

Earthquake-induced slope movements in Western Greece during the last decade

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Western Greece has recently experienced the destructive impact of four strong earthquakes, namely the June 8, 2008 Mw 6.4 Andravida (Northwestern Peloponnese), the January 26 and the February 3, 2014 Mw 6.0 Cephalonia (Ionian Sea) and the November 17, 2015 Mw 6.4 Lefkas (Ionian Sea) earthquakes. The most common characteristic of all four events is their generation by the activation of NNE-SSW to NE-SW strike-slip faults. Another similarity of these events is that they all have induced many secondary environmental effects including slope movements among others.

The 2008 Andravida earthquake induced slope movements in 8 sites. They are classified into landslides (6 from 8 total cases) and rockfalls (2). The minimum occurrence distance (odmin) from the epicenter of the main shock is 5.91km, while the maximum (odmax) 24.4km. The volume of mobilized geological material did not exceed 10m³ corresponding to an intensity V(ESI-07) assigned to each site.

The 2014 Cephalonia earthquakes induced slope movements in 21 sites classified into landslides (3), rockfalls (2), while the majority of them (16) comprised mixed types of slope failures including rotational slides or slumps, translational slides, rockfalls and rock toppling failures. The odmin are 3.13km and 1.57km for the first and the second event respectively, while the odmax 20.92km and 16.59km respectively. The volume of the mobilized geological materials varied from 1m³ in small rockfalls to larger than 103m³ in mixed type phenomena corresponding to intensities that varied from V(ESI-07) to VII(ESI-07).

The 2015 Lefkas earthquake induced slope movements in 15 sites: landslides (7), rockfalls (4), mixed type phenomena comprising rockfalls and landslides (3) and mixed type phenomena comprising landslides, rockfalls and rockslides (1). The odmin was 1.09km, while the maximum 17.39km. The volume of the mobilized geological material varied from 103m³ in relatively small phenomena to 105-106m³ in large landslides corresponding to intensities that varied from VI to VIII(ESI-07).

The affected formations include alpine and post-alpine formations. The most vulnerable lithologies are carbonate rocks, and sequences and alternations of marls, clays, silts, sands with consolidated or non-consolidated conglomerates. The main controlling factors are: (a) the strong ground shaking, (b) the presence of formations with mechanical characteristics that make formations susceptible to failure, (c) the strong heterogeneity and the rapid change of the mechanical characteristics in the different horizons both vertically and horizontally resulting in non-uniform and anisotropic mechanical behavior of formations, (d) the intense and multiple fracturing, erosion and weathering contributing to the decreased cohesion along steep mountain slopes, (e) the intense tectonic deformation along active fault zones resulting in a dense net of discontinuities and sectors of decreased cohesion and formations loosening.

Based on all available data, the recorded phenomena were highly concentrated in specific zones strongly associated with lithology, tectonic structure and geomorphology. Taking into account that NW Peloponnese and Ionian Islands are among the most tectonically active areas, these phenomena are characterized as structurally controlled. Their distribution supports earlier studies suggesting that earthquake-induced slope movements are concentrated in specific zones associated with bedrock geology, geomorphology, topography, and human factors.