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Comparison of consequences in the environment after the earthquakes in 1998 and 2004 in the area of the Julian Alps, Slovenia

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It rarely occurs that within a couple of years two large-scale earthquakes take place in the same area. In 1998, the first earthquake occurred in the upper Soca Valley area (Julian Alps, NW Slovenia) with a magnitude of M = 5.6 and an estimated intensity between VII and VIII according to the European Macroseismic Scale; the other one took place in 2004 with a magnitude of M = 4.9 and an estimated intensity between VI and VII according to the EMS. The epicenters were located only several hundred meters apart. They originated at the lateral strike slip movement along the same fault. Despite the much damage in the environment, there were no human casualties at the first earthquake; however, due to fall of the rock block the second one claimed the life of a walker in the mountains. Despite the 1998 earthquake being the strongest earthquake in Slovenia in the 20th century, both earthquakes were far weaker than the strongest possible earthquake predicted for the region. The effects on the natural surroundings during the earthquake were assessed with morphological and geological characteristics of the Alps, characterized by steep, even vertical slopes of glaciated valleys, consisting of cracked carbonate rock. In comparison to less mountainous areas, the Alpine region is characterized by other features and types of damage. In the environment, both earthquakes caused many failures in nature however different magnitude of earthquakes resulted in different consequences. During the 1998 earthquake, four large-size (several 10,000 m3 of material) and five extreme-size rock falls occurred (more than 100,000 m3 of material). Several other types of failures, such as different types of landslides occurred. On the other hand, the 2004 earthquake caused significantly smaller damage in the environment, which mostly demonstrated in shal-

low surface sliding, which did not exceed several 1,000 m3. All the phenomena in the environment during both earthquakes were recorded as to their location, geological structure of rock, size, thickness, type of sliding, slope inclination and vegetation cover. Based on these parameters a comparison of both earthquakes was made in relation to the rock fall events. Several interesting characteristics were identified, as well as the relationship between the magnitude of the earthquake and scale of damage in the environment. The aim of studying failures in the nature was to draw up a forecast as to the consequences of the strongest possible earthquake in the region, where an intensity of IX according to the EMS can be achieved. An overview of historical events in the area has shown that catastrophic events can occur in the Alpine area. Thus, the 1348 earthquake with an estimated magnitude of M = 6.5 with a probable epicenter in Furlania triggered a massive rock fall with several 100 million m3 from the south slope of the Dobrac mountain, which buried underneath several villages and restricted the flow of the Zilja River. Consequently, several thousand people died. The results of the analysis of earthquake effects in nature can be summarized as follows: - damages in the environment in the Alpine areas have their own characteristics, which are related to the carbonate composition of the Alps, steep slopes due to glacier activity and local distribution of tectonically induced discontinuities and layering of rock; - when establishing the effects of an earthquake one needs to consider the local morphogeological characteristics, since different morphogeological conditions bring about completely different phenomena; - so far, based on the study of failure phenomena in the environment during both earthquakes it is for the Slovenian Alpine region possible to predict earthquake intensity with the same certainty as the one based on damage on buildings, which is especially important in sparsely populated areas; - clear connection between rock fall type and local conditions has been identified; - clear connection between distance from the epicenter and size of damage in nature has been identified; - clear connection between the magnitude of the earthquake and the rock fall size for natural phenomena during the earthquake has been identified; - the basis for establishing the most critical regions in the Alps has been set, where during very strong earthquakes extreme phenomena destroying the natural balance can occur. We hope that through juxtaposition of both earthquakes from 1998 and 2004, and by taking into account historical events, will in future enable that preventive passive and active measures are drawn up for the Julian Alps region. On the one hand, this means that we should strive to increase the knowledge on earthquake threat due to natural phenomena on the part of local institutions and population, and on the other hand, building in the known areas under threat of rock fall phenomena should be restricted.