QUARRY ARTS: PLAYING WITH AGGREGATES

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Abstract

June 11th, 1785; '*found my 6 first music stones at the Tip end or North end of long tongue*'. Peter Crosthwaite said he found these stones on Skiddaw in perfect tune; the remaining ten of the set were found and tuned. The result was a lithophone, a stone xylophone, which he used to play to attract visitors to his museum in Keswick.

In 2010 two new lithophones were made for Brantwood, John Ruskin's home in Coniston, using a range of rocks, including aggregates. These Ruskin Rocks projects were two of seven projects undertaken by Yorkshire Quarry Arts (YQA) and funded by the Mineral Industry Research Organisation (MIRO) and Natural England through Defra's Aggregates Levy Sustainability Fund (ALSF), between 2003 and 2011. The projects drew the public's attention to quarries and the quarrying industry. In this paper novel approaches used by YQA to engage the public and change its perception of quarrying are described. Through activities in in geology, art and music, with a range of communities and in natural, historic, cultural and built environments the use of these innovative approaches has encouraged further study, exploration and understanding of geology, quarrying and hard rock landscapes.

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Introduction

Yorkshire Quarry Arts (YQA) was formed in 2003 at the University of Leeds by members of the Earth Sciences, Inter-disciplinary Initiatives, Interdisciplinary Centre for Scientific Research in Music and Fine Art departments, to develop opportunities for the general public to engage in creative and scientific activities relating to quarries and the quarrying industry.

Between 2003 and 2011 seven projects were undertaken which drew the public's attention to quarries and the quarrying industry, specifically;

- Yorkshire Quarry Arts: Feasibility Study (2003-2004)
- Yorkshire Quarry Arts: Public Participation (2004-2007)
- Yorkshire Quarry Arts: Changing Public Perceptions (2007-2008
- Yorkshire Quarry Arts: Threshfield Quarry Development (2007-2008)
- Threshfield Quarry Community Project (2008-2009)
- Ruskin Rocks Pilot project (2008-2009)
- Ruskin Rocks : the sound of nature – the nature of sound (2009-2011)

The first three projects were funded by MIRO's Minerals Industries Sustainable Technologies (MIST) programme and the later four by Natural England both through Defra's Aggregates Levy Sustainability Fund (ALSF). Through activities in geology, art and music YQA worked with a large number of communities in natural, historic, cultural and built environments and addressed the social and economic impact of disused quarries on local communities.

These projects were supported by a number of eminent geologists both at the University of Leeds and in Yorkshire and Cumbria and successful working partnerships with operators, stone companies and craftsmen within the quarrying industry were essential to their success. Projects show the public that there are creative, imaginative and even magical outputs from quarries and the quarrying industry. The quarrying process can reveal much to stimulate and enlighten.

An important aim of all projects was to help the public to understand why mineral extraction is important in our changing society and to counter negative perceptions of the industry; to engage them in new and exciting ways and to change their perception of quarrying. This was achieved through events including quarry visits for school children of all ages, workshops, concerts and recitals, artists in residence, exhibitions, and attendance at trade shows, science fairs and conferences. The YQA approach is unique in using interdisciplinary activities in geology, art and music and using these intriguing and innovative approaches to encourage further study, exploration and understanding of the quarrying environment (Figure 1).

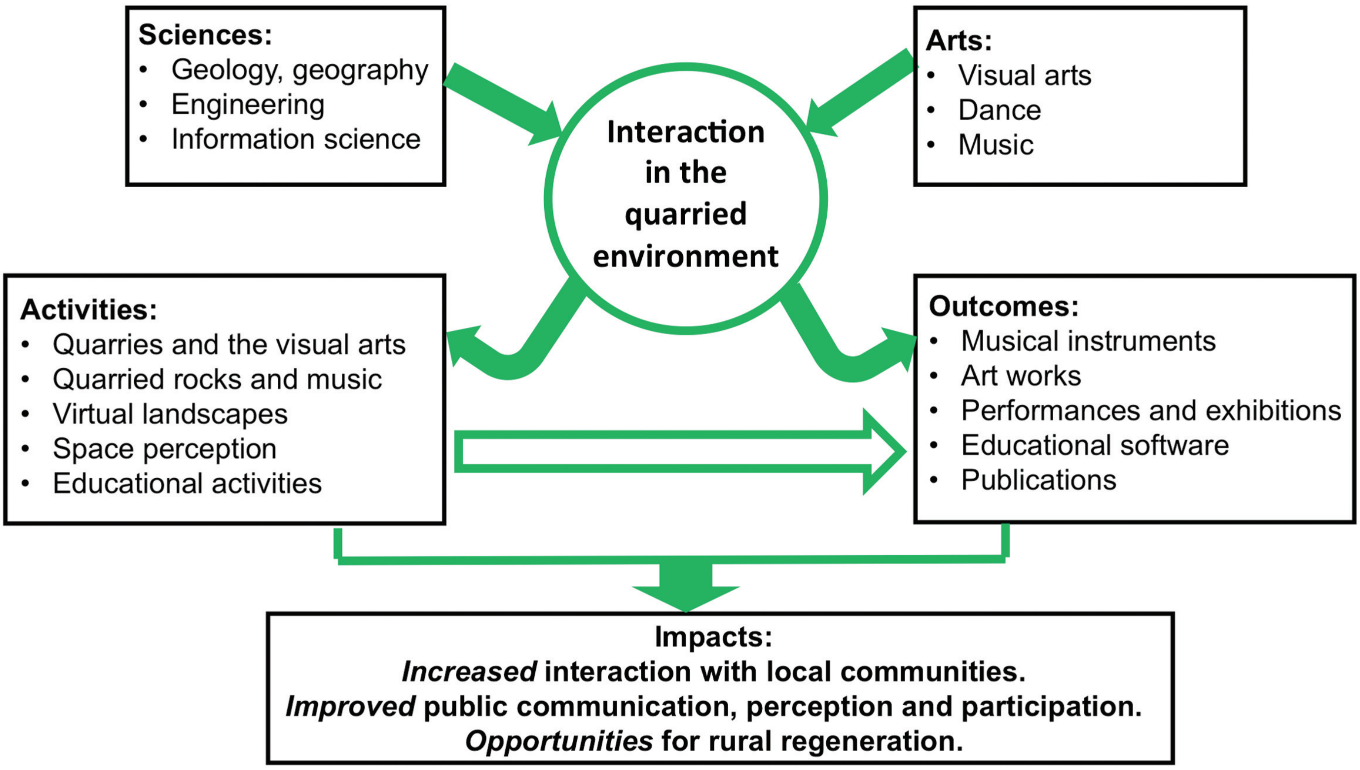

Figure 1. *Yorkshire Quarry Arts model innovative approach to encouraging understanding of the quarrying environment.*

In this paper, novel approaches and some of the funded projects used to engage the public and change its perception of quarrying are described. The focus is on finding ringing rocks and making them into musical instruments with the purpose of learning about geology and the quarried landscape. By working with geologists; musicians, technologists and arts educators can begin to identify which rocks ring, and more importantly, why? Some progress has been made but there is still scope for a systematic study of ringing rocks. This paper presents some of the findings, and examples of instruments made with the aid of modern science and technology.

Musical Rock Instruments

June 11th, 1785: '*found my 6 first music stones at the Tip end or North end of long tongue*'. Peter Crosthwaite said he found these stones on Skiddaw in perfect tune; the remaining ten of the set took six months to find and tune. The result was a lithophone, a stone xylophone, known as 'Musical Stones' which he used to play to attract visitors to his Museum in Keswick. The stone xylophone made from Hornfels, an igneous metamorphic rock, is displayed in the Keswick Museum and Art Gallery.

During the 19th century further instruments were made using Hornfels from Skiddaw and they can be found in museums in Keswick, Kendal, Coniston and Keighley. The most famous of these was the 'Rock, Bell and Steel Band' completed by Joseph Richardson in 1840. He collected Hornfels from Skiddaw and spent 13 years making an instrument that has 63 keys spanning five and a half octaves. He almost bankrupted his family in the process. He subsequently toured the country with great success, even giving performances for Queen Victoria (Keswick Historical Society, 2006).

Later William Till made a number of instruments from Hornfels including a set made in 1880, now in the Metropolitan Museum of Art, New York and a set in 1884 for John Ruskin. This instrument has been in the Ruskin Museum in Coniston for at least the last 60 years. The instrument was originally kept at Brantwood, the home of John Ruskin.

In 2003, on discovering the Musical Stones of Skiddaw via the Friends of Keswick Museum & Art Gallery Newsletter, Murray Mitchell of YQA suggested that an exploration of the geological properties of rocks in Ingleton and Skiddaw might reveal ringing rock in Ingleton. This set the scene for the first three MIST funded projects, located in Ingleton, Coldstones and Jackdaw Crag Quarries. During the Public Participation project, some of the Greywacke and Ingletonian Slates were found to ring. Original clay minerals had been chloritised and filled with metamorphic fluids which deposited a range of minerals including quartz, calcite and chlorite to form the greywacke (Odling and Barker, 2008). The greywacke rocks rang with a warm mellow tone whereas hornfels had a more metallic and shrill tone. This work led to further studies of the Keswick Stones, where a correspondence between the hornfels rock bar length and the pitch was found (Millar et al, 2006).

Ruskin Rocks

During the making of a BBC Radio 4 programme in 2005 on 'The World's first rock band', percussionist Evelyn Glennie and representatives from Brantwood and Yorkshire Quarry Arts (YQA) agreed that Brantwood should have its own 21st century lithophone. Funding was obtained through Defra's ALSF for two Ruskin Rocks projects. In 2010 two new lithophones; the four octave lithophone and the iRock, collectively known as 'The Brantwood Musical Stones' were launched by Evelyn Glennie (Figure 2) providing an opportunity to introduce the public to the geology of the Lake District by using musical bars from a range of different rocks, including aggregates.

During the development of the proposal for the Ruskin Rocks project a field study was undertaken to determine the precise origin of and composition of the hornfels. These hornfels were found in Sinen Gill in the inner aureole of the Skiddaw Granite. A significant feature that made these rocks ring particularly well was the presence of cordierite and andalusite together with recrystallized micas. 'Hence it is not the presence of cordierite and andalustite per se that makes the inner hornfels so distinctive, but the fact that the abundant micas have completely recrystallized to an interlocking hornfels texture and no pervasive cleavage remains. Furthermore the rocks have a very strong embedded fabric and importantly is seen to break easily into flat slabs close to the optimum thickness of 2.5 – 3cm as seen in the musical stones.' (Smith and Yardley, 2008).

The four octave lithophone

The 49 key, four octave lithophone was made from 4 different rock types; green slate from High Fell Quarry, Tilberthwaite, Coniston; Shap blue andesite from the CEMEX Quarry at Shap; hornfels from Skiddaw, courtesy of the Lowther Estate and Lake District National Park Rangers; and limestone from the Tarmac Quarry at Stainton with Adgarley, Barrow in Furness. All were sliced, polished and cut and then fine- tuned to concert pitch. The bars were prepared by Burlington Stone, High Fell Slate and Blencathra Stone Crafts and were fixed to a frame using specially created cradles, designed by the Keyworth Institute, University of Leeds, to prevent the bars from being stolen. It was not possible to drill through the bars to fix them to the frame as some of the bars fractured during research. Instead a brass pin was glued into a small hole in the sides of the rock bars at their nodal points to secure them to the frame.

The iRock

The iRock (interactive Rock) is a smaller, interactive multimedia instrument which explores the natural beauty of rock vibrations through the rich geological diversity of Cumbria. The iRock software contains a database of information and images for each rock type including Scanning Electron Microscope images of the crystalline structure. The vibrations from each individual key of iRock are monitored continuously. If a strike is detected, the computer software goes into action, displaying images and information about the rock key.

The iRock screen shows different visualisations of the iRock sounds. The waveform display in blue shows the vibrating pressure waves radiating from the iRock keys. The frequency spectrum of these vibrations is sampled continuously and is shown in green. Illustrating the harmonic structure of the sound is a Lissajous plot, shown in red. This is a curved shape that reflects the complexity of the note and shows how the sound changes as the key continues to ring. This enables the player to see as well as hear when the vibration ceases.

Figure 2. *Evelyn Glennie demonstrating the new Brantwood Musical Stones lithophone at the launch, August 2010. The iRock is on the left.*

The iRock is a one octave chromatic scale instrument made from thirteen different ringing rocks. The rock bars are arranged in order of greater resonance so that the higher the pitch the longer the rock vibrates. Shap pink granite at the lower end only made a brief clink and the thirteen ringing rocks were arranged in order of resonance as follows: Tilberthwaite green slate; andesitic tuff from Ghyll Scaur; slates from Brandy Crag, Broughton Moor, Elterwater; Kirkby blue; greywacke from Holmescales; Shap blue andesite; hornfels from Skiddaw; Knipe Scar limestone; Urswick limestone from Stainton; Park limestone from Stainton and limestone from Sandside (Millar, 2012).

Finding and tuning rock bars for the Brantwood Musical Stones

The original intention was to make a lithophone from local slate. However, slate did not attract the ALSF and so old slate and aggregate quarries in Cumbria and Lancashire were searched for ringing rock. The rock needed to be made up of tightly packed fine grained minerals, be very hard and of a high quality. Seventeen ringing rock of varying quality and quantity were found, of which eight came from aggregate quarries. As the quarrying process introduces additional fractures it was difficult to find large pieces of rock that could be sliced into rock bars.

Sufficient rock was found at the slate and aggregate quarries to make both of the instruments and have some to spare in case of unforeseen breakages. Indeed all of the rock bars were dropped onto a concrete floor before tuning to ensure that the bars that were tuned were not likely to break when played by the public. Consequently limestone had to be used for the shortest octave on the four octave lithophone. It was also the most resonant. This particular limestone from Stainton was very pure and had been used in the past to make acetylene gas. The other aggregate used in the four octave instrument was Shap blue andesite, a source of rail ballast. In order to get sufficiently long pieces of rock, slate was used for the lowest octave as this was quarried with almost no explosive. The last of the four octaves was hornfels, important for comparison with the existing historic instruments.

The array of rocks therefore included aggregate and also represented the three basic rock types; sedimentary, igneous and metamorphic, though it was found that all of the rocks used had been altered in some way over hundreds of millions of years. The green slate, Shap blue andesite and the hornfels had all be metamorphosed. The limestone from Stainton had been deposited below limestone pavements and therefore subjected to long periods of emergence above sea level and hardening.

In creating the iRock there was a desire to use the green slate from High Fell as it is the nearest source of ringing rock to Brantwood. The limestone from Stainton and Sandside was very fractured from the quarrying process, fragile and broke easily. Rock bars needed to be cut to about 15mm thick, 42mm wide and varying in length from 195mm to about 780mm. Consequently limestone was used for the higher notes as those rock bars had to be cut to a short length and they had the longest resonance.

The physics of the rock sounds were researched and a mathematical formula was created that determined the length of rock needed for a required pitch. The bars were then cut and fine-tuned by a team of musicians and technicians, taking four people, one week to tune each octave to within one hundredth of a Hertz. It was decided to have rock bars machine sawn, polished and cut to 15mm thick which gave best resonance for bars about 200 to 500mm long. It was also important for them all to be the same thickness so that the length of each bar could be calculated and the tuning be precise. This was not possible with the rough hewn rocks of the historic instruments (Millar, 2012).

Having calculated the length of each bar the nodal points had to be found. If the bars rested on their nodal points (where the sound waves crossed) the resonance of the rocks would be increased. Determining the nodal points provided opportunities for school pupils involved in the project to develop an interest in and an understanding of physics and maths from a new perspective, and the properties of rocks. The nodal points of the rock bars were found to be 22.4% in length from each end.

A vibrating object moves the air molecules closest to it, pushing them together as the object moves in one direction, then pulling them apart as it moves the opposite way. These air molecules collide with their neighbours causing a wave to propagate. When the air's vibration reaches the ear, the eardrum vibrates and our brain processes this as sound. A ringing rock key can stopped by touching it, because this dampens the vibrations. The rate at which the rock keys vibrate determines the pitch of the sound. The more vibrations, the higher the frequency and so the higher the pitch of the sound heard. Most sounds do not consist of a single frequency, but are made up of many frequencies at different intensities. The changing combinations of frequency and intensity (the spectrum) determine the colour or timbre of the sound.

For a rock to ring, the grains must be grown tightly together so that vibrations pass from one grain to the next without losing energy. If there are pores or spaces between the grains, the vibrations will not be able to pass across and the sound will be lost. A cracked rock will make a noise when struck, but does not ring. A sandstone that is full of holes between the grains will make little noise and will never ring. The rock keys' thickness and length both influence the rate of vibration. The shorter keys make a higher note. Half the length equals four times the frequency (the same note but two octaves higher).

The rock instruments provide an opportunity to explore the geology of the Lake District in a novel and innovative way. An exhibition at Brantwood, in addition to the instruments includes large panels describing; the geological processes through which the Lake District geology was formed; a map showing the source location of each of the rocks used in the instruments; the local historical context of ringing rock instruments and, why rocks ring (Figure 3).

Figure 3. *Panels showing the formation of igneous and sedimentary rocks, and the Brantwood Musical Stones*

Clitheroe Castle Lithophone

A two octave lithophone was made for the geology exhibition in Clitheroe Castle Museum in 2013-2014. The project was funded by Lancashire County Council and used Kirkby Blue Slate provided by Burlington Stone for the Ruskin Rocks project. This blue slate was originally intended for the lower octave at Brantwood but was replaced by the more local green slate from Tilberthwaite. This top quality roofing slate is ideal for public instruments as it is very strong and robust allowing the bars to be secured to the frame with brass screws. It has a very pleasant mellow sound and was tuned to concert pitch with each bar being within one hundredth of a hertz when installed. Adjustments had to be made after the instrument had been in place for three months as the rocks dried out and adjusted to their new environment. The instrument was accompanied by a resource box for school visits.

It is intended to make more of these instruments from rock bars left over from the Ruskin Rocks project and to conduct further research into why rocks ring and why different kinds of rocks sound so different.

Future Projects

Post ALSF, in April 2014 and from YQA, Quarry Arts Limited was created. It continues to work with communities to engage them with quarrying environments. Current activities include;

- Working with MIRO to submit a proposal to the Heritage Lottery Fund (HLF) on the 'Quarry Tales: Clitheroe project'. This will broaden the range of projects with which MIRO is currently engaged and should assist them with public engagement.
- Working with the Yorkshire Dales National Park Authority to bid to the Arts Council England (ACE) to create an outdoor lithophone for Malham Visitor Centre in the Yorkshire Dales National Park.
- Involvement in a proposal from the Yorkshire Dales Millennium Trust for the Ingleborough Dales Landscape Partnership 'Stories in Stone' funded by HLF with the expectation of two projects within the scheme: 'Musical Rocks' and 'Quarry Tales: Ingleborough Dales.'

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