Karst Engineering Beneath an Early Australian Railway

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A railway constructed in the late 1890s to connect a mine and smelter to a port in western Tasmania traversed a belt of karst topography developed on limestone. Crossing a small cave system necessitated minor engineering works within the cave and careful alignment of the railway to avoid sinkholes. This may be the earliest example of karst engineering on a major Australian development project.

INTRODUCTION

Karst is the term of German origin applied to terrain formed by the dissolving of rocks, generally carbonates. Karst terrain is characterised by distinctive landforms and drainage features. Much of the drainage flows underground through caves while the surface is commonly pitted by collapse and subsidence features known as sinkholes. In western Tasmania karst has developed in limestone of Ordovican and Precambrian age and dolomite of Precambrian age. This paper briefly describes the response of railway engineers around the turn of the century to karst along the North Mt Lyell Company railway line in western Tasmania. Their efforts may be Australia's earliest example of karst engineering being necessary to the success of a major development project. The paper commences by reviewing the impact of karst upon engineering and particularly upon the development of communications. It then describes in turn the history of the North Mt Lyell Company railway development, the karst terrain encountered by the railway engineers, and how the engineers responded to the difficulties imposed by the karst.

KARST AND COMMUNICATIONS

Karst terrain presents engineers and land managers with some special problems including vulnerable soils, sensitive ecosystems, rockfall, instability of the ground surface, unpredictable foundation depth and stability, difficulties obtaining and storing surface water, unexpected catastrophic flooding, and scarce, unpredictable and highly vulnerable groundwater supplies. There have been numerous cases of structures collapsing, sinkholes engulfing roads, buildings disappearing and resultant loss of lives in karst areas.[1,2] The establishment of road and rail communications can be affected by the presence of karst terrain.[3]

Karst may impinge upon communications in a number of ways. Because the directions of underground drainage tend to be dominated by geological structures rather than by surface topography, the evolution of karst tends towards chaotic topography with no clear relationship between hills and valleys. Sinkholes and high rock bluffs may be juxtaposed in a manner that greatly complicates the location of suitable continuous communication routes. A constant threat is posed by the potential for collapse of caves, or of sudden collapse or gradual subsidence of soil mantles eroded by subsurface waters. During construction of some railways through the karsts of China, tunnel construction has been complicated by encounters with unexpected natural caverns and underground rivers that have entailed the additional difficulties of constructing railway bridges underground.[4]

However, the impact of karst is not always negative. For example, in Rockbridge County, Virginia, in the United States, Highway 11 takes advantage of a natural rock bridge to cross a 60-metre deep gorge while in Scott County, Virginia, a railway has been constructed through a 300-metre long natural tunnel.[5,6] Similarly, roads have been built through natural karst tunnels as at Jenolan in New South Wales. The stability of the walls and ceiling of the tunnel and the propensity to flooding must be considered where exploitation of such natural features is planned.[7,8]

It is the threat of collapse of surface structures that is of greatest concern. Drainage changes caused by the development itself may often be the cause. Within Australia, roads have collapsed in north-western Tasmania, South Australia and New South Wales.[9] In one American case 184 sinkholes formed along a 7-kilometre section of road between 1972 and 1984 owing to enhanced infiltration of runoff into roadside ditches.[10]

THE NORTH MT LYELL RAILWAY

Macquarie Harbour penetrates deeply into Tasmania's western coastline. It was first brought to European attention by Captain James Kelly in 1815 but was known to the Tasmanian Aborigines tens of millenia earlier. It terminates the mineralised West Coast Range. The earliest European settlement was the penal settlement on Sarah Island which operated from 1822 to 1833 and again briefly as a probation station in 1846–1847.[11,12] The shores of the harbour were in those times exploited for timber and coal, while gangs were taken by boat to the lower reaches of the Gordon River where Australia's first limestone quarry was developed to supply agricultural lime. Mining of metallic minerals in the West Coast Range area dates from 1881

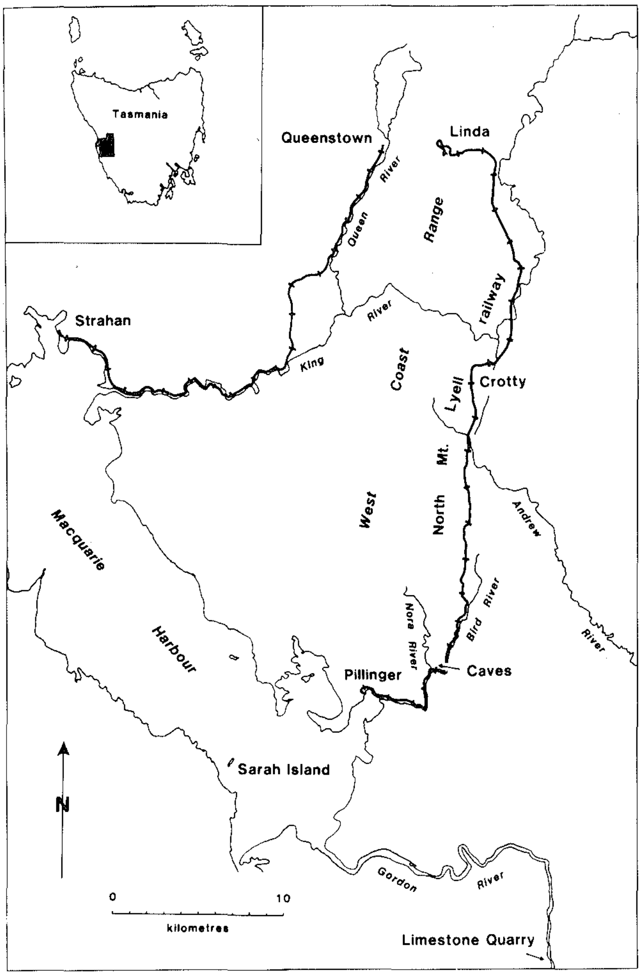

Fig. 1: Location of the Kelly Basin railway

when gold was discovered in the King River Valley 30 kilometres north of Macquarie Harbour. Small goldrushes were followed in 1883 by the discovery in the Linda Valley of an ore body named the Iron Blow. This property was ultimately acquired by the Mt Lyell Gold Mining Company and gold mining was overtaken by exploitation of the site for copper. In 1893 the company was superseded by the Mt Lyell Mining and Railway Company Limited and a railway was constructed (1894–1899) down the King and Queen river valleys to Macquarie Harbour. A second mine was established by the rival North Lyell Copper Company following the discovery of a smaller but richer ore body a little over a kilometre from the Iron Blow in 1897. A 45-kilometre long railway was constructed (1898–90) down the eastern side of the West Coast Range, following an easier route than that through the King Gorge, to link the mining site with Kelly Basin at the eastern end of Macquarie Harbour. The North Mt Lyell smelters were established at Crotty 19.3 kilometres from the Linda Valley (Fig. 1).[13]

The preliminary survey for the railway in early 1897 revealed 'no engineering difficulties to be surmounted'[14], and construction work started in December that year. The railway was built by Baxter and Saddler at a cost of £316,638. Hundreds of men were employed and in the summer of 1899 the line between Kelly Basin and Nineteen Mile Gap was cleared of timber.[15] It was opened for goods traffic in September 1900. A settlement known as Pillinger was established at Kelly Basin with wharves, quarries, a machine shop, sawmills and a brickworks. A specially designed steamship was obtained from England. Six hundred people were in residence at the time of the 1901 census. However, smelting difficulties put paid to the venture and in 1903 the two rival companies amalgamated resulting in the rationalisation of infrastructure and the ultimate abandonment of the old North Mt Lyell Company's facilities. The railway continued in use for some time to supply timber.[16] Pillinger has now been engulfed by forest. The extant remains have been inventoried as part of a regional archaeological survey for cultural resource management purposes. They comprise the remains of a house, hotel and other building sites indicated by collapsed brick chimneys, dumps disturbed by bottle hunters or the presence of exotic plants, collapsed wharves, abandoned railway equipment and the ruins of three double scotch brick kilns. Although the railway from East Pillinger to Crotty has been removed, some associated structures remain and much of the railbed is extant.[17]

KARST ADJACENT TO THE BIRD RIVER

Ordovician limestone crops out in only a few localities in the valleys east of the West Coast Range, but underlies surficial deposits of Quaternary age that cover many of the valley floors. There is evidence of surface karst in only a few areas[18,19] but buried karst and karstic aquifers are developed more widely beneath the subdued terrain, as in the area of the Andrew Divide hydro-electric damsite. Limestone is exposed in several cuttings along the route of the Kelly Basin railway, and some 500 metres north of the Nora River Bridge a very small area of pronounced surface karst is evident in the lower reaches of a valley that drains into the Bird River. A blind valley terminates a few hundred metres west of the railway formation. One principal stream and two smaller tributaries vanish underground. A few small sinkholes up to 20 metres in diameter and 8 metres deep have developed between the streamsinks and the resurgence of the waters from the foot of an 8-metre high escarpment at the foot of a karst limestone bench close to the Bird River.

The underground streams drain through a small cave system (Fig. 2). Towards the upstream end of this cave

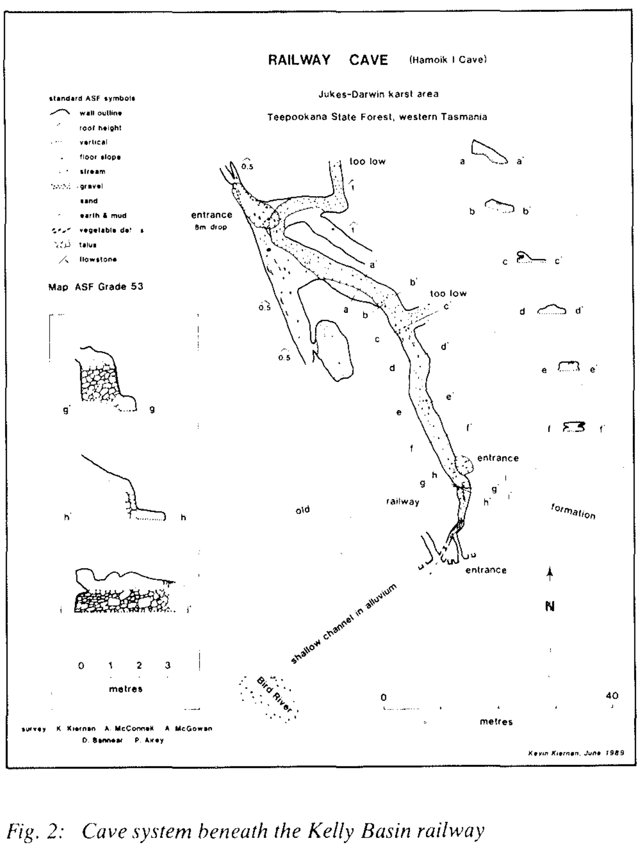

Fig. 2: Cave system beneath the Kelly Basin railway

system are chambers up to five metres high. The development of a high chamber, coupled with the shallow depth of the cave, has facilitated the formation by collapse of a steep-sided rift that is open to the surface. The cave is developed on three levels, the floors of the uppermost and intermediate levels being respectively about 4 metres and 1.5 to 2 metres above present stream level. The uppermost passages are blocked at their downstream end by carbonate speleothems, while floor deposits of carbonate also block the intermediate level. The active stream level diverges from the orientation of the earlier passages. While vadose and collapse speleogens are prominent in the upstream part of the cave the downstream section is characterised more by epiphreatic forms and the roof height seldom exceeds two metres. A small collapse entrance exists near the downstream end and beyond that lies a former outflow entrance which has the form of a narrow rift. Close to the downstream end of the cave lies a cascade 1 to 1.5 metres high where the stream drops into a tiny passage only about 30 metres wide by means of which it leaves the cave. A larger but unnegotiable cave entrance four to six metres further upslope may be a former outflow related to the upper level passages at the upstream end of the cave.

Caves in this locality were apparently first discovered by F. Egan in 1899 with a total of five caves recorded at the time. They became a recreational destination for local residents who, according to the local newspaper, highly praised their natural beauty.[20]

As only two principal caves have been recorded during more recent times it is possible that others remain to be relocated or that the reference should be to five entrances rather than five caves, as five entrances were located by the authors. Later the caves were recorded by Tasmanian government geologist Loftus Hills, who remarked that 'at the 4½ mile [peg from Kelly Basin] there is a development of caves in the limestone and these are regarded by the people in the district as being of great beauty'.[21] With the impending demise of Pillinger some effort was made by local people to stimulate tourism in the district through the use of the caves. Despite the attractiveness of some areas of the main cave and also one of the inflow caves, it is doubtful whether these caves were suited to tourist development.

The authors visited these caves as part of the survey of the North Mt Lyell Company railway line and exploration of the limestone outcrop for Aboriginal sites in May 1989.

KARST ENGINEERING BENEATH THE KELLY BASIN RAILWAY

It appears likely that the existence of the caves was discovered during the construction phase in 1899 rather than during the preliminary survey in 1897.

Although small in area this karst terrain held a number of immediate and potential implications for the railway engineers. The first implication was for the alignment of the railway. The presence of the small escarpment above the stream resurgence, and collapses up to 8 metres deep a short distance up the valley, constrained the options for location of the railbed. The railway engineers did not fall prey to the frequent and often expensive error of simply filling sinkholes so that the railway could maintain a predetermined alignment. Had the latter been done, the likelihood existed that the railbed may have been eroded by subsurface waters. It would not have been possible to extend the railway up the valley from the main sinkholes without necessitating a tighter radius to the curve. The chosen route follows the edge of the limestone bench between the resurgence and the collapse entrance to the cave 15 metres further upstream.

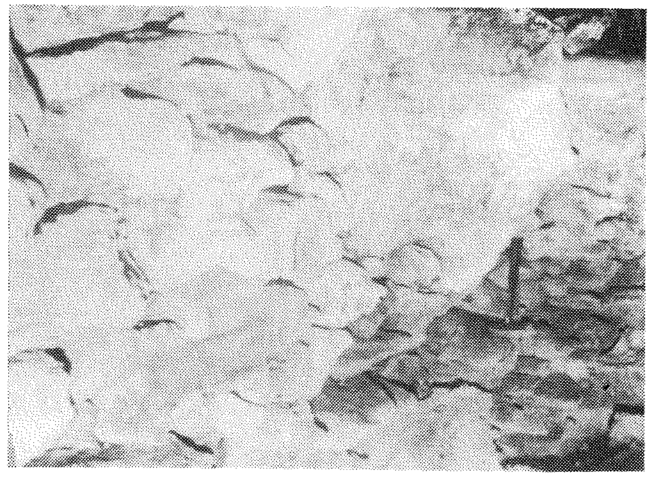

Fig. 3: Wall constructed beneath the railbed parallel to the cave system (Photo: A. McConnell)

Secondly, the question still remained as to the stability of the terrain between the sinkholes. The largest cave passages occur at the upstream end of the cave system, while the divergence between the old upper level and more recent stream level passages towards the downstream end of the cave implied that the size of the known subsurface voids to be spanned by the railway was smallest at the downstream end of the cave. Moreover, the advantage of crossing at the downstream end was increased by the fact that the two tributary streams had merged by this point such that they were centralised into a single natural culvert.

Thirdly, the potential existed for stability difficulties with the railbed at the chosen site. It is no longer possible to determine whether a further entrance open to the surface or an aven (vertical shaft) that appeared to offer potential for collapse existed beneath the chosen route. For whichever reason, construction activities took place within the cave system beneath the railbed. These works involved the construction of two dry stone walls to hold back fill placed in an upward sloping passage on the northern side of the cave stream. These walls were probably constructed in 1899, but could have been installed later in response to stability problems with the railbed.

One wall about 2.9 metres long and up to about 1.4 metres high was constructed parallel to the stream primarily from blocks about 100 to 400 mm long. Most of the wall consists of small limestone slabs but one large block about 530 mm long is also included (Fig. 3). Some flowstone has formed on a few of the blocks. The debris impounded behind the wall, the uppermost part of which may be sand, has also been covered by a film of carbonate in the 90 years since construction. At the upstream end of this wall and at right angles to it is a somewhat more roughly constructed wall about one metre high, built from irregularly shaped blocks (Fig. 4). Blocks visible behind interstices in this wall also appear to be stacked in a systematic manner suggesting that the debris wall is at least two layers thick, raising the possibility of systematic block stacking to the centre of the construction. In contrast to the other wall which stands virtually vertical, the upstream wall slopes at about 80-85 degrees.

The underground structure was located in a position that would allow a sufficient outlet for the cave stream to remain available. The parallel wall was founded on the bedrock floor of the cave thereby reducing the risk of basal sapping by the eroding waters of the stream running past its foot. There is no evidence of flood damage to the construction since it was put in place.

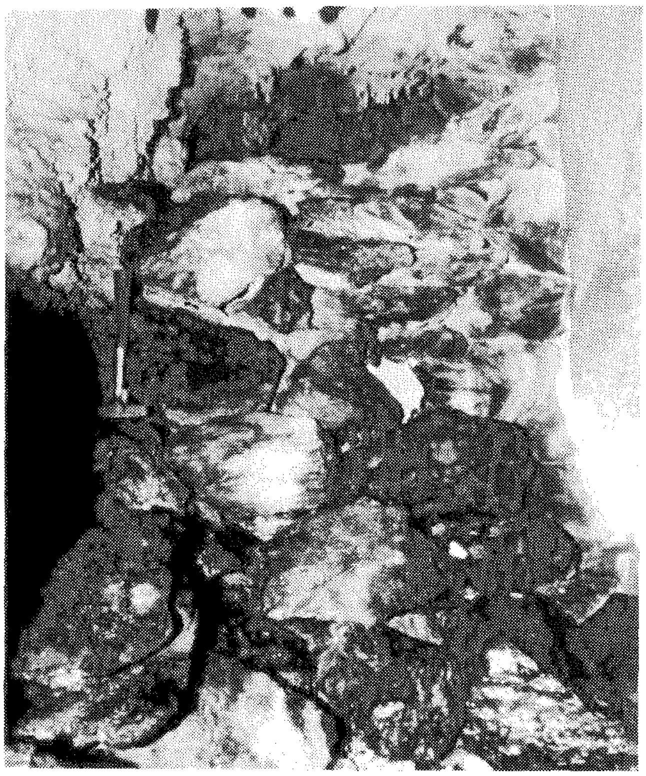

Fig. 4: Upstream wall constructed in the cave system beneath the railbed (Photo: A. McConnell)

DISCUSSION

Although small in area the karst beside the Bird River had the potential to promote instability of the railbed if not properly addressed. That the work done by the railway engineers has withstood the test of time attests to its effectiveness. The topography of the railway formation remains fresh, and the stability of the rock walls built underground has been such that flowstone has formed over them with no evidence of any displacement. Such results are not always achieved. For example, collapses have occurred in fills used to construct a timber cutter's tramline one to two metres above the valley floor in Missouri in the 1880s, a decade or so earlier than the Kelly Basin railway was constructed.[22] A small karst collapse is reported to have occurred between the sleepers of a much more recently constructed railway line at Railton in northern Tasmania. A major road collapse in another nearby karst in 1974 appears to have been the result of a failure to allow adequate egress of a subterranean stream.[23] This mistake was not made beneath the Kelly Basin railway more than half a century earlier.

Beneath the Kelly Basin railway construction lies what is perhaps the earliest example in Australia of karst engineering as part of a major development project. The site warrants recognition and a management sensitive both to the historical values of the karst engineering works and to the bush engulfed legacy surrounding it. Together these stand as testimony both to the transience of human aspirations and the potential longevity of a job well done.

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GLOSSARY OF KARST GEOMORPHOLOGICAL TERMS

epiphreatic – groundwater zone at the base of the vadose zone and above the totally saturated (phreatic) zone where water may flow at high velocity due to an hydraulic gradient.

speleogens – a feature formed by erosion or weathering in a cave

speleothems – a secondary mineral deposit formed in a cave, often consisting of calcite; includes stalactites, stalagmites, and flowstones.

streamsink – location at which a surface stream disappears underground.

vadose – groundwater zone in which voids in the limestone are partly filled with air and where water is able to move downward in response to an hydraulic grandient.

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