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GEOMORPHOLOGICAL HAZARDS: CHARACTERISTICS AND HUMAN RESPONSE

Geomorphological hazards may be defined as those events or processes, natural or man-induced, that cause a change in earth-surface characteristics detrimental to Man and his activities. They form a sub-set of the broader range of *natural hazards* that represent a world problem of growing importance, in which the cost to mankind is measured in billions of dollars annually. Man's sensitivity to all types of hazard is increasing as world population rises, as technological advances and economic development place ever-greater demands on the environment and its resources, and as societies and economies grow in complexity, thus becoming more vulnerable to disasters. The recurrence of violent earthquakes, volcanic eruptions, catastrophic floods and droughts serves to heighten human awareness of these potential threats and of the need for protection against them. In developed countries, natural disasters may usually be contained and absorbed within the economic and social fabric of the region; but in developing countries they can be a most serious threat to economic advancement, sometimes affecting the economy of the whole nation.

On our dynamic planet there are, of course, areas that are more subject to natural catastrophes than others, areas where endogenic forces are more active, where hillslopes are more unstable, or where certain climatic phenomena are more extreme. In recent decades, human activities have also brought about great changes in the environment, often for the worse. In areas characterised by a precarious morpho-climatic equilibrium, Man himself has sometimes triggered off disastrous events or increased their effects, witness the results of deforestation, of river diversion, or of unsuitable land-use practices.

The specific field of geomorphological hazards represents, in reality, a wide spectrum of physical phenomena and processes, ranging from the sudden and rapid to the slow and long-lasting; from the intense to the diffuse, and the predictable to the unpredictable. A classification in terms of dominant process is given in table 1, together with some approximate qualifications in respect of the degree of catastrophism, predictability and possible control. The term «geomorphological» is used in a broad sense, as it is in this volume of papers, to include geophysical and hydrological phenomena that cause earth-surface changes.

Several international organisations and programmes are today concerned with the scientific investigation of geomorphological hazards. Some are involved with one particular type of hazard, such as the Japan Landslide Society or the World Landslide Inventory of the International Geotechnical Society. Others have a more general remit, but one that is concerned with a specific area, such as the Centre Europeen pour les Risques Géomorphologiques. At the world level, the International Geographical Union set up in 1988 a *Study Group on Rapid Geomorphological Hazards*. This body, under the chairmanship of Prof. C. Embleton of London University, was partly formed from the union of three previous Working Groups that coordinated the meetings at which the papers in this volume were presented. (These were the Working Groups on Geomorphological Survey and Mapping, the Geomorphology of River and Coastal Plains, and Morphotectonics). The three groups met in Italy (Firenze - Modena - Padova) from 28 May to 4 June 1988 at a meeting sponsored by the *International Geographical Union* and by the *International Council of Scientific Unions*, with a special grant from C.N.R. (*National Council for Scientific Research in Italy*) and several universities and public institutions in Italy.

The papers contained in this volume cover a range of geomorphological hazards. They were compiled by twenty-three authors from nine countries, and the areas of study include parts of Europe, south-east Asia, Africa, the Soviet Union and the Middle East. *Mass movements* as a threat to Man and his activities provide the focus of interest in three papers, dealing with the collapse of river bluffs along the Danube in Hungary (LOCZY, BALOGH & RINGER), the

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TABLE 1
A CLASSIFICATION OF GEOMORPHOLOGICAL HAZARDS

Major process	Potentially hazardous Earth surface processes	Possibly man-induced	Possibly sudden and catastrophic	Ability of Man to control	Predict-ability
Seismic	Destabilisation by ground shaking and secondary effects, e.g. landslides, subsidence	—	X	N	P
Volcanic	Explosive eruptions Lava flows Lahars, mudflows Ash deposition River damming Volcanic jökulhlaups	—	X	N	P
Gravity	Mass movements: Rockfalls Slides Flows Creep	X	X	M	G, M
Subsidence	Lowering of surface levels Collapse Creation of enclosed basins	X	rare	M, P	G
Fluvial	Flooding Bank erosion Soil erosion by water (sheet, gully)	X	X	G, M	G, M
Glacial	Advancing glacial Ice/glacier falls Glacial lake dams Jökulhlaups Ice-jams on rivers	—	X	P	G, M
Nival	Avalanches	X	X	M	G, M
Marine	Coastal erosion Silting, accretion Salt-water intrusion	X	—	G, M	G
Eolian	Soil erosion by wind Dune migration Sand/silt covers	X	—	M, P	G

G — good; M — moderate; N — nil; P — poor

frequency of debris flows in the Italian Alps (STRUNK), and the tectonic-related catastrophic rockfalls and boulder fans of the Lake Baikal area (UFIMTSEV).

Flooding hazards are considered in six of the papers. The term «flooding» is unfortunately a rather vague one: it can refer to overbank flooding of rivers, to coastal flooding by the sea, or to periodic inundation of low-lying areas caused by a combination of one or more of the factors of river flooding, sea-level rise, tidal surge or land subsidence. It is a major problem for Man to control in several areas of Italy studied during the Symposium, notably the Po delta (BONDESAN), the plain of Pisa (FEDERICI & MAZZANTI) and the area around Modena (CASTALDINI & PELLEGRINI). A very different type of environment is that of South Yemen (VILLWOCK) with its arid to semi-arid climate in which flash-floods are a distinctive and sometimes devastating phenomenon. In parts of Czechoslovakia, HRADEK shows how damaging floods are caused both by rainstorms and snow-

melt, natural processes that are aggravated by unsuitable land-use practices and causing severe problems of soil erosion.

Soil erosion forms a focus of attention not only in Hradek's paper but also in the study of land degradation in south-eastern Zaire by DE DAPPER, GOOSSENS & ONGENA, and in the case of the Mugello valley in Tuscany dealt with by GARZONIO, MORETTI, RODOLFI & ZANCHI. In Zaire, the principal cause is Man himself, destroying the savanna vegetation for wood and charcoal. In the Mugello, it is again Man who introduced, first, unsuitable agricultural practices and, later, urbanisation and industrial development, giving rise to a range of problems including soil erosion, mass movements and flooding. VILLWOCK describes another form of soil erosion due to wind action in areas of South Yemen.

Coastal hazards present a range of problems for Man, such as marine erosion of coastlines, flooding due to tides or storm surges, subsidence of coastal areas, and salt-water incursion affecting the quality of river and ground-water. CHANG and SHIH describe the latter problem in the case of the Keelung River in Taiwan, but it is also a well-known problem in several coastal areas of Italy. The Po delta and heighbouring coasts offer a series of geomorphological and hydrological problems for Man, strongly related to human activity past and present: the sinking of Venice has been going on for centuries and is probably the most widely known example of *subsidence* in the world. On the other side of Italy, the plain of Pisa suffers from a similar range of hazards related to reclamation and alteration of the natural drainage system-danger of flooding, coast erosion, salt-water intrusion, and immense problems in attempting to control these hazards without further upsetting the delicate balance of natural processes.

The identification of particularly hazardous areas and the monitoring of geomorphological hazards have been undertaken by various techniques, including geomorphological mapping and, more recently, remote sensing. VERSTAPPEN shows how *hazard zoning* based on mapping or aerospace survey can be a most valuable aid in the delimitation of particularly hazardous areas and the implementation of measures aimed at control or mitigation. He illustrates the procedures with reference to earthquake hazard zoning in southern Italy and in Nepal. PANIZZA looks more generally at the problems posed by earthquakes, showing how geomorphological indicators can help in the assessment of *seismic hazards*. Certain geomorphological factors, including slope angle, the nature of the slope debris, the possible existence of palaeo-landslides waiting to be reactivated by seismic tremors, and the dangers inherent in karstic areas from underground collapse, are well-known causes of enhancement of seismic risk.

At the present day there is a meeting of interests between basic scientific research on the one hand, and applied hazard research vital to the civil and political authorities on the other. Attention has been turned to the identification of the phenomena that are potential causes of disasters, to the recognition of the most vulnerable areas, and to the extent of their effects, in order to attempt to predict future occurrences, where possible, and to prevent or at least mitigate their worst effects. It is hoped that this volume, highlighting a number of problems and case-studies, will help in the further understanding and management of geomorphological hazards.