limit equilibrium analysis. This model requires geotechnical parameters for producing the landslide susceptibility map, not always easy to extract at medium scales correctly (1:25,000-1:10,000). However, deterministic models are the unique alternative if previous landslide inventories are not available. (2) LR is a probabilistic method based on a mathematical approach that highlights the difference between the landslide conditioning factors of a portion of the study area containing landslides and the remainder. The higher the differences, the better is the prediction capability of the conditioning factors. This method considers the entire study area for computing the model and no high computational demands are required. (3) GAM is a statistical approach based on regression analyses. It is a semi-parametric extension of the linear regression technique that combines linear and non-linear relationships between predictor and response variables. As most of the statistical approaches, GAM uses a sample extracted from the study area to produce a model and usually needs higher computational time than the LR method. We assessed the predictive performance of the three methods through a 2-fold cross-validation technique and analyzing prediction rate curves (PRC). The above mentioned methods have already been extensively applied to landslide susceptibility modelling, but a comparison between them has not yet been performed. We tested the performance of the three methods in a small catchment of Northern Apennines (Pogliaschina, Vara Valley, Italy). This catchment (25 km^2 wide) was affected by an intense rainstorm that triggered at least 658 shallow landslides on 25 October 2011 that caused extensive damage in the study area and killed 7 people. Most of the landslides (>85%) was classified as complex translational debris slide-flows. Therefore, it is a priority to produce a reliable shallow landslide susceptibility model in the study area. With this purpose, we analysed the method showing the highest predictive performance for identifying the most landslide-prone areas in order to take the best mitigation actions and avoid further economic and human losses in the future.