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LANDSLIDES AND COLLAPSES IN SEISMIC ZONES AND THEIR PREDICTION

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Great sums are allotted and the efforts of many scientists are directed to the solution of the problem of earthquake prediction, a solution which is necessary for protection from the destructive seismic forces of the Earth. Some things are often not considered: the precise prediction of the place and time of earthquakes is impossible at present; and sometimes during earthquakes most of the damage (up to 80–90 %) is due not to the earthquake itself but to the accompanying seismogravitational phenomena.

Dangerous landslide-collapse zones cover areas of some hundreds of thousands of square kilometres during the strongest earthquakes and coincide approximately with the total area of possible deformation of the earth's crust according to the equation:

$$\log S = (0.99 \pm 0.07)\ M - 3.60 \qquad (1)$$

where S is the surface area in km^2 and M is the earthquake magnitude.

Stability changes in rock masses may be due to many factors, the main ones being: seismic acceleration and decrease of strength of rock masses, change of gradient angle of unstable planes; and thixotropic weakening of the ground.

On metastable slopes a change of gradient angle of tens of minutes may disturb the equilibrium, and may occur in all types of seismotectonic deformation – regional, zonal, and local.

Regional movements of the earth's crust accompany all strong earthquakes and cover areas from hundreds (M=6.5) to some hundreds of thousands of square kilometres (M greater than 8.5) with amplitude of vertical displacement up to 15 m and more. The area of deformation for earthquakes with crust foci is approximately determined by the equation (1).

Zonal seismotectonic movements are accompanied by a considerable number of local seismotectonic deformations (faults, upthrusts, grabens, transcurrent shifts, etc.). The total length of the local deformations may be determined from the magnitudes of expected earthquakes according to the equation-

$$\log L = (1.01 \pm 0.02)\ M - 6.18 \qquad (2)$$

where L is the total length in km and M the earthquake magnitude.

These movements can change the gradient angles of weakened zones in an area extending up to 20 km away. However, most instability of rock masses during an earthquake and its aftershocks is due to seismic acceleration.

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The following main types of seismogenic landslides and collapses are distinguished:

1. **Gravitational-seismotectonic wedges.** Large earthquakes with I_0=XI-XII (M greater than 8) which affect active fractures, may cause subsidence of wedges of the earth's crust.
2. **Collapses along faults** are common where seismogenic faults cut off slopes and spurs. During strong earthquakes sections of mountains subside and move towards the valley, sometimes collapsing.
3. **Toppling of mountain peaks** occurs during the strongest earthquakes with translational-return movement of the earth's crust. Sometimes toppled peaks turn around an axis and collapses occur along the perimeter.
4. **Slipping landslides.** In regional composed of moderately fractured or layered formations, benches several square kilometres in area can slide during earthquakes. Slipping landslides also take place in regions of crystalline rocks with weakened planes.
5. **Seismogravitational landslides and collapses.** On the Black Sea shore landslides and collapses have been observed whose formation may be connected with seismogenic-vibrational creep, caused by continuous earthquake vibrations of moderate force.
6. **Seismotectonic landslides and collapses.** The majority of giant landslides and collapses are confined to zones of seismically active fractures. Seismotectonic movements of the earth's crust cause instability of rock masses; catastrophic landslides are generally connected with earthquakes.
7. **Seismogenic collapses due to seismic vibrations.** Two conditions are necessary for this type of collapse: the instant collapse and crushing of rock masses, and the effect of strong earthquake vibrations on sliding ground masses. Seismically vibrated collapsed masses can cover an area of about 30 km with rapid movement across wide valleys and up the opposite slopes.
8. **Seismogravitational collapses on "air-cushin"(?)** The unique collapse from the Guaskaran mountain during the earthquake of 31 May 1970 in Peru (M=7.7) moved at a rate of 280–335 km/h. In places the slide did not destroy the vegetation and soil layer, leading some investigators to believe that the slide moved on an "air-cushion".
9. **Seismogenic ground avalanches and flows.** In regions with thick unconsolidated sediments on slopes of more than 10–12°, ground avalanches and flows up to some scores of kilometres long may occur.

In the paleoseismological method of determining location, itensity and recurrence of strong earthquakes, traces of ancient seismogravitational phenomena are widely used. The largest landslides and collapses frequently occur in the same regions.

Prediction of large seismogravitational phenomena and estimation of slope stability on the basis of mathematical models is impossible. The estimation of seismogravitational danger should be made on the basis of seismic statistics and paleoseismological data.

THE DEVELOPMENT OF GRAVITATIONAL PROCESSES

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Various gravitation processes particularly those arising under the direct influence of gravitational forces, such as slips, rockfalls, and scree formation, form a constant threat to the stability of slopes, existing structures and those under construction or design. Some form a constant threat to people's life and activity.

Gravitational displacement of rock masses is reponsible for disturbance of slopes and excarpments. It is produced by gravity, hydrodynamic pressure, seismic and other forces, and is possible only if the shearing force exceeds either the strength of the rock substance or that along existing or possible discontinuities. However, such a force distribution does not necessarily result in slips, rockfalls and scree; these phenomena may be produced by other means of disturbing the balance of the rock mass as well as realization of the shearing force.

The analysis of the causes of gravitation phenomena enables us to conclude that in the long run they can be produced by an increase of absolute or of relative values of shearing forces. An increase of absolute values of shearing forces conducive to rock mass displacement down the slope or escarpment, may be due to changes in slope gradient, the increase of rock weight with moistening, hydro-