

Soluble rocks



Sinkhole formed by the dissolution of Permian gypsum in the village of Sutton Howgrave, near Ripon. The hole formed on 14 February 2001 and was 5–6 m in diameter and 11 m deep. Image © NERC.

What are soluble rocks?

Soluble rocks dissolve leading to the formation of caves and cavities that may eventually collapse or act as holes into which overlying materials funnel, causing subsidence at the surface. The collapse mechanism can be natural or man-made and a major trigger is infiltration of water (e.g. by heavy rainfall, burst pipes or leaking drains).

What are the hazards from soluble rocks?

One of the hazards from soluble rocks is collapse of the ground, which can range from gentle saucer-shaped depressions forming over a period of time (dolines) to sudden and catastrophic collapses (sinkholes) that may occur without warning. The largest recorded catastrophic collapses in the UK are up to 30 m across and tens of metres deep. Internationally, they can reach up to 160 m in diameter (Sierra de las Cotorras, Chiapas, Mexico) or more. Dissolution of soluble rocks can cause subsidence of ground, buildings and roads plus damage to services such as water, gas and drainage. Dissolution can also cause poor ground conditions and engineering problems.

Overview

- Soluble (or karstic) rocks in the UK cause underground cavities leading to ground collapse, ranging from slight subsidence to dramatic sinkholes. These rocks, in increasing order of solubility, include dolomite, chalk, limestone, gypsum and salt.
- Poor foundation conditions and difficult mitigation of subsidence problems are commonly encountered in these soluble-rock areas.
- Water ingress and changes in the local groundwater levels can trigger collapses in these areas.
- Soluble rocks can strongly influence the local hydrogeology and may contain fissures and caves that act as conduits for the rapid transmission of water, or aqueous pollution.
- One of the hazards from soluble rocks is ground collapse, which in turn can lead to collapse of buildings and roads and damage to infrastructure.

The hazard can be triggered by water soaking into the ground, for example, by the presence of leaking drainage systems and soakaways. Severe subsidence can be caused by burst water mains and there is one case of subsidence being caused by the emptying of a swimming pool near to a house. The rapid transmission of water by soluble rocks means that karstic aquifers are very susceptible to pollution and contamination.

What is the cost to the UK economy?

The total cost to the UK economy from this hazard is difficult to estimate. However, based on a few reported incidents of subsidence, it is likely that damage due to soluble rocks costs in the order of 5 to 10 million pounds per year. Poor ground conditions probably cost a similar additional amount.

In the Ripon area, the water-filled cave system in the thick gypsum that underlies much of the area is

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prone to collapse. It was calculated that this damage cost around £130 000 in 2000, a figure that may have more than doubled since then. Similar cases across the UK have caused collapse and closure of buildings and infrastructure, costing hundreds of thousands of pounds.

Susceptible locations

The five main soluble rock types found in Britain (dolomite, limestone, chalk, gypsum and salt) each have different solubilities, dissolution rates and geological settings. These produce different geomorphological environments and associated geohazards. Where these rocks occur, dissolution

may induce ground subsidence, often triggered by man-made disturbance, either by loading, surface-water disposal or by altering the groundwater regime. Associated rock types and areas with subsidence are the salt in Cheshire, gypsum in Ripon, chalk in southern England and limestone in the Pennines, Bristol and parts of Wales. Other areas with limestone and dolomite deposits are also susceptible.

Scientific detail

Monitoring and measurement

The British Geological Survey is compiling and maintaining a national database of karst features that currently holds information for about half of the country. This dataset was founded on, and has improved on, information that was initially gathered for a database of natural cavities compiled for the UK Government. Data is collected on the major karstic features including sinkholes (dolines), caves, stream sinks, springs and instances of building damage. The database for each of these entities includes dimensions, dates of subsidence and indications of water flows.

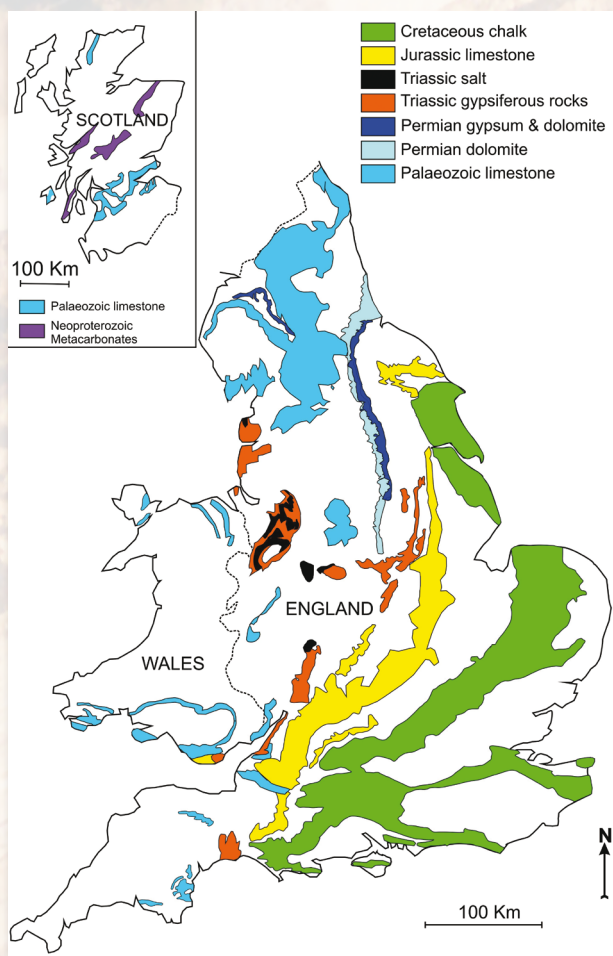
How often is the hazard measured/surveyed?

In general, the soluble rock subsidence features are not actively monitored by the BGS, but reports of new events are attended and recorded.

The hazard can be detected by geophysics and boreholes to investigate sites before they are developed. Geophysical methods have the capability of showing changes within a subsidence feature. Some infrastructure, such as bridges that are susceptible to subsidence, have real-time monitoring incorporated into their structure.

How is the hazard characterised?

The measurement of subsidence features (dolines) is fairly standard based on measurements, and recorded using a geographic information system (GIS), which includes functionality to record directly in the field. In a few places such as Ripon, the BGS



Soluble rock types and their distribution in Great Britain. Based on the BGS 1:625 000 scale Bedrock Geology map of the UK. Image © NERC.

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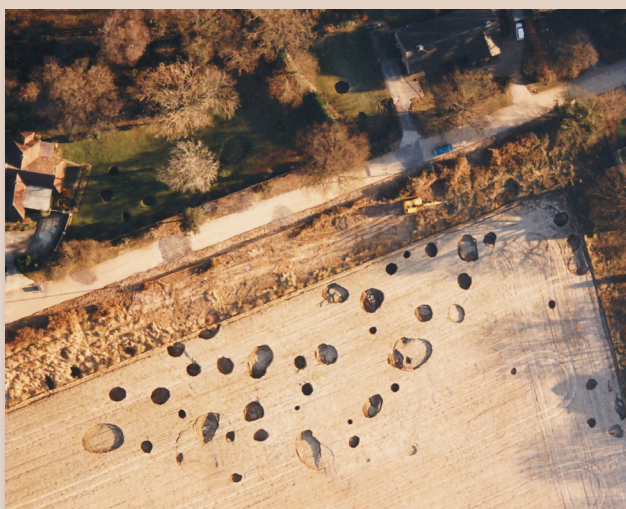
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UK Examples

The Chalk

Chalk is the most widespread carbonate rock and a major aquifer in England. Karst features include extensive dry valleys, permanent and seasonal springs, sinkholes and buried sinkholes. Problems include metastable cavities, irregular rockhead and localised subsidence associated with the development of clay-filled pipes and fissures. More subsidence features are present in the south of England because this area was not glaciated like it was further north.

Particularly vulnerable areas are those where covering materials, such as sand and gravel, mantle the soluble chalk that has dissolved over a long period, leaving cavities at a few metres depth. Heavy rainfall, or in the case of Fontwell, Sussex, a burst water main, have the capability of causing subsidence. Localised input of water and groundwater abstraction are also implicated in severe subsidence and the collapse of houses. Even the act of emptying a swimming pool has caused subsidence and expensive remediation.



Sinkholes formed on Chalk due to a burst water main at, Fontwell, Sussex, 1985. Image © Sealand Aerial Photography Ltd, Chichester, reproduced under licence.

Limestone

Karst is most often seen in limestone, a rock made up mainly of calcium carbonate. In Great Britain, the best developed karst landscapes and the longest cave systems are associated with the Carboniferous Limestone. This rock forms the karst landscapes of the **Mendip Hills**, the Yorkshire Dales, the Peak District and parts of Wales. Typical problems on this rock type include sinkholes, which can be triggered by extreme rainfall events and by inappropriate drainage.



Large sinkhole formed when the ground subsided into an underlying cave system in the Carboniferous Limestone, following heavy rain in 1968. GB Cave, near Cheddar, Somerset. Image © NERC.

Gypsum

Gypsum of Permian and Triassic age is present in many parts of central and northern England. Gypsum is highly soluble — a van-sized block that fell from a cliff into the River Ure near Ripon, dissolved in about 18 months. Where the dissolution occurs underground in places such as Ripon and southern Darlington, cave systems can form causing a subsidence problem. The solubility of the rock means that such cave systems are evolving on a human rather than a geological timescale. Subsidence in these areas

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can be triggered by changes in groundwater levels due to rainfall, inappropriate localised drainage to the ground or by groundwater abstraction.



Collapse of four garages into subsidence caused by the dissolution of gypsum at Ripon, North Yorkshire. Image © NERC.

Salt

Salt can dissolve very quickly leading to salt springs (or wiches/wyches) characteristic of several towns in Cheshire (e.g Nantwich, Middlewich, Northwich etc). Many brine springs became the centre for salt extraction accelerating the formation of the salt karst and causing subsidence. This practice of near-surface salt extraction has ceased and saline groundwater levels have returned towards their pre-pumping state. Brine springs are becoming re-established and natural karstification and subsidence may be expected to occur, as seen by distorted railway lines and adjustable electrical gantries to the north of Crewe.



Distorted railway lines near Crewe caused by salt dissolution aggravated by past brine extraction. Image © NERC.

monitors building damage using a scheme based on the Coal Authority mining subsidence recording scheme, but extended to include more severe damage and building collapse. The ratings range from 1 for hairline cracks not visible outside the property, to 7 for complete destruction.

Secondary hazards and triggers

Minor landsliding of unconsolidated deposits towards the subsidence features may occur as the sides of the

features fail. The main triggering mechanism is input of water into the ground or changes in groundwater level. The input of water can be natural, caused by heavy rainfall, or it can be induced by man. Man-made causes include broken pipes (water and sewage), soakaways, irrigation and poorly designed drainage from roads and infrastructure.

In addition, groundwater abstraction can lower the local water levels, causing material to funnel into existing cavities or to fail due to the lack of buoyant support.



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Possible worst-case scenario

The most likely worst-case scenario would be the collapse of a building killing people inside or the failure of a gas main leading to gas migration and explosion. The collapse of a road or road bridge could also occur. The high-pressure gas pipeline system could also be affected, although much of this has already been assessed for susceptibility.

BGS response and data

BGS have staff who are experienced in karst geohazards and have responded on numerous occasions to karstic collapse problems. They visit sites and record the damage, reporting back to the client and advising on the possible development of future problems. BGS data products include:

- GeoSure for soluble rocks
- Karst database

References

- 1 BGS soluble rocks website: www.bgs.ac.uk/caves including links to limestone, chalk, gypsum and salt karst pages
- 2 Mendips karst geology: http://www.bgs.ac.uk/mendips/caveskarst/karst_1.htm
- 3 National Karst Database: <http://www.bgs.ac.uk/caves/NKD.html>
- 4 GeoSure soluble rocks dataset: <http://www.bgs.ac.uk/products/geosure/soluble.html>
- 5 Farrant, A R, and Cooper, A H. 2008. Karst geohazards in the UK: the use of digital data for hazard management. *Quarterly Journal of Engineering Geology and Hydrogeology*, 41 (3). 339–356. <http://nora.nerc.ac.uk/4227/>
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- 7 Cooper, A H. 2002. Halite karst geohazards (natural and man-made) in the United Kingdom. *Environmental Geology*, 42 (5). 505–512. <http://nora.nerc.ac.uk/6218/>
- 8 Cooper, A H. 2008. The classification, recording, databasing and use of information about building damage caused by subsidence and landslides. *Quarterly Journal of Engineering Geology and Hydrogeology*, 41 (3). 409–424. <http://nora.nerc.ac.uk/4780/>
- 9 Cooper, A H. 1998. Subsidence hazards caused by the dissolution of Permian gypsum in England: geology, investigation and remediation. 265–275 in: *Geohazards in engineering geology*, Maund, J G, Eddleston, M (eds.). Geological Society of London. Special Publications in Engineering Geology, 15. <http://nora.nerc.ac.uk/14308/>

Further information

BGS caves, subsidence and soluble rocks web pages: <http://www.bgs.ac.uk/caves/>
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