SINKHOLE HAZARD AND RISK MANAGEMENT IN POST MINING AREAS
RFCS PROJECT NO 101157400

Co-funded by the European Union

Deliverable D.2.2

Sinkhole database

WP.2. Data bases creation and advanced analysis.

Responsible Partner: Institut National de L'Environnement Industriel et des Risques - INERIS, France

Contributing Partners:

1. Główny Instytut Górnictwa – Państwowy Instytut Badawczy, Poland
2. DMT-Gesellschaft fur Lehre und Bildung mbH - THGA, Germany
3. Systra Subterra Ingenieria SL, Spain

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This Deliverable has been made as a result of the SIRIMA project – Sinkhole hazard and risk management in post mining areas.

December 2025

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Executive summary

The SIRIMA: Sinkhole Hazard and Risk Management in Post-Mining Areas project is carried out with co-financing from the Research Fund for Coal and Steel of the European Union as the action RFCS-2023-01-RPJ Coal Research Projects under Grant Agreement No. 101157400.

The issue of sinkholes (or pit hole, crown hole - sudden, localized collapses of the ground surface) associated with shallow coal mines in Europe is a critical challenge in post-mining regions, as it is one of the main risks affecting these areas in transition. These events are classified as discontinuous deformations of the earth's surface and can occur without warning, posing a danger to human life and property. The formation of sinkholes is an inevitable process in shallow underground mining of mineral deposits.

One of the objectives of the SIRIMA project is the creation of a database of sinkhole (Work Package 2 – Task 2.2) linked to shallow abandoned coal mines in Europe (WP2 - T2.1) including those due to the collapse of old mining shafts. This document entitled “Sinkhole database”, represents the deliverable for Task 2.2 and is denoted as D.2.2. The objectives of the database are:

- collecting the maximum number of well-documented cases across the Partner’s countries including information on the circumstances of the occurrence of sinkholes ;
- constructing Web-map for displaying of the identified cases at different scales: sub-regional, national and continental one.

The Task 2.2. leader is INERIS and the its Beneficiaries are: GIG-PIB, DMT-THGA, Systra Subterra, IMG-PAN and BRGM. Associated partner in this task is GEODERIS.

The database covers data from the partner countries participating in the implementation of the project: France, Germany, Poland and Spain. However, Spain has no information on sinkholes due to the characteristics of its mines: depth, mining methods, etc.

The database is in MS Excel format. The GIG-PIB has also developed a publicly accessible web platform for locating the sinkholes recorded.

The database contains data on sinkholes, mining works and reclamation. Unfortunately, not all fields in the database could be filled in. The work carried out by the partners highlights the difficulty of obtaining complete information due to the loss of information over time. It should also be noted that the census of sinkholes is not exhaustive, as some mines are very old and the information has not been archived. Furthermore, in Germany, not all data is public. Finally, the German and Polish partners have initially chosen to focus only on certain mining basins.

At the end of December, the SIRIMA database contained 1,814 sinkholes.

The database will be analysed in work packages 4 and 5 of the project in order to highlight the main parameters that play a role in the occurrence of sinkholes in shallow European coal mines, with the aim of improving their prediction.

Finally, the SIRIMA database helps to preserve the memory of events on a European scale.

1 Introduction

Document Overview

This document entitled "Sinkhole database", represents the deliverable for Task 2.2 of the RFCS project SIRIMA Sinkhole Hazard and Risk Management in Post-Mining Areas.

The purpose of the delivery is to present information on the acquired data, its processing and integration for the needs of the interactive map of shallow coal deposits in the areas of closed underground coal mines on the SIRIMA project website. Due to the complexity of the issues for the entire European Union, limitations in access to materials, the analysed data are limited to the Partner countries participating in the project implementation: France, Germany, Poland and Spain. The report concerns the following sections:

- Introduction
- General description of sinkhole hazard in areas of abandoned mines (Section 2)
- Database structure and processing information about sinkholes from the project's partner countries (Section 3)
- Creation of an integrated map as part of the SIRIMA project website (Section 4)
- Conclusions (Section 5).

Contributing Partners

The SIRIMA Project Consortium consists of seven Partners and one Associated Partner. The table below presents the Consortium participants along with the contact details of the persons responsible for the implementation of the SIRIMA project in their home institutions:

Table 1 : Contact list of persons responsible for the implementation of the SIRIMA project at the Consortium Partners

Partners	Full Name	Contact Person	Contact Email
GIG-PIB	Główny Instytut Górnictwa - Państwowy Instytut Badawczy	Sławomir Siwek	ssiwek@gig.eu
INERIS	Institut national de l'environnement industriel et des risques	Isabelle Vuidart	isabelle.vuidart@ineris.fr
BRGM	Bureau de recherches géologiques et minières	Pascal Dominique	pascal.dominique@brgm.fr
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IMG-PAM	Instytut Mechaniki Górotworu - Polskiej Akademii Nauk	Krzysztof Tajduś	tajdus@imgpan.pl
SUBTERRA	Systra Subterra Ingenieria SLU	Beatriz Garcia Bernabeu	bgarcia2@systra.com

Partners	Full Name	Contact Person	Contact Email
UL	Université De Lorraine	Rasool Mehdizadeh	rasool.mehdizadeh@univ-lorraine.fr
GEODERIS	GEODERIS	Pascal Bigarre	pascal.bigarre@geoderis.fr

General Information about Project "SIRIMA"

The SIRIMA project focuses on increasing knowledge and experience related to the threats of post-mining areas in EU Member States. The main objective of the project is to reduce the occurrence of uncontrolled and unexpected movements of the Earth's surface in the areas of abandoned shallow coal mines. These movements, apart from subsidence related to the conducted mining or movements resulting from the impact of mining tremors, can also take the form of uplifts caused by the lifting of the groundwater table in the rock mass and sudden - discontinuous deformations of the ground surface, i.e. sinkholes. The sinkhole hazard is the main type of hazard affecting coal regions in transition. It is due to existence of shallow mining workings and the resulting risk of damage to the buildings, infrastructure or threat to people living in in post-mining areas.

Figure 1 - Graphical presentation of the Partners in the SIRIMA project

2 General description of sinkhole hazard in areas of abandoned coal mines.

The issue of sinkholes (or pit hole, crown hole - sudden, localized collapses of the ground surface) associated with shallow coal mines in Europe is a critical challenge in post-mining regions, as it is one of the main risks affecting these areas in transition. These events are classified as discontinuous deformations of the earth's surface and can occur without warning, posing a danger to human life and property.

The formation of sinkholes is an inevitable process in shallow underground mining of mineral deposits. It is characterized by the sudden formation at the surface of a crater, with a horizontal extent and a depth generally ranging from a few meters to, in some cases, several tens of meters (Figure 2). Shallow mining, which is defined as mining to a depth of 80-100 m below ground level (bgl) (Kotyrba, 2005, Kotyrba et al., 2006, Didier et al., 2008), has been carried out in most European countries over time.

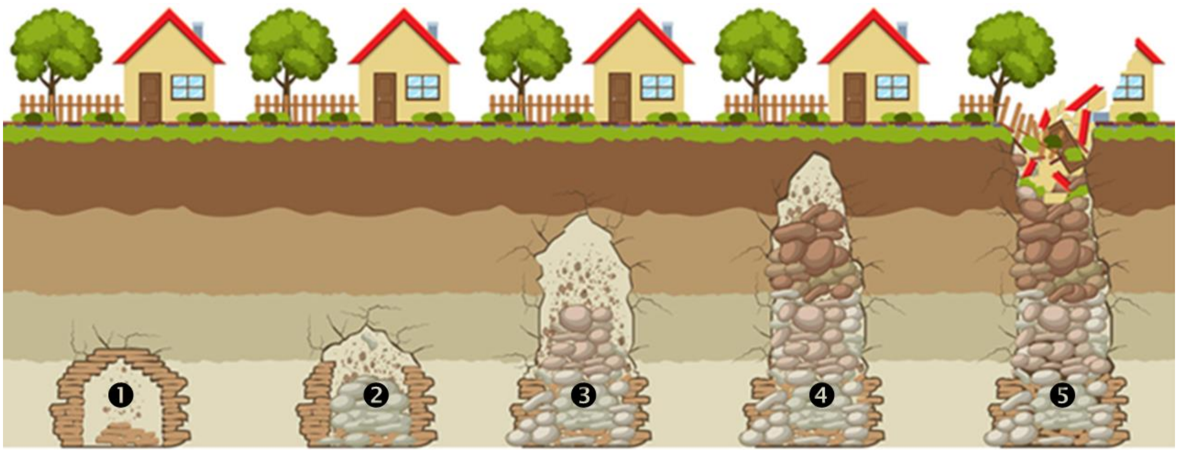


Figure 2 - Mechanism of sinkhole formation (source GEODERIS)

Sinkholes occur when voids filled with air or water are left in the ground (without backfilling). The loss of stability of the rocks and soil covering the mining void causes them to break up. Gravity causes the rock to sink, simultaneously pushing the voids towards the surface. This process is called post-mining void migration. When a void reaches the ground surface, it causes discontinuous deformation. The timing of the deformation in the surface is difficult to estimate due to the complexity of the phenomenon and the role of different internal and external factors. It can be estimated that the vast majority of sinkholes are associated with mining operations carried out at very shallow depths below the surface (up to 20-30 meters or even 50 meters in some specific cases). Discontinuous deformations appear during, immediately after or very shortly after the exploitation of the seam, but sometimes a long time afterwards.

October 9, 2013, at 12:00 p.m.

October 9, 2013, at 4:00 p.m.

October 9, 2013, at 8:00 p.m.

Figure 3 - Montjean-sur-Loire coal mine (France) - Evolution of a surface sinkhole.

In some European countries (such as France, Poland, Germany, Belgium, Spain and the United Kingdom), coal deposits are very significant and have given rise to numerous mines, some of which are still in operation. The last underground active mines are enough deep, and no sinkhole hazard should be considered.

In France, around 80% of mapped mining hazard areas are affected by sinkholes. The country has identified nearly 4,000 sinkholes, around half of which affect former coal mines, with an average of 5 to 15 new ones appearing each year.

In the Upper Silesia region of Poland, the intensity of the sinkhole threat increased between 2022 and 2024, particularly above the two closed mines (Siersza and Pomorzany), which are in the final phase of their water filling process (with the flood front between 0 and 20 m).

In Germany, the state of North Rhine-Westphalia is characterised by intensive mining activities that date back to Roman times and beyond. Spectacular collapses have occurred, such as the Höntrop crater in Bochum in 2000, which prompted the state to set up a risk management system for mining heritage. The mining authority is aware of around 3,700 collapses and sinkholes since the mid-1960s and estimates that around 90 incidents occur each year in the North Rhine-Westphalia region.

In Spain, the main coalfields are located mainly in the north of the country. Many mines are very deep (up to 900 meters in Asturias), Thus, coal mining has followed a pattern determined by the depth at which coal seams are found and the economic viability of extraction methods. Coal mines located at depths between 0 and 150/200 meters below sea level are generally not exploited through underground mining but rather through open-pit methods. This is due to several technical and economic reasons. The deep depth of coalmine limits the occurrence of sinkholes. So, there is no sinkhole in Spain.

One of the objectives of the SIRIMA project is the creation of a database of sinkhole (Work Package 2 – Task 2.2) linked to shallow abandoned coal mines in Europe (WP2 - T2.1) including those due to the collapse of old mining shafts. Therefore, the objectives of the database are:

- collecting the maximum number of well-documented cases across the Partner's countries including information on the circumstances of the occurrence of sinkholes ;
- constructing Web-map for displaying of the identified cases at different scales: sub-regional, national and continental one.

The Task 2.2. leader is INERIS and the it's Beneficiaries are: GIG-PIB, DMT-THGA, Subterra, IMG-PAN and BRGM. Associated partner in this task is GEODERIS.As with task 2.1, the measures taken within the framework of the adopted objectives aim to inform the many consumers, residents and businesses operating in European Union countries, where their regions may face threats resulting from historical coal mining, in our case sinkholes. This database also provides a basis for analyzing the conditions of the occurrence of the sinkhole to better manage the hazard in the future by the coal region in transition.

The structure of the database and information relating to the data collected, processed and provided by the project partners to INERIS are presented in chapters (3) and (4), classified by country. The data was uploaded to the website by GIG (chapter 5). Despite the completion of this document, project partners will continue to work on expanding the database.

The information generated as part of the implementation of task T.2.2 is available on the SIRIMA project website (https://sirima.gig.eu/).

3 Database structure

The first step was to define the data that would be collected. Ineris has identified the criteria relating to the predisposition of occurrences (depth, date, nature, etc.) of mining work and the intensity (diameter, depth, etc. of disorder) of the listed sinkholes. The structure of the database also integrates the characteristics of mining work and the overburden characteristics.

The information collected is organized by theme :

- Localisation (12 data)
- Sinkhole characteristics (10 data)
- Characteristics of mining work (shaft/cavity-drift), (12 data)
- Overburden characteristics (5 data)
- Surface consequences : presence of building and dam(2 data)
- Observation and bibliographic references used.

All the fields in the database are shown in Figure 2.

The Appendix 1 gives in detail the Explanation of each field in the database. This helps the partners to fill in the database.

The database is deliberately very comprehensive, with numerous parameters and information to be filled in. This choice was made in order to have as much data as possible for WP4 and WP5. It should be noted, however, that for many sinkholes, not all of this data is available.

Localisation											
ID BD SINKHOLE	Name	ID Sinkhole	Coordinate X	Coordinate Y	Projected Coordinate System	X_WGS84	Y_WGS84	Measurement uncertainty (m)	Name of the mine	Country	Municipality

Sinkhole characteristics									
Number of sinkholes	Impacted surface (m²)	Length / diameter (m)	Width (m)	Depth of the sinkhole (m)	In-situ measurement or estimation	Date of appearance of the sinkhole	Uncertainty of date (years)	Origin of collapse	Similar phenomena known nearby

Characteristics of mining work (shaft/cavity-drift)											
Start date of the mining	End date of the mining	Accuracy of date	Dip of the exploited layer (degree)	Type of mining work (shaft/cavity-drift)	Width / diameter	Working thickness / Shaft deep	Void density	Depth of the drift relative to the surface (m)	Uncertainity (m)	Ground support	Accessibility

Overburden characteristics*				
Geology of the overburden	Roof fracture condition	Material overbuden resistance	Water conditions in the minig work	Presence of an aquifer in the overburden

Surface consequences	
Presence of buildings or infrastructure	Damage observed

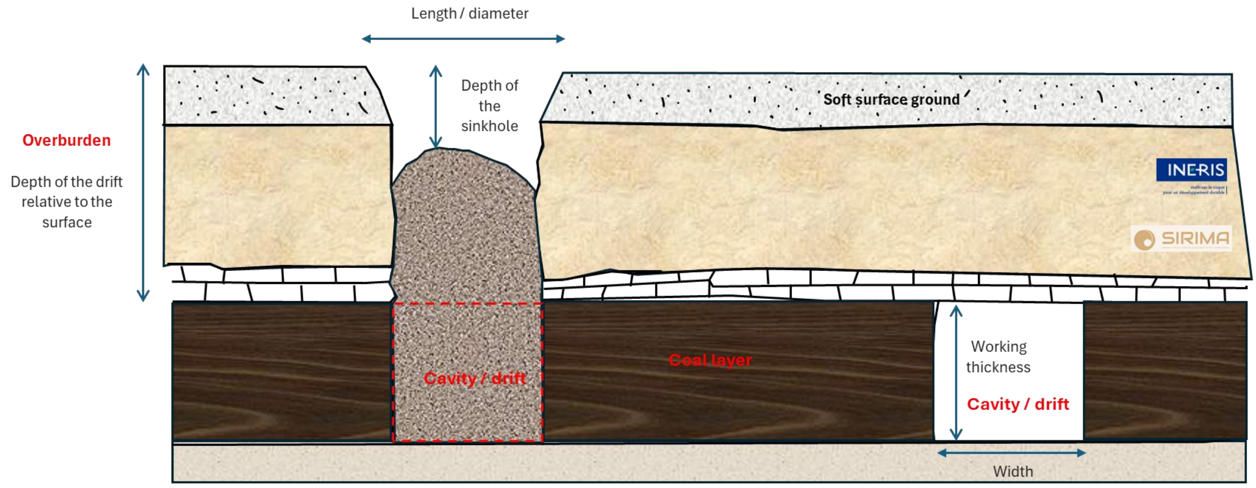
Observations	Bibliographic references

Figure 4 - Database fields grouped by theme

The database is MS Excel sheets with several tabs:

- The "Sinkhole DB" tab corresponds to the table to be filled in.
- The "explanations" tab specifies each field in the database. They are presented in Appendix 1 of this report.
- In addition, some diagrams have been created to complete the explanations ("Explanatory diagrams" tab).

The diagrams are shown in Figures 3, 4 and 5.



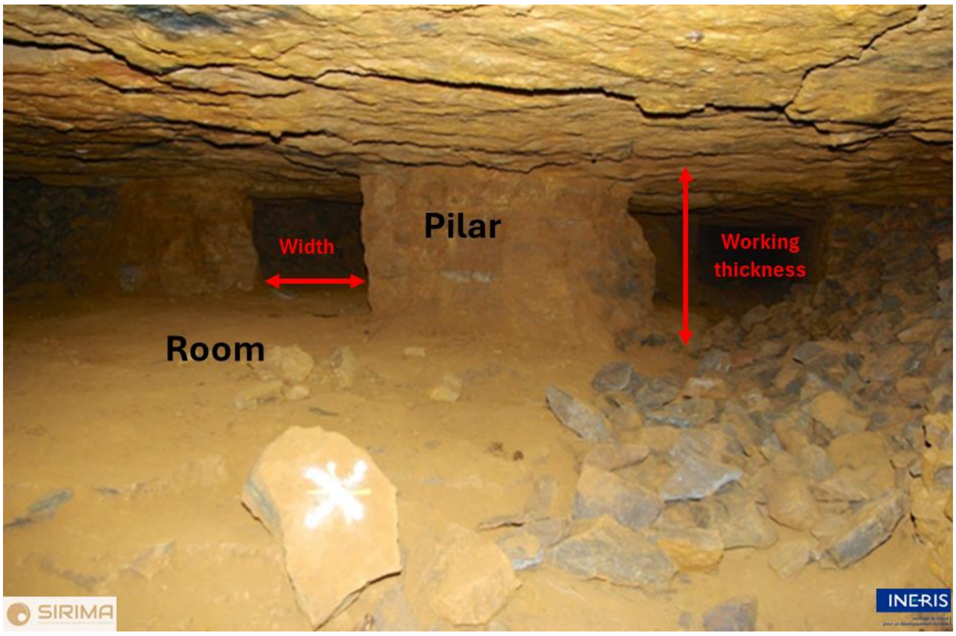


Figure 5 - Explanatory diagram of the sinkhole (above) and the mining work (down)- Sub horizontal drift/cavity

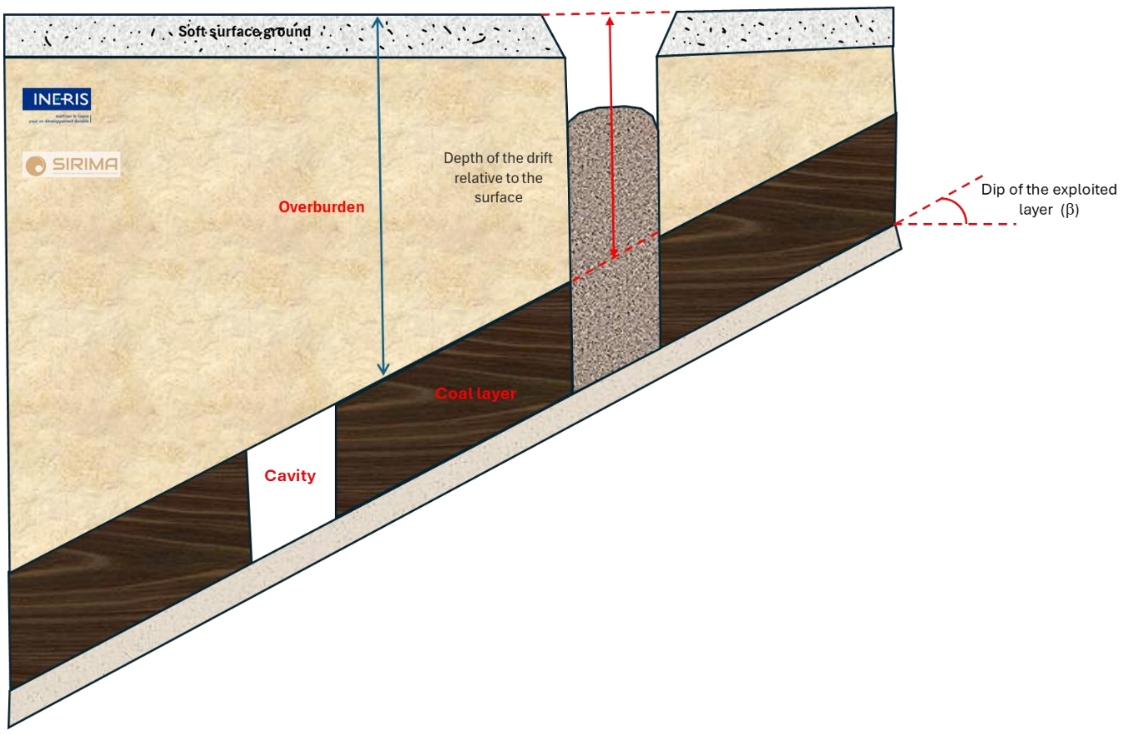


Figure 6 - Explanatory diagram – Mining works with dip (inclined coal seam)

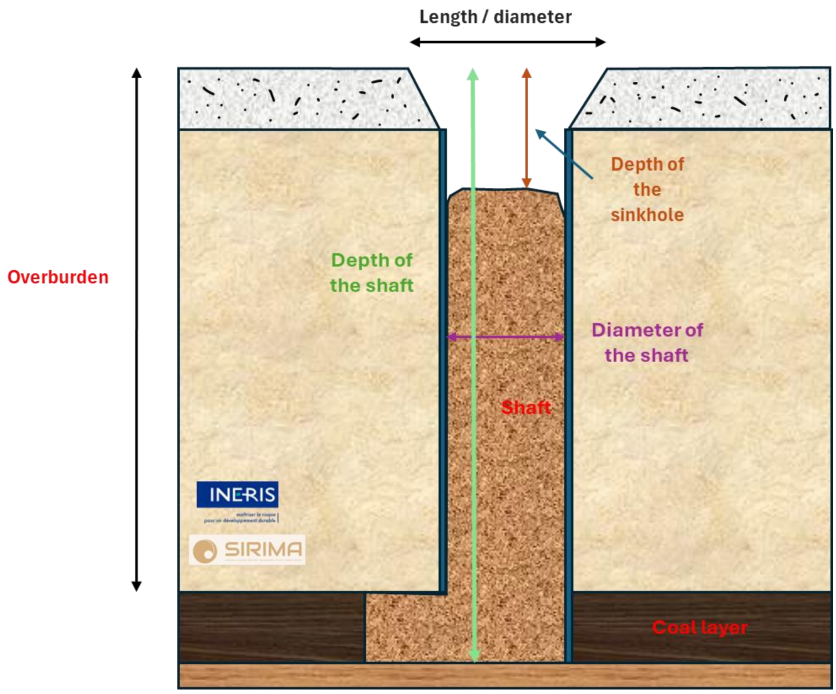


Figure 7 - Explanatory diagram – Shaft

The structure of the base was submitted to the project Partners for validation. The final version of the structure was submitted to the partners in December 2024. The next step was for each member country of the project to collect information and fill in the database.

4 Processing information about sinkholes by project partner countries

4.1 Germany

Because sinkhole data in Germany is considered sensitive, access to it is restricted—whether the sinkholes are related to mining activities or natural causes. Due to these restrictions, DMT-THGA faced difficulties in collecting and completing the sinkhole dataset.

The cases identified are located exclusively in the Ruhr coal mining basin. The German partner DMT-THGA has chosen to focus on this sector as a priority because there are many cases and they are sometimes problematic due to their location in urban areas.

397 sinkholes cases have been recorded by DMT-THGA. The first 18 sinkholes were collected within the framework of the *Gemeinsamkeit* project and were recorded between 2015 and 2018. Two additional sinkholes were documented in the city of Essen shortly after they occurred in 2025.

The remaining 377 sinkholes were provided by the Department of Geoinformation, Surveying and Cadastre of Essen city (*Amt für Geoinformation, Vermessung und Kataster*). Due to data restrictions, only sinkholes that occurred between 1991 and 2010 could be shared. More recent data is not permitted for release under the current regulations.” Unfortunately, very little information is available for these cases. Furthermore, the distinction between natural and mining origins is not established in the Essen city database. Thus, not all cases recorded are systematically of mining origin.

4.2 Poland

In the Upper Silesian Coal Basin (USCB), shallow underground mining operations were conducted over a significant area. Shallow underground mining was carried out in the central, northeastern, eastern and, to a much lesser extent, southwestern parts of the USCB (see https://sirima.gig.eu/integrated-map/). The sinkhole database provided for the SIRIMA project contains a total of 906 records of discontinuous deformations. It covers the areas of three abandoned hard coal mines in the Upper Silesian Coal Basin (Siersza, Kazimierz-Juliusz, and Jan Kanty mines), the area where the project is being implemented. Limiting the number of mines for the Sinkhole Database project was necessary to conduct extensive analytical work necessary to obtain and supplement information about sinkholes. Data collection was based on archival mining materials (coal seam mining maps, shaft profiles, and cross-sections).

In Poland, the primary source of information on sinkholes is a report on continuous and discontinuous deformations. It is maintained by the mining company as part of the geological survey documentation of the deposit. Maintaining a register of sinkholes for areas of mining operations at depths less than 80 m, as well as for shafts and other excavations connected to the ground surface, was introduced in Poland in 1967 by a regulation of the then Minister of Mining. It was not until the Act of 4 February 1994 – "Geological and Mining Law" – that the issues of mining plant surveying and geological documentation were finally regulated, including the obligation to maintain records of terrain deformations (sinkholes, subsidence). Regulations issued on its basis (e.g., in 1995) specified requirements for maintaining maps and records of mining damage. The amendment to the Geological and Mining Law Act in 2011 and the Regulation of the Minister of the Environment of 28 October 2015 on geological survey documentation specified that mines are obliged, as part of their geological survey documentation, to maintain maps of the ground surface with marked sinkholes and registers of sinkholes containing the date, location and its origin.

Due to the lack of detailed guidelines, the registers of sinkholes in the period from 1965 to 1995 were kept under various names: *Register of sinkholes, File of discontinuous deformations, Record of discontinuous deformations, Collection of deformations*, etc., depending on the mine. This information consisted of data, the scope of which depended on the individual actions of the mine's Measurement and Geology Department staff. Typically, it included a tabulated summary of the sinkhole's date, location, and dimensions, as well as its location on a 1:5 000 or 1:10 000 scale map. Occasionally, sketches of the sinkhole are available, including dimensions and information on the amount of material used to refill it (e.g., the number of trucks loaded with rock/mining waste). In the vast majority of cases, there is no information on the sinkhole's connection to the mine workings or the depth of the mining operations. However, documentation maintained after 1995 contains a small number of recorded events. This was due to the closure of a significant number of mines whose mining areas contained shallow hard coal deposits in late 1999. Until the Główny Instytut Górnictwa obtained the status of a national research institute, there was no institution in these areas dedicated to collecting information on discontinuous deformations in the form of sinkholes observed in the Upper Silesian Coal Basin.

During the development of the Sinkhole Database for the SIRIMA project, information was primarily drawn from three sources. First, there were sinkhole records from the Kazimierz-Juliusz Coal Mine in Sosnowiec (Kazimierz-Juliusz test site), the Jan Kanty Coal Mine in Jaworzno, and the Siersza Coal Mine (Siersza test site) in Trzebinia. Second, this database was supplemented with information collected by GIG-PIB over the years of the Institute's operations, which was not recorded in the mine records. In the third stage, an analysis of additional information was carried out for the Siersza Coal Mine area, due to increased sinkhole activity in the years 2021–2024. For this area, sinkhole locations from the inventory conducted in 2023 by employees of the Polish Geological Institute – National Research Institute (PIG-PIB), which performs the tasks of the state geological service in Poland, were used (https://www.pgi.gov.pl/zapadliska-home//zapadliska-alias/rejon-trzebini).

The best material for developing the Sinkhole Database was the archival register of the Jan Kanty Coal Mine. This register was maintained since June 7, 1966, and consists of seven volumes with sinkhole cards and overview maps. Each recorded sinkhole was compiled into a set of two or even four documents. Figure 8 presents an example of information about a sinkhole recorded within the Jan Kanty Coal Mine mining area. It contains a sinkhole "file" containing a simplified sketch of the location, a sketch of the deformation, coordinates in the local coordinate system used in the mine, a description of the damage, damage to buildings, land use, and information about the method its of liquidation. In the case shown in Figure 8, the file includes a 1:1000 scale map of the sinkhole, an additional sketch, and an inspection report.

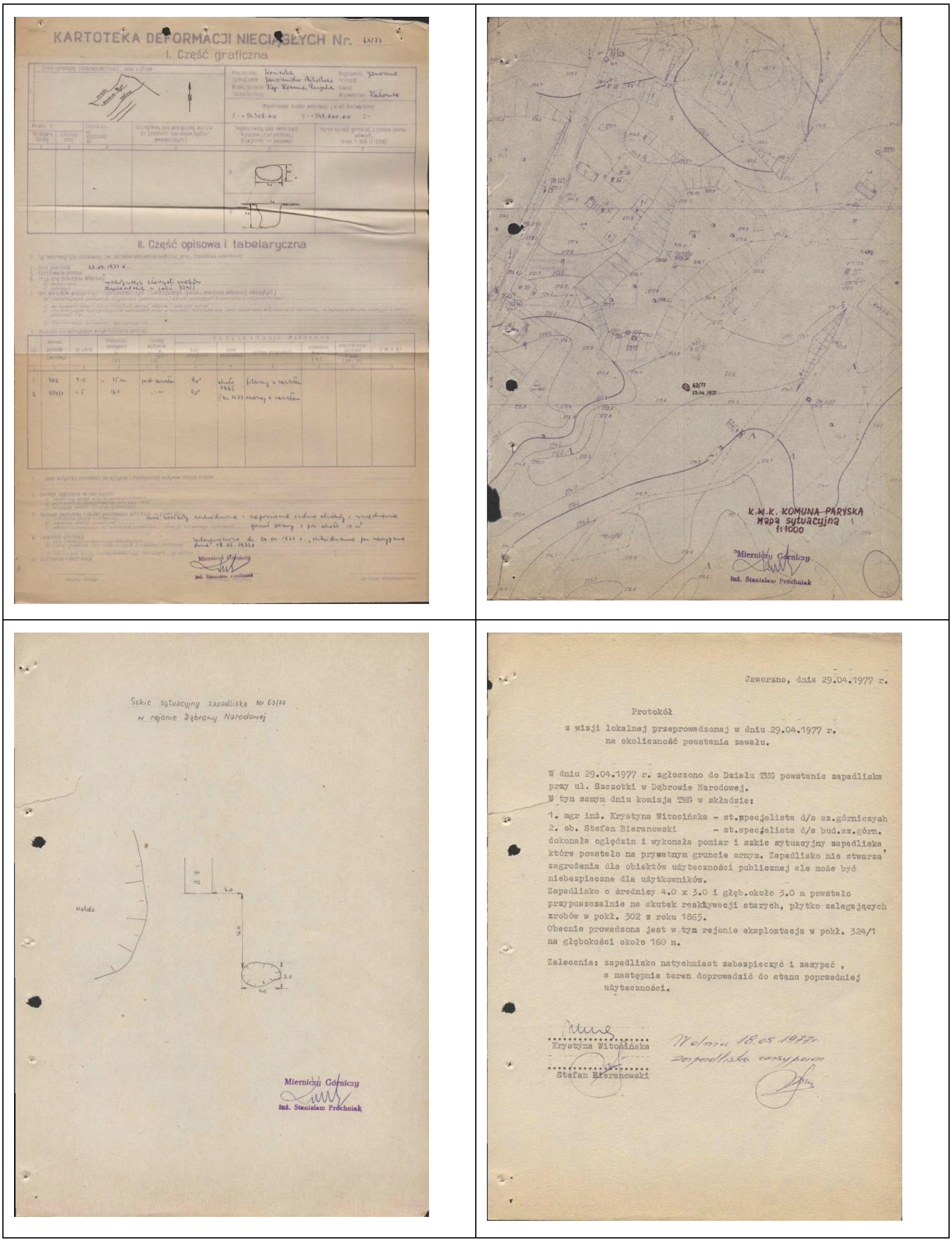
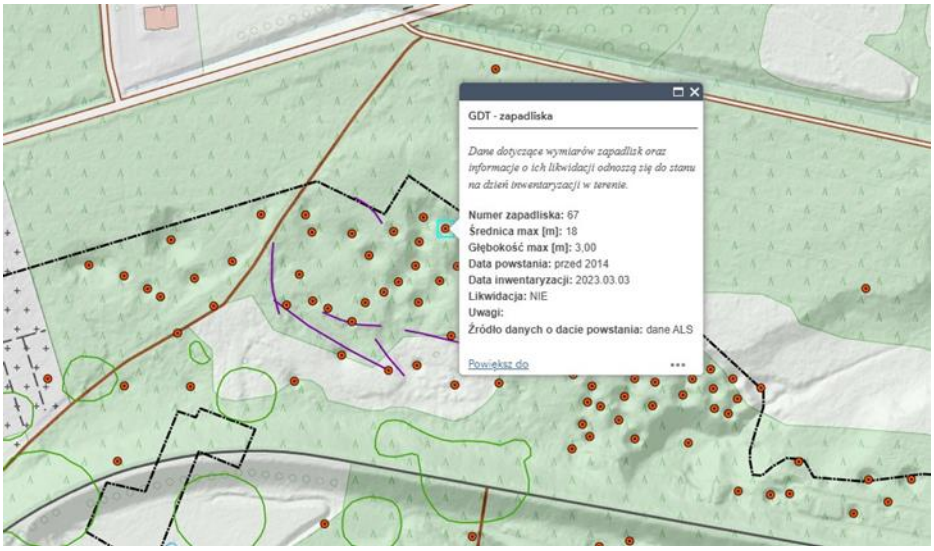


Figure 8 - Discontinuous Deformation File in the Jan Kanty Coal Mine Mining Area. Material from the Surveying and Geological Documentation Archive of the State Mining Authority in Katowice.

In the case of the Kazimierz-Juliusz and Siersza mines, the registers used for survey and geological documentation were very simplified. At the Kazimierz-Juliusz mine, the register, available in the Archive of Mine Survey and Geological Documentation The Polish State Mining Authority, was established on August 5, 2002, 13 years before the mine closed. It contains only six records, of which only one occurred in the earlier period (1997). The register is presented in a table format with several columns containing information about the sinkhole's location (address, local coordinates), its dimensions, and its connection to mining operations (noted as 'shallow mining operations' in the register). The register is accompanied by a 1:5000 scale map illustrating the location of these sinkholes within the mine's mining area. Similarly, for the Siersza mine, the primary documenting sinkhole occurrences is a 1:5000 scale map, marking their location and the approximate date of occurrence.

As part of the SIRIMA project, the largest number of sinkholes were inventoried at the decommissioned Siersza mine (SIRIMA "Siersza" testing ground). The first group of deformations consists of those inventoried immediately after their formation or depicted on archival mining maps of coal seam exploitation. These sinkholes were included in the Siersza mine register. The second, and largest, group consists of deformations inventoried between December 2022 and April 2023 by the Polish Geological Institute – National Research Institute. This inventory was conducted due to the increased occurrence of sinkholes at the Siersza Test Site from 2021 to 2024, due to the constant rise of the groundwater table during the mine's flooding. This inventory involved analysing available archival maps and photographs of the ground surface, satellite imaging of the ground surface, and measurements using LIDAR technology (https://www.pgi.gov.pl/zapadliska-home//zapadliska-alias/rejon-trzebini). These studies revealed the occurrence of 488 depressions in the ground surface during the indicated period, which were classified as sinkholes associated with past shallow mining operations (Figure 9), without any analysis of the validity of such a connection. The collected and shared data include the location of the sinkhole, its dimensions, and the estimated time of formation based on analysis of archival data.



(https://www.pgi.gov.pl/zapadliska-home//zapadliska-alias/rejon-trzebini).

Figure 9 - A section of the map documenting the inventory of sinkholes made by PIG-PIB in 2023, along with a description of the sinkhole, sinkhole is presented by a red circle

For the development of the SIRIMA Project's Sinkhole Database, the primary dataset consisted of the collected coordinates, time of occurrence, and dimensions of the sinkholes. For each of the 906 records covering the Siersza, Kazimierz-Juliusz, and Jan Kanty mines, the data was supplemented with information such as:

- Number of sinkholes in the immediate vicinity
- Origin of the sinkhole
- Similar phenomena known in the vicinity
- Date of commencement and termination of mine operation
- Slope of the mined layer in degrees
- Thickness of the mined layer or shaft depth
- Mining depth of the shallowest coal seam
- Accessibility to workings
- Overburden geology
- Water conditions during mining operations
- Presence of an aquifer in the overburden
- Observation
- Bibliography

Sinkhole characteristics							
Length / diameter (m)	Width (m)	Depth of the sinkhole (m)	In-situ measurement or estimation	Date of appearance of the sinkhole	Uncertainty of date (years)	Origin of collapse	Similar phenomeina known nearby
1	1	1,5	In situ measurement	27.05.1967		Faillure of the roof room or roof gallery	yes
2	1	6	In situ measurement	25.07.1969		Collapse of the shaft filling material	no
6	5	6	In situ measurement	24.05.1969		Collapse of the shaft filling material	yes
1,5	0,5	1,5	In situ measurement	09.10.1968		Pillar failure	no
2	1,5	1,5	In situ measurement	27.08.1968		Pillar failure	no
2	1,5	1,2	In situ measurement	29.07.1968		Faillure of the roof room or roof gallery	no
2		4	In situ measurement	06.11.1970		Faillure of the roof room or roof gallery	no
1,5		6	In situ measurement	23.01.1971		Faillure of the roof room or roof gallery	no
1		1,5	In situ measurement	24.03.1971		Collapse of the shaft filling material	no
0,8		4	In situ measurement	24.03.1971		Collapse of the shaft filling material	yes
4	3	4	In situ measurement	25.07.1970		Collapse of the shaft filling material	yes
3	2	3	In situ measurement	01.08.1970		Faillure of the roof room or roof gallery	yes
0,8		1	In situ measurement	06.07.1971		Faillure of the roof room or roof gallery	no
2,6		3,5	In situ measurement	03.07.1971		Faillure of the roof room	no
0,8	0,5	1	In situ measurement	01.04.1972		Faillure of the roof room or roof gallery	no

Figure 10 - A fragment of the SIRIMA project's Sinkhole Database prepared at GIG-PIB

The primary problem in developing the Sinkhole Database was the incompleteness of available materials and the lack of data from the 19th and first half of the 20th centuries. This stems from the fact that, during this period, issues related to surface mining damage were neglected. This information was irretrievably lost. In supplementing the information on the resulting sinkholes, it was assumed that their formation was associated with the shallowest, mined coal seam, despite the fact that within the assumed depth of up to 80 meters in the subsurface, one or two coal seams were mined deeper.

4.3 Spain

Coal mining in Spain has been characterised by its ability to adapt to a particularly complex geological environment. The peculiarity of Spanish deposits, marked by intricate tectonics, influenced the extraction methods employed and surface effects.

The main coal deposits in Spain, such as those in the Asturias, Northern León, and Palencia basins, are located in Palaeozoic terrains dating back 300 to 360 million years. These deposits were formed during the Carboniferous period, but their current structure is the result of two major orogenic events: the Variscan and, subsequently, the Alpine. These tectonic forces subjected the coal seams and surrounding rocks to intense compression, resulting in folding and fault generation. In the Palencia basin, for example, Alpine movements dragged and folded the coal-bearing formation, creating a complex faulted structure that hosts the deposits. This tectonic legacy is the principal cause of the difficult mining conditions that defined Spanish coal mining.

The tectonics of the Iberian Peninsula endowed its coal basins with specific characteristics. One of the most defining features of Spanish deposits is the steep inclination of their seams, classified according to dip angle, ranging from 20°/35° up to 60°.

In addition to their inclination, Spanish coal seams often exhibit limited thickness, usually less than one meter, with widths of 30 to 60 cm. In the Palencia coalfield, for instance, both bituminous coal and anthracite seams average approximately one meter in thickness.

The intense tectonic activity generated a high density of faults and folds that fragmented the coal seams, disrupting their continuity. This not only complicated mine planning but also limited the applicability of large-scale, highly mechanised extraction methods, which require greater regularity of the deposit.

These geological conditions constituted the fundamental constraint that shaped the entire coal industry in Spain and forced Spanish mining to develop and adapt a much more complex and specific range of techniques, designed to operate under such particular conditions (seam inclination and thickness, geomechanical behaviour of the roof rock...)

In Spanish underground coal mining, the management of the void created after extraction was mainly carried out using two techniques. On the one hand, backfilling systems were applied in inclined, thinner seams, filling the empty space with waste material to stabilise the structure. On the other hand, caving systems, favoured by mechanisation, predominated in thicker seams and consisted of allowing the controlled collapse of the roof once the coal had been extracted, provided the rock met the necessary stability and safety conditions.

Over time, the mechanised longwall method became consolidated as the most productive extraction system in industrial mines, particularly in the Castilla y León basins. Conversely, the room-and-pillar method, had limited presence in Spain due to unfavourable geological conditions.

The combination of deep mining, the use of total extraction methods, and the competent nature of the overburden rock in Spain did not generate the conditions conducive to the occurrence of sinkholes. Instead, the main surface impact was gradual subsidence: an extensive, predictable lowering of the ground forming wide depressions. Thus no existing data can be used for integrating into the SIRIMA database, the subject of the project.

4.4 France

France has a long mining tradition dating back to the Neolithic era, with small-scale artisanal operations continuing for centuries. The Industrial Revolution in the 17th–18th centuries marked a turning point, leading to the development of major mining basins for coal, iron, salt, and other resources. Mining thrived in the first half of the 20th century, driven by the two world wars and post-war reconstruction efforts. Coal production peaked at 60 million tonnes in 1958. However, economic changes, the rise of hydrocarbons, foreign competition, and resource depletion caused a gradual decline starting in the 1960s for coal and iron, and in the 1980s for other minerals. This decline accelerated in the 1990s, and coal mining ended in 2004. France’s mining history is extensive, with over 4,000 mining titles and a wide range of exploited substances, including coal, iron, aluminum, uranium, salt, potash, gold, and silver. There are many coal mines throughout the territory, some of them are very old.

Currently, administrative and sovereign control is managed by the Ministry for the Ecological and Inclusive Transition and its Regional Division (DREAL). Mining expertise is carried out by an independent entity, GEODERIS, a French "Public Interest Group".

In France, all old mines are being studied. The aim is for each phenomenon, to delimit areas where hazards exist and assess their level, in order to determine the risk for the existing stakes and the possibilities of construction or development in terms of land planning. GEODERIS is responsible for conducting these studies, with the assistance of INERIS and BRGM. GEODERIS has carried out around 250 risk studies (large mining "sites" and those with many surface buildings). The results are 12 350 hectares of mapped hazards. About 80% of the hazard areas are concerned by sinkholes.

The first step of these studies is to collect and analyze old mining data: the configuration of mining works (depths, dimensions, exploitation methods, mining plans) and the characteristics of the environment: geology, hydrogeology. Some field investigations (light and non-heavy drilling campaigns) are carried out, visit to the mine if it is accessible.

The data collected from different resources is stored in a dedicated database. This database is linked to an application that allows information to be viewed in a GIS or a web application. Figure 11 shows a view of this application, named "Base de Données des Sites et Titres Miniers & LorFer (BDSTM)".

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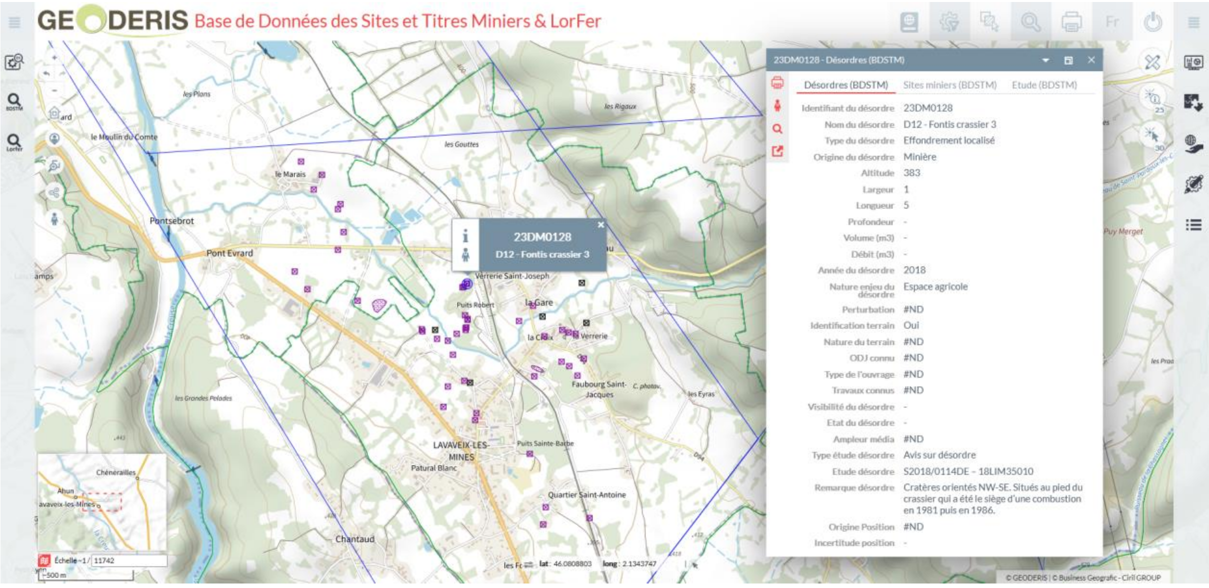

Figure 11 – View of the GEODERIS Database

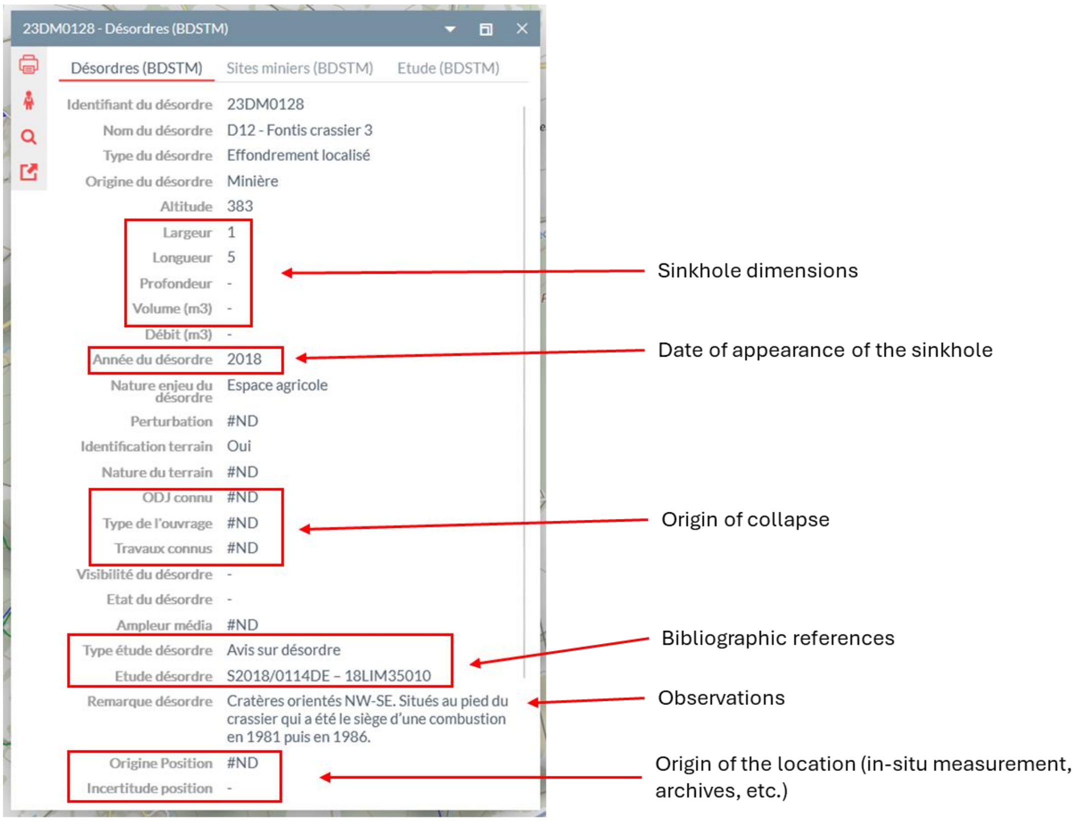

Figure 12 - Information available in the GEODERIS database

For the SIRIMA project, INERIS had access to this database as well as various reports, including studies of mining hazards and expert assessments of sinkholes that have occurred over the past 20 years.

To fill in the SIRIMA sinkhole database, Ineris first collected information on sinkholes from the GEODERIS database. The data in this database is more limited than that in the SIRIMA database. In particular, information relating to the overburden and mining works is not directly available in the table of disorders from GEODERIS database.

Additional bibliographic research had to be carried out to supplement the SIRIMA database.

This step was tedious and time-consuming, as it required cross-referencing information from multiple sources. Unfortunately, some data could not be found, as some sinkholes are very old (several decades old). The information comes from the archives of former operators and the mining administration, as well as from site visits. Most of the time, these are surface visits to locate shafts, drift entrances, and mining disturbances. In fact, most of the mining work is old and inaccessible.

At the time of writing, 512 sinkholes have been recorded in the SIRIMA database, affecting around fifty mines distributed across the entire French metropolitan territory. The vast majority of sinkholes are ancient, and their date of occurrence is unknown. They occurred during or after mining operations. Data on overburden and mining operations are derived from information found in GEODERIS reports. Unfortunately, some mines are very old, and we have little or no information on mining operations. Some data could be found in the archives of the mining administration or former operators, but this would require considerable work and is not feasible within the scope of this project. The site where sinkholes are most numerous is the Messeix coal basin, located in central France (71 cases).

Sinkhole characteristics									
Number of sinkholes	Impacted surface (m^2)	Length / diameter (m)	Width (m)	Depth of the sinkhole (m)	In-situ measurement or estimation	Date of appearance of the sinkhole	Uncertainty of date (years)	Origin of collapse	Similar phenomena known nearby
1		1	1		estimation	Unknown		Faillure of the roof gallery	yes
1		1	1		estimation	Unknown		Faillure of the roof gallery	yes
1					estimation	Unknown		Faillure of the roof gallery	yes
1		1	1	2.5	estimation	Unknown		Faillure of the roof gallery	yes
1		4	3	< 10 cm	estimation	1991 et 2013		Faillure of the roof room	yes
1		1			estimation	1919		Faillure of the roof room	yes
1		1			estimation	1919		Faillure of the roof room	yes
1		2			estimation	Unknown		Faillure of the roof room	yes
1		2.5			estimation	Unknown		Faillure of the roof room	yes
3		3	2		In-situ measurement	1958, 1991		Faillure of the roof room	yes
1		10	10		In-situ measurement	Unknown		Faillure of the roof room	yes
1		1		2	In-situ measurement	2008		Collapse of the shaft filling material	yes
1						1980		Faillure of the roof room	no
1		15	15		In-situ measurement	Unknown		Faillure of the roof room	yes

Figure 13 - A fragment of the SIRIMA project's Sinkhole Database prepared at Ineris

Despite the completion of this document, Ineris will continue to work on expanding the database.

5 Implementation of the database in a specific, publicly available Web-map form on the project website

GIG-PIB role within this task was managing the implementation of the database in a specific, publicly available Web-map form on the project website with a description about the utilization of the data.

At the beginning it was decided to enter only some general data concerning sinkholes from the MS Excel spread sheets prepared by INERIS into the Integrated Map of Shallow Mining in the Partner's Countries. In the preliminary version of the Map apart from shallow mining content it includes only sinkhole location (Figure 14). Apart from localization each sinkhole (after pointing on it) displays it's ID and link to the partners other web service which contains more information about the case. The background situation map is one of six types to choose from Google Maps "My Maps" service. For SIRIMA purposes the "White water" style is applied.

In Figure 15 on the right there is a zoom from Siersza mine in Poland showing how the "more info" was displayed after clicking the single sinkhole location.

After making some arrangements during the project Nancy-Meeting in October (2025) Partners agreed to include also the dimensions of the sinkhole, it's depth and the date of the discontinuous deformation (sinkhole) occurrence into the Web map.

When you click on the selected chasm on the integrated map, its ID and the above-mentioned information will be displayed in the following format:

- Dimensions: width and length of the sinkhole in the surface (m).
- Depth: D m.
- Date of occurrence (field "Date of appearance of the sinkhole"in the database): [different formats i.e.: YYYY, DD.MM.YYYY, MM.YYYY, before/after YYYYY, and others]."

Where two dimensions of the sinkhole are known (length N1, Width N2), both are indicated in the general information in the form: "N1 x N2 m" In cases where only the diameter of the circular sinkhole is indicated, the second dimension is equal to the first. The depth of the discontinuous deformation is also indicated in [m]. At the end, the date of appearance of the sinkhole is indicated in different formats depending on availability in the sources. In each record, unfilled fields are replaced by the string 'Unknown'.

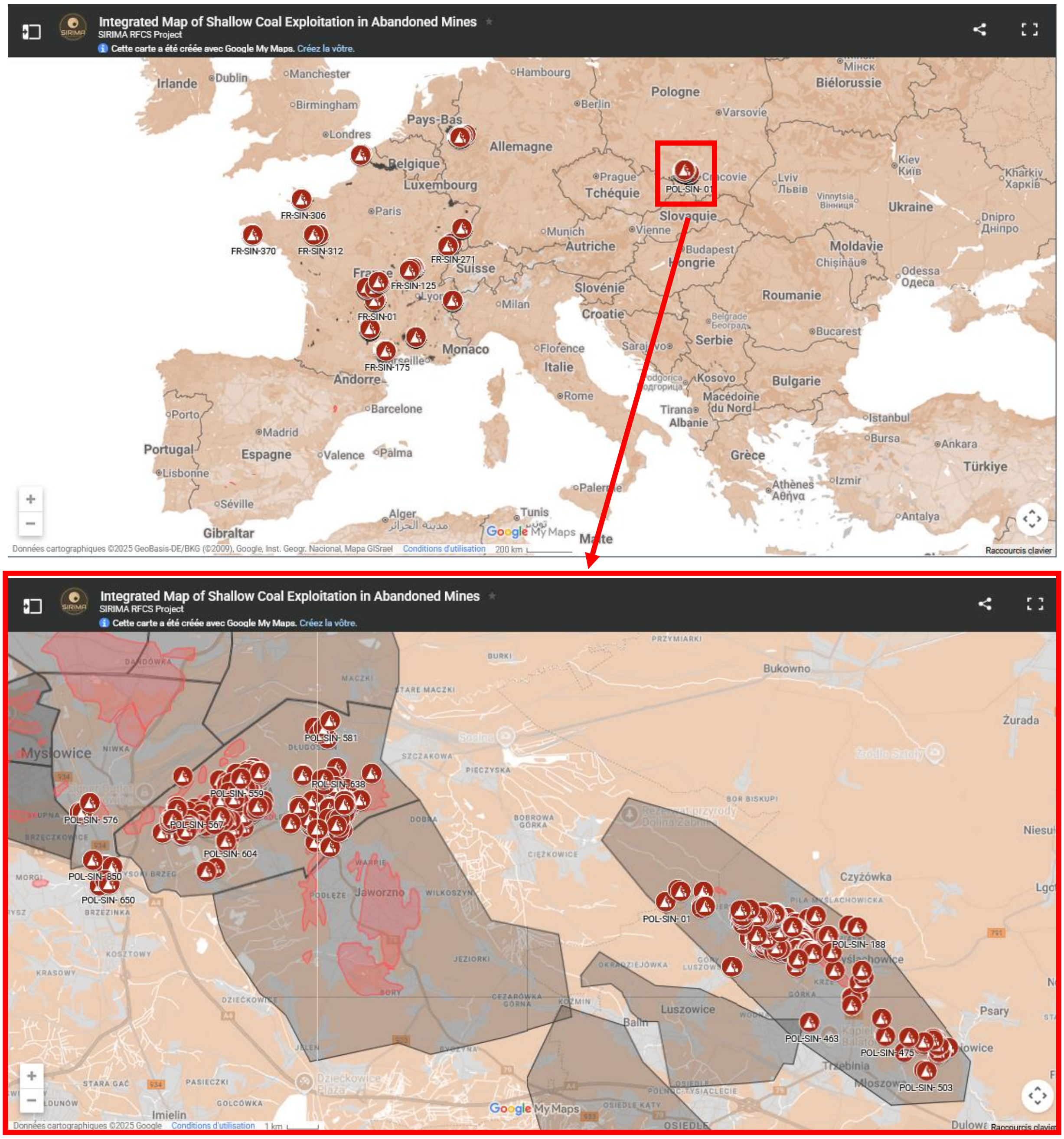

Figure 14 - Preliminary version of graphical representation of the sinkhole database in the Partner's Countries.

The implementation of the additional sinkhole data into the Integrated Map of Shallow Mining was performed in the end of November 2025. The final graphical visualisation of the Sinkhole Database is presented on and is available publicly as a Map under the following link: https://sirima.gig.eu/integrated-map/.

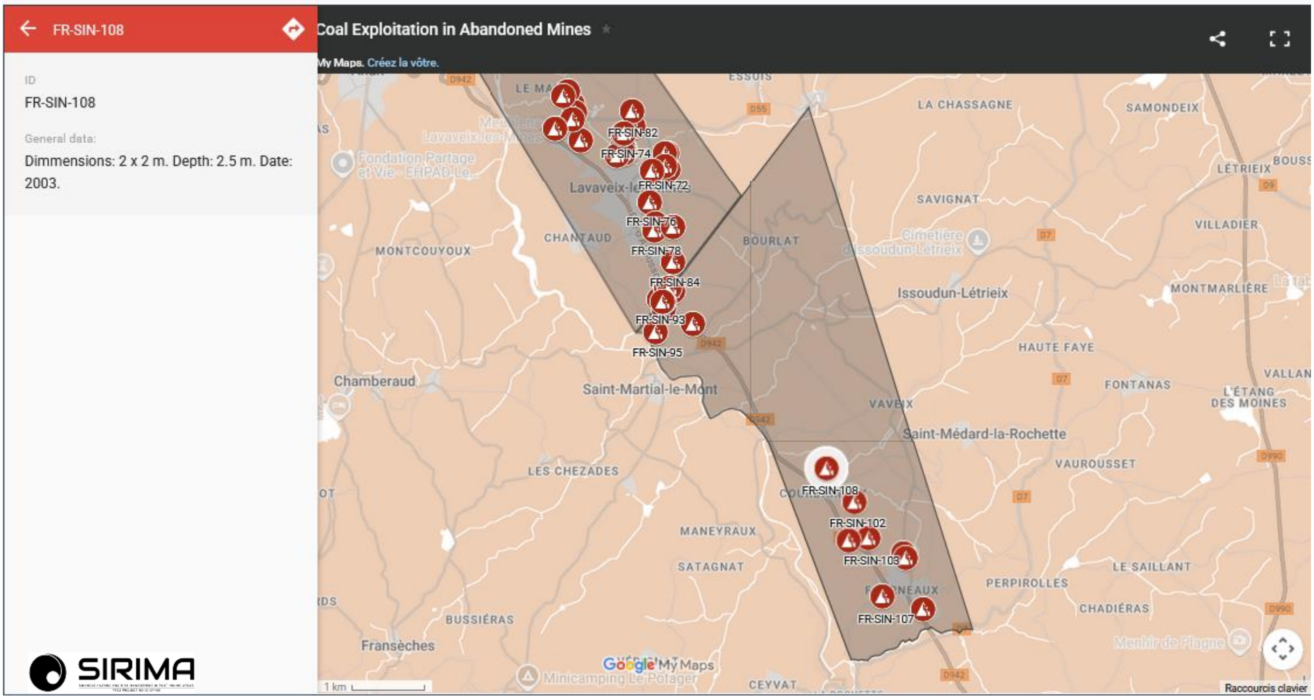

Figure 15 - Final version of graphical representation of the sinkhole database in the Partner's Countries with additional data. Examples from France

6 Conclusion

The objective of this deliverable is to present the database on sinkholes in shallow coal mines in Europe. The database covers data from the partner countries participating in the implementation of the project: France, Germany, Poland and Spain. However, Spain has no information on sinkholes due to the characteristics of its mines: depth, mining methods, etc.

The database is in MS Excel format. The GIG-PIB has also developed a publicly accessible web platform for locating the sinkholes recorded.

The database summarises data on sinkholes, mining works and reclamation. Unfortunately, not all fields in the database could be filled in. The work carried out by the partners highlights the difficulty of obtaining complete information due to the loss of information over time. It should also be noted that the census of sinkholes is not exhaustive, as some mines are very old and the information has not been archived. Furthermore, in Germany, not all data is public. Finally, the German and Polish partners have initially chosen to focus only on certain mining basins.

At the end of December, the SIRIMA database contained 1,814 sinkholes. Despite reaching the stage of this document, the partners will continue to work on expanding the database.

The database will be analysed in work packages 4 and 5 of the project in order to highlight the main parameters that play a role in the occurrence of sinkholes in shallow European coal mines, with the aim of improving their prediction.

Finally, the SIRIMA database helps to preserve the memory of events on a European scale.

Appendix 1- Explanation of each field in the database

Sinkhole characteristics

Object	Comments
Number of sinkholes	In some cases, there may be many sinkholes on a small surface area. Each sinkhole will not be described, but the number of sinkholes observed will be indicated. The characteristics retained will be the most representative of the sinkholes in the area.
Surface impacted (m²)	Area of the zone or surface of the sinkhole
Length (m)	If the sinkhole is circular, enter the diameter only in the length field. If the information is unknown, enter “unknown”
Width (m)	Width of the impacted surface
Depth of the sinkhole (m)	cf. explanatory diagram
In-situ measurement or estimation	Specify whether the dimensions were measured on site or whether they are an estimate (e.g. archive data)
Date of appearance of the sinkhole	Specify the date of appearance of the sinkhole. If it is not known, give an approximate date or period and specify the uncertainty in the following field
Uncertainty of date (years)	
Origin of collapse	Failure of the shaft head Collapse of the shaft filling material Faillure of the roof room Faillure of the roof gallery Pillar failure Unknow
Similar phenomena known nearby	Yes or no

Characteristics of mining work (shaft/cavity-drift)

Object	Comments
Start date of the mining	Specify the start date of mining operations in the sinkhole sector
End date of the mining	Specify the end date of mining operations in the sinkhole sector
Accuracy of date	
Dip of the exploited layer (°)	cf. explanatory diagram
Type of mining work (shaft/cavity-drift)	shaft/cavity-drift
Width / diameter	Width of the cavity / drift, Diameter of the shaft (cf. explanatory diagram)
Working thickness / Deep of the shaft	In the case of a gallery or a stope, specify the height of the galleries (cf. explanatory diagram)
Void density	Specify whether it is an isolated galley (low density) or room and pillars or slotes or block caving
Depth of the drift relative to the surface (m)	Taken from the roof (cf. explanatory diagram)
Uncertainity (m)	Uncertainity of the depth of the drift relative to the surface
Ground support	Concrate, lining segments, Set, rock bolting, masonry, bricks, none
Accessibility	Is the cavity or shaft accessible for inspections or monitoring ?

Overburden characteristics*

Object	Comments
Water conditions in the minig work	Specify if there are water inlets in the mine and their nature: dry, seepage, runoff, flooded
Roof fracture condition	No fracturation, fractured, highly fractured
Geology of the overburden	Short description of the nature of rocks (limestone, sandstone, marl,,,)
Overburden resistance	highly resistant, resistant, weakly resistant, low strength powdery
Presence of an aquifer in the hanging wall	yes or no
*	The high of the overburden is given in the characteristics of mining work (Depth of the drift relative to the surface)