**FP7 PROGRAMME**

**DORIS -** Ground Deformations Risk Scenarios:
An Advanced Assessment Service

GRANT AGREEMENT NO. 242212
COLLABORATIVE PROJECT
START DATE: 1 OCTOBER 2010

# WP5 – Assessment Maps Delivery and Design of Risk Scenarios

## DELIVERABLE No. D5.1
## Large scale thematic maps for selected test-sites (1:50.000)

# DOCUMENT INFORMATION

| | |
|---|---|
| Acronym of lead partner for the deliverable | CNR |
| Work package | WP 5 |
| Contractual date of delivery | Month 12 |
| Date of delivery | November 2011 |
| Nature | O |
| Dissemination level | PU |

| | |
|---|---|
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| | |
|---|---|
| Release | 2 |
| Version | 2 |
| Date | 17 October 2011 |

## REFERENCE DOCUMENTS

| | |
|---|---|
| DR-1 | Annex I - Description of Work of DORIS – "Ground Deformations Risk Scenarios: An Advanced Assessment Service" |
| DR-2 | Deliverable 2.1 – "User and Service Requirements" |
| DR-3 | Deliverable 2.2 – "Procedural interface design" |

## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ALTAMIRA | Altamira Information |
| CA | Consortium Agreement |
| CNR | Consiglio Nazionale delle Ricerche |
| CP | Civil Protection |
| DAP | Data Access Portfolio |
| DInSAR | Differential Synthetic Aperture Radar Interferometry |
| DOW | Description of Work |
| DPC | Dipartimento della Protezione Civile |
| EC | European Commission |
| ELGI | Magyar Állami Eötvös Loránd Geofizikai Intézet |
| EO | Earth Observation |
| ERCS | Emergency Response Core Service |
| ERS | Emergency Response Service |
| ESA | European Space Agency |
| EU | European Union |
| EUAC | External User Advisory Committee |
| FOEN | Bundesamt fuer Umwelt |
| FP | Focal Point |
| FP7 | 7th Framework Programme |
| FTS | Fast Track Service |
| GAMMA | Gamma Remote Sensing Research and Consulting |
| GMES | Global Monitoring for Environment and Security |
| IGME | Instituto Geológico y Minero De España |
| INSPIRE | Infrastructure for Spatial Information in Europe |
| IT | Information Technology |
| NFP | National Focal Point |
| PGI | Panstwowy Instytut Geologiczny - Panstwowy Instytut Badawczy |
| R&D | Research and Development |
| SAFER | Services and Application For Emergency Response |
| TRE | Tele-Rilevamento Europa |
| UNIFI | Università degli Studi di Firenze |
| WP | Work Package |

## EXECUTIVE SUMMARY

In the DORIS project, Work Package 5 WP5 represents the thematic core for the DORIS downstream service. The scope of WP5 is to generate and deliver relevant and accurate maps and timely information for managing the different Civil Defence phases involved with the onset of ground deformations, primarily mass movements and land subsidence. WP5 will receive direct input from WP4 (EO data processing and management) and from WP3 (research and technology development), and will deliver outputs for the end users, and to WP6 (product validation). WP5 will further interact with WP7, providing necessary information for the assessment of the service sustainability.

The scope of this document is to describe the six study areas located in Europe where we propose to test the DORIS downstream service. Two study areas are located in Italy, and one study area in each of the following European Countries: Hungary, Poland, Spain, and Switzerland. For the selected study areas we describe the main characteristics, including: (i) the country, (ii) the geographical coordinates, (iii) the dominant physiographical setting, (iv) the main types of ground deformation phenomena that will be investigated, (v) a brief description of the area, (vi) a list of the thematic available information (vii) a list of the expected products as described in the deliverable 2.2 and (viii) a list of selected scientific and technical reports available in the test area.

The thematic information available for each test site and listed in this document are also described in the deliverable D6.1 “Selected test sites and geo-database” that contains information related to: b) the enrolled end users; c) the geo-database description of every site; d) and a description of the related web services.

## TABLE OF CONTENTS

# 1. INTRODUCTION

In the DORIS project, WP5 represents the core of the proposed downstream service. The scope of the WP5 is to generate and deliver relevant products, maps and timely information useful to manage the pre-event, event and post-event phases of natural and human induced hazards that result in ground deformations, primarily mass-movements and land subsidence. A significant effort will be made to adapt existing products and operational procedures to the specific user requirements, exploiting the indications delivered by WP2 and the EO products delivered by WP4. New and innovative products will be implemented based on the outcome of WP3, including, e.g. estimates of the total number of slope failures caused by an individual trigger. Deliverables of this WP include assessment maps concerning the event timing, location, extent, level of hazard and damage, from the local scale to the regional scale. Activities within this WP can be subdivided in seven main tasks, and are conveniently grouped based on the primary phase of a Civil Defence Emergency.

The scope of this document is to describe the six study areas located in Europe where we propose to test the DORIS downstream service. Two study areas are located in Italy, and one study area in each of the following European Countries: Hungary, Poland, Spain, and Switzerland. For the selected study areas we describe the main characteristics, including: (i) the country, (ii) the geographical coordinates, (iii) the dominant physiographical setting, (iv) the main types of ground deformation phenomena that will be investigated, (v) a brief description of the area, (vi) a list of the thematic available information, (vii) a list of the expected products as described in the deliverable 2.2 and (viii) a list of selected scientific and technical reports available in the test area.

The thematic information available for each test site and listed in this document are also described in the deliverable D6.1 “Selected test sites and geo-database” that contains information related to: b) the enrolled end users; c) the geo-database description of every site; d) and a description of the related web services.

## 2. TEST SITES

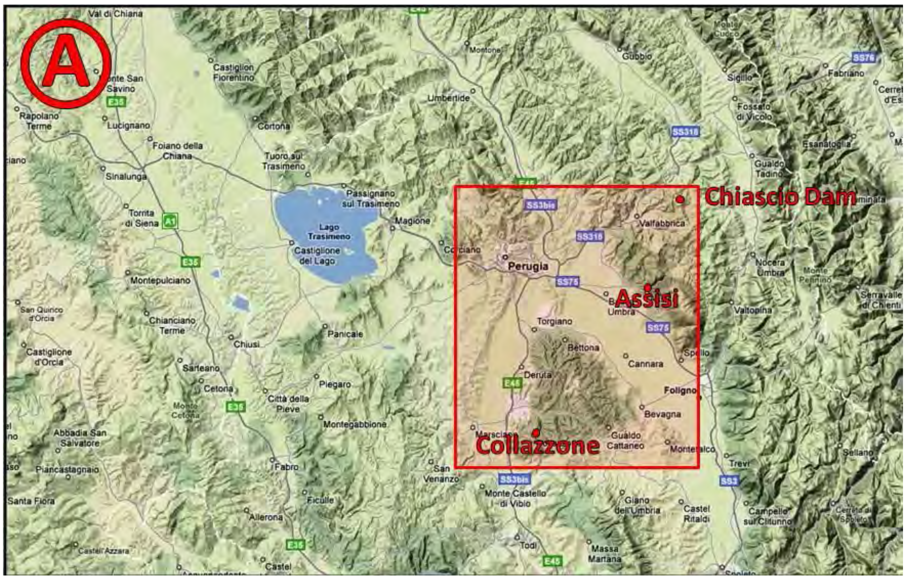
We propose to test the DORIS downstream service in six study areas in Europe, including two study areas in Italy, and one study area in each of the following European Countries: Hungary, Poland, Spain, and Switzerland. Overall, the selected study areas represent a wide range of physiographical and environmental settings, and include the majority of the types of ground deformations for which the service is designed. Successful application of the service in the selected study areas will guarantee that the service will work in Europe, and in most of the surrounding territories. Selection of the study areas was based on: (i) the relevance and variability of the phenomena present (known) in each study area, with emphasis on phenomena with known or potential Civil Defence problems, (ii) the availability of relevant thematic and environmental data, including information that can be used for the validation of the downstream service, and (iii) a specific interest of individual Civil Defence agencies or National Focal Points. The geographical location and extent of the six selected study areas has been determined provisionally. The Task 5.1 within WP5 will determine the final and precise location of each study site in collaboration with the end-user partners.

In the document, we give the main characteristics of the selected study areas, including: (i) the country, (ii) the geographical coordinates, (iii) the dominant physiographical setting, (iv) the main types of ground deformation phenomena that will be investigated, (v) a brief description of the area, (vi) a list of the thematic available information (vii) a list of the expected products and (viii) a list of selected scientific and technical reports available in the test area.

# 3. ASSISI E COLLAZZONE, UMBRIA, ITALY (TS-ITA1)

| | |
|---|---|
| **Study area A** | Central Umbria |
| **Country** | Italy |
| **Cities, towns** | Perugia, Assisi, Collazzone |
| **Physiographic setting** | Hilly or mountainous landscape with large open valleys and intra mountain basins drained by the Tiber River and its tributaries. |
| **Relevant phenomena** | Shallow and deep-seated, rapid to slow moving landslides, in urban and suburban areas. Ground subsidence caused by over-exploitation of confined and unconfined aquifers. |

**Location map**




**Description**

The study areas are located in Umbria, central Italy, where climate is Mediterranean and rainfall occurs mostly from October to December and from March to May. In the region crop out sedimentary rocks, pertaining to the Umbria-Marche stratigraphic sequence, Lias to Eocene in age, overlaid by lake deposits, lower Pliocene to Quaternary in age, and by fluvial deposits of Recent age. The lake and fluvial deposits host deep-seated and shallow aquifers exploited for human and agricultural uses. The structural setting is complex, and results from the superposition of two tectonic phases associated to the formation of the Apennines mountain chain. The area is seismically active, and earthquakes with local magnitude ranging between ML 4.6 and ML 5.8 have occurred repeatedly. The last earthquake sequence in the area occurred between May 1997 and April 1998. Due to the geological and climatic settings, landslides are abundant in the area and contribute to shape the landscape. More than 80% of the area is covered by vegetation, including 41% forest, 10% grassland, and 42% cultivated areas. The research will focus mainly in two study areas: 1) The Collazzone basin and 2) the town of Assisi.

The Collazzone study area extends for 78.89 $km^2$ in Umbria, central Italy, with elevations ranging between 145 m along the Tiber River flood plain and 634 m at Monte di Grutti. Landscape is predominantly hilly, and lithology and the attitude of bedding planes control the morphology of the slopes. Valleys oriented N–S are shorter, asymmetrical, and parallel to the main direction of the bedding plains,

whereas valleys oriented E–W are longer, symmetrical, and mostly perpendicular to the direction of the bedding planes. In the area crop out sedimentary rocks, including: (i) recent fluvial deposits, chiefly along the main valley bottoms, (ii) continental gravel, sand and clay, Plio-Pleistocene in age, (iii) travertine deposits, Pleistocene in age, (iv) layered sandstone and marl in various percentages, Miocene in age, and (v) thinly layered limestone, Lias to Oligocene in age. Mass movements in the area include shallow soil slides and flows, deep-seated slides and flows, and compound failures. Shallow landslides occur primarily on cultivated or abandoned areas, and are rare in forested terrain.
The town of Assisi extends along the NW sector of the mountain ridge represented by the Monte Subasio, a distinct physiographical feature in central Umbria, and is bounded to the SW by the ample Valle Umbra plain. Sedimentary rocks crop out in the area. Layered and massive limestone, marl, and clay pertaining to the Umbria-Marche stratigraphic sequence, Lias to Eocene in age, are overlaid by lake deposits, lower Pliocene to Quaternary in age, and by fluvial deposits, recent in age. Ivancich is a neighborhood in the Assisi municipality located SE of the mediaeval part of the town. Built mainly in the period 1960 – 1970, the neighborhood is a residential area of one- to three-storied private homes, and it hosts the Assisi hospital and a Franciscan convent. In the area, a deep-seated landslide is present. Geomorphological, geotechnical, and topographical investigations revealed that the Ivancich landslide is an old (ancient) translational slide that involves the debris deposit that covers the bedrock, represented by a pelitic sandstone unit. More recent, slides have developed inside the old landslide deposit. The recent slope failures have caused damage to roads, private and public buildings, including the Assisi hospital, and retaining structures, since the 1970s.

Table 3.1. List of the thematic information available for the study area. For all information the table provides: the name, the scale and the availability level (PP = project participants; WMS service; PU=public).

| **Thematic information** | **Area** | **Scale** | **Dissemination** |
|---|---|---|---|
| DTM | Collazzone | 10 m x 10 m | PP/WMS |
| Land use map | Collazzone | 1:10,000 | PP/WMS |
| Geology map | Collazzone | 1:10,000 | PP/WMS |
| Structural map | Collazzone | 1:10,000 | PP/WMS |
| Multi-temporal landslide inventory | Collazzone | 1:10,000 | PP/WMS |
| Basin subdivision | Collazzone | 1:10,000 | PP/WMS |
| Geomorphologic landslide inventory map | Umbria | 1:10,000 | PP/WMS |
| DTM | Umbria | 25 m x 25 m | PP/WMS |

For the Collazzone area, the geographical distribution of landslides was obtained from a multi-temporal landslide inventory map prepared at 1:10,000-scale through the interpretation of five sets of aerial photographs covering unsystematically the period 1941–1997, and with field surveys conducted following rainfall events or periods between May 2004 and December 2005. In the landslide inventory, for the deep-seated slope failures the crown area was mapped separately from the deposit. The distinction was not made for the shallow failures. Lithological, structural and bedding information was obtained from a geological map, at 1:10,000 scale, prepared through field mapping aided by the interpretation of medium- and large-scale aerial photographs. The lithological map showed nine lithological units, and an additional class for the stabilized landslides. Bedding domains were decided based on the geometrical interaction between bedding attitude and the local slope. The land-use map was obtained from a map compiled in 1977 by the Umbria Regional Government, locally updated by interpreting recent aerial photographs, with limited field checks. In the Collazzone area, slope units (basin subdivisions) were obtained using specialised software that, starting from a 10m×10m digital representation of the terrain (DTM), generated coherent networks of drainage and divide lines. By combining the drainage and divide lines, the software automatically identified 894 slope units which represent the mapping units of reference for the determination of the landslide susceptibility zonation.

Table 3.2. List of the expected products for the study area.

| **Product** | |
|---|---|
| Landslide inventory map | yes |
| Landslide susceptibility map | yes |
| Landslide vulnerability map | no |
| Map of areas at landslide risk | no |
| Thematic (ancillary) maps (Maps showing specific thematic information, e.g., lithology, soil moisture, land use, land cover) | no |
| Damage assessment map | yes |
| Ground-deformation DInSAR map | yes |
| Ground-deformation DInSAR time series | yes |
| Ground-deformation velocity maps | yes |

Table 3.3. List of selected scientific and technical reports available in the test area

Guzzetti F., Reichenbach P., Ardizzone F., Cardinali M. & Galli M. (2006). Estimating the quality of landslide susceptibility models. Geomorphology, 81, 166-184.

Guzzetti F., Galli M., Reichenbach P., Ardizzone F., Cardinali M. (2006). Landslide hazard assessment in the Collazzone area, Umbria, central Italy. Natural Hazards and Earth System Sciences, 6, 115–131.

Galli M., Ardizzone F., Cardinali M., Guzzetti F., Reichenbach P. (2008). Comparing landslide inventory maps. Geomorphology, 94, 268–289.

Guzzetti F., Ardizzone F., Cardinali M., Rossi M. & Valigi D. (2009). Landslide volumes and landslide mobilization rates in Umbria, central Italy". Earth and Planetary Science Letters, 279, 222–229.

Guzzetti F., Reichenbach P., Ardizzone F., Cardinali M., Galli M. (2009). Landslide hazard assessment, vulnerability estimation and risk evaluation: an example from the Collazzone area (central Umbria, Italy). Geografia Fisica e Dinamica Quaternaria, 32, 2, 183-192

Rossi M., Guzzetti F., Reichenbach P., Mondini A., Peruccacci S. (2010). Optimal landslide susceptibility zonation based on multiple forecasts. Geomorphology, 114, 129-142.

Fiorucci F., Cardinali M., Carlà R., Rossi M., Mondini A.C., Santurri L., Ardizzone F., Guzzetti F. (2011). Seasonal landslide mapping and estimation of landslide mobilization rates using aerial and satellite images. Geomorphology, 129, 59-70.

Canuti P., Marcucci E., Trastulli S., Ventura P. and Vincenti G. (1986). Studi per la stabilizzazione della frana di Assisi. Italian National Geotechnical Congress, Bologna, 14-16 May 1986, 1, 165-174.

Felicioni G., Martini E. and Ribaldi C. (1994). Studio dei Centri Abitati Instabili in Umbria. Rubettino Publisher, 418 p. (in Italian).

Guzzetti F., Manunta M., Ardizzone F., Pepe A., Cardinali M., Zeni G., Reichenbach P. and Lanari R. (2009). Analysis of Ground Deformation detected using the SBAS-DInSAR Technique in Umbria, Central Italy. Pure Applied Geophysics 166, 1425-1459.

Fastellini G., Radicioni F. and Stoppini A. (2011). The Assisi landslide monitoring: a multi-year activity based on geomatic techniques. Applied Geomatics, 3(2), 91-100.

# 4. MESSINA PROVINCE, SICILY, ITALY (TS-ITA2)

| | |
|---|---|
| **Study area** | South Italy |
| **Country** | Italy |
| **Cities, towns** | Messina Province, Sicily |
| **Physiographic setting** | Coastal chain drained by several narrow streams perpendicular by the coast. |
| **Relevant phenomena** | Debris flow, rotational and translational slides, rock falls and shallow and deep-seated landslides. |
| **Location map** |  |



**Description**

The study area (Monti Nebrodi e Giampilieri) is located along the north eastern part of Sicily (south Italy). In the period from October 2009 to February 2010, the area was highly affected by several landslide events that caused intense damages and casualties. The landslide events continue till today as testified by the event occurred during March 2011 in San Fratello where 12 peoples were evacuated. The Monti Nebrodi ridge is 70 km long with ENE-WSW direction and is part of the Sicilian Apennines. The altitude of the area span from the sea level to 1847 m (Monte Soro). From a lithological point of view the western part is characterized by terrigenous formations (mainly marls and claystone), whereas the central by clay deposits. The eastern sector is also composed by terrigenous formation showing a coarser grain size with respect to the western deposits. Close to San Fratello (West) and Frazzanò (East) limestone and dolomite crop out. Intense and exceptional rainfall event was the main factor that combined with the steep slopes, triggered several slope movements along the Monti Nebrodi. In particular debris flow, rotational and translational slides, rock falls and shallow and deep-seated landslides. Gianpilieri is located on the eastern coast of Sicily, in the Peloritani Mountain Belt which represents a segment of the Apennine-Maghrebide Orogen. This area is characterized by the presence of the Kabilo-Calabride Units, formed by continental crust fragments deriving from the European margin and, in particular, by Hercinian crystalline rocks with their Mesozoic-Tertiary cover. The morphology of the area is characterized by steep slopes eroded by torrent-like straight watercourses which became very rich in solid material during the rainy season. The altitude span from the sea level to 1040 m a.s.l. The investigated area, 75 $km^2$ wide, is located in the coastal area south of the city of Messina. It is delimited by the Ionian sea on the East side and by the Peloritani ridge on the West side. Five municipal towns are included in this area: Alì, Alì Terme, Itala, Scaletta Zanclea and Messina. The main villages are scattered along the strongly urbanized coastal area. The hilly area opposite to the Ionian Sea is characterized by the presence of smaller settlements, connected with the populated coastal area by a single road axis climbing upward along very steep slopes. The geomorphology of the area is strongly influenced by the geo-structural conditions, by the crystalline competence of the outcropping rock (mainly medium grade metamorphic rocks) and by the recent tectonic activity. The coastal landscape is typical of the recently uplifted areas: steep slopes, narrow valleys and high relief energy are the main geomorphologic feature. The morphometric characteristics of the river basins, represented by a watercourse network having regular and parallel path, are influenced by the short distance separating the watershed from the coast. River catchments have a reduced widening with a significant transport of solid materials; incisions are short and deeply entrenched into V-shaped valleys, especially in the mountainous sector. Several small alluvial plains, formed where riverbeds become over-flooded, characterise the coastal area. The presence of the so-called "fiumare", straight, steep course, gravel-bed river draining mountain areas is typical of Mediterranean climate region. Their flow varies seasonally and their regime is torrential with catastrophic transport of solid materials following heavy rainfall, causing severe damages if flooding occurs close to populated centres. In this area the main landslides type occurred can be prevalently classified as debris flow and debris avalanches. More than 600 landslides in a day were triggered by exceptionally intense and localized rainfalls.

Table 4.1. List of the thematic information available for the study area. For all thematic information the table provides: the name, the scale and the dissemination level (PP = project participants; WMS service; PU=public).

| Thematic information | Scale | Dissemination |
|---|---|---|
| LIDAR DTM (pre event, post-event) | 4p/m2<br>8p/m2 | PP |
| Corine land cover map | 1:50 000 | PU |
| Geological map | 1:50.000 | PU |
| Ortophoto map | pixel 0,25 | WMS |
| Landslide inventory map (IFFI) | vector (1:25 000 – 1:50 000) | PU |
| Geomorphological map | 1:25000 | WMS |
| Geomorphological schematic map of San Fratello (San Fratello Municipality) | 1:25 000 | WMS |
| Lithological map of the Torrente Inganno Basin (San Fratello) | 1:50 000 | PU |
| Land use map of the Torrente Inganno Basin (San Fratello) | 1:50 000 | PU |

The available 1:50 000 geological map (Carta Geologica della Provincia di Messina), founded and produced by the Provincia di Messina, cover the whole study area. The geological survey was performed using the 1:10 000 CTR (Carta Tecnica Regionale) as topographic base. This map covers an area 3300 $Km^2$. The CORINE Land Cover map (1:50 000) is a public product, produced by the European Environment Agency using a method for land data collection based on an hardcopy inventory from satellite image printouts. The IFFI Landslides Inventory map is a free product available at http://www.mais.sinanet.apat.it/cartanetiffi/default_nosso.asp website. This product, prepared using a common framework, is an updated map where the distribution of landslides within the Italian landscape is reported. Pre-event and post-event LIDAR DTM and the ortophoto map are available only for the eastern sector of the study area, between the Peloritani Mountains and the Ionian Sea. These data were delivered by the Dipartimento Regionale della Protezione Civile - Regione Siciliana for the monitoring of the area of Gianpilieri. Lithological and land use maps of the area of San Fratello produced by the Assessorato Territorio e Ambiente - Regione Siciliana are available at scale 1:50 000. The 1:25 000 geomorphological map, produced by IRPI and UNIFI, is available for the river basins located in the Peloritani mountains.

Table 4.2. List of the products that will be prepared for the study area.

| **Product** | |
|---|---|
| Landslide inventory map | yes |
| Landslide susceptibility map | no |
| Landslide vulnerability map | no |
| Map of areas at landslide risk | no |
| Thematic (ancillary) maps (Maps showing specific thematic information, e.g., lithology , land use, land cover) | yes |
| Damage assessment map | no |
| Ground-deformation DInSAR map | yes |
| Ground-deformation DInSAR time series | yes |
| Ground-deformation velocity maps | yes |

Map of areas at landslide risk and damage assessment map will be produced in case of the occurrence of new landslide events in the study area.

Table 4.3. List of selected scientific and technical reports available in the test area.

Casagli N., Guzzetti F., Moretti S., Del Conte S., Raspini F., Cardinali M., Reichenbach P., Ardizzone F. (2009). O.P.C.M. 10 Ottobre 2009, n. 3815 - Carta geomorfologica dell'evento calamitoso del 1° Ottobre 2009 nel territorio della provincia di Messina. Tavola I: Bacino del Torrente Briga e Bacino del Torrente Giampilieri. Rapporto 1.0. Internal report, 12 pp.

Casagli N., Gigli G., Del Conte S., Del Ventisette C., Foti E., Cancelliere A., La Rocca C., Musumeci R.E., Nicolosi V., Motta E., Ferraro A., Raciti E., Basile G., Panebianco A., Guzzetti F., Rossi M., Cardinali M. (2009). Criterio d'intervento per la messa in sicurezza degli abitati di Itala e Scaletta colpiti dall'alluvione del 1° ottobre 2009. Descrizione dei dissesti e degli interventi immediati negli abitati di Itala e Scaletta. Internal report, 93 pp.

Casagli N., Gigli G., Del Conte S., Del Ventisette C., Foti E., Cancelliere A., La Rocca C., Musumeci R.E., Nicolosi V., Motta E., Ferraro A., Raciti E., Basile G., Panebianco A., Guzzetti F., Rossi M., Cardinali M. (2009). Criteri d'intervento per la messa in sicurezza dei territori della Provincia di Messina colpiti dall'alluvione del 1° ottobre 2009. Descrizione dei dissesti e degli interventi immediati negli abitati di Altolia, Molino, Giampilieri e Giampilieri Marina. Internal report, 93 pp.

Casagli N., Fanti R., Raspini F., Del Ventisette C., Gigli G., Foti E., Musumeci R.E., Stancanelli L., Motta E., Ferraro A., La Rocca C., Nicolosi V., Raciti E., Guzzetti F., Rossi M., Cardinali M. (2009). Relazione sulle osservazioni e sui quesiti posti da

comitati civici e singoli cittadini sulla perimetrazione del rischio residuo dei centri abitati da cui all'O.P.C.M. 3815/09. Internal report, 105 pp.

Raspini F., Moretti S., Casagli N. (2011). Landslide mapping using SqueeSAR data: Giampilieri (Italy) case study. Proceedings of the second World Landslide Forum. 3-7 October 2011. Rome. 6 pp.

Casagli N., Moretti S., Raspini F., Righini G., Del Conte S., Gigli G., Del Ventisette C., Garfagnoli F., Lu P. (2011). Mappatura delle aree a rischio idrogeologico nei dintorni di Giampilieri (Messina) mediante interferometria satellitare. Internal Report. 122 pp.

Moretti S., Fanti R., Bianchini S., Cigna F., Del Ventisette C., Frodella W., Gigli G., Proietti C., Raspini F., Ferretti A., Colombo D., Del Conte S., Leva D., Rivolta C., Liguori V., Lovisolo M. (2011). Analisi dei dissesti idrogeologici in Sicilia e Calabria. Rapporto 1.0. Internal report. 39 pp.

# 5. RÁCALMAS, DUNASZEKCSŐ, HUNGARY (TS-HUN)

**Study area** High loess river bank collapses along the Danube; Former volcanic mountain area with several ground deformation events

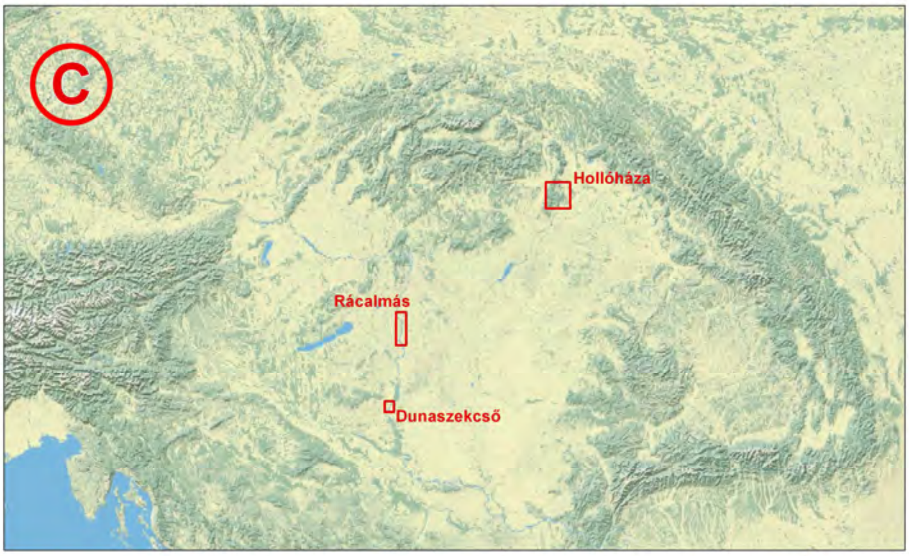
**Country** Hungary

**Cities, towns** Hollóháza, Rácalmas, Dunaszekcső

**Physiographic setting** High instable loess river banks and former steep volcanic mountain area with several ground deformation events.

**Relevant phenomena** Deep seated landslides affecting urban areas and infrastructures.

**Location map**




**Description** The Hungarian lowland is located to the south and to west of the Carpathian mountain range and bounded to the south-east by the Transylvanian Alps. Landscape is characterized by plains, rolling hills and low mountains. The area is drained by tributaries of the Tisza River, which drains into the Danube. Climate is continental to sub-continental, with a mean annual precipitation less than 1000 mm. In the area crop out sedimentary rocks (sandstone and conglomerates), crystalline schist with limestone, and volcanic material. A Loess cover is present in the area. Due to local morphological and geological settings, mass movements of different types are common, and cause extensive damage to buildings and the infrastructure. Three landslide sites have been preliminarily singled out:

(i) Hollóháza village is situated in a NNW-SSE direction valley in the northern part of Zemplén mountains. It is 2,5 km along the valley, but only few hundred meters wide. The foot of the valley in the village is 280-360 m, the surrounding peaks are 450-520 m high. Different thickness rhyolite tuff and sea sediments lie on the base mountain floor. These sediments dip in the direction of the valley forming a natural pervious layer. Another important factor is the mostly bentonitic rhyolite tuff, but the clays too, have high (40-50%) montmorillonite content. The recurring, swelling tuff and clay layers recline on steep volcanic rock and receive their water content through the contact surface. According to the morphological and geological situation the settlement and its close environment has high landslide hazard

(ii) The Danube river bank of Dunaszekcső is built up of 40 m thick loess dissected by clay stripes, and below this is upper-pannonian sand. The borderline is indefinite, but is around flood level and soaked by high groundwater levels; the upper-pannonian sand layer is tiered by movements from the waters under pressure. As a result of this, the stability of the steep slopes and rock walls gradually decreases causing surface deformations.

(iii) The Rácalmás area, similar to Dunaszekcső, is on the left bank of the Danube river and is part of the steep, high bank ridge, which can be followed down to the country border. The erosion and collapse of loess's along the Danube, as well as the eastern shores of Lake Balaton and other hilly areas is a general problem in Hungary.

In Rácalmás, on the surface a thick (50 m) of Pleistocene loess bed lays on the upper-pannonian sand and clay layers. In rainy periods or in times of high water level in the Danube these layers get saturated, which causes the development of slides. The morphology of the high banks is also an additional factor.

Table 5.1. List of the thematic information available for the study area. For all thematic information the table provides: the name, the scale and the dissemination level (PP = project participants; WMS service; PU=public).

| Thematic information | Scale | Dissemination |
|---|---|---|
| DTM | 50 m x 50 m | PP/WMS |
| Land use map | 1:100.000 | PP/WMS |
| Surface geological map of Hungary | 1:100.000 | PP/WMS |
| Structural map | 1:100.000 | PP/WMS |
| Landslide inventory | 1:25.000 | PU/WMS |
| Basin subdivision | 1:100.000 | PP/WMS |
| Shallow drilling database | - | PP/WMS |
| Unified drilling database | - | PP/WMS |
| Hydrogeological maps of Hungary | 1:100.000 | PP/WMS |
| Strata type map of Hungary 0-10 m | 1:100.000 | PP/WMS |
| Surface geological map of Hungary derived version: Sensitivity map | 1:100.000 | PP/WMS |
| Surface geological map of Hungary derived version: Engineer-geological map | 1:100.000 | PP/WMS |
| Hydrogeological maps of Hungary | 1:500.000 | PP/WMS |
| Geological hazard maps | 1:100.000 | PP/WMS |
| Topographical maps | 1:100.000 | PP/WMS |
| Geophysical properties maps and databases | 1:100.000 – 1:10.000 | PP/WMS |

The maps and databases listed above were prepared and are maintained by the Geological Institute of Hungary (MÁFI). The geological and hydrogeological maps are all in digital format and use a unified legend.
Surface geological map of Hungary 1:100.000: The surface formations have been classified on lithostratigraphic basis.

Hydrogeological maps of Hungary 1:100.000: Independent, national groundwater elevation map shows the groundwater levels in depth intervals (1, 2, 4, 8 m).
Surface geological map of Hungary 1:100.000 derived version - Sensitivity map: The map is derived from the surface geological map. The formations occurring on the geological map are listed into 4 sensitivity categories according to their hydraulic conductivity.

Surface geological map of Hungary 1:100.000 derived version - Engineer-geological map: The map is derived from the surface geological map. The formations occurring on the geological map are listed into 8 categories according to their bearing capacity (compressive stress value).

Hydrogeological maps of Hungary 1:500.000: Hydrogeologic interpretation of the 1:100000 surface geological map. Hydrogeostratigraphic versions: aquifer type, lithology-geochemistry, formation environment.

The landslide inventory contains the spatial (1:25.000) and descriptive (type, dimensions, geological and hydrogeological setting, reports, etc.) data of the landslides in Hungary. The database is under construction, it contains mostly the digitized results of a survey closed in 1980. We continuously update it with the recent events (especially on the test sites).

Geological hazard maps of Hungary 1:100.000: Hazard maps are assembled by MÁFI and MBFH (Hungarian Office for Mining and Geology). Landslide inventory and landslide risk categories are represented on the maps.

Strata type map of Hungary 0-10 m 1:100.000: Independent, national map created from the shallow drilling database. It shows the formation ratios of 10 m deep subsurface (gravel, sand, clay, flour rock). Each area has a unique identifier which links it to a strata type.

Shallow drilling database: The shallow drillings were made for mapping needs. According to query needs interpretation of the data can be prepared for specific questions. The database contains water level data.

Unified drilling database (deep drilling database): Contains two data types - master and stratigraphic data (raw or interpreted).

Table 5.2. List of the products that will be prepared for the study area

| **Product** | |
|---|---|
| Landslide inventory map | yes |
| Landslide susceptibility map | yes |
| Landslide vulnerability map | yes |
| Map of areas at landslide risk | no |
| Thematic (ancillary) maps (Maps showing specific thematic information, e.g., lithology, soil moisture, land use, land cover) | yes |
| Damage assessment map | no |
| Ground-deformation DInSAR map | yes |
| Ground-deformation DInSAR time series | yes |
| Ground-deformation velocity maps | yes |

Table 5.3. List of selected scientific and technical reports available in the test area.

Farkas József (2011): Szakértői vélemény Kulcs felszínmozgásos területeinek vizsgálatáról.

Fodor Tamásné-Kleb Béla (1986): Magyarország mérnökgeológiai áttekintése. –A Magyar Állami Földtani Intézet alkalmi kiadványa.

Földessy János (1992): Füzérradvány (caolin and gold).

Hegedűs Endre (2008): A megcsúszott dunaszekcsői löszfal aktív és passzív szeizmikus vizsgálata. [kézirat]

Jámbor S., Czerny Gy. (1980): Rácalmás község belterület M=1:4000 méretarányú mérnökgeológiai térképezése.

Józsa Gábor (1985): A felszínmozgásos kataszterezés tapasztalatai Borsod-Abaúj-Zemplén megyében. – Mérnökgeológiai Szemle 1985. 34. pp. 213-220.

Kenézlői László, Moyzes Antal, Horváth Zsolt (1979): Rácalmás község belterület és Kulcs község üdülőterület M=1:4000 méretarányú mérnökgeológiai térképezése.

Kilényi Éva, Zsadányi Éva (1990): Magyarország Geofizikai Felmértsége EOTR 45 DunaújvárosKassai M. (1978): Magyarországi felszínmozgások katasztere. Baranya megye.

Kéri János-Józsa Gábor (1977): Észak-magyarországi felszínmozgásos területek földtani feldolgozása. – Kézirat. MBFH Adattár.

Kéri J., Kneifel F. (1979): Magyarországi felszínmozgások katasztere. Fejér megye. (Rácalmás, Újbarok, Zámoly; Ercsi, Fehérvárcsurgó, Kulcs, Enying; Dunaújváros)

Kovács József (2003): Rácalmás partfal-omlás, földcsuszamlás

Kraft János, Petz Rudolf, Bernáth Zoltán (1992): Dunaszekcső löszfalainak és pincéinek mérnökgeológiai állapotfelvétele. Felszínmozgás.

Kraft János (1996): Dunaszekcső településen 1996.01.16-án helyszínelt káresemények szakvéleményezése.

Oszvald Tamás (1999): Partfal és felszínmozgások 1999-ben. – Földtani Kutatás 1999. 3. pp. 5-7.

Schmidt Eligius Róbert (1964): A Dunaújvárosi 1964. évi partomlás.

Schweitzer F., Bálint G., Kövesi G. (1981):Dunaszekcső 1:4000-es méretarányú mérnökgeológiai térképezése. (Magyarország felszínmozgás veszélyes területeinek földtani-műszaki vizsgálata és katasztere).

Síkhegyi Ferenc (1999): A felszínmozgások megjelenése légi fényképeken. – Földtani Kutatás 1999. 3. pp. 8-13.

Stickel János (1999): Jelentés a hollóházi talajcsúszás okainak feltárására végzett geoelektromos vizsgálatokról

Stickel János (1999): Jelentés a hollóházi talajcsúszás okainak feltárására végzett mérnökgeofizikai vizsgálatokról

Zelenka Tibor (1999): A hollóházi földmozgások földtani okai. – Földtani Kutatás 1999. 3. pp. 27-33.

T. Zelenka, P. Kovács-Pálffy, N. Trauer (2005): The role of the expanding clay minerals in mass movements at Hollóháza, Tokaj Mts. – Acta Mineralogica-Petrographica, Szeged 2005, Vol. 46, pp. 63-67

# 6. KATOWICE AND TYCHY, POLAND (TS-POL)

| | |
|---|---|
| **Study area** | Upper Silesian Coal Basin (USCB) |
| **Country** | Poland |
| **Cities, towns** | Katowice, Zabrze |
| **Physiographic setting** | A highland in southern Poland located between the upper Vistula and the upper Oder rivers. |
| **Relevant phenomena** | Land subsidence, and related hazards, caused by coal mining activities. |

**Location map**


**Description**

The study area is located to the north of the Carpathian mountain range, in the central part of the Upper Silesian Coal Basin (USCB), in southern Poland. The USCB basin forms the western part of the Silesia-Cracow Upland and peripherial part of the Silesian Beskids. It is bounded by line Ostrava-Tarnowskie Góry-Skawina-Ostrava. The south-west part of the Basin extends into Czech Republic, where it occupies the Ostrava and Karvina mining areas. It covers an area of about 5000 $km^2$.This foredeep consist of Carboniferous molasse developed on the Precambrian block of the Upper Silesian Massif. Cambrian, Devonian and Carboniferous rocks were recorded. Carboniferous rocks continuously overlie Devonian deposits. The profile includes the top of the pre-flysch carbonate association, marine clastic sediments that correspond to the flysch succession 1000 m thick as well as the coal-bearing molasse of a foredeep depression. Lower Carboniferous deposits of the carbonate association do not have an established lithostratigraphic division whereas Upper Visean and Lower Serpukhovian marine clastic deposits have been classified into two lithostratigraphic units of a formation rank. The Upper Carboniferous coal-bearing sequence has been divided into lithostratigraphic units of different rank but they are not defined according to the principles of the stratigraphic code. Four lithostratigraphic series have been distinguished as follows: the Paralic Series, the Upper Silesian Sandstone Series, the Mudstone Series and Cracow Sandstone Series. The pattern of coal quality zones in the USCB does not correspond to principal stratigraphical boundaries as well as

main geological structures.
Coal mining activity in the USCB has been conducted since XVII-th century. In 1979 the largest amount of coal 200x10 Mg/year was mined. At present there are 30 active coal mines in the USCB. Total exploitation of coal is estimated at $70x10^6$ Mg/year. In the study area, hazardous ground deformations are caused primarily by the extensive and longwall mining operations, chiefly in the vicinities of the cities of Katowice, Zabrze and Ruda Śląska. The subsidence in Upper Silesia reaches velocities commonly of a few centimeters per month but there are many areas with subsidence of one centimeter daily.
Exploitation of coal deposits, conducted in the USCB for over 200 years, has created a complicated state of stress and deformation, which is the cause of dynamic phenomena manifested in the form of rock mass shock. Systematic seismic observations have been here for about 60 years. Currently, Central Mining Institute conducts and develops bank "of strong mining tremors" on the basis of data sent by the Upper Silesian Regional seismic network (GRSS) and mining seismological network (KSS).
The level of induced recorded seismic intensity is very diverse and ranges from weak shocks impalpable by the people to strong shocks of a weak earthquake, causing damage.
Places indicating increased mobility of the substrate should be strictly taken into account during the mining activities and the development of spatial plans. Areas that should be surveyed in the first place, are the Halemba coal mine district, adjacent to the Kłodnicki fault, area of KWK Murcki designated by lines of fault: Kłodnicki (north), Wojciech (east) and unnamed (west) in the form of a wedge zones, faults in the region KWK Sobieski - Jaworzno III, and the entire zone of Będziński fault.

Table 6.1. List of the thematic information available for the study area. For all thematic information the table provides: the name, the scale and the dissemination level (PP = project participants; WMS service; PU=public).

| Thematic information | Scale | Dissemination |
|---|---|---|
| non-EO | | |
| Geological Map of Poland | 1:500.000 | PP/WMS |
| Geological Map of Poland | 1:200.000 | PP |
| Detailed Geological Map of Poland | 1:50.000 | PP |
| Hydro-geological Map of Poland | 1:50.000 | PP |
| Geo-environmental map of Poland | 1:50.000 | PP |
| Landslide Counteracting Systems (SOPO) | 1:10.000 | PGI/WMS |
| Structural-geological map of the carboniferous coal-bearing deposits | 1:200.000 | PP |
| Geological atlas of coal deposits of the Polish and Czech part of the Upper Silesian Coal Basin | 1:200.000 | PP |
| Structural map | 1:50.000 | PP |
| DTM (DTED) | 30 m x 30 m | PP |
| Topographic map | 1: 50.000 | PP |
| Land use map | 1:10.000 | PU |
| Vector (GIS) data containing information about the mining areas in Upper Silesia | 1: 50 000 | PP |
| EO | | |
| Ground-deformation ALOS-PALSAR (DInSAR) map for USCB (5 sets: 22.02.2007-10.07.2007; 10.07.2007-25.08.2007; 25.08.2007-25.11.2007; 25.11.2007-25.02.2008 i 25.02.2008-27.05.2008) | 1:100.000 | PP |

The first Geological Maps of Poland 1: 200 000 scale (MGP) was started by the Polish Geological Institute in 1955, the first printed sheet of MGP dated back in 1969 (sheet Radom) and another in the years 1971-1998. This map was developed based on archival geological materials (including the existing sheets of Detailed Geological Map of Poland 1: 50 000 and drillings) and a review of geological images, therefore presented the state of geological reconnaissance of the country mainly from the 70s of the XX century. A more detailed Geological Map of Poland at the scale 1: 50 000 (SMGP) is a development of mapping the country in single sheet (total of 1069 sheets - each covering an area of approximately 300 km²), with explanatory text, explaining the complex geological structure including lithology, genesis, stratigraphy and the geomorphology and tectonics. Editing SMGP was the biggest project in the history of Polish geology - was started in 1956, and completed in 2009. Polish Geological Institute was the coordinator of all activities. In this task about 1,400 geologists have been involved, including many employed at universities, sciences and geological enterprises.

The General Contractor of Hydro-geological Map of Poland at scale 1:50 000 (MHP) is Polish Geological Institute. Map was made on request of the Minister of Environment with funds paid by the National Fund for Environmental Protection and Water Management. First edition of MHP was implemented in late 1996 -2004. Development of 1069 sheets, covering the whole Poland took place in four two-years tranches. MHP is a series of maps, done on the background of topographic sheets in scale 1:50 000 in the national coordinate system '1942'. Map is made in a uniform manner as to the scope and presentation of information layers. Each map sheet is a separate hydrogeological GIS database. MHP provides useful information on normal levels of groundwater and interpretation of the main floor / aquifer, which is the most important source of water supply.

The Geo-environmental map of Poland at 1:50 000 scale (MGsP) containing the protected areas, hydrographic features, cultural heritage objects and elements of mining and processing of geological resources is carried out since 2002. MGsP sheets are updated on a five-year cycle. The main contractor of MGsP 1:50 000 is Polish Geological Institute, which coordinates all the work and deals with the final edited sheets. Map is made be all major geological enterprises in Poland and several smaller companies and research units. The map was created on request of the Minister of the Environment and funded by the National Fund for Environmental Protection and Water Management

The Landslide Counteracting Systems (SOPO) is a project of national importance. Its primary purpose is to identify, document and map at a scale of 1: 10 000 all landslides and areas potentially at risk of mass movements in Poland and the establishment of a deep and surface monitoring system for 100 selected landslides. The entire project is to assist local authorities in meeting the responsibilities and issues of mass movements. The planned project duration is 9 years. Completion of the project is foreseen in 2016.

Structural-geological map of the carboniferous coal-bearing deposits, Geological atlas of coal deposits of the Polish and Czech part of the Upper Silesian Coal Basin. Geological maps made at a branch of the Polish Geological Institute in Sosnowiec, dedicated for the area of the Upper Silesian Coal Basin.

The DTM and the topographic maps are prepared and delivered by the Board of Military Geography of the Polish Army General Staff.

The land use map prepared for the project CORINE LAND COVER 2000.

For the study area are also available vector data containing information about the mining areas in Upper Silesia. The data contains information about activities, concession, estimated shallow exploration, isolines of predicted subsidence, areas at risk. They have been digitized and acquired on the basis of mining maps and information gathered from mining areas.

Ground-deformation obtained from ALOS-PALSAR: Data from the southern part of Upper Silesian Coal Basin prepared by Gamma Remote Sensing in Switzerland contains five differential interferograms showing the height differences in the periods: 22.02.2007-10.07.2007, 10.07.2007-25.08.2007, 25.08.2007-25.11.2007, 25.11. 200725.02.2008, 25.02.2008-27.05.2007.

Table 6.2. List of the products that will be prepared for the study area.

| **Product** | |
|---|---|
| Landslide inventory map | no |
| Landslide susceptibility map | no |
| Landslide vulnerability map | no |
| Map of areas at landslide risk | yes |
| Thematic (ancillary) maps : lithology, land use, geo-environment, hydrogeology, dtm, dsm | yes |
| Damage assessment map | yes |
| Ground-deformation DInSAR map | yes |
| Ground-deformation DInSAR time series | yes |
| Ground-deformation velocity maps | yes |

Table 6.3. List of selected scientific and technical reports available in the test area.

Buła Z., Kotas A. (1994). Geological atlas of the Upper Silesian Coal Basin, part III – Structural geological maps. Polish Geological Institute, Warszawa.

Jureczka J., Aust J., Buła Z., Dopita M., Zdanowski A. (1995). Geological map of the Upper Silesian Coal Basin (Carboniferous subcrop) 1;200 000, Polish Geological Institute, Warsaw.

Jureczka J., Dopita M., Gałka M., Krieger W., Kwarciński J., Martinec P. (2005). Geological atlas of coal deposits of the Polish and Czech part of the Upper Silesian Coal Basin 1:200 000, Polish Geological Institute, Warsaw.

Karwasiecka M. (1996). Geotermal atlas of the Upper Silesian Coal Basin 1: 300 000, Polish Geological Institute, Warszawa.

Kotas A. (1983). Geological atlas of the Upper Silesian Coal Basin, part II – Coal quality maps, Wydawnictwo Geologiczne, Warszawa.

Kotas A. (1994). Coal-bed methane potential of the Upper Silesian Coal Basin, Poland. Prace PGI CXLII, Warszawa.

Kwarciński J. (1999). Geological atlas of the Upper Silesian Coal Basin – Coal-bearing potential maps 1:300 000, Polish Geological Institute, Warszawa.

Zdanowski A. and Żakowa H. (1995). The Carboniferou system in Poland, Prace Polish Geological Institute, v. CXLVIII, Warszawa.

AA. VV. (1972). The Carboniferous of the Upper Silesian Coal Basin, Work of PGI. nr 61, Warszawa.

# 7. TRAMUNTANA RANGE, PALMA DI MALLORCA, SPAIN (TS-SPA)

**Study area** Tramuntana range, Mallorca

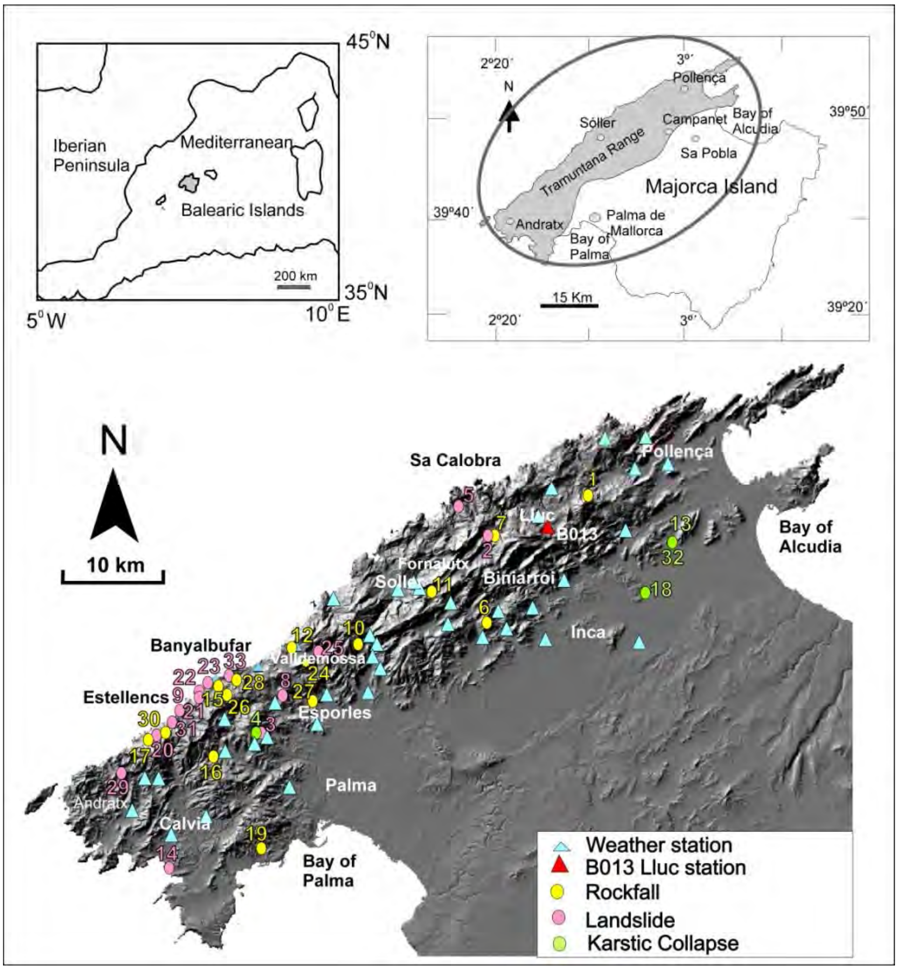
**Country** Spain

**Cities, towns** Andratx, Sóller, Calvià and others

**Physiographic setting** Steep relief and geological diversity.

**Relevant phenomena** Rock-falls, rock-slides, earth slides and karstic collapses

**Location map**




**Description** The island of Majorca (Spain), located in the western Mediterranean, has a variety of different geomorphological domains, most prominently the Tramuntana Range (1,100 km$^2$) in the north-western part of the island. The steep topography of this chain, which is linked to its geological complexity and Mediterranean climate, determines intense slope dynamics with the consequent movements of all categories. The main income of the island of Majorca comes from tourism (83% of its GDP), as it welcomes 10 million visitors each year. The urban development that the

Tramuntana region has undergone in the past 30 years has considerably increased the risk originating from mass movements.

Practically all the slope movements recorded on Majorca have taken place in the Tramuntana Range. The variety of lithologies cropping out in this mountain chain determines a wide range of slope movements. Landslides and earth flows are frequent phenomena, primarily affecting soft sediments from the Late Triassic (Keuper), made up of clays with gypsum, as well as an entire series of loamy materials from the Palaeogene and Neogene that occasionally outcrop along the mountain range. The most prominent movements include the Fornalutx landslide which took place on the 17 December 1924, affecting an area of around 150,000 $m^2$. However, the most important mass movement in the Balearic Islands, because of both its dimensions and the damage it caused, was the Biniarroi landslide in spring 1721, with later local reactivations in 1816, 1857 and 1943. This landslide affected an area measuring around 300,000 $m^2$ and totally modified the original topography in the region.

Rockfalls are the most frequent slope movements in the Tramuntana Range due to the predominance of Jurassic rocky massifs made up of limestone and dolostone. Historically, there are records of several major rockfalls. On the 16 March 1857, a huge rockfall on the Valldemossa area razed and buried a large extension of cropland, leaving reports in the daily news. More recently, numerous rockfalls have made the news as well, such as the one in Cala de Banyalbufar (1993), which affected several fishing huts and the rockfall in Son Matge (Valldemossa) in 2005, in which one of the most important archaeological sites from Majorca's prehistory was buried. The main traffic arteries in the mountain range, both road and rail, have often been intercepted by slope movements, triggering serious circulation problems as well as major economic losses. The historical compilation of the slope movements on the island, as well as the record of those that have occurred more recently, reveal that all processes have taken place after short-intense and/or continuous rainfall. Between 2008 and 2010, the island of Majorca experienced the coldest and wettest winters of the last 40 years. Accumulated rainfall was twice the average and values of intense rainfall up to 296 mm /24 h were recorded. Additionally, high precipitation coincided with anomalous, low temperatures and freezing in the highest zones of the Tramuntana range. As a result, 34 mass movements were recorded: 14 rockfalls, 1 rock avalanche, 15 landslides and 4 karstic collapses. Fortunately, there were no deaths but there were numerous cases of damage to dwellings, holiday apartment blocks, barns and power stations, and especially the road network in the range, most significantly the numerous blockages on the Ma-10 road, which caused significant economic losses in the different tourist resorts. On the southern coast of the range, 17 holiday homes have been evacuated recently due to the impending risk of a large rockfall. Total economic losses are valued at approximately 11M Euro, which represents 0.042% of the Balearic Autonomous Region GDP.

Table 7.1. List of the thematic information available for the study area. For all thematic information the table provides: the name, the scale and the dissemination level (PP = project participants; WMS service; PU=public).

| **Thematic information** | **Scale** | **Dissemination** |
|---|---|---|
| DEM | 25 m x 25m | PP/WMS |
| Slope | 25 m x 25 m | PP/WMS |
| Aspect | 25 m x 25 m | PP/WMS |
| Hillshade | 25 m x 25 m | PP/WMS |
| Geology map | 1:50.000 and 1:25.000 | PP/WMS |
| Topography map | 1:50.000 | PP/WMS |
| Geomorphology map | 1:25.000 | PP/WMS |
| Geotechnical map | 1:50.000 | PP/WMS |
| Permeability map | 1:50.000 | PP/WMS |
| Susceptibility map | 1:25.000 | PP/WMS |
| Landslide inventory | 1:25.000 | PP/WMS |

Table 7.2. List of the products that will be prepared for the study area.

| **Product** | |
|---|---|
| Landslide inventory map | yes |
| Landslide susceptibility map | yes |
| Landslide vulnerability map | No |
| Map of areas at landslide risk | yes |
| Thematic (ancillary) maps (Maps showing specific thematic information, e.g., lithology, soil moisture, land use, land cover) | yes |
| Damage assessment map | yes |
| Ground-deformation DInSAR map | yes |
| Ground-deformation DInSAR time series | yes |
| Ground-deformation velocity maps | yes |

Table 7.3. List of selected scientific and technical reports available in the test area.

Mateos R.M. (2002). Slope movements in the Majorca Island (Spain). Hazard Analysis. Instability, Planning and Management. Seeking Sustainable Solutions to Ground Movements Problems. Edited by Robin G. McInnes and Jenny Jakeways. Thomas Telford, London, 2002. 339-346.

Mateos R.M., Azañón J.M., Morales R. and López-Chicano M. (2007). Regional prediction of landslides in the Tramuntana Range (Majorca) using probability analysis of intense rainfall. Zeitschrift für Geomorphology, Nº 51, 3. 287-306.

Mateos R.M. (2007). Natural Hazard and Land-Use planning in Spain. Journal of the European Federation of Geologists. Nº 23, June 2007.

Mateos R.M., Azañón J.M., García- Moreno I. (2009). Landslides caused by the recent heavy snow and rainfall (December 2008) on the Island of Majorca (Spain). Confirmation of previous forecast. Geophysical Research Abstracts. Vol. I1, EGU 2009-10999.

Mateos R.M., Garcia-Moreno I., Azañón J.M. (2011). Freeze-thaw cycles and rainfall as triggering factors of mass movements in a warm Mediterranean region: the case of the Tramuntana Range (Majorca, Spain). Landslides DOI: 10.1007/s10346-011-0290-8

García Moreno I. and Mateos R.M. (2011). Sinkholes related to discontinuous pumping: susceptibility mapping based on geophysical studies. The case of Crestatx (Majorca). Environmental Earth Sciences. Volume 64, Issue 2, 523-537.

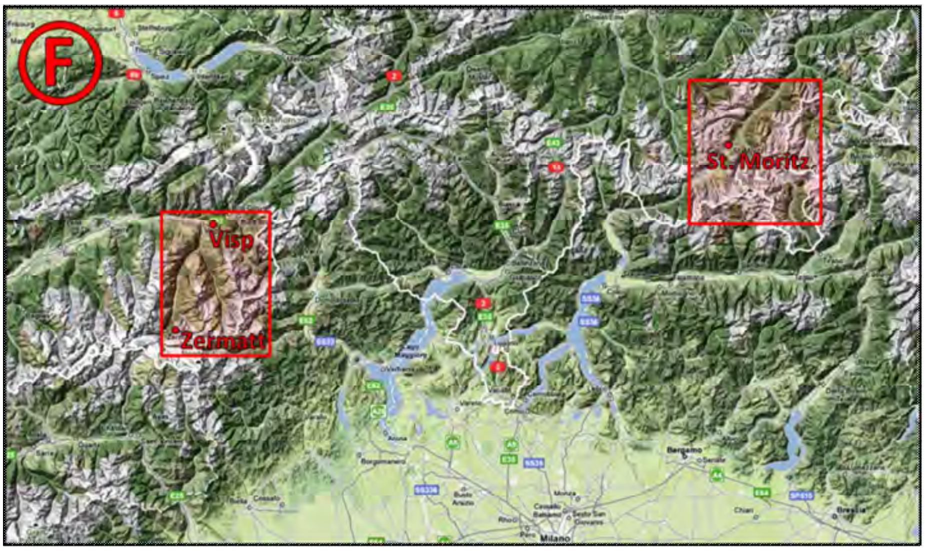
Mateos R.M., Garcia-Moreno I, Herrera G., Mulas J. (2011). Recent mass movements related to inusual rainfall and cold temperatures (2008-2010) in the westwrn mediterranean. Tramuntana range (Majorca, Spain). Proceedings of the second Landslide Forum. Rome, 3-7 October 2011-Rome. (Long abstract accepted for publication).

Mateos R.M., Garcia-Moreno I, Herrera G., Mulas J. (2011). Losses caused by recent mass-movements in Majorca (Spain). Proceedings of the second Landslide Forum. Rome, 3-7 October 2011-Rome. (Long abstract accepted for publication).

# 8. ZERMATT AND ST. MORITZ-ENGADINE VALLEY, SWITZERLAND (TS-SWI)

| | |
|---|---|
| **Study area** | Switzerland, Zermatt |
| **Country** | Switzerland |
| **Cities, towns** | Zermatt, St. Moritz-Engadine Valley |
| **Physiographic setting** | Alpine mountain environment. In the area permafrost is present. |
| **Relevant phenomena** | Rockslides, rock falls, debris flows and rock glaciers (related to presence of permafrost) |

**Location map**

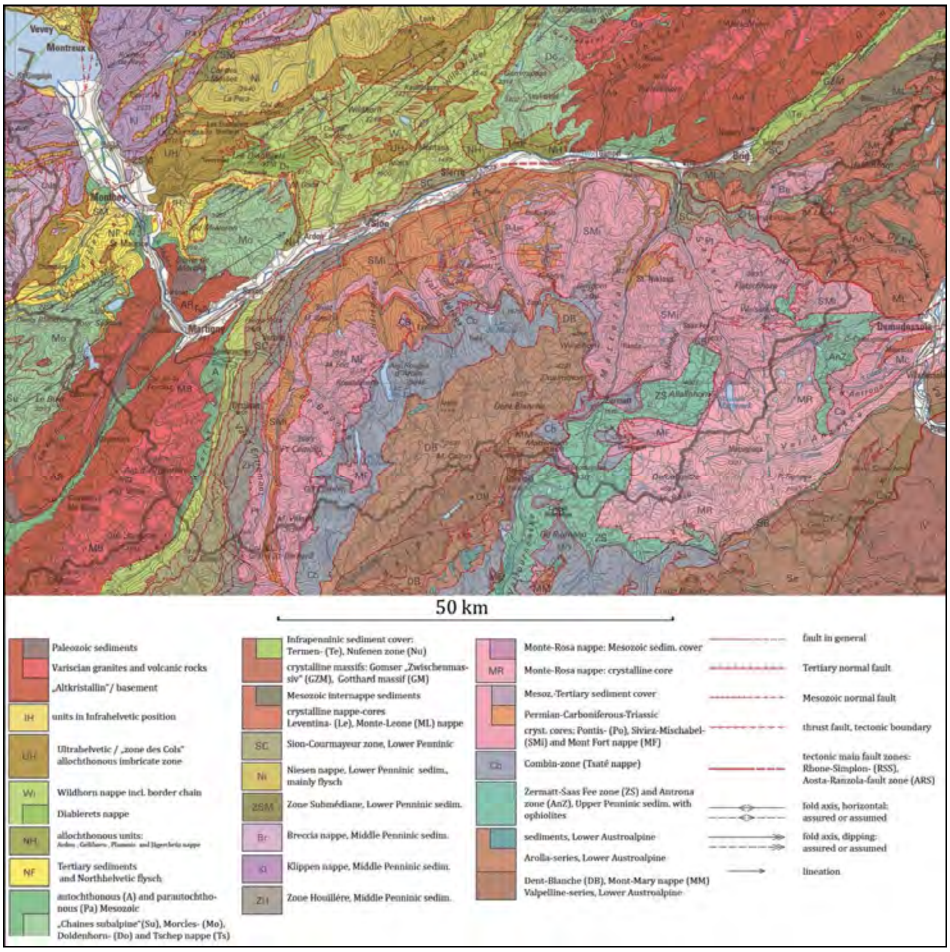



**Description**

The study area comprises two zones both located in the Swiss Alps: (i) the Matter Valley, going up from Visp in the bottom of the Rhone Valley to Zermatt, and (ii) the St. Moritz - Engadine valley area. In the Matter Valley area mainly metamorphic rocks (schists and gniesses) crop out. In the valley there are numerous instable slopes, including some densely populated regions prone to landslides. Many landslides, rockslides, and rock falls are still active and there are high annually costs for the mitigation and countermeasures. Several large landslides are monitored in the study area, allowing an integration of the InSAR technique for hazard assessment. Numerous active rock glaciers (related to the presence of permafrost in the area) common above 2200 to 2500 m a.s.l., are recognized in the Matter Valley, showing an increasing velocity since the 1980s, in response to a significant permafrost warming. Most active rock glaciers are well detectable with ERS, ENVISAT, JERS, ALOS and TERRA SAR interferometry at monthly time lapse, whereas the slowest are only visible at yearly interval. The St. Moritz - Engadine valley area is close to the Piz Bernina in central Alps. In the area Middle and Upper Triassic platform carbonates, mainly dolomites, crop out, overlain by hemipelagic limestone-marl-alternations of Early Jurassic to Early Cretaceous age. The Mesozoic sediments are partly still in contact with the basement, but have also been partly sheared off. Landslides, rock falls and permafrost activities are widespread. Due to climate change, these hazards should be integrated into an inventory and hazard assessment is planned. Satellite and terrestrial SAR interferometry would be an important value added information.

Table 8.1. List of the thematic information available for the study area. For all thematic information the table provides: the name, the scale and the dissemination level (PP = project participants; WMS service; PU=public).

| **Thematic information** | **Scale** | **Dissemination** |
|---|---|---|
| DTM | 10 m x 10 m | PP |
| Land use map | 1:10.000 | PP |
| Geology map | 1:10.000 | PP/WMS |
| Structural map | 1:10.000 | PP |




Tectonic overview of Valais (Tektonische Karte der Schweiz 1:500'000)

In the Matter Valley area mainly metamorphic rocks (schists and gniesses) crop out. In the valley there are numerous instable slopes, including some densely populated regions prone to landslides. Many landslides, rockslides, and rock falls are still active and there are high annually costs for the mitigation and countermeasures. Several large landslides are monitored in the study area, allowing an integration of the InSAR technique for hazard assessment. Numerous active rock glaciers (related to the presence of permafrost in the area) common above 2200 to 2500 m a.s.l., are recognized in the Matter Valley, showing an increasing velocity since the 1980s, in response to a significant permafrost warming. Most active rock glaciers are well detectable with ERS, ENVISAT, JERS, ALOS and TERRA SAR interferometry at monthly time lapse, whereas the slowest are only visible at yearly interval.

A typical rock type in the central- and eastern Penninic Alps are the “Bündnerschiefer”. This formation is about 1 km thick and difficult to sub-divide stratigraphically as dating is problematic, especially paleontological data must be used careful because resedimentation was the dominating process responsible for the filling of the VS-trough. Also the Niesen-flysch building the base of the Prealps was deposited in this basin stratigraphically between Helvetic shelf and Briançonnais-terrane mainly during the Cretaceous, but the following tectonic and metamorphic evolution is very different in the Penninic of the Valais, compared to the Prealps.

Zone Houllière and Pontis nappes

Both nappes are exclusively built by sediments and contain coal or more precisely anthracite. Such beds were found in the Alps within Carboniferous beds and mined during Second. World War (Labhart, 2005). Thelin (1993) placed the basin where the Permian sediments were dumped in the WNW of the early Briançonnais-swell. Magmatic activity is responsible for dikes, sills and cones occurring between the fluvial sediments. On top of the filling quartzites are found that make a transition without cease to rocks with Triassic age (Pfiffner, 2009).

Siviez-Mischabel nappe

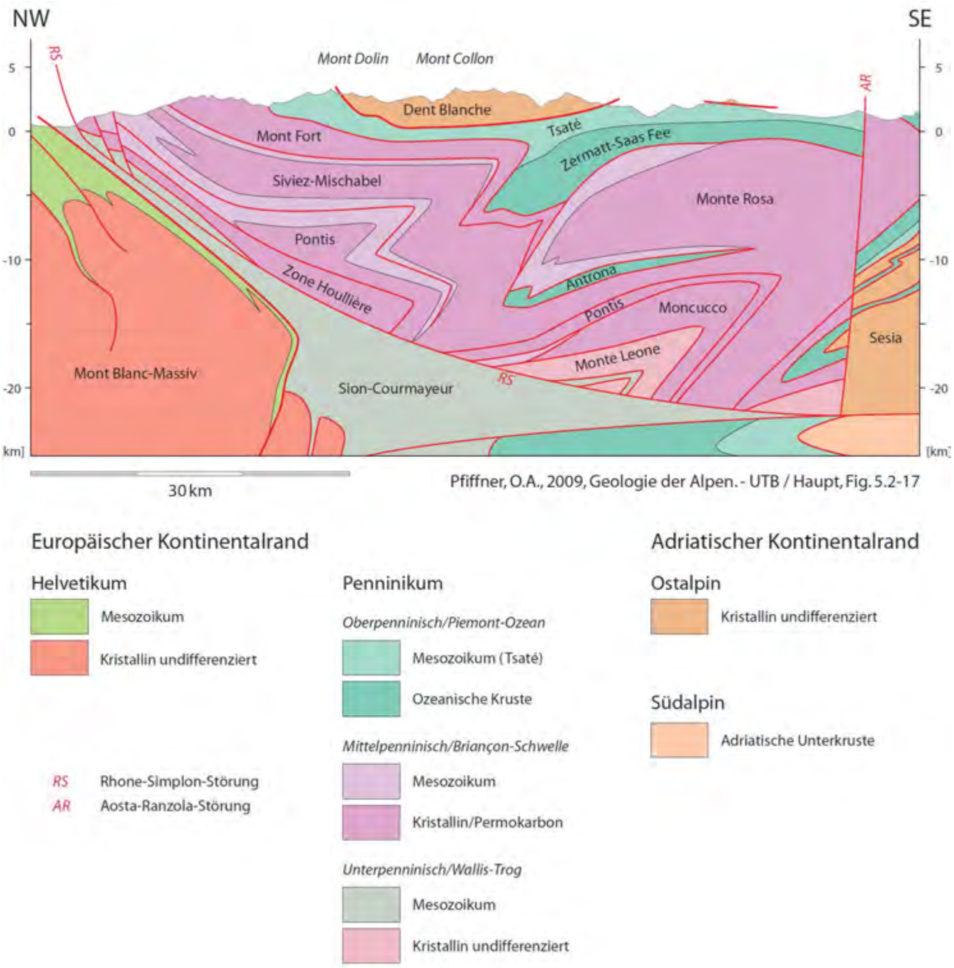
Several km of thickness and an enormous variability of rock types specify this unit. Observed were Permian to Carboniferous conglomerates and sandstones in the lowest part, followed by a thick main body out of paragneiss, micaschists and lots of amphibolites, including the “Randa-Augengneiss”, metamorphic Permian granite. Concerning ore content the Siviez-Mischabel-nappe is unique in the Swiss Alps, another hint for special magmatic processes delivering rare elements because of repeated fractionating crystallization of the rising magma (Labhart, 2005). Escher et al. (1997) described huge isoclinal folds that are back folded in the rear part of the Bernhard nappe-complex being the characteristic internal structure in this impressing nappe.

Zermatt – Saas Fee zone and Tsaté nappe

Enveloping the Monte Rosa- and lying above Bernhard complex the highest Penninic units in the nappe-stack are essential remnants that prove the existence of an ocean, what is required to understand the geological evolution of the domains between Europe and Africa. In the base of the Tsaté nappe Escher et al. (1997) reported about basaltic pillow-lava, most likely of Jurassic age. Following this interpretation the ophiolites were built during the rifting stage between the continents, when crustal thinning allowed mobilizing melts from the mantle. Additionally to the basalts, pelagic oceanic sediments deliver another argument that the highest Penninic unit is a suture zone originating from the Piemonte-Liguria Ocean.

Dent Blanche nappe

A huge eastern-alpine klippe by the name of Dent Blanche-nappe terminates the preserved part of the orogen that grew due to the compression of the lithosphere in the Alpine environment between the late Cretaceous and today. Of course isostasy controlled the erosion going on temporally parallel to the thrusting and internal deformation of every tectonic bloc. By this interplay of surface- and deeply reaching processes the creation of the spectacular topography became possible. The uppermost nappe, a remnant of the Adriatic continent and possibly one of the best examples for a geologic klippe worldwide, is made of gneisses and granites and makes a strong contrast in the field to underlying ophiolites. Many of the most famous 4000 m.a.s.l.-mountains in the Alps are made of the Dent Blanche nappe, some spectacular examples are: Matterhorn, Dent Blanche, Dent d' Hérens, Obergabelhorn, Zinalrothorn or Weisshorn (Labhart, 2005).




Geological cross-section trough the Penninic nappes of the Valais along the western section of NFP20 (Pfiffner, 2009)

Table 8.2. List of the products that will be prepared for the study area (CH-West Zermatt).

| **Product** | |
|---|---|
| Landslide inventory map | yes |
| Landslide susceptibility map | yes |
| Landslide vulnerability map | no |
| Map of areas at landslide risk | no |
| Thematic (ancillary) maps (Maps showing specific thematic information, e.g., lithology, soil moisture, land use, land cover) | no |
| Damage assessment map | no |
| Ground-deformation DInSAR map | yes |
| Ground-deformation DInSAR time series | yes |
| Ground-deformation velocity maps | yes |

Table 8.3. List of selected scientific and technical reports available in the test area.

Geologischer Atlas der Schweiz, 1:25’000, Kartenbl. St. Niklaus, Zermatt, Matterhorn, Bernina