

IMPACTS OF FRACTURING CAUSED BY VALLEY FORMATION AND PILLAR COLLAPSE ON THE HUNTER EXPRESSWAY PROJECT

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ABSTRACT

The Hunter Expressway is a new government funded dual carriageway motorway built to relieve congestion between Newcastle and Thornton, Maitland and Rutherford. The expressway is continuous over 40 km between the F3 at Seahampton and Branxton. The easternmost 13 km between the F3 and Kurri Kurri is being built by the Hunter Expressway Alliance (HEA), comprising constructors Thiess and designers Parsons Brinckerhoff and Hyder Consulting partnering with NSW Roads and Maritime Services (RMS). A solution was required to manage the risk of mine subsidence under the viaduct and bridge foundations. The solution used was to fill the mine voids out to a distance of half the seam depth.

The extent and depth of the mine voids and related subsidence fractures was required before treating the voids. First assessment was to complete a detailed geological long section of key existing boreholes. Following this, further boreholes with video camera footage were made to assess the mine workings. The footage, with GIS, was used to map and correlate pillar and roadway networks with existing mining surveys, to accurately determine the volume of mining space to grout. After grouting, 140 validation holes were made to assess if the mine voids had been filled successfully.

The assessment of video footage also helped the geological and geotechnical assessment of abutment structures on the viaducts as there were numerous joints and fractures. With mapping, and from assessing the videos, the team could decide whether these fractures were formed by earlier tectonic events, stress relief due to valley formation, or mine subsidence.

The fractures are differentiated by their source — stress relief fractures related to valley formation, fractures caused by pillar collapse, and fractures related to tectonic joint/fault systems. The valley-forming fractures were found in an upper sandstone layer (Figure 3). These fractures are consistent in the three viaducts where bridge abutments have been exposed. The fractures caused by pillar collapse were found in a sandstone layer about 40 m above the mined horizon, between two coal bearing layers.

There were several outcomes from the work done. It has been demonstrated video camera monitoring can play a significant role in mining and geotechnical applications, and have a positive impact on time and budget-related issues.

1 INTRODUCTION

The Hunter Expressway is a four-lane dual carriageway motorway jointly funded by the Australian and New South Wales Governments to improve freight movement in the region by relieving congestion on the New England Highway.

The expressway passes over an area where coal has been previously mined for over a century, as shown in Figure 1. The alliance is constructing 28 bridges, including three twin-bridge viaducts crossing valleys up to 40 m deep and 6 km of road pavement within the mined area, which will be the main focus of this paper.

The eastern section of the expressway, from the F3 interchange at Minmi, is underlain by a number of abandoned coal mine workings in the Young Wallsend Seam at around -5 m RL (Australian Height Datum) and the Borehole Seam at around -20 m RL. Record tracings indicate the coal in the Borehole Seam was mined by various collieries in the early 1900s, while the Young Wallsend Seam was mined in the 1980s. The mine plans indicate the layout of the mines, i.e. location and width of roadways and pillars, and surveyed conditions. The working heights are about 1.3 m to 1.7 m in the Borehole Seam, and 2.4 m in the Young Wallsend Seam (Figure 3 shows the typical geology across the project, including the two coal seams).

The section of the expressway between Skyline Ridge and Buchanan, from chainage 4000 m to 6000 m, is located above the abandoned workings in the Borehole Seam. This section of workings has been mined by relatively modern mining

techniques; the pillars formed are considered to be long-term stable with little risk of subsidence. Some future longwall mining in deeper seams in this area is anticipated. A more complete description of the project, the subsidence hazards and mitigation strategies may be found in Kingsland *et al.* (2011).

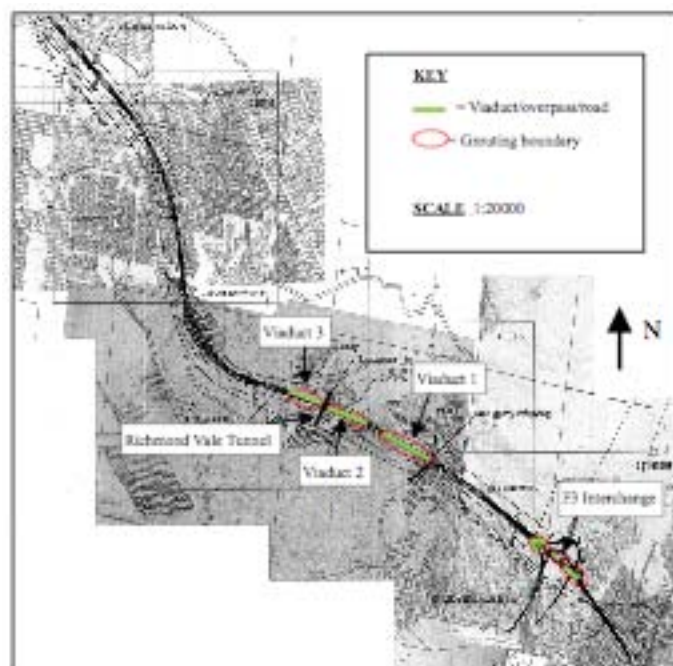


Figure 1: Abandoned coal mine workings below Hunter Expressway

Significant fractures, which were discovered mainly as a result of an extensive HEA mine-fill video monitoring program, as well as site investigation and construction works, can be sourced from pillar collapse, stress relief or tectonic joint systems. In areas where pillars collapsed, fractures occur in a major sandstone layer about 40 m above mine void level, sloping from west to east. The fractures are caused by pillars, which supported the previous mine workings, collapsing due to subsidence after mining.

This paper aims to:

- i) present evidence of fractures caused by stress release, pillar collapse, and tectonic joint/fault systems, and
- ii) demonstrate how mine-fill videos show how the mine voids were treated by the filling with grout.

2 MINE FILL MONITORING

The validation involved in the mine-fill process was threefold — core logging, video and geophysical downhole monitoring. Video monitoring was very important because it gathered accurate footage of the fractures *in situ*. Then further footage was taken during or after the holes were grouted, showing the fractures being filled for a mine-fill process — even though fractures are less than 10 mm thick, very thin relative to the typical mine void thickness of 1.5 m. This is because the grout consists of a mixture of sand, fly ash and water; hence it can penetrate and form up into very small fractures or cracks. The core logging was necessary as it provided actual hard evidence of the material, and a rock and grout sample. Suspected hardened grout could be found and confirmed in the core sample, showing proof of hardened grout being retained in defects and mine voids, in amongst the rock profile. An example of evidence of hardened grout forming in a mine void and in fractures of collapsed material on the mine floor (fracture thickness is 10–30 mm) is given in Figure 2.

Geophysical downhole logging could provide a guide of whether any mine voids were remaining after grouting, as well as what the approximate rock profile was in a location. The voids and defects remaining could be detected by callipers trailing the wall of the borehole. A density geophysical test was used on the profile to decipher what was being mapped at depth. This made it possible to distinguish the prevalent sandstone and siltstone from coal and grout. This could be

backed up by a gamma test to act as a secondary test to distinguish clays and coal from sandstone. The geophysical logging complemented the video monitoring and coring, or could be used as a non-intrusive method to replace coring.

At each hole, validation and non-validation was video monitored multiple times. Each hole was monitored before grouting, mainly to map the mine void (or semblance of) positioning and depth, while also finding any major defects requiring treatment. If there was a significant mine void then a compass shot video was taken scanning 360° to detect the extent of the void and location of pillars and roadways for comparison with mine maps. A camera shot was also taken after grouting the hole and usually during grouting holes close by on the drill platform. The holes were to show that the hole has been filled (after grouting the hole) or was in the process of being filled (from a nearby hole), and therefore the mine void was filled. Often a hole could be videoed several more times to show grout flow to surrounding holes or to the rest of the drill platform; it was sometimes difficult to ensure the grout hardens and dries in the hole and surrounding mine void. Validation holes were video monitored usually once at the end of the grouting program for an area, to determine at depth to mine void level that grout had filled the mine void enough, as well as defects.

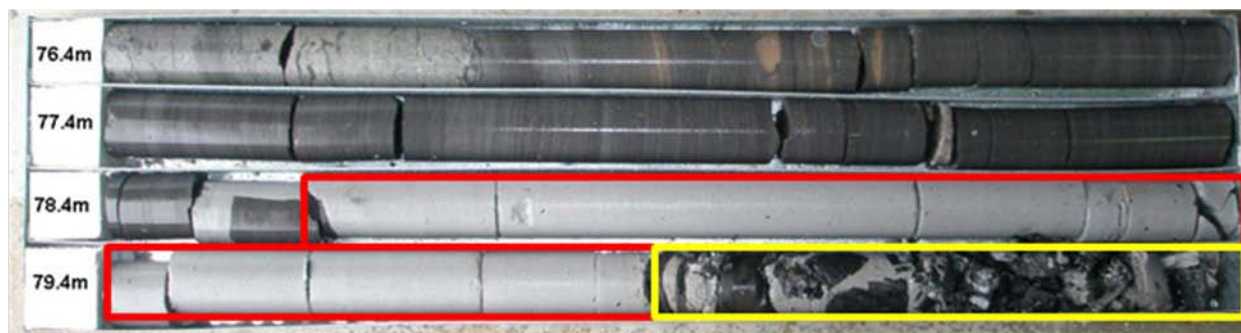


Figure 2: Core showing solid grout core (red) and grout permeation in fractured coal (yellow)

3 FRACTURES

Mine subsidence defects have been formed due to sagging of the above strata as a result of the collapse of small standing pillars, causing subsidence at the ground surface. The consequences of a sudden collapse below any structure, particularly the viaducts, would make the structure unserviceable, and construction above the ground would be difficult. Pillar collapse may also be caused by other external factors, such as rising mine water levels, adjacent mining activities, and earthquakes, most of which are possible in the lifetime of the expressway. Additionally fractures from 20 mm to 500 mm thickness have been observed due to collapse of the mine void, as well as fractures created above the mining horizon during mine roof collapse. Many prominent fractures were found mainly from video monitoring, and occasionally from the cores of validation holes. These fractures are characteristically clean breaks. At several places on site there was evidence of fractures close to the ground surface. A notable example was the Richmond Vale Tunnel, between Viaduct 2 and 3.

The valley-forming joints are generally vertical, open and associated with massive high strength sandstone units (Figure 3). The joints dip between 70° and vertical, and strike between 25–30° in sandstone and 60° in siltstone parallel to valley direction. The joint sets are usually orthogonal, and are widely spaced (>3 m) in sandstone, and appear to die out when traced into the siltstone, most likely due to the differences in mechanical properties of the rocks. The joint openings are up to 200 mm wide (possibly jacked open by tree roots) in the sandstone, and at times filled with sandy clay and tree roots. No movement was anticipated and measured to date as there is a lack of any adverse dipping bedding or joint planes that can trigger further movement of this rock mass. An example of these joints is shown in Figures 4 and 5 during excavation and video monitoring respectively.

The other notable joint sets across the HEA site are the occurrence of steeply dipping (>70°) tectonic joints, with dominant strikes to the NNE and NW developing due to tectonic processes associated with the early stages of the rifting of East Gondwana. Further explanation of the tectonic event can be found in Och *et al.* (2009). These joint sets occur as dominantly widely spaced, but in some areas (e.g. Viaduct 1) zonally closely spaced joint sets (NNE and NW striking) are commonly observed now the site is being exposed. Where discrete joint sets (widely spaced) are observed, zones of transpression (cataclastic zones) have been observed, and as a result of lateral displacement along these joint or discrete fault systems vary in thickness from 0.5 m to 3 m. Figures 6 and 7 show detailed mapping of a joint system found in the

bridge abutment at Viaduct 3. Continuation of these joint sets has been mapped across the project area, and their strikes have been used to predict with success their continuation into the large cuts along the project.

The defects found from the video monitoring were confirmed to be more widespread defects during excavation.

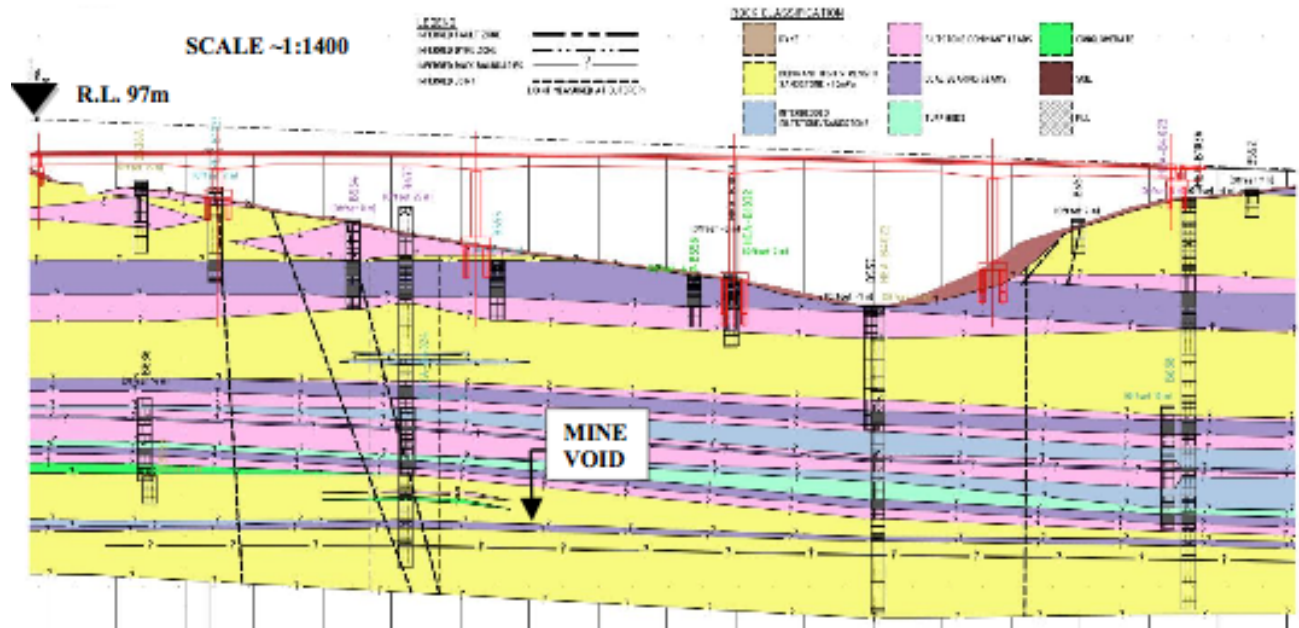


Figure 3: Geological long section of viaduct 1 – South facing

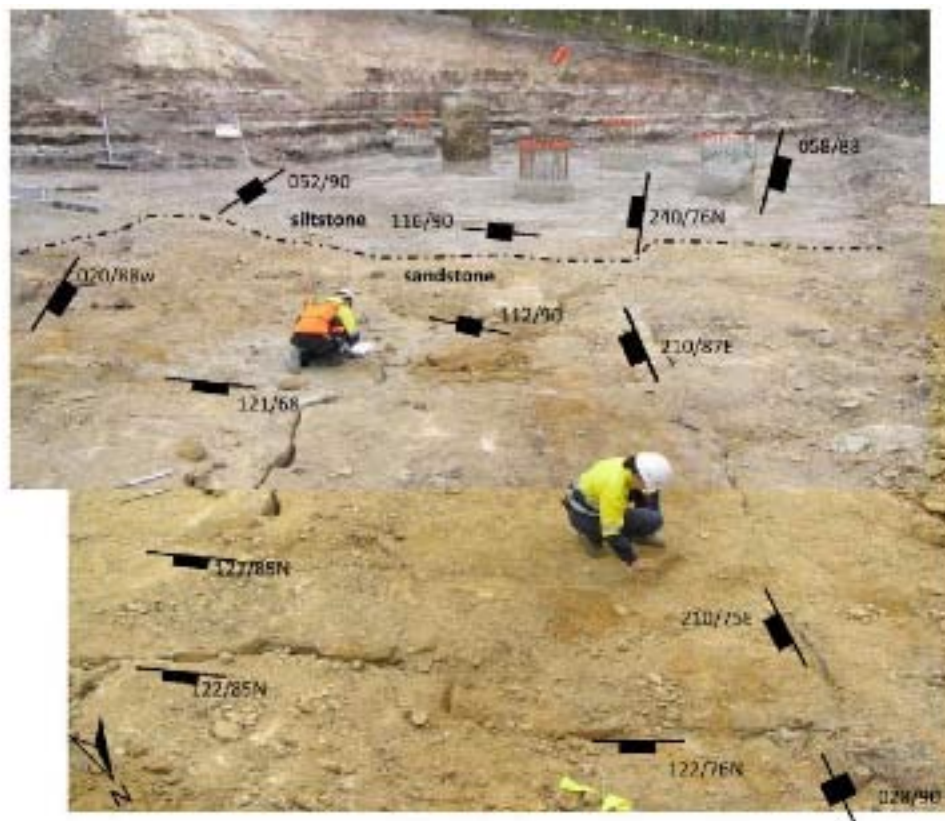


Figure 4: Viaduct 3 Abutment A excavation for abutment foundation



Figure 5: Vertical fracture in borehole beneath viaduct location

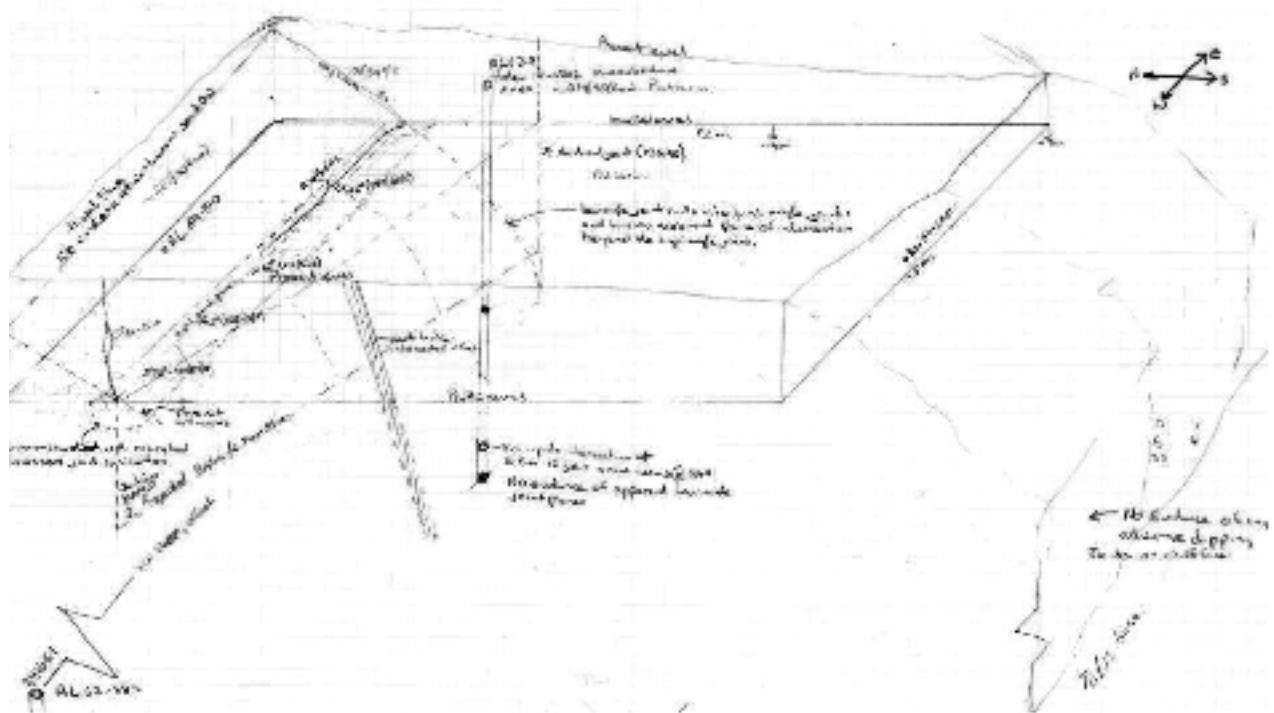


Figure 6: Mapping geological defects observed at Abutment B, westbound, Viaduct 3.

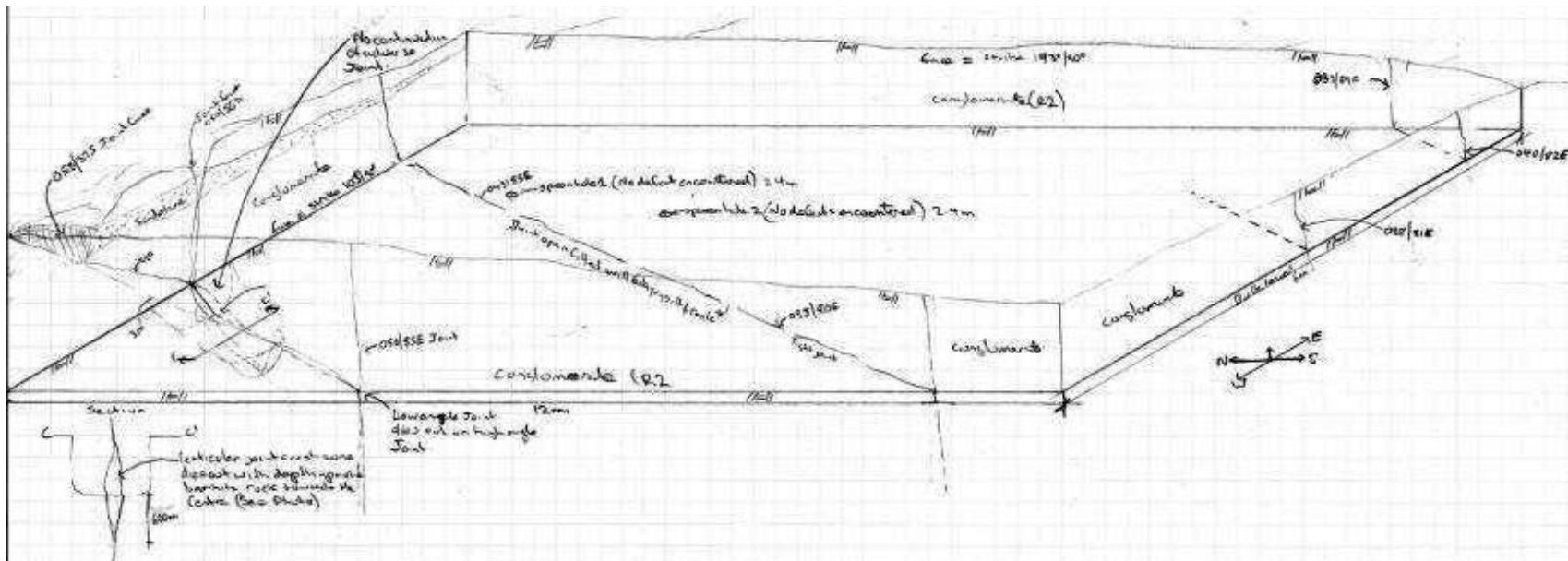


Figure 7: Mapping geological defects observed at Abutment B, eastbound, Viaduct 3.

4 CONCLUSION

Mine-fill video monitoring has become a very useful tool for several reasons. Firstly to monitor the mine voids, not only identifying the extent of the mine voids but also if they had been filled after grouting. Secondly, it can be used as a tool to identify major and minor defects as small as about 50 mm thick, and is an example that more extensive geological mapping can be created with video imaging. As a result, potentially major widespread fracturing and faulting systems could be picked up, such as both the valley forming and tectonic-related fracture systems found on Viaduct 3 abutments, as they were picked up during video monitoring downhole. Monitoring and other project site investigations during construction works demonstrated complex fracturing systems — which include also the mine subsidence fractures — which have required additional extensive inspections and resources to ensure the successful construction and maintenance of the Hunter Expressway. These defects are typical features of the complex geology of the Hunter region. The benefit of the extra evidence of the fracture systems is the ability to provide better solutions to further potential geotechnical issues. Some common issues for valley forming and tectonic-related fracture systems include increased presence of groundwater and water from mining activities causing more stress in surrounding rock, and stress and additional fracture zones causing failure and movement in high risk areas, such as valley channels. Finally, it should be noted that video monitoring could provide added financial savings for future projects, especially those where mine treatment and solutions to complex geology are required.

5 ACKNOWLEDGEMENTS

The authors wish to thank the Roads and Maritime Services and the Hunter Expressway Alliance for permission to publish this paper. We also acknowledge the development of the design, specification, validation procedures and video monitoring have been done with the close cooperation of the Hunter Mine-fill Sub-Alliance and in particular Keller Minefill.

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