Feature



Impact of mass movements in the Kocaeli Province, Turkey

Recent mass movements in the Kocaeli Province, Turkey in 2010 caused damage to people, property and infrastructure, especially in Izmit and its vicinity. The causes and impact of these mass movements are outlined, so as to increase awareness of their dangerous aspects. Some of these mass movement events took place in urban areas, bringing attention to the need for better and more effective land use practices. The impact of these movements indicates the benefit there would be from geology and engineering geology in the planning of any property development and land use.

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Mass movement is the downward movement of materials such as soils, rock fragments and the combination of these on a slope due to the gravitational force. These movements are categorized based on the type of movements such as falls, slides and flows. A number of mass movements occurred in several places during the first two months of 2010 within the Kocaeli Province, which is located in north-west Turkey. A rock fall, two landslides and several earthflow types of mass movement were observed and caused injury and damage to property, and damaged and blocked the main roads. This damage was reported in both the local and national newspapers and was also covered on television channels. Although the details of these movements were broadcast, little was known of their geological and engineering geological perspective. Therefore, we set out to define and locate the mass movements, consider their geological background, and make some recommendations. Geographical Information System (GIS) was used to map the geology and the mass movement locations. Figure 1 displays the location of the study area, location of the mass movements and the geological formations and units in the region.

Geology

The geology of the region presents variations in lithology. There are two tectonic units brought by the North Anatolian Fault (hereafter, NAF) in the region of the Kocaeli Province. The northern tectonic unit consists of sedimentary lithologies of broad Palaeozoic to Quaternary age, while the southern tectonic unit has metamorphic base rocks (Pm) overlain by Cretaceous sedimentary rocks (K) and the Tertiary volcanic rocks (Tv) and Pliocene terrestrial sedimentary units (Ta). There is a depression area that was developed by the NAF along the boundary of the two tectonic units. The north tectonic unit has mainly geological formations consisting of a thick folded and faulted sandstone-limestone sequence. This thick sedimentary sequence was deposited in another broad time

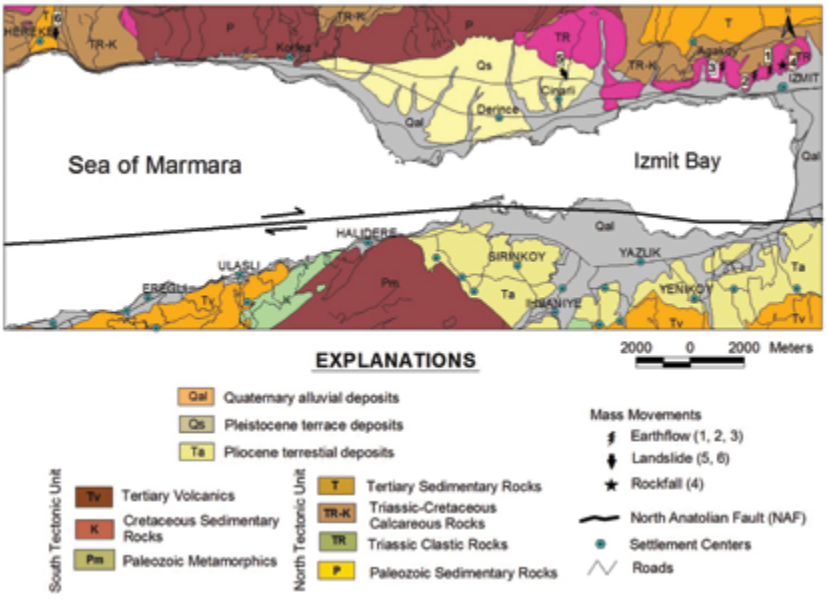


Fig. 1. Location of the study area, location of the mass movements and the geological formations and units in the region.

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interval, from the Palaeozoic to the Eocene (P, TR, TR–K, T). There are younger sediments deposited on the sedimentary base units. Younger sediments deposited in a time interval from Pliocene to Quaternary consist of generally weakly cemented (Ta and Qs) and alluvial deposits (Qal) (Fig. 1).

The heterogenous lithologies and discontinuities such as unconformities, faults and fractures, significantly affect the stability of slopes located on a base of sedimentary rocks. Younger deposits are susceptible to generating flow-slide type mass movements on the higher angle slopes. Another main factor that triggers mass movements on the slopes with stability problems is the earthquake activity of the NAF. The landforms developed on both tectonic units are quite different. The topography of the region is rugged in the south of the NAF whilst to the north it is peneplained. Although several mass movements took place on the formations of the southern tectonic unit, only the mass movements which took place on the formations of the northern tectonic unit are considered here.

Types of mass movement

There are several different types of mass movements, each with different mechanisms and natural processes. Earthflow, landslide and rockfall type mass movements were observed in the field. Earthflow is characterized by a rapid-slow flow of fine-coarse grained earth material down slope due to gravity and climatic conditions. Landslide is a sliding event caused by down slope movement of a distinct mass of rock, soil or the combination of these two on a slope due to gravity, slope steepness and climatic conditions. Rockfall takes places on steep slopes of hard rock with intense discontinuities. Weathering and climatic conditions such as freeze–thaw cycles and intense precipitation, break the rock slope into pieces that fall rapidly and pile up at the base of the slope.

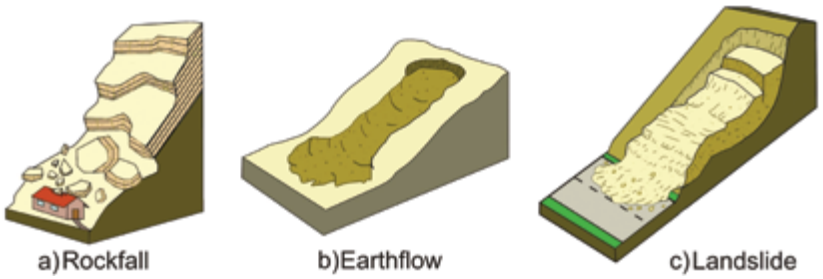


Fig. 2. Types of mass movements observed in the region.

Earthflows were mainly observed on the steep slopes of extremely weathered Triassic clastic rocks (arkosic sandstone) of the Izmit Formation. The weathered zones, composed of mainly fine materials on steep slopes, moved as earth flows when heavy rain saturated the upper weathered zones. Only moderately weathered zones of the Izmit Formation, however, with closely spaced joints, led to rock fall type mass movements. Two landslide type mass movements took place on different locations and geological formations. One of the landslides moved downward from a steep



Fig. 3. Earthflow in Terzi Bayırı Kale Sokak. Damage to the road, retaining wall and house.

Table 1. Details of the mass movements

Location	Type	Lithology	Eng. Properties	Impacts
Terzi Bayırı Kale Street, İzmit (1)	Earthflow	Triassic clastic rocks (arkose sandstone, Izmit Formation)	Extremely weathered, very weak-weak strength	1 person injured, 3 houses damaged, 1 car damaged, 17 houses evacuated, road collapsed
Terzi Bayırı Korniş Street, İzmit (2)	Earthflow	Triassic clastic rocks (arkose sandstone, Izmit Formation)	Extremely weathered, very weak-weak strength	1 house and 2 cars damaged, 20 houses evacuated, road and retaining wall collapsed
Dereboğazı Çıkmaz Street, İzmit (3)	Earthflow	Triassic clastic rocks (arkose sandstone, Izmit Formation)	Extremely weathered, very weak-weak strength	Several houses evacuated
Cedit District Mercan Street, İzmit (4)	Rock fall	Triassic clastic rocks (arkose sandstone, Izmit Formation)	Moderately-Slightly weathered, closely spaced joints, weak-moderately strength	A few houses evacuated,
Mersincik District, Derince (5)	Landsilde	Pleistocene terrace deposits (mudstone, Sirintepe Formation)	Extremely weathered, very weak strength	Road blocked, traffic obstructed
Hereke (6)	Landslide	Triassic-Cretaceous Calcareous Rocks (clayey limestone-marl, Akveren Formation)	Extremely weathered marl with very weak strength and slightly weathered limestone with moderately spaced joints, moderately strength	Road blocked, traffic obstructed

slope consisting of extremely weathered thick zones of Pleistocene terrace deposits (mudstone of the Sirintepe Formation) in Derince Mersincik district. The other landslide took place on a steep slope located at the side of a highway with congested traffic in Hereke. This landslide happened in Triassic-Cretaceous calcareous rocks, slightly weathered clayey limestone and extremely weathered marl of the Akveren Formation. Figure 2 displays the three types of mass movements that occurred in the study area.

Causes of mass movements

Mass movements took place on the south facing slopes of the depression area formed by the NAF. Steep slopes, lithologies with different resistances, intense discontinuities based on tectonic activity along the NAF, land use and climatic conditions are the main factors that triggered the mass movements. Mass movements have been observed since the begining of the rainy season in the region. Also, continuous rain for two days in February 2010 triggered mass movements in the region. This heavy precipitation dropped 44 litres of rain per square metre. It is obvious that several mass movements would have taken place on highly inclined slopes and at least six mass movements were observed in the urban areas within the two-day precipitation period. Thus, heavy rain, steep slopes, discontinuities and lithology type were the main reasons for the occurrence of the mass movements.

Impacts of mass movements

Mass movements caused some trouble to people, properties and infrastructure. The impacts of these mass movements were not as severe on human life because the houses that were damaged by the movements were vacant at the time; loss of life would have been inevitable had the houses been occupied. Luckily only minor injuries were suffered. However, a total of six houses and three cars were damaged and some sections of the roads and retaining walls collapsed. A total of 37 houses were evacuated in case of sliding and rock fall hazards, and two main roads were blocked by these landslides. Table 1 details the mass movements and their effects. Figures 3–8 give graphic examples of the effects of the mass movement events in Izmit, as detailed below.

Figure 3 shows the damage to the road, retaining wall and house by an earthflow in the Terzi Bayırı district of Kale Street. Figure 4 displays the damage to the road, retaining wall and house by an earthflow in the Terzi Bayırı district of Korniş Street. Figure 5 also presents the damage to the road, retaining wall and houses by an earthflow in Dereboğazı Çıkmaz Street, while Fig. 6 illustrates the rockfall on a steep slope in Cedit District Mercan Street. Figure 7 depicts the landslide that took place in the Mersincik district of Derince. Finally, Fig. 8 shows the landslide that occurred nearby a motorway with heavy traffic in Hereke district of Kocaeli. These mass movements caused economic loss and inconvenience, destroying houses and forcing evacuations, disrupting traffic movement and requiring considerable effort in the clean-up, putting a strain on the local municipalities. The total cost of these mass movements during the two-day rain period has been estimated at around $400 000. These mass movements are those noticed in the field during the two-day heavy rainfall. Taking the whole rainy season into consideration, the damage and economic loss related to mass movements could be very high.



Fig. 4. Earthflow in Terzi Bayırı Korniş Street. Damage to the road, retaining wall and house.



Fig. 5. Earthflow in Dereboğazı Çıkmaz Street. Damage to the road, retaining wall and house.



Fig. 6. Rockfall in Cedit District Mercan Street, İzmit.

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Fig. 7. Landslide in Mersincik District, Derince.

Recommendations

What these studies show is that, in order to reduce the impact of such mass movements, some precautionary measurements should be taken before the rainy seasons. These measurements could include frequent field investigations, detailed geological and engineering geological studies, slope analysis, the avoidance of disturbing the balance of slopes and the construction of new dwellings or roads on steep slopes. Water is one of the triggering factors, so installing vertical and horizontal drainage systems is essential for a slope that has the potential for mass movement. Building retention structures such as retaining walls or ground covers at the base of slopes is a way of stopping the slope from sliding. Slopes that have mass movement potential should be assessed for stability conditions within the entire slope in case of settlement planning and developments. Any individual development might cause instabilities in the loading conditions of a slope. Intensity of buildings and distribution of settlements must be maintained at a low level on such slopes. Other preventive measures could be using wire sheet and rock bolting for rock slopes and soil nailing for soil slopes. Stepping the slopes could be applied to both rock and soil slopes. Additionally, slopes next to roads and nearby to developments should be analysed and controlled for stability problems by using engineering geological investigations.



Fig. 8. Landslide in Hereke.

Suggestions for further reading

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