



## CATALOGUING NATURAL GEOLOGICAL HAZARDS OVER POLAND’S TERRITORY

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**Abstract.** Geological risks in Poland are related to surface mass movements and processes stimulated by human activity. The main geological risks include landslides occurring in mountain slopes, river slopes and coastal cliffs. Lately, the geodynamic processes have activated especially in the Carpathians and the Baltic Sea coast. The development of landslides is most probably related to strong atmospheric precipitation or other factors of natural origin, however, it can be also induced by incompetent human activity.

Since the question of natural geological risks is growing, the State administration has taken measures to identify the range of the problem, control hazardous phenomena and eliminate their negative effects. The undertaken actions include the project “Identifying and cataloguing natural geological hazards (especially landslides and other geodynamic phenomena) over Poland’s territory”. The goal of the project is to create a domestic database with geodynamic risks, which can be used in taking preventive action and spatial management of areas at risk. The inventory is carried out based on archive data which are verified and updated and supplemented with new field data. The acquired data are stored in an open-structure digital database which is adapted to the needs of the State administration. The database will be used to make maps of hazards for administrative units of Poland.

**Key words:** geodynamic hazard, mass movements, landslides, inventory, database.

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**Abstrakt.** Na obszarze Polski zagrożenia geodynamiczne wiążą się głównie z powierzchniowymi ruchami masowymi oraz procesami stymulowanymi przez działalność człowieka. Najważniejsze spośród nich to procesy osuwiskowe, zaznaczające się na górskich zboczach, w skarpach dolin rzecznych oraz strefach wybrzeża klifowego. W ostatnich latach odnotowano uaktywnienie tych procesów, zwłaszcza w Karpatach i w niektórych strefach wybrzeża Bałtyku, gdzie miejscami przybrały rozmiary katastrofalne. Nasilenie procesów osuwiskowych wiąże się prawdopodobnie z intensywnymi opadami atmosferycznymi lub innymi czynnikami naturalnymi, może być jednak stymulowane przez nieracjonalną działalność człowieka. Narastający problem zagrożeń naturalnych wymusił działania administracji państwowej zmierzające do rozpoznania skali zjawisk, ich kontroli oraz likwidacji ich negatywnych skutków. Jednym z przejawów tej działalności jest projekt geologiczny „Rejestracja i inwentaryzacja naturalnych zagrożeń geologicznych (ze szczególnym uwzględnieniem osuwisk i innych zjawisk geodynamicznych) na terenie całego kraju”. Jego głównym zadaniem jest opracowanie krajowej bazy danych na temat zagrożeń wywołanych zjawiskami geodynamicznymi, niezbędnej dla planowania działań profilaktycznych i zagospodarowania przestrzennego obszarów zagrożonych. Inwentaryzacja wykonywana jest na podstawie danych archiwalnych oraz weryfikowana i uzupełniana poprzez badania terenowe. Zgromadzone informacje umieszczane są w elektronicznej bazie danych o otwartej strukturze, dostosowanej do potrzeb administracji terytorialnej państwa. Na ich podstawie opracowane zostaną mapy zagrożeń zgodne z administracyjnym podziałem kraju.

**Słowa kluczowe:** zagrożenia geodynamiczne, ruchy masowe, osuwiska, inwentaryzacja, baza danych.

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## INTRODUCTION

Geodynamic phenomena, particularly rapid movements, pose a hazard to man. Due to the geology of Poland, most dangerous geological processes, i.e. active volcanism and strong earthquakes, do not occur there. Geological hazards in Poland are related to surface mass movements and processes stimulated by human activity. Large-scale mass movements with catastrophic effects are known from high mountains including the Andes, the Alps and the Himalayas. There, they occur mostly as mudflows or glacier melting. In Poland, such processes are gentle and do not cause large destruction. The main geological hazards of Poland include the effects of landslides occurring in regions with strong ground surface undulations such as: mountain slopes, steep river slopes or coastal cliffs un-

dercut by abrasion (Fig. 1). The development of landslides depends on the geology of the area, topography, groundwater migration and surface water activity. The Flysch Carpathians are a region where landslide processes frequently occur (Oszycko *et al.*, 2002; Łukasik, 2002; Poprawa, Rączkowski, 2003). There, the joint effects of the lithology and structure of near-surface rocks, steep slopes and strong erosion of surface and groundwaters overlap. As a result, about 90% of observed landslide activity is recorded in the Carpathians (Łukasik, 2002). In the rest of the country, landslide processes develop mainly at river banks and steep slopes of ice-marginal valleys (Fig. 2). An increased development of landslides is observed in young glacial moraines of northern Poland. High mechanical



Fig. 1. Natural geological hazards of Poland (compiled from archive materials and own field research)

**Fig. 2. Hebdow — landslide in the escarpment of the Wisła river valley**  
(Photo by D. Ilcewicz-Stefaniuk)



resistance of rocks is a probable reason of the limited intensity of landslide processes in the Sudetes and Holly Cross Mts. despite significant height differences of the terrain (Synowiec, 2003). Landslide processes in loess develop in a specific way and are stimulated by the suffosion together with destructive action of floral root systems (Łukasik, 2002).

Mass movements developing in Baltic Sea cliffs (Fig. 1) are related to the marine abrasion. A type of the mass movement depends on the geological structure of the shore (Uścińowicz *et al.*, 2004). Debris falls and landslides occur in areas of flu-

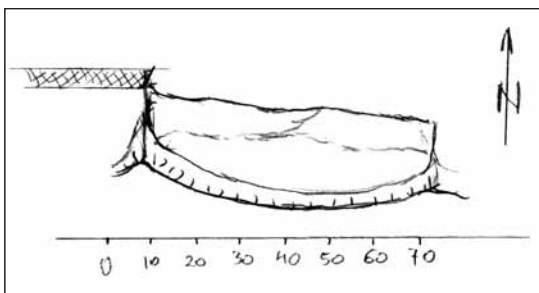
vioglacial and eolic sediments (Fig. 3) while rock falls and landslides are observed at shore built of resistant till (Fig. 4). Limnoglacial clayey sediments play an important role since they form horizons impervious to groundwater.

Landslides, and generally surface mass movements, cause deformation of the ground surface and put a risk to man activity, particularly in urban regions (Łukasik, 2002). Surface deformation can be also a result of mining exploitation and karst processes (Fig. 5). Regions endangered by karst processes are related with outcropping carbonate and gypsum rocks of south-

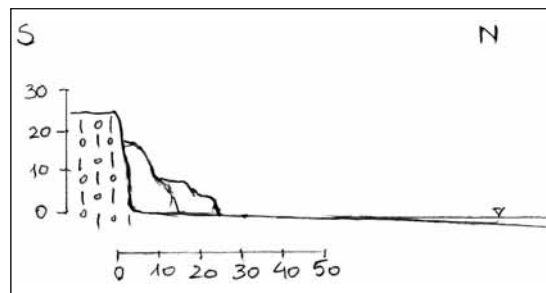
A



B



C



**Fig. 3. Jastrzębia Góra — landslide in the cliff (A) (Photo. by T. Leśniak) and terrain data (B, C)**





**Fig. 4.** Gdynia-Orlowo — rockfall in the cliff and abrasion of the seashore (Photo. by M. Stefaniuk)



**Fig. 5.** Ligota Dolna sink — karst (Photo. by J. Kędzierski)



**Fig. 6.** Turów — landslide in the dump of the opencast mine (Photo. by S. Rybicki)

ern Poland (Fig. 1). Surface deformations caused by mining exploitation are most often observed in areas of old mines in the Upper Silesia and Lower Silesia. Opencast mining that brings about waste-tips is a specific stimulator of anthropogenic mass movements (Fig. 6).

Surface mass movements do not close a list of hazardous geological processes. The neo-tectonic activity plays also a certain role. There are no noticeable destructive effects of the neo-tectonic activity in Poland, however, earth tremors with small or medium energy can endanger buildings and technical infrastructure. Natural tremors in mining areas are accompanied by numerous mining-induced shocks and it is often difficult to differentiate one from another. An increased seismic activity is observed in mountainous regions of southern Poland as well as in the Upper Silesia Coal Basin, Bełchatów Coal Basin and Lubin Copper Basin.



**Fig. 7.** Łeba — migrating dune (Photo. by M. Stefaniuk)



**Fig. 8.** Wilczka river valley (Sudetes Mts., Śnieżnik Massif near Kłodzko) after 1997 flood (left) and after damage removal in 2002 (right) (Photo. by M. Stefaniuk)

Of minor importance is a hazard put by the migratory sand. Hard to control and dangerous at the margins of great deserts, the migratory sand in Poland occurs locally at those parts of the Baltic Sea shore where accumulation dominates (Fig. 7) and near Olkusz where the groundwater level has been lowered as a result of mine draining.

Lately, the geodynamic processes in Poland have been activated and reached a catastrophic size, especially in the Carpathians and coastal cliffs of the Baltic Sea. The development of landslides is most probably related to strong atmospheric precipitation or other factors of natural origin, however, it can be also caused by incompetent human activity.

Violent rainfalls and resulting floods are not regarded as geological hazards, however, they activate surface mass movements, destructive erosion and deposition of alluvial sediments. The destructive floods were noted many times during 1997–2002, particularly in mountain regions and upper courses of rivers (Fig. 8).

Since the problem of natural geological risks is growing, the State administration has taken measures to identify the range of the problem, to control the hazardous phenomena and to eliminate their negative effects. The undertaken actions include the project “Identifying and cataloguing natural geological hazards (especially landslides and other geodynamic

phenomena) over Poland's territory”, which is financed by the Ministry of Environment through the National Fund for Environmental Protection and Water Management. The main executors of the project are the research staff of the Faculty of Geology, Geophysics and Environmental Protection of the AGH University of Science and Technology, Kraków.

The goal of the project is to create a database containing risks caused by the geodynamic phenomena. The database will be used to plan preventive actions and spatial management of the threatened areas. The inventory is carried out on the basis of archive data which are verified and updated and supplemented with new field data. The project focuses on the documentation of landslides and other surface mass movements over Poland's territory excluding the Carpathians (which are the subject of a separate project). Special attention has been paid to morphological forms, such as mountain slopes, steep river slopes, moraine hills and coastal cliffs of the Baltic Sea, where the above-mentioned phenomena are likely to occur. Moreover, areas threatened with karst subsidence and mining-induced deformations have also been catalogued.

The acquired data are stored in an open-structure digital database which is adapted to the needs of the State administration. The database will be the basis for creating maps of hazards for each administrative unit of Poland.

## METHODS AND RANGE OF LANDSLIDE INVENTORY

Data acquisition was based on information from local administration offices and local geological services, as well as archive geological maps, landslide catalogues, aerial photographs and documentation of road, bridge and railway constructions. The project included also field research.

To effectively handle landslide data, a Landslide Inventory Card (a landslide report) has been created. It contains the following information:

1. Detailed location of the landslide:
  - a. geographical coordinates,



- b. location on topographic map.
2. Features of the landslide:
  - a. geomorphologic setting,
  - b. geologic setting,
  - c. size (dimensions),
  - d. type of landslide,
  - e. hydrogeological conditions,
  - f. development of the landslide in time,
  - g. reasons of landslide development.
3. Damage caused by the landslide.
4. Instructions for protection works.
5. Map and profile of the landslide.
6. Recent picture of the landslide.

While preparing a Landslide Inventory Card, suggested methods for landslide reporting of the UNESCO Working Party on World Landslides Inventory and the nomenclature proposed by the IAEG Commission on Landslides were taken into account (A suggested method..., 1990; A suggested nomenclature..., 1990). Patterns of inventory cards from the Polish Geological Institute (Rączkowski, 2001) and General Man-

agement of Public Roads (Instrukcja obserwacji..., 1999) and papers dealing with landslides (Sroczynski, 1994; Varnes, 1978, Zabuski *et al.*, 1999) were also studied.

A general rule was that a researcher had a choice from options listed in the Inventory Card rather than made a written description of landslide features. This allows appropriate information to be easily obtained from the database as well as data comparison and further processing to be made.

A Karst Inventory Card was created to catalogue karst regions in Poland. The card has two parts. Part one refers to the whole study area in which a few objects (single karst forms or groups) that pose geodynamic threaten should be chosen. The data include location, geological setting, hydrogeological environment, age and type of karst as well as damage caused by karst processes. Part two contains inventory cards for the objects with information on detailed location, geological and geometrical characteristics of karst forms, map and profile, damage caused, preventive action suggested, and photographs. Since there are no guidelines in worldwide literature, we based on information from papers by Klimaszewski (1978), Kowalski (1988), Liszkowski (1966) and Paulina (1999) in preparing a Karst Inventory Card.

## DATABASE

The database is created based on data from Inventory Cards. The managing application for landslide data was made under Microsoft Access environment. The Microsoft Access is an advanced professional program for creation and administration of relational database. It uses a single file to manage all necessary information. In that file, the data are divided into separate parts called tables. Data in tables can be viewed, added and updated by means of online documents. The data that are necessary at the moment are found and downloaded by means of queries. The reports enable the data to be analysed and printed under a defined system. The packet architecture includes program functions for a designer, interactive tools for data management, and an interpreter for ready applications.

The creation of the database comprised four basic stages: designing of database structure, designing of applications, program testing and technical documentation.

1. Designing of database structure included:
  - a. definition of the goal and analysis of available data;
  - b. identification of tables and fields contained in the database;
  - c. construction of diagrams of entities through imaging fundamental database components and relationships between them;
  - d. database normalization by elimination of ambiguous relations and limiting attribute values to simple values.
2. Designing of applications.

Application designing consisted of reflecting the designed database structure into objects of the Microsoft Access program.

- a. creation of data structure
  - definition of tables (structure, data type, main key, limitations, indexes),
  - definition of relations (integrity constraints),
  - filling-in dictionary tables,
  - input of test data;
- b. creation of online documents
  - making graphic image of a document,
  - use of a document creator,
  - modification of field types and image of a document,
  - modification of document and field properties,
  - creation of function keys of document programming events;
- c. macro generation;
- d. additional software for applications.

The application and all documents were written in Visual Basic for Application language. The code was divided into modules. Each document is related to a single standard module. Classes pre-defined to operate Access objects were used.

3. Testing of the program. Test data were loaded by external users what enabled errors in application operation to be detected.
4. Technical documentation. A complete technical documentation included a list of all objects in the system and a database scheme presenting relationships between tables.

**Karta dokumentacyjna naturalnego zagrożenia geologicznego - GEOMORPHOLOGY**

Numer ewidencyjny 11 Data 11/28/2002 Autor karty Knapczyk, Joanna Lasak

Lokalizacja Charakterystyka Geomorfologia Geologia Geomorfologia

**Typ osuwiska**

<input type="checkbox"/>	zbocze wyżynne dolna część zbocza
<input type="checkbox"/>	zbocze wyżynne górna część zbocza
<input type="checkbox"/>	zbocze wyżynne środkowa część zbocza
<input checked="" type="checkbox"/>	

Inne

Nach. zbocza

Azytmut poch.

**Karta dokumentacyjna naturalnego zagrożenia geologicznego - osuwisko**

Numer ewidencyjny 11 Data 11/28/2002 Autor karty Knapczyk, Joanna Lasak

Geologia Geomorfologia Powstałe szkody i zagrożenia Inne Schematyczny plan i przekrój przez osuwisko Położenie osuwiska

Plan Przekrój

**METAFILES:** cross-sections, location map, photographs

**GEOLOGY:** surrounding and sliding sediments

**Karta dokumentacyjna naturalnego zagrożenia geologicznego - osuwisko**

Numer ewidencyjny 11 Data 11/28/2002 Autor karty Knapczyk, Joanna Lasak

Lokalizacja Charakterystyka Geomorfologia Geologia Geomorfologia

Typ osuwiska gruntowe

Wiek gruntów

Zaleganie warstw grunty jednorod

Beta

**Rodzaj warstw w rejonie osuwiska**

<input checked="" type="checkbox"/>	lessy (utwory lessopodobne)
<input type="checkbox"/>	
<input type="checkbox"/>	

**GEOLOGY:** surrounding and sliding sediments

**METAFILES:** cross-sections, location map, photographs

Fig. 9. Database — example of landslide report (Karta osuwiska...)

## SUMMARY

A result of the project will include:

1. A computer open-structure database of natural hazards for administration units.
2. Maps of hazards.
3. Principles of monitoring, prevention and elimination of effects of geological processes, especially surface mass movements.

4. It is known from experience that the archive research cannot be fully relied on because some landslides do not exist any more. Therefore, a periodic check of listed landslides is necessary.

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