The following talk was presented at the **British Association for the Advancement of Science Meeting** in Sheffield Tuesday 14th September 1999 at 14.45. This press release includes some corrections to the original courtesy of the Lewis Carroll Society especially Mr Edward Wakeling. Like many interpretations of literary works and their connections to real events, the links are sometimes difficult to prove and other workers have different interpretations.

MY HOUSE FELL IN A HOLE: problems with soluble rocks!
(And the inspiration for Alice in Wonderland?)

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Alice fell down- down- down- deep into the earth, following the white rabbit. Curiouser and curiouser she thought, in this underground wonderland the walls are made of sparkly gypsum - $CaSO_4.2H_2O$ (with apologies to Lewis Carroll). It has been suggested that the author's vision of Alice falling down a deep vertical hole into an underground land was inspired by natural geological events, notably subsidence at Ripon in North Yorkshire. There *is* a connection between the author, the city of Ripon, and dramatic subsidence that occurred at Ure Lodge, where the alleged model for the published "Alice" illustrations used to live. Beneath this area, the gypsum has a water-filled cave system within it, but gypsum dissolves quickly so that the caves enlarge and commonly collapse. Collapse at Ure Lodge has continued to the present day. It recently caused the destruction of four modern garages and the evacuation of several houses, including the Lodge itself. Subsidence in Ripon, and many other places underlain by gypsum poses a severe constraint on the development of those areas.

Charles Dodgson, who's later pen name was Lewis Carroll, was born in Cheshire and moved at the age of 11 to Croft Rectory south of Darlington, in the North of England. About one mile from the rectory there are three ponds called *Hells Kettles*. These formed by a dramatic collapse of the ground in 1179, they overflow with foul sulphurous water; they were reputed to boil and be bottomless. Folk-law said that a diver from the far-east swam underground from the pits to the river. It was also told that a farmer who worked on St Barnaby's Day was swallowed up and could be seen doing eternal penance in the deep water. In 1958 divers proved the pits to be 22 feet deep and we now know that they were formed by gypsum dissolving underground. However, these strange pits would have been known to the young inquisitive Charles Dodgson.

When he grew up Charles Dodgson went to Christ Church, Oxford University where he was awarded degrees in Mathematics and Classics. In 1855 he became a mathematical lecturer at the college and started to write under the pen name of Lewis Carroll in 1856. In 1862, while boating on the River Isis, he told the story of *Alice's Adventures under Ground* to Alice Liddell and her sisters. Later he presented her with the manuscript, illustrated with his own pictures and completed with a photograph of Alice herself. Urged by the author George McDonald he started work on *Alice in Wonderland* and asked Sir John Tenniel to draw the illustrations. It is reputed in some

accounts (but discounted in others), that a photograph of Mary Badcock of Ripon was the model for face of Alice in these illustrations.

Charles Dodgson's father was Canon Dodgson of Ripon. Canon Badcock a contemporary of his, lived in Ure Lodge, and was the father of Mary on whose photograph Alice in Wonderland's illustration may have been based. In the garden of Ure Lodge there was a subsidence area which has plagued the local residents to the present day. The Maisters, also acquaintances of the author, lived at Littlethorpe, near Ripon, where a major collapse occurred in 1796. In 1860 the Reverend Dunwell of Ripon was walking with some school children along the banks of the River Ure when there was a dramatic collapse leaving a crater about forty feet deep and 20 feet across. While Lewis Carroll's father was resident in Ripon, the Reverend J.S.Tute of Markington, near Ripon, wrote the first scientific paper about the local subsidence events. Like the current residents of Ripon, Lewis Carroll was almost certainly aware of the problems. He would have seen the collapses in his friends gardens and the numerous collapses in the field opposite Ure Lodge. It is likely he would have visited the collapse that occurred in 1834 about 300m north-east of Ure Lodge. This event near the Railway Station left a 20m deep and 11m diameter shaft with solid rock exposed in its sides. There are many other contemporary descriptions of collapses in the area. These and more modern records show that the subsidence is an ongoing problem.

The most recent collapse at Ure Lodge, Ripon, on 23rd and 24th April 1997, formed a major hole about 10m in diameter and up to 6m deep. It was the latest in a series of collapses on that site; it destroyed four recently built garages and seriously damaged two nearby houses. These were immediately evacuated and so was Ure Lodge next to them. The local road was closed and the gas main re-routed over the road surface; even today the road is still closed. The collapse is difficult to deal with and there is considerable debate about who should be responsible for the remediation of this natural collapse. The event made the front pages of the national newspapers and the main television news programmes. The collapse was the latest in a series of subsidences that have affected the Ripon area, and continue to do so. Locally the subsidence damage costs are estimated to be around £1,300,000 for the last 10 years. The subsidence that has occurred is natural. It is caused by the partial collapse of a water-filled cave system developed in thick gypsum layers that are present under most of the Ripon area. Gypsum ($CaSO_4.2H_2O$, the raw material for plaster) dissolves very quickly and the caves form about 100 times faster than limestone caves. Consequently, the caves in the gypsum are continually expanding and collapsing. A collapse occurs about once every ten years in the built up area of Ripon and every two or three years if the surrounding rural areas are included. Many of the collapses are small, but the larger ones leave craters 10-30m across and up to 20m deep. Most of the subsidence hollows occur in lines, or in close groupings. The caves responsible for the subsidence lie at a depth of between 10m and 100m, being deeper towards the east.

The pattern of subsidence, and comparison with other gypsum cave systems, suggests that the caves follow the joints in the rock. At the intersections of the joints larger chambers develop. By further dissolution, these chambers enlarge and become unstable. The roof rock then fails in a piecemeal way, partially filling the void with broken rock fragments. The cavity then work its way upwards leaving a breccia pipe below it. Eventually, the cavity nears the surface and the covering "bridge" of material collapses.

Alternatively, the roof of the cavity opens slightly allowing unconsolidated material to funnel in, rather like sand in an egg-timer. Erosion of material in the cave system can also occur, so the egg-timer effect carries on and the resultant collapses grow and may become difficult or impossible to choke up. On the other hand, the collapsed material can also choke up the cave forcing water to dissolve the adjacent rock; this can lead to closely spaced subsidence hollows at the surface.

Clearly, the presence of unstable ground can have a profound effect on the development of an area such as Ripon. The city now has a planning zonation to take account of the gypsum subsidence problems. In the main subsidence-prone area, new developments require substantial site investigation to avoid the worst areas. They also need reinforced foundation designs to prevent their sudden failure and collapse. In this belt, the new Ripon bypass has a special plastic reinforcing net within its embankments, while the new Ure Bridge is designed to withstand the sudden loss of one upright support. Although the planning process has adapted to the subsidence problem, the insurance business has not. There is a need for comprehensive subsidence insurance cover for the people of the area. Currently, insurance covers the property, not the land and any liability laid against it. The risk to any individual building is fairly small, but the lack of insurance cover for these problems is devastating to those affected. In some states of the USA subsidence insurance is compulsory, here it is largely unavailable.

Gypsum-related subsidence is not unique to Ripon in England. It affects many parts of Europe including Italy, Spain, Switzerland, Cyprus, Lithuania, Latvia, Poland, Romania, Turkey, Ukraine and Russia. In Spain, areas surrounding the city of Zaragoza are affected; the town of Calatayud has suffered severe subsidence and the new village of Puilatos had to be abandoned and demolished. In France, around Paris, and around Stuttgart and towns peripheral to the Hartz Mountains in Germany, gypsum dissolution caves have caused problems for road and building construction. The town of Pasvalys and Biržai in northern Lithuania also suffer from subsidence, but here it is aggravated by ground water abstraction. Gypsum geohazards are a world-wide problem that affect the USA, Canada, China and many more countries. In China large subsidence features, caused by gypsum dissolution, have occurred in the Taiyuan and Yangquan regions of Shanxi Coalfield and in the adjacent Hebei Coalfield. Wherever there is groundwater movement and gypsum together, dissolution and subsidence can occur. Gypsum karst geohazards have been responsible for leakage or failure in more than 24 dams world-wide.