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GEOHAZARDS IN POLAND – REA WP3 ACTIVITY

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Abstract. The geohazards – floods, hurricanes, earthquakes, volcanic eruption, tsunamis, mass movements, avalanches etc. are reasons of many catastrophes and tragedies in the scale of our Globe. Thanks to the geographical position of Poland, it is missing at the list of the biggest natural disasters in the XX century. A breakthrough moment for awakening of social consciousness in relation to natural catastrophes happened in summer 1997. At that time the catastrophic regional flood took place in the Odra River and affected substantial areas in Poland, and other countries of Central Europe innundaing many towns and villages. Over 100 people were killed and material losses were counted in millions of dollars. Soon after the flood, the enormous amounts of landslides were activated, mainly in the Carpathians. The list of the main geohazards in Poland includes: mass movements, coastal erosion, soil erosion and floods. Geohazard phenomena are measured and monitored by different means, mainly precise levelling, GPS and other geodetic methods. In the last years the new technology appeared – Persistant Scatterer Interferometry (PSI), based on the remote sensing radar satellites. The technology uses the data collected by European Radar Satellites (ERS-1, ERS-2 and ENVISAT) in a process called Synthetic Aperture Radar Interferometry, or PSI for short. PSI can cover whole cities and regions, and because an archive exist of "repeat" satellite data, measurements can uniquely be provided back in time for the last twelve years. It will be effective operative tool for geohazards monitoring in the nearest future.

Key words: geohazards, mass movements, coastal erosion, soil erosion, floods, Permanent Scatterer Interferometry.

Abstrakt. Geozagrożenia, takie jak powodzie, huragany, trzęsienia ziemi, wulkanizm, tsunami, powierzchniowe ruchy masowe itp. są przyczyną wielu katastrof i tragedii w skali całej naszej planety. Dzięki usytuowaniu geograficznemu i geologicznemu, Polska szczęśliwie nie znajduje się na liście krajów, w których w XX wieku miały miejsce wielkie naturalne katastrofy przyrodnicze. Przełomowym momentem dla obudzenia świadomości społeczeństwa w odniesieniu do katastrof przyrodniczych były wydarzenia, które wystąpiły latem 1997 r. W tym okresie miała miejsce katastrofalna powódź regionalna na Odrze i jej dopływach, która zalała wiele miast i wiosek w Polsce i przyległych krajach oraz spowodowała śmierć ponad 100 osób i ogromne straty materialne. Wkrótce potem zaktywizowały się na ogromna skalę osuwiska, głównie w Karpatach. Lista głównych zagrożeń w Polsce obejmuje: powierzchniowe ruchy masowe, erozję brzegową, erozję gleb oraz powodzie. Geozagrożenia są identyfikowane i monitorowane przy pomocy różnych metod: niwelacji precyzyjnej, lokalizatorów GPS i innych metod geodezyjnych. W ostatnich latach doszła nowa metoda, PSI – Satelitarna Interferometria Radarowa (wykorzystująca ciągłe punkty pomiarowe). Metoda ta bazuje na danych z europejskich satelitów radarowych (ERS-1, ERS-2 oraz ENVISAT) oraz wykorzystuje analizę interferometryczną – PSI. PSI może objąć analizą znaczne obszary, a istnienie archiwalnych danych radarowych umożliwia przeprowadzenie studiów w ciągu ostatnich 12 lat. W niedługiej przyszłości PSI będzie jedną z głównych operacyjnych metod dla detekcji i monitorowania geozagrożeń.

S³owa kluczowe: geozagrożenia, powierzchniowe ruchy masowe, erozja brzegowa, erozja gleb, powodzie, PSI.

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INTRODUCTION

Until quite lately Poland was considered as a country deprived of geohazards. As a matter of fact our country is distinguished positively in comparison to the other countries of Europe like Mediterranean Region, countries of Iberian Pennisula or the Balkan Penninsula.

Geohazards – floods, hurricanes, earthquakes, volcanic eruption, tsunamis, mass movements, avalanches etc. are reasons of many catastrophes and tragedies in the scale of our Globe. According to confirmed statistics between 1947 and 1967, about 450,000 people were killed in effect of the natural catastrophes. It is much more casualties than during war conflicts (excluding world conflicts). Figure 1 shows distribution of some geomorphological hazards in Poland.

Thanks to the geographical position of Poland, it is missing at the list of the biggest natural disasters in the XX century. I does not mean that the natural catastrophes were totally absent in Poland. The historical sources show evidences of seismic events in Southern Poland in the Podhale region in XVIII-th century. Quite often the floods took place, including our main rivers Vistula and Odra. The amount of casualties should be numbered in tenth and hundreds.

Breakthrough moment for awakening of social consciousness in relation to natural catastrophes happened in summer 1997. At that time the catastrophic regional flood took place in the Odra River and affected substantial areas in Poland, Austria, Czech Republic and Germany inundating many towns (including Wrocław, Kłodzko, Słubice and Kostrzyn) and villages. Over 100 people were killed and material losses were counted in millions of dollars. Soon after flood the enormous amount of landslides were activated, mainly in the Carpathian Mountains.

The Polish Geological Institute systematically improves the methodology of mass movement studies, starting from the analysis of remote sensing data (aerial photos, high resolution satellite images, interferometric data), creation and management of spatial data bases (remote sensing, DTM, GIS – thematic maps), creation of the GIS hazard maps, geodetic measurements (GPS, Total Station *etc.*), geophysical methods (Georadar, Seismic) and dendrochronological methods.

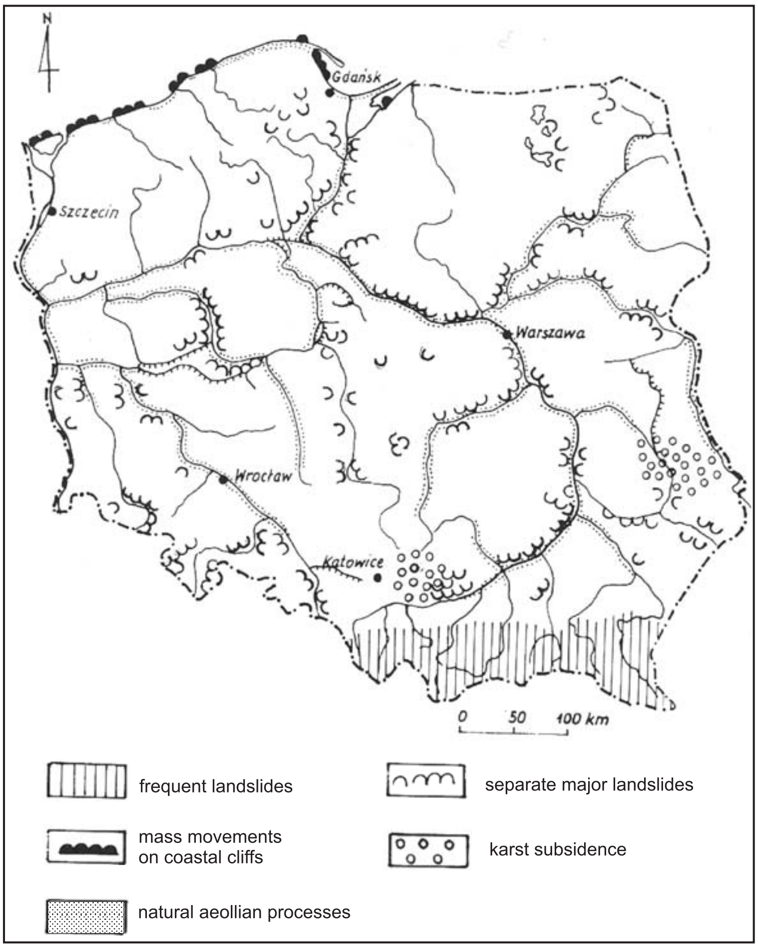

Fig. 1. Location of some geomorphological hazards in Poland (according to Embelton, Embleton, 1997)

A development of different methodologies is also achieved through cooperation with Polish southern neighbours, the Czech and Slovaks, within the project granted by the Polish Ministry of Science and Education and EU 5PR grant "ALARM".

MASS MOVEMENTS

The term "a mass movement" describes the movement of the earth material down-slope primary under the influence of gravity.

There is no sharp boundary between block falls and rock falls or between the rock falls and the landslides, except that rock falls only occur on bare rock walls and landslides also take place on less steep, soil covered slopes. To be defined as a landslide, four criteria must be fulfilled:

1. The movement must be rapid, lasting seconds or at most a few minutes;

2. The sliding surface, the shear plane, must go through the bedrock composes the largest part of the landslide;
3. The sliding mass disintegrate during the movement;
4. The slope area affected by the movement and the volume of the rock mass in motion must be large enough for it to be defined as a landslide by the people living in the area. A relative definition of the size of the mass seems more appropriate than one express by an arbitrary number of square metres, tonnes or cubic metres.

The characteristic feature of Poland is that mass movements are both concentrated in certain localities or regions and widely dispersed across the territory. This concerns both most spectacular and catastrophic landslides and the less obvious and longer – acting processes such as soil creep and slope wash which can be monitored only by careful measurements. Major landslides in Poland are most characteristic of the Carpathians in the south-east part of the country, but they can be also found in valleys of big rivers, along deeply incised valleys and on the Baltic coastal cliffs.

The location of the areas at risk from major landslides is controlled by two main factors: the presence of slopes with a favourable geological structure, and high levels of precipitation. Both of these conditions are fulfilled in the case of the Flysch Carpathians, consisting of interbedded shales and sandstones, deeply dissected by numerous valleys. The annual precipitation reaches here 800–1100 mm, being sometimes concentrated in rainstorms.

The present estimation indicates that over 95% of all landslides in Poland occur in the Flysch Carpathians. According to investigations carried out by the Polish Geological Institute about 10% of the area of the Polish Carpathians has been in past, or is being at present, endangered by landslides or other forms of mass movements.

The temporal incidence of the mass movement is strongly correlated with the climate. During wet years, or soon after, an increasing number of fresh or revitalised landslides is reported. Such a situation took place after heavy rainstorms and flood in summer 1997. Since that time, numerous landslides in the Polish Carpathians were activated. Serious damages of houses and the communication infrastructure were reported (Fig. 2). Over 20,000 landslides were registered until 2003.

Fig. 2. Landslide in the Western Carpathians

In 2002, landsliding was officially a in the list of events causing a natural disaster for the first time. Efforts of the Polish Government yield to a proposal of changes in certain legal acts. The landsliding hazard and risk must be considered in the spatial planning and management. This is probably the best method of mitigating the related hazards (Gerlach *et al.*,1958; Rączkowski, 2001).

The temporal incidence of mass movements is strongly correlated with the climate. During wet years, or soon after, an increasing number of fresh or revitalised landslides is reported. According to Ziętara the recurrence interval of wet years in the Carpathians is about 30–32 years (Ziętara,1968). The meteorological causes acting as the final trigger for slope failure, the effect of earthquakes, possibly far away, should not be overlooked. In 1957, for example, a landslide with a surface area of 20,000 m^2 at Lipownica in the Eastern Carpathians was released by an earthquake epicentre of which was situated in Thessaly, Greece (Gerlach *et al*., 1958).

Sooner or later, all landslide tongues reach the floors of the valleys, where they are the subject to fluvial erosion. Their impact on the development of the Carpathians relief seems to be quite significant estimated, that during the Holocene about 500,000 m^3 of material has been removed by mass movement from each 1 km^2 of the Flysch Carpathians. (Starkel, 1962)

The Polish Geological Institute have developed several projects including a registration of landslides in the Carpathians, monitoring its activity and making prognosis for future. These prognoses are connected with a necessity of changing local plans of the territorial development. Such plans are prepared in smallest administration units (“gmina”). All available modern mapping technologies will be applied during the project realisation, including remote sensing, GIS and GPS measurements.

Stereo pairs of aerial photos (B&W, normal colour and IR colour) have been long used to recognise slides and a slide-prone terrain. Zones of the previous sliding activity are easily identified on aerial photos by characteristic crescent scarps and the hummocky topography exhibited by the debris flow. It is obviously more difficult to identify areas that have a potential for sliding or slumping, but the following characteristics may help to identify such zones. Because the key features in such cases are rather small, large-scale photos (about 1:10,000) have been found to be the most useful.

In the regional scale, the satellite images could be also useful for landslide studies. On these images the recognition of the unstable terrain where the slides occur could be possible. Such analysis is enriched when satellite images are applied together with DTM. The satellite images could be also useful for monitoring of land surface changes related to landslide activity (Graniczny *et al*., 2001).

Such studies were performed between Gorlice and Szymbark. Numerous landslides have been developed here, on the slopes of the Maślana Mt. and Miejska Mt. The landslides were mapped during geological mapping made in the scale 1:50,000. The contours of the landslides were superimposed at the land use map, elaborated on the basis of the Landsat TM satellite image interpretation. It was found that about 50% of landslides are located at the areas covered by forests. It means that they constitute a low hazard. In the next stage of the analysis mapped landslides were compared with DTM (Graniczny *et al*., 2001). The analysis revealed that most of the mapped landslide areas correspond to the mountain slopes 8–10°. The same analysis showed that the landslide areas are located beneath slopes 11–14°. Another aspect of the analysis concerned localities of landslides versus slope exposures. The above-presented digital analysis is fast and helpful for further terrain investigations.

During the field works, GPS measurements are performed. Instruments enabled measurements with sub- centimetre accuracy are quite good for mapping in the scale of 1:10,000 and the monitoring purposes.

Finally, on the basis of the remote sensing data interpretation field works and measurements, the GIS database will be created. Maps of landslide prone areas will be elaborated, too. Besides that, the landslides information system will be organised using INTERNET. There is a special questionnaire in the PGI website enabling collection of information concerning new landslides. These information will be processed and verified by PGI specialists. They will be taken into account during preparation and verification of the local territorial planning policy.

Another, international project was established by the Polish Geological Institute, Czech and Slovak Geological Surveys devoted the common landslide studies in the Carpathians. Sometimes landslides cause the "international" problem. For example, the landslide Osturnia located in the Podhale, just on the Polish–Slovakian border was recognized in the 60th. A escarpment of the landslide is situated at the Polish side of the border but the mass movement and transported material stopped at the Slovakian side. The main aim of the project are integrated multi-thematic data collected during field works and the analysis of satellite images, aerial photos, digital elevation models, geophysical and meteorological data. Three test areas have been chosen; Lachowice in Poland, Vcklov Sedlo in the Czech Republic and Oravska Lesna in Slovakia.

All landslides are localized at the similar geological conditions – the Magura Unit. The preparation of the unified technology of the landslide monitoring and risk evaluation will be final outcome of the project.

High-resolution satellite images IKONOS were tested for the interpretation and monitoring of the Lachowice landslide and compared with the aerial photos. The images have fully confirmed its utility for identification of damages and observing of the landslide development.

In the Sudetes in south-west Poland, mass movements are not so frequent or serious, largely because of different geological conditions. Throughout a long geological history, the Sudetes have passed through all the main European orogenic phases, as a result of which the structure now consists of a mosaic of resistant igneous and metamorphic rocks. Although dissected by numerous faults, the lithological conditions for major mass movements are lacking.

As already mentioned, the mass movements are by no means confined to the south of Poland, but can occur in any area where the geological structure is favourable and the relief is characterized by slopes of sufficient height and gradient. They are thus most frequent in the area of the Pleistocene plateaus in Central and Northern Poland, valleys of big rivers (Dobrzyń, Wyszogród, Płock, Sandomierz) and along deeply incised valleys in different places of the country.

COASTAL EROSION

Processes and phenomena forming of the coastline, are generated by many interrelated factors, such as: the geological structure, geomorphology, climatic phenomena, hydrological and hydrodynamical conditions, biotic resources of the environment, type and a way of development and utilization of the coastal zone. In the dynamic picture of the coastal zone, none of these factors has an unequivocal and long lasting priority; also none of them can be viewed, analyzed and interpreted without taking all other factors into account.

The Polish Baltic coastal zone should be considered as a region of a strong conflict between economical development (urbanization, tourism, recreation, transport, industry) and the need to maintain the natural landscape and the existing geo-ecosystems. Therefore, the selection of a proper method of developing the coastal zone resulting from its natural predisposition, is a basic task in the process of the economical utilization of this zone.

Main types of hazards on the Polish coasts are related to coastal zone morphology, and the geological structure, including the lithology and the amount of sediments. Coastal erosion caused by the sea-level rise and climatic changes the main factor of the hazards, an increased is the most important is frequency of heavy storm surges.

For example, for the last 100 years the average sea level rise in the Gdańsk region is about 1.5 mm/year. Beginning from the 50-ties this rate has increased to 5 mm/year. The frequency of dangerous storm surges increased also in the Gulf of Gdańsk from 11 situations in the 60-ties to 38 in the 80-ties. Because of these both factors, many parts of the coast, which were inactive (cliffs) or persisted in the equilibrium state (barriers), became activated during the last decades (Uścinowicz *et al*., 2004).

The cliff on the Polish coasts is built mainly of the Pleistocene glacial tills, clays and fluvioglacial sands. The heights of the cliffs, are generally between a few to 20–30 m. In some places they still increase as, up to 52 m at the Rozewie cape and 70 m on the Wolin Island. The rate of the coastal cliffs retreat depends on its geological structure and is related to types of mass movements. It also depends on regional/local hydrodynamic activity. A long term average rate of the coastal cliff retreat for the period of 1875–1979, was 0.23 m/year on the western Polish coast and 0.55 m/year for the eastern part. The cliffs retreat rate increased in the last decades (1971–1983) to 0.78 m/year on the western and to 1.49 m/year on the eastern part of the coast (Zawadzka, 1999). Figure 3a, b shows cliff in Jastrzębia Góra before and after remediation works.

Catastrophic events related to mass movements are most dangerous for the hinterland. Generally, three types of the mass movements can be distinguished on the Polish coast: rock falls dominating on the cliffs, built mainly of tills, talus and landslip dominating on the sandy cliffs and typical landslides occurred on cliff stretches with a complex structure, where the main role play clay layers being initial slide layers for other deposits. The landslides are most hazardous on the coast because, opposite to rock falls and taluses, then sometimes affect zones of hundred metres away from the cliff edge.

The type and range of risks on the coast depends mainly on morphological and geological features of the coast. Therefore, the detailed knowledge of the coast geology is strongly needed. Figure 3a, b shows cliff in Jastrzębia Góra before and after remediation works.

Remote sensing methods strongly contribute to solve some problems by fast delivering of the data. For example, they can provide nearly instantaneous images of sea circulation patterns over very large areas. Current systems are mapped by recognizing some properties of water that differs from that of the surrounding water. The interpretation of Landsat MSS and Landsat TM satellite images of the Gdańsk Bay enabled to record following properties of water:

- a colour due to the suspended material such as sediment and plankton;
- a radiant temperature.

On the Landsat MSS scene of 8th July 1991, water masses from the Vistula are clearly visible as they move east along the coast. The currents are clear because of the alga bloom synonymous at this time of year with the drift of warm water masses. In this same image the Russian port of Baltijsk can be identified as a possible major source of pollution. At the Landsat TM imagery, significantly more structures of algae blooms are visible, especially in a 15 km diameter from the mouth of the Vistula river.

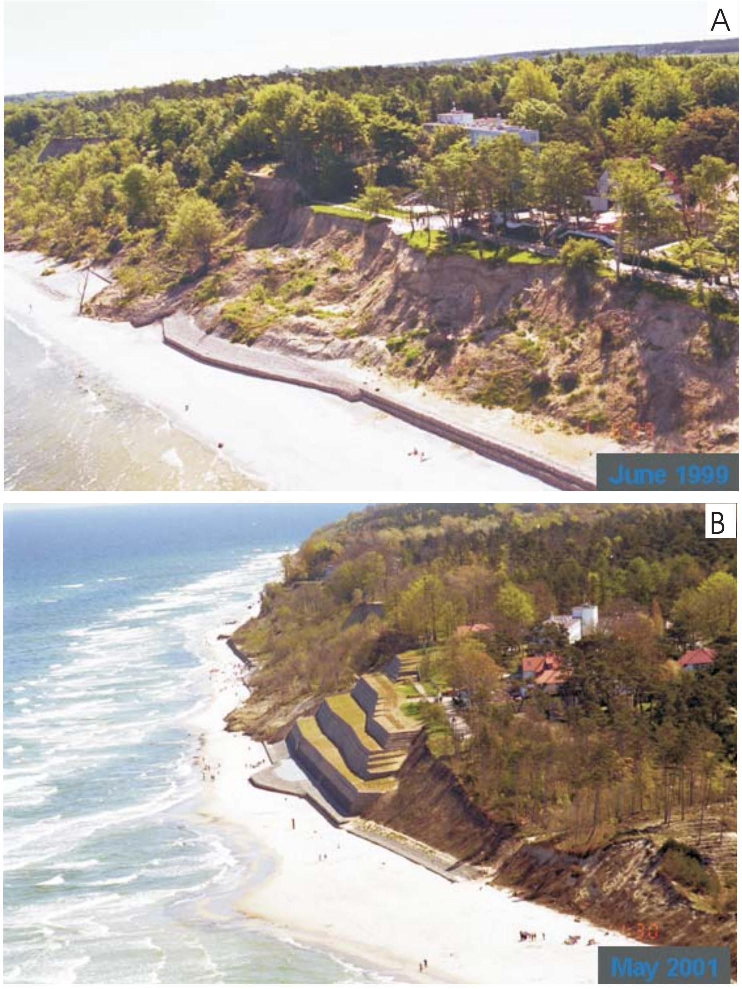

Fig. 3. Cliff in Jastrzêbia Góra – eastern coast; A – before remediation in 1999; B – after remediation in 2001

There are several other problems, which were studied effectively the remote sensing (satellite images and aerial photos):

- the rate of erosion of cliffs (in different subenvironments: open sea, gulf and lagoon coasts);
- the dynamics of the dune coast (mainly a strong erosion with a local accumulation) influenced by human activity like artificial beach nourishment and protection by groins and other constructions on the example of the Hel Peninsula;
- the dynamics of natural, non protected dune coast on the example of the Vistula Spit;
- the erosion of the old Vistula River outlet cones;
- the rate of accretion processes of the recent outlet cone in the Vistula mouth;
- the sediment (sand) transport along the shore – its rate and range;
- pathways of a suspended matter and related pollutants transportation from Vistula mouth to the Gulf of Gdańsk;
- the assessment of the influence of harbours and coastal protection constructions on the coastal processes.

On the basis of field works (mapping, drilling on land and sea, seismoacoustic, sonar and microseismic sounding), laboratory analyses, collecting of archive materials, interpretation of aerial photos and studies of satellite images concept of the "Geodynamic map of the Polish Coastal Zone" was developed at the scale of 1:10,000. The concept of the GIS datebase structure was elaborated, too. Two pilot sheets Władysławowo and Rewal have been made. The MapInfo software was applied for its preparation.

The future projects should also focus on the socio-economic and environmental assessment of the climate change in the Polish Baltic Sea coast, especially on the sea level rise, the increased coastal erosion, changing runoff pattern of rivers and the groundwater contamination. These can lead to better understanding of major flooding events having severe impacts on the spatial development of cities and regions as well as to sustainable development of the entire Polish coast.

SOIL EROSION

This is one of the most serious geohazards in Poland, the more so because of its insidious nature. According to GUS (Main Statistical Office) Yearbook (1992) about 56% of total arable area in Poland is threatened by degradation and falling agricultural yields. The flat areas of central Poland are particularly at risk from wind erosion, as a result of several factors: a lack of sufficient precipitation, extensive deforestation and removal of windbreaks, and unsuitable agricultural practices that cause further drying of the soil and expose the soil to wind erosion at certain times of the year.

It is estimated that gully erosion affects altogether no less than 20% of Poland. The total lengths of gullies is of order of 40,000 kilometres. The areas that are worst affected are in the south and north (Józefaciuk, Józefaciuk, 1980; Józefaciuk, 1990). The average density of gullies varies between 0.1 and 1.0 km/km^2, but in southern Poland the equivalent figure can rise to over 2.0 and in the loess areas of Wyżyna Lubelska, it can exceed 10 km/km^2 (Maruszczak, 1958). The picturesque region of the Kazimierz Dolny vicinity is especially liable to gully erosion.

SUBSIDENCE

Subsidences are mainly human-induced hazards. Hazards of this type in Poland are mostly connected with deep mining of coal and mineral ores in the industrial area of the Upper Silesia. In this mining region, already 60,000 ha suffer from the subsidence (Busek, Dominik, 1990). The surface becomes pitted with numerous collapse cavities or basins the depth which may even reach tens of metres. They may remain dry or may be filled with water depending on the local hydrogeological conditions. The subsidence is particularly dangerous in urban areas, causing severe damage to gas and water pipelines, electric cables and sewage disposal systems. In such areas it is common to find houses being strengthened with iron bars anchored in the walls to try to prevent further damage or collapse, but even such reinforced buildings will show cracks and joints in the walls. Another region suffering from subsidence caused by deep mining lies in south-west Poland. This is the Lower Silesian industrial region with numerous coal mines for non-ferrous metals. The area near Lubin–Polkowice contains Poland's largest copper mines, one of the biggest in the world.

The subsidence is measured and monitored by different means, mainly precise leveling, GPS and other geodetic methods. In the last years the new technology appeared – the Persistant Scatter Interferometry, based on the remote sensing radar satellites.

The technology uses the data collected by European radar satellites (ERS-1, ERS-2 and ENVISAT) in a process called Synthetic Aperture Radar Interferometry, or PSI for short. PSI can cover whole cities and regions, measurements can uniquely be provided back in time for the last twelve years, due to the archive record of "repeat" satellite data,

The InSAR has been available to us for over a decade, providing ground deformation data at centimetres resolution. In the past 2 years, new ways of processing satellite radar images have been invented, that allow ground movements to be mapped and monitored to better than 1 mm per year. This process is called Permanent Scatter Synthetic Aperture Radar Interferometry, or PSInSAR for short. The technique depends on the existence of radar scatters which consistently reflect signals from successive satellite passes. This means it works best in urban and arid conditions where vegetation cannot interfere with the coherence. Several tens of images taken during last twelve years (1992 – launching of the ERS-1 satellite) can be processed simultaneously according to the PSInSAR technology.

FLOODS

Because such a large part of Poland consists of lowlands traversed by major rivers with very variable regimes, one of the chief hazards is the risk of flooding. There are three basic causes of river flooding in Poland: heavy rainfall, snow thaw and ice jams. Severe rains affect Poland almost every year and cause floods, bringing serious damages to towns, roads, agriculture and to the environment in general, sometimes with a loss of human life's.

The protection against flooding has a long history. Still only in comparatively recent times, the technology for defence against floods and its monitoring on big rivers has been available.

The Polish Geological Institute and BGR (Geological Survey of Germany) started common studies in the Odra valley on the beginning of 90th. The multitemporal Landsat TM images, satellite radar data and aerial photos were widely used for mapping purposes.

In the first half of July 1997, heavy rains falling on the border areas between Poland, the the Czech Republic, Austria and Slovakia, swelled the water courses and caused floods in the southern part of this region. Within a 10-day period, over 100 people died in Poland and in Czech Republic.

The Polish Geological Institute in cooperation with the German enterprise PHONESAT processed and interpreted a set of different satellite images.

On July 15ERS-2 SAR data revealed consistent floods near Wrocław on the Odra river and westwards, along the river course. The extent of the flooding along the Odra River was revealed by ERS-2 SAR multitemporal images on July18. Additional SAR data, collected from ERS-2 on July21, provided, up-to-date information on the event. The flooding along the Odra reached the border between Germany and Poland with a high water pressure that seriously threatened the resistance of a 160-km dike along the Odra near Frankfurt. Threatened zones of the dike could be identified at the Landsat TM data, registered 22nd July. On July 23 a 160-km dike collapsed. Two days later, the residents in the Frankfurt neighbourhood had to be evacuated. In the Czech Republic, thousand of homes were destroyed and thousand of acres of farmlands badly affected. In Poland over 149 villages were submerged and almost as many were threatened by new floods. On 26 July about 15,000 citizens had to leave the town of Słubice on the Odra. The Polish side of the Odra was more in danger than the German side, because of the height difference between the two river banks (1–3 m lower in Poland). In the night 27–28 July, the water level in Frankfurt reached a record height of 6.75 m. The situation improved during the second half of August. Waters retreated, thus reducing the risk of further dike cracks, with the exception of the Oderbruck region. Here, the high water level was still threating villages and farmlands.

By using the satellite information (optical and microwave), local authorities, civil protection entities and insurance and re-insurance companies are offered one more tool to monitor flood events and to assess damages. Furthermore, by combining the satellite information with topographic data (DTM), geological and hydrological data, even more end-user-oriented products can be obtained for the direct utilization by entities in charge of risk management and hazard prevention.

The support from the Centre of Excellence REA established in Polish Geological Institute in 2003 was essential for development of geohazard studies. The working group “Geohazards” was established under leadership of Marek Graniczny. Many scientists and specialists from Institute were also involved in different working group actions, among them: Anna Piątkowska, Magdalena Czarnogórska, Zbigniew Kowalski, Piotr Nescieruk, Wojciech Rączkowski, Antoni Wójcik and Teresa Mrozek.

Working group acting within this initiative between 2003 and 2005 organized and participated in many events, including conferences, invited lectures, exploratory meetings, trainings, coordination meetings *etc*. Two international conferences: *Risks caused by the geodynamic phenomena in Europe* and *Mass movement hazard in various environment.* This programme has enabled also contacts with different leading organisations involved in geohazards investigations eg. Italian Research Institute (IRPI) in Padua and Bari, and Universities in Milano, Barcelona and Strasbourg as well as geological surveys – French, Irish and British.

REFERENCES

BUSEK B., DOMINIK A., 1990 — Czynniki degradacji środowiska przyrodniczego oraz formy jego ochrony. *Zesz. Nauk. Akad. Ek*., **112**: 11–48.

EMBELTON C., EMBLETON C., 1997 — Geomorphological hazards of Europe. Developments in Earth surface processe 5. Elsevier: 368–389.

GERLACH T. i in., 1958 — Osuwisko w Lipnicy. *Prz. Geogr*., **30**, 4: 685–700.

GRANICZNY M., KOWALSKI Z., RĄCZKOWSKI W., ZIMNAL Z., 2001 — Komputerowa analiza danych przestrzennych w aspekcie zagrożeń osuwiskowych. *Prz. Geol*., **49**, 1: 33–38.

JÓZEFACIUK CZ., 1990 — Procesy spłukiwania i erozji wąwozowej. *W*: Geografia Polski (red. L. Starkel): 420–425.

JÓZEFACIUK CZ., JÓZEFACIUK A., 1980 — Zasady rekultywacji i zagospodarowania wąwozów. *Pr. IUNG*, *Puławy*, **74**.

MARUSZCZAK H., 1958 — Charakterystyczne formy rzeźby obszarów lessowych. *Czas. Geogr*., **38**, 2: 335–353.

RĄCZKOWSKI W., 2001 — Osuwiska polskich Karpat fliszowych, Przew. 72 Zjazdu Pol. Tow. Geol. i MAEGS-12, 10–15 września 2001, Kraków: 259–262.

STARKEL L., 1962 — Stań badań nad współczesnymi procesami morfogenetycznymi w Karpatach. *Czas. Geogr*., **23,** 4: 459–471.

UŚCINOWICZ SZ., ZACHOWICZ J., GRANICZNY M., DOBRACKI R., 2004 — Geological structure of the Southern Baltic coast and related hazards. *Pol. Geol. Inst. Sp. Pap*., **15**: 61–67.

ZAWADZKA E., 1999 — Trends of development of the Polish Southern Baltic coastline (in Polish, with English summary). Gdańskie Towarzystwo Naukowe, Gdańsk: 1–147.

ZIĘTARA T., 1968 — Rola gwałtownych ulew i powodzi w modelowaniu rzeźby Beskidów. *Prz. Geogr*., *PAN*: **116**.