Norman B. Keevil Institute of Mining Engineering
2009 Graduating Research Trip

New South Wales, Australia
May 3rd – May 16th, 2009
SPONSORS

DIAVIK DIAMOND MINES INC.

SMG CONSULTANTS

Yukon Zinc Corp.

LEDCOR Group

FINNING CAT

Genuity

c™

newgold

NORTH AMERICAN TUNGSTEN CORPORATION LTD

WorleyParsons

resources & energy

WEYMARK ENGINEERING LTD.

SCOTT WILSON ROSCOE POSTLE ASSOCIATES
COAST MOUNTAIN GEOLOGICAL LTD.
GOLDER ASSOCIATES
IMPERIAL METALS
BANK OF MONTREAL
NEPTUNE TERMINALS
ROBERTSON GEOCONSULTANTS
MULTIEURATHANES

SANDY LAIRD
ALF HILLS
JOHN SWAINSON
GEORGE POLING
BILL MYCKATYN
# Table of Contents

1.0 Introduction ................................................................................................................. 4  
1.1 Travellers ....................................................................................................................... 5  
1.2 Trip Itinerary ................................................................................................................... 5  

2.0 Singleton ......................................................................................................................... 6  
2.1 Mt. Thorley Warkworth Mine ...................................................................................... 6  
2.2 Westrac Caterpillar Dealer ......................................................................................... 8  
2.3 Hunter Valley Wineries ............................................................................................... 9  

3.0 Newcastle ....................................................................................................................... 10  
3.1 Sandvik Local Assembly Centre ............................................................................... 10  
3.1.1 Sandvik History and Presentation ...................................................................... 10  
3.1.2 Shop Tour ............................................................................................................... 10  
3.2 HVCCLT and PWCS ................................................................................................... 11  
3.2.1 HVCCLT ............................................................................................................... 11  
3.2.2 PWCS .................................................................................................................. 12  
3.3 Newcastle Sights ........................................................................................................ 13  

4.0 Orange .......................................................................................................................... 14  
4.1 Cadia Mine ................................................................................................................... 14  
4.1.1 History .................................................................................................................... 14  
4.1.2 Mining at Cadia Valley Operations ..................................................................... 14  
4.1.3 Cadia Hill Open Pit ............................................................................................. 14  
4.1.4 Ridgeway Underground ..................................................................................... 15  
4.1.5 Ridgeway Deeps .................................................................................................. 16  
4.1.6 Cadia East ............................................................................................................ 17  
4.1.7 Ore Treatment ..................................................................................................... 18  
4.1.8 Cadia Circuit ....................................................................................................... 18  
4.1.9 Ridgeway Circuit ................................................................................................. 18  

5.0 Sydney ........................................................................................................................... 19  
5.1 University of New South Wales ............................................................................... 19  
5.2 Sydney Sights .............................................................................................................. 19  
5.2.1 Darling Harbour .................................................................................................. 20  
5.2.2 Bondi to Coogee Coastal Walk ......................................................................... 20  
5.2.3 Taronga Zoo ........................................................................................................ 21  

6.0 Conclusion and Acknowledgements ........................................................................... 22
1.0 Introduction

From May 3 to May 17 of 2009, the graduating class at the Norman B. Keevil Institute of Mining Engineering took part in a research trip to various mining sites in New South Wales, Australia (Figure 1). Among the places visited were mines, machine shops, equipment dealers, port facilities, a university, and local attractions. The trip took 8 months to plan and was organized by the grad class representative, Ryan Weymark. This report summarizes the sites and shares some of the knowledge gained during the experience.

![Figure 1 - Map of NSW, Australia. Source: Google Maps 2009](image)
1.1 Travellers

The group that participated on the trip consisted of 23 members: 20 students, the department administrator, and two professors. They are listed in Table 1.

<table>
<thead>
<tr>
<th>Students</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrew Baker</td>
<td>Fiona Liem</td>
</tr>
<tr>
<td>Jonathan Chan</td>
<td>Marc Mains</td>
</tr>
<tr>
<td>Mimi Chien</td>
<td>Luke Moger</td>
</tr>
<tr>
<td>Michael Dean</td>
<td>Patricia Oka</td>
</tr>
<tr>
<td>Maryam Esfahanian</td>
<td>Michael Oxciano</td>
</tr>
<tr>
<td>Nicolas Fung</td>
<td>Derrick Pattenden</td>
</tr>
<tr>
<td>Devon Golobic</td>
<td>Toma Stamenov</td>
</tr>
<tr>
<td>Paul Hughes</td>
<td>Daniel Stein</td>
</tr>
<tr>
<td>Talha Khan</td>
<td>Gordon Webb</td>
</tr>
<tr>
<td>Garner Lea</td>
<td>Ryan Weymark</td>
</tr>
<tr>
<td>Department Staff</td>
<td></td>
</tr>
<tr>
<td>Malcolm Maclachlan</td>
<td></td>
</tr>
<tr>
<td>Professors</td>
<td>Professors</td>
</tr>
<tr>
<td>Dr. Rimas Pakalnis</td>
<td></td>
</tr>
<tr>
<td>Dr. Marek Pawlik</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 - Trip Members

1.2 Trip Itinerary

Table 2 lists the cities visited as well as the main activities of each day.

<table>
<thead>
<tr>
<th>Date</th>
<th>City</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday</td>
<td>May-3</td>
<td>Vancouver Fly Vancouver to Sydney</td>
</tr>
<tr>
<td>Monday</td>
<td>May-4</td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td>May-5</td>
<td>Singleton Train from Sydney to Singleton</td>
</tr>
<tr>
<td>Wednesday</td>
<td>May-6</td>
<td>Singleton Mt. Thorley Warkworth Mine Tour</td>
</tr>
<tr>
<td>Thursday</td>
<td>May-7</td>
<td>Singleton Westrac - Caterpillar Tour</td>
</tr>
<tr>
<td>Friday</td>
<td>May-8</td>
<td>Newcastle Sandvik Tour</td>
</tr>
<tr>
<td>Saturday</td>
<td>May-9</td>
<td>Newcastle Newcastle Coal Port Tour</td>
</tr>
<tr>
<td>Sunday</td>
<td>May-10</td>
<td>Newcastle Newcastle Sightseeing</td>
</tr>
<tr>
<td>Monday</td>
<td>May-11</td>
<td>Sydney Train from Newcastle to Sydney</td>
</tr>
<tr>
<td>Tuesday</td>
<td>May-12</td>
<td>Sydney University of New South Wales Visit</td>
</tr>
<tr>
<td>Wednesday</td>
<td>May-13</td>
<td>Orange Train from Sydney to Orange</td>
</tr>
<tr>
<td>Thursday</td>
<td>May-14</td>
<td>Sydney Cadia Mine Tour, Return to Sydney</td>
</tr>
<tr>
<td>Friday</td>
<td>May-15</td>
<td>Sydney Sydney Sightseeing</td>
</tr>
<tr>
<td>Saturday</td>
<td>May-16</td>
<td>Sydney Sydney Sightseeing</td>
</tr>
<tr>
<td>Sunday</td>
<td>May-17</td>
<td>Vancouver Fly Sydney to Vancouver</td>
</tr>
</tbody>
</table>

Table 2 - Trip Itinerary
2.0 Singleton
Singleton, a town of just under 15,000 people, is located approximately 183 km Northwest of Sydney. It is situated in the Hunter Region (also known as the Hunter Valley) where the major industries are coal mining, power generation, cattle farming, and wine production. This section outlines the activities of May 6th and May 7th.

2.1 Mt. Thorley Warkworth Mine
Mount Thorley Warkworth (MTW) Mine is an open pit coal mine located 15 kilometres southwest of Singleton in the Hunter Valley. MTW is owned by a number of companies, but in majority by Coal & Allied (Rio Tinto) and Mitsubishi Development Pty Ltd. Mount Thorley and Warkworth Mine, previously two separate mining operations, were merged into one operation in 2004. Rio Tinto operates 10 mines on the East coast of Australia, with coal, aluminum, copper, and gold being the primary minerals mined. In the Hunter Valley, Rio Tinto holds interest in four coal operations: Bengalla, Mt. Pleasant, Hunter Valley Operations, and Mt. Thorley Warkworth Mine.

On May 6, 2009, our class arrived at MTW, where our tour began with an introductory presentation on the mining operations, an introduction to Rio Tinto, and Rio Tinto Coal Australia, and a Safety talk by David Bennett, the Manager of Mine Technical Services. Following the presentation, our class was given a tour of the mine by Colby Miller, a previous UBC graduate who now works there as an EIT. After the presentation and tours, MTW's staff kindly hosted a barbeque for our class.

During Mr. Bennett's presentation, the mining fleet, employee structure, current and future mining operations, wash plant, and community relations were described. Some of the notable equipment operating at MTW includes a P&H 5700 Shovel, which is one of the largest operating shovels, as well as a P&H 9020 Dragline, which is the largest dirt moving piece of equipment on site. MTW's mining fleet includes three draglines with 49m$^3$, 57m$^3$, and 79m$^3$ bucket capacities, three electric rope shovels, and 16 dozers. Future plans include adding a fourth shovel, two excavators, four front end loaders, 2 dozers and increasing to 38 trucks. This large fleet is operated by 650 full time employees, 20-50 special contractors, and 30-300 shut down contractors bringing the total to 650-1000 employees at any given time. When comparing the tonnes mined per year to the number of employees, MTW produces 300,000 tonnes per person per year.

MTW's daily production of 30,000 tonnes is limited most by the rail's capacity, not the mine's. Roughly 40 coal seams are mined ranging from 30cm and 6 meters in thickness. Currently, there are about 15 working seams with an average dip of 6-8%. The coal in the Hunter Valley is of high quality and has low sulphur content. The total depth of the final pit is 300 meters, and the strip ratio is 8 to 1 (bcu) with the key to successful mining being effective waste handling. The blocky spoil material provides a good pad for their draglines, an important factor considering that 9-10 million tonnes of coal are exposed per year. In 2008, 180 million tonnes of material was moved, and 9 million tonnes of saleable coal was produced. MTW's current mining cost is $48/tonne to get the product on to rail, and a target is to reduce costs by $10/tonne by increasing machine efficiency. With over 500 million tonnes of coal remaining, the mine should continue to operate for 25 to 30 years.
Mount Thorley Warkworth has two washplants as it was previously two separate operations. The mine has ROM stockpiles of 160,000 and 340,000 tonnes at the North and South plants, and the capability of producing different products at the different plants. 72% of production is exported as thermal coal, 2% is used domestically in power stations, 20% is exported as semi-soft coking coal, and 6% is BDT coal. MTW's current processing cost is $7/tonne.

As the mine is located near Singleton, many environmental and community issues arise. Main issues include land rehab, community relations, water/air pollution, and blasting issues. During 2009, 80 hectares of rehab were planned, displaying MTW's high standards, and contributing to a good relationship with neighbouring communities and industries. In addition, MTW has an environmental department that monitors dust, water quality, and vibrations.

Mr. Bennett explained Rio Tinto’s Take 5 safety program, asking us to identify hazards we would encounter during our tour of the mine and ways to eliminate any risks.

Following our presentation, Colby Miller gave our class a tour of MTW's operations, and gave our class the chance to take a picture inside one of their dragline buckets.

![Figure 2 - Standing in a Dragline Bucket](image)

Following our tour MTW provided a barbecue lunch, giving our class the opportunity to talk with their employees and learn more about the mining operations, community and culture.
2.2 Westrac Caterpillar Dealer

Westrac, one of 500 Caterpillar dealers in the world, is the dealer for New South Wales, Western Australia, and China. In the Hunter Valley Region, Westrac Australia’s major business is supplying mining equipment to the many coal mines operated by companies such as Rio Tinto (Coal & Allied,) BHP Billiton, Anglo Coal, Xstrata, and Vale.

On May 7th, we visited the Westrac office and shop in the Mt. Thorley industrial area. First, an office presentation was given by one of their account managers Rebecca March. This was followed by a walking tour of their Component Rebuild Center (CRC.)

![Figure 3 - Gordon Webb and a D11T Dozer](image)

During the presentation, Rebecca took us through the catalogue of mining equipment offered by Westrac including coal and overburden haul trucks, dozers, graders, loaders, and wheel dozers. Of particular interest was the 797B, a 345 tonne haul truck. Although none have been sold to any mines in the Hunter Valley, Mount Thorley Warkworth currently has a few ordered. It takes six to eight weeks to ship the trucks to Australia where they are received in Wollongong. After being received, it takes another eight weeks to perform modifications to the trucks as New South Wales has the strictest machine and safety standards in the world.

On a 797B haul truck, $300,000-$400,000 AUD must be spent on upgrades such as machine access, electrical insulation, fire suppression, greasing systems, pressure release systems, and sound suppression. For example, the noise level of the haul truck must be reduced from 122 dBA to 113 dBA to meet NSW requirements. This is largely to accommodate the many wineries and communities near the mines. Since noise is of such concern, Westrac has a noise test facility located at Mount Arthur Mine where microphones are placed around a pad to measure noise levels on test trucks. Finally, it was also explained to us that the Hunter Valley region has not been as adversely affected by the economic downturn because it produces thermal coal which is exported to Asia. This is in contrast to the coking coal produced in Queensland used for steelmaking.
2.3 Hunter Valley Wineries

The Hunter Valley is Australia’s oldest wine region, and hosts many spectacular wines that our class was fortunate to experience. The most famous wines in the Hunter Valley Region are the Semillon and the Shiraz, although their Chardonnays and Verdelhos are also highly recognised. The Hunter Valley region has been developing wine making techniques for over 150 years, and has grown to host more than 120 cellar doors in the area to date.

The students were surprised by the proximity of the wineries to the mines in the region, which appear to co-exist perfectly. The Hunter Valley is a special place with rows of vines surrounding large open pit mines. These surroundings provide a nice environment for students who would consider working in the region.

During our tour of the Hunter Valley wineries, we had the opportunity to taste some of the Valley’s spectacular wine, cheese, chocolate, and local beer. The experience gave insight to the culture in the area, and the history behind the region that was not mining related. During our tour we visited several wineries including Rosemount and Lindemans, the Stinky Cheese Shop, and Bluetongue Brewery.

At the wineries we learnt how to taste wine properly, an art not yet learnt during four years as poor university students. Students swirled their glasses, checked the colouring of the wine, smelt the aromas, sipped the wine, and evaluated the bouquet of flavours each unique wine offered. At the cheese and chocolate shops students were given the opportunity to taste local foods and chat with the Hunter Valley residents. Finally, students went to Bluetongue Brewery and tasted several unique local beers.

The Hunter Valley winery experience was a huge success and was a well deserved break after having completed exams and the planning the trip. We would all recommend that anyone that has the opportunity to work or vacation in the Hunter Valley to do so as it was a great experience in all respects.
3.0 Newcastle

May 8th to May 10th was spent in Newcastle. With a population of roughly 300,000 people, Newcastle is a port city that acts as a hub for coal and industry. It is also a young and vibrant urban centre, attracting people to its beach walks and dining in town at cafes and restaurants.

3.1 Sandvik Local Assembly Centre

On May 8th, after traveling from Singleton to Newcastle, we had a tour of the Sandvik Mining and Construction (SMC) local assembly centre. There, we were given a presentation on the company as well a tour of their shops.

3.1.1 Sandvik History and Presentation

Sandvik was founded in 1862 by Goran Fredrik Goransson in the business of steel production. In 1907 Sandvik started producing drill steel for rock-drilling equipment. In 1990 Sandvik acquired 25% of Tamrock an underground mining equipment company and in 1998 Sandvik Mining and Construction was formed.

Sandvik has since acquired a number of companies that specialize in underground mining equipment including: Toro, Voest-Alpine, Tamrock, Rammer and Driltech. Almost half of Sandvik’s sales and activity take place in Europe, North America and Australia each occupy about a quarter, and South America and Africa make up the remaining sales.

It was explained that Sandvik’s business approach is to only acquire companies that put them in the top three of a given sector, such as underground mining equipment. In doing this, they become immediately competitive without further developing the technology. Also, SMC local assembly centres, such as the one visited, are critical to ensure timely response, increase flexibility and decrease costs.

From the presentation the group learned new things about the large company. Many people still think of Toro trucks and Voest-Alpine miners without realizing that these companies have been acquired by Sandvik and they now produce the equipment under that name. We talked about the importance of brand recognition for Sandvik and how this outweighs the benefits of keeping well known names like Toro. We also learned about the business of producing specialized goods and that it is important to be at the top of the market.

3.1.2 Shop Tour

As underground mines are comprised of tight spaces, it is often hard for large groups to see working equipment. However, the shop tour allowed for close inspection of equipment such as LHDs and bolter-miners in various stages of repair. Rebuilding a machine can take up to three months and is done every couple of years depending on utilization. From sitting inside machinery, students appreciated the vision restrictions on operators. Some noteworthy sights were the cutting head of a continuous miner, a bare 1000 HP engine block, and electrical operating systems. The tour guides discussed the various safety systems required for underground coal mining while students were able to examine these details up close. This allowed students to appreciate the size and complexity of coal mining equipment not previously seen.
3.2 **HVCCLT and PWCS**

On May 9th, the group toured the office of the Hunter Valley Coal Chain Logistics Team (HVCCLT) as well as a port operated by Port Waratah Coal Services (PWCS.) The office tour included a presentation of HVCCLT and a demonstration of the computer systems that are used for scheduling by the planners. The port tour allowed for the tour bus to drive along the coal stockpiles and the docked ships while coal was being loaded.

3.2.1 **HVCCLT**

HVCCLT is an independent logistics team that plans the movement of all coal in the Hunter Valley region. This consists primarily of the scheduling of the trains that take the coal from each of the mine sites to the ports in Newcastle where they are loaded on to ships. 10% of the coal produced in NSW is consumed domestically while the remaining 90% is exported. Of the exports, 65% goes to Japan. In 2008, coal throughput was over 95 Mt. A map of the coal rail network managed by HVCCLT is shown in Figure 4.

![Figure 4 - Coal Rail Network](image-url)
3.2.2 PWCS

PWCS is the world’s largest and most efficient coal handling operation, having two ports: one at Carrington, and the other on Kooragang Island. Our group was given a tour of the larger port, the Kooragang Coal Terminal, which has a ship loading capacity of 31,500 tonnes per hour compared to 5000 tph capacity at Carrington. Currently, the combined PWCS annual capacity is 102 Mt but an expansion is underway to increase capacity to 113 Mt.

Coal is transported by rail from the Hunter Valley to the PWCS terminals. The trains dump the coal at the end of the rail line and conveyors take the coal to stackers where the coal is stacked on one of four stockpiles. These stockpiles are 56 metres wide and up to 2.5 km long with a maximum combined capacity of 3.6 Mt. When it comes to loading, bucket wheel reclaimers move the coal to another system of conveyors which take coal to the shiploaders. Up to five ships can be loaded at a time. The tour provided perspective on the magnitude of this type of operation. A large amount of planning and control is required to maintain such a process and the size of the equipment was quite impressive when witnessed up close.
3.3 Newcastle Sights

On May 10th, students were given a free day in Newcastle and chose to partake in a variety of activities. The walk to Nobby's Beach was popular, as this beautiful (but windy!) beach is the site of NSW's third ever lighthouse. Nobby's Head, where the lighthouse sits, juts out into the Pacific Ocean and gives visitors a clear view of the city, its beaches, and the ocean.

The way to Nobby's Beach is full of different sights such as a wharf where restaurants such as The Brewery are frequented on every sunny day. Live music on the weekends and at night sets a great atmosphere for dinner or drinks. Nearby are patches of grass field where students enjoyed a game of soccer in the sun.

More inland is Darby Street which is lined with various shops, restaurants and cafes. It is one the busiest areas in Newcastle with patios to enjoy your day. At night, the highlight for students was the popular Fanny's Nightclub. With a three rooms playing different genres of music, a good time was guaranteed for all.
4.0 Orange

The night of May 13th was spent in the city of Orange so that on the following day a visit could be made to Newcrest’s Cadia Mine, located 20 km Southwest of Orange. Orange is located in the highlands, approximately 250 km west of Sydney, and is easily accessible by train. The five hour train ride from Sydney provides an excellent look at the coast and the variable Australian countryside. With a population of over 31,000, Orange is a major provincial centre. At an elevation of 862 meters, it is one of only a few cities in the country that experiences seasonal snowfall. Key industries in the surrounding area are agriculture, mining, health services, and education.

4.1 Cadia Mine

Cadia Valley Operations (CVO) is the largest copper/gold producer in Australia following a production of 715,588 ounces of gold and 60,687 tonnes of copper in 2007/2008. Owned by Newcrest Mining Limited, the mine currently employs 1,540 full time employees. Capital is being invested towards expanding mill throughput and mine capacity.

4.1.1 History

The history of the Cadia Valley is engrained in mining. Copper was first discovered in the Cadia Valley in 1851. Over the next hundred years mining continued in the valley and produced several copper mines along with iron ore in the early twentieth century. Modern exploration of the valley was not undertaken until the late 1960’s and was largely completed by 1985. Newcrest Mining purchased the mining leases in 1990 and commissioned the Cadia Hill open pit in 1998. Underground extraction of the Ridgeway ore body commenced in 2002 with a further expansion of the Ridgeway Deeps excavation in the works. Furthermore, a separate new underground mine is planned in the next few years.

With the rich history of mining in the Cadia Valley, CVO has had several unique issues arise relating to heritage sites and historical areas. One of which was that the original Cadia cemetery was located within Cadia Hill open pit limits. Before commencing mining, the historical site first had to be relocated. With the approval of as many as 100 families of the buried, the cemetery was relocated and a monument erected in order to maintain the history of the area. Archaeologists were employed to investigate the site and this provided insight into the Cadia community’s lifestyle, careers, socio-economic standing and early Australian burial customs and practices.

4.1.2 Mining at Cadia Valley Operations

There are currently three operations that CVO operate on site: a single open pit nearing the end of its production, an underground sub level caving operation that is also near the end of its life, and a block cave under the existing underground mine that is currently in development. In addition, there is the prospect of another high-tonnage, low-grade underground ore body that is expected to be extracted using the panel caving method.

4.1.3 Cadia Hill Open Pit

The Cadia Hill open pit is one of the largest metalliferous open cut mines in Australia. The pit is 1.3 km wide and 615 meters deep. Roughly 50,000 tonnes of rock are mined each day with a total of 17 million tonnes moved per annum. The estimated average grade for the life of Cadia Hill is 0.70 g/t gold and 0.17% copper. In 2007/08 Cadia Hill produced
414,171 ounces of gold and 26,352 tonnes of copper. After the completion of three pushbacks, the pit is expected to be exhausted by July 2021. At this time the pit floor will be lowered another 90m.

Figure 6 - Cadia Pit (left), Marc Mains Taking a Picture (right)

The ore body is located in a monzonite host and dips 60° southwest. Pit wall design is governed by 20 geotechnical ground regimes. Blasting occurs with fifteen meter benches and double benching used where practical. Numerical modeling has shown that double benching improves strip ratios and safety against falling debris.

A Six Sigma initiative was undertaken directed towards the concept of mine to mill blasting techniques. The key point of this initiative was to provide better run of mine (ROM) feed to the mill by improved blasting. Drill holes are spaced at 15 meters with a 1.5 meter sub drill and are 290mm in diameter. A typical blast of 170 holes breaks 270,000 tonnes of rock. To increase mill throughput, experiments over several years have aimed to increase fragmentation. Blasting engineers determined that an increase in powder factor from 0.9 kg/bcm to 1.2 kg/bcm and a low slash angle of less than 10° obtained a cost saving of $1.3 million per annum.

Another improvement was the switch to electric detonators. A cost neutral blast design compared to non-electric detonators was tested, requiring the burden and spacing to be increased by 0.5m to offset the additional cost of electric detonators. High speed video recordings showed a large reduction in misfires and out of sequence firings. Even with the increased burden and spacing, fragmentation was improved due to improved blast control. After more tests, powder factors were reduced by 0.2 kg/bcm and further increases in spacing were made.

4.1.4 Ridgeway Underground

Ridgeway is one of the largest underground mines in Australia. The ore body was discovered in 1996 and mining commenced in April of 2002. The top of the Ridgeway ore body is 500m below surface with its lowest planned level of excavation 400m beneath that. Roughly six million tonnes of material are moved to surface each year with average grades of 2.3 g/t Au and 0.8% Cu. During the 2007/08 year Ridgeway produced 301,417 ounces of gold and 34,335 tonnes of copper. The ore body is expected to be depleted by January 2010.

Sublevel caving (SLC) is employed where perimeter drives are first developed at 25m levels. These provide access for further development and ventilation. Parallel slot drives
are excavated under the levels to be mined and are used for production drilling and loading. The drill pattern is a fan pattern of 7 to 8 holes reaching a height of 30m from the drift back. The holes are 102mm in diameter with an average blast consuming 1300kg of ANFO (Ammonium Nitrate Fuel Oil) and breaking 3000 tonnes of rock. The fan blast design pattern ensures that holes from adjacent slot drives interact with each other and that no pillars are left. It also helps to ensure sufficient fragmentation for crusher throughput. Over time, it has been determined that a drive spacing of 14 meters gives the largest span that provides adequate recovery.

At lower levels the drive size had to be reduced from 6m width to 4m width due to critical span requirements. As a result of this, the underground haul trucks utilized were unable to travel into the production areas. The haul distances for bogggers (LHDs) to ore chutes would have resulted in excessive cycle times so graded drives were dedicated to loading, providing easy dumping to haul trucks and eliminating loading in high traffic areas. Production rates were improved as a result. Ore is dropped down chutes to the crusher level 845m below the surface. It is then reduced to a top size of 200mm by a gyratory crusher and is conveyed to surface stockpiles.

Below the lowest planned SLC level the stresses in the rock begin to make the rock unstable for further excavation using 14m drifts because the pillars left between drifts are not wide enough to hold the above load. As such, SLC mining becomes unfeasible at Ridgeway below this level.

4.1.5 Ridgeway Deeps

The Ridgeway Deeps mine is under construction 1200m below the surface and is situated below the existing Ridgeway SLC. The planned output of the block cave operation is 6 million tonnes of ore per annum, with a total of 1.4 million ounces of gold and 191,100 tonnes of copper at an average grade of 1.05 g/t Au and 0.41% Cu. Development of the block cave commenced in July 2007 with production expected in July of 2009. Final construction of the block cave will be complete in 2010 with production going until 2018.

Development of a block cave requires a large amount of initial development. This development includes ramps to reach the depth, construction of a 5m high undercut, an extraction level, and extraction draw bells. There is a limited number of modern block cave mines so the science is not fully developed.

One key concept of block cave construction, related mainly to the undercut and extraction levels, is the stress shadow. When a section of rock above an underground rock mass is excavated, there is no longer a stress transfer from the above weight of rock and earth. When applied to block cave construction, if the undercut precedes the extraction level construction, there will be less stress on the extraction level rock and less damage to draw bells and roadways. This helps ensure the long term stability and production of the block cave mine. During development of the extraction level and undercut, a 30° offset in development is maintained. Empirical data and numerical modeling show that this offset reduces stress on the extraction level.

The undercut level is developed using parallel slot drives as access points to initiate the cave. Both horizontal and angled drill holes are utilized to create a crinkle cut undercut. It is believed that the zigzag pattern that results from this crinkle cut helps to destabilize the initial cave zone and helps ensure a full slice is taken out so that the cave will propagate upwards predictably. Leaving pillars intact leads to ore loss due to hang-ups as the cave progresses.
The extraction level is heavily reinforced using rebar and shotcrete. Furthermore, the roadways are paved to increase equipment productivity and reduce wear on tires. The extraction level roadways must be built to last in high stress conditions for the life of the mine while maintaining a high quality work surface.

After the initial infrastructure development has been completed, the mine relies on the force of gravity and the instability of the large span to cause the remaining ore body to cave in on itself. This lack of control lends itself to two problems. First the cave propagates on its own and must be monitored and can only be partially controlled by a drawdown strategy. Secondly, areas of different rock strength will cave differently possibly resulting in uneven draw.

To monitor the cave propagation a couple of strategies are utilized at Ridgeway Deeps. Time-domain reflectometry extensometers and observation holes allow engineers to monitor the physical deformation of the rock mass. A seismic array of accelerometers and geophones allow for triangulation of vibrations resulting from rock breaking and shearing.

A key method of ensuring proper cave propagation is through draw control. A strategy of drawdown while using the monitoring data lets engineers control the amount of void space in the cave. Controlling the air gap between the caved and uncaved rock mitigates the risk of air blasts from large amounts of material falling great distances. Effective draw control requires a systematic approach with respect to which draw bells are used at which time. The temptation of pulling from the easiest drawpoints in order to increase production must be avoided. It is forecast that the entire bogger fleet will be tele-remote and largely automated, allowing for the strategy to be implemented without operator interference. Although equipment will tram along pre-programmed routes, operators will still be required to do the mucking part of the operation. It also allows for a single operator to work up to three boggers at a time.

To ensure that the rock mass behaves as uniformly as possible, areas of high rock strength were subjected to hydrofracture. By matching the amount of fractures in the less competent rock mass as closely as possible it is hoped that the cave will extend through the boundary without much deflection. A separate array of geophones and accelerometers was installed to help monitor this program, and will be used in conjunction with the cave monitoring array for the life of mine to monitor the cave.

A major concern with block caving is the infiltration of fine material. Experience has shown that fines tend to migrate downwards faster than the large rock material. At Ridgeway Deeps, the top cover of soil is a clay material that is very difficult to deal with. It clogs crushers, causes problems in the plant, and has the potential to close draw points completely. Once the cave propagates to the existing Ridgeway development above, clay infiltration may be an issue.

4.1.6 Cadia East

Cadia East is an ore body that is yet to be exploited. The ore body is 2.5 km long and up to 600m wide extending 1.9 km below the surface. It contains an estimated 21.4 million ounces of gold and 3.6 million tonnes of copper.

The proposed development is a 27 million tonne per annum (tpa) panel cave mine with a 21 year mine life. This will also require infrastructure upgrades to the mill and tailings facility as well as additional processing facilities. Since the ore body is much longer than it is wide, panel caving will allow for a bulk extraction in segments to reduce operating costs.
as well as the up front capital costs of constructing extraction and undercut levels for the entire ore body.

4.1.7 Ore Treatment

Due to ore variability between the multiple operations at CVO, there are two separate mill set ups for each mine. Each circuit includes crushing, grinding and floatation as well as gravity separation.

A notable point about the flotation circuit at CVO is that a total of three collectors in their circuit are introduced at various stages starting at the SAG mill. One collector is an off-the-shelf variety but the remaining two were custom-developed to which Newcrest owns the intellectual property rights. Trials over the course of the mine have shown that the custom collectors give the best recovery and are worth the extra cost.

Figure 7 - Talha Khan and Flotation Cells (left), Tour guide and SAG Mill (right)

4.1.8 Cadia Circuit

The Cadia circuit runs at a throughput of 12 million tpa. The circuit is designed for a feed grade of 0.15% copper. The sulphide-associated gold is floated with the copper minerals. The rougher concentrate is roughly 4-6% and is regrind to less than 75 micrometers. A SAG mill runs at 2130 tonnes per hour and consumes 114 tonnes per week of 125mm grinding balls. A ball mill runs in closed circuit with a circulating load of 250-600%. Free gold is recovered using a Falcon concentrator. Gold and copper recoveries through the Cadia circuit are 75% and 80-85% respectively.

4.1.9 Ridgeway Circuit

The Ridgeway circuit is smaller than the Cadia circuit with a throughput of 5.6 million tpa but produces roughly the same amount of concentrate as Cadia due to the higher feed grade of 1.5 g/t Au and 5000 ppm Cu. The liberation size is smaller than for the Cadia ore. The gold concentrate has a grade of 50 g/t and gold and copper recoveries are 75-85% and 85-89% respectively.
5.0 Sydney

May 11th to 16th was spent in Sydney (except for the one day in Orange). Sydney is the state capital city of New South Wales, and the largest city in Australia with a population of approximately 4.34 million people. While in Sydney, the group visited the School of Mining at the University of New South Wales and had time to see other local attractions.

5.1 University of New South Wales

On May 12th, a visit to the University of New South Wales (UNSW) was hosted by Duncan Chalmers, Senior Lecturer at their School of Mining. Duncan is well known to the students at the NBK Institute of Mining Engineering as he has guest lectured in the mine ventilation course for the past few years.

The group was given a tour of the mining school's facilities including their virtual reality lab. The lab uses a circular dome-like theatre and projects an Advanced Visualisation and Interactive Environment (AVIE.) Using 3-D glasses, users are placed in locations that have been captured by camera or computer generated. The simulations can be used for multiple purposes such as underground training, aiding students in mine site design, and communicating development stage concepts to community stakeholders.

There are many training modules in the program for simulating underground mining problems such as rib and roof stability, truck pre-shift inspections, equipment isolation, coal outbursts, hazard awareness, unaided self escape, and spontaneous combustion. Each module has interactive functions which help the user to become knowledgeable with the scenario.

During our virtual tour, we were first placed at a surface uranium mine. We were then taken into an underground coal mine where a module demonstrated coal outburst risks and warning signs. The module simulated the occurrence of a rock outburst where the mining occurred in a zone before the coal seam gas had been pre-drained. After the violent outburst had occurred, damage to equipment and the excavation was apparent. Finally, a list of outburst warning signs was provided and the group was required to identify them in the scenario.

As we were shown, the virtual reality cinema can be useful in the mining industry for showing different mining scenarios and can be a useful learning tool for students or mine employees before they even enter a mine. It also has potential to be used in engineering design and public communications.

5.2 Sydney Sights

As the past site for the 2000 Summer Olympics, Sydney’s infrastructure is extremely pedestrian friendly and allows visitors to take advantage of the brilliant landscape from all angles. The atmosphere and general setting can be likened to that of Vancouver’s and at times felt like home. There is an obvious multicultural diversity and streets are lined with a variety of ethnic restaurants and shops. The city has many tourist attractions such as the Sydney Opera House, the Harbour Bridge, Taronga Zoo, Sydney Aquarium and Bondi Beach. This section shows some of the sights we enjoyed seeing during our visit.
5.2.1 Darling Harbour

After arriving in Sydney, most of the group visited Darling Harbour. There is a zoo, an aquarium, a museum, and many restaurants and shopping centers at the harbour side. Just a 10 minute walk from our hotel, most of the group had dinner at the harbour side and experienced night life in Sydney.

Figure 8 - Sydney's Darling Harbour

5.2.2 Bondi to Coogee Coastal Walk

The walk from Bondi Beach to Coogee beach is a two hour walk along the coast that many students did on May 15th. This started with a bus ride to Bondi Beach where a soccer game was played on the sand before the walk. Along the way are smaller beaches, cafes, and a cemetery to pause at for a break and to enjoy the view.

Figure 9 – Coogee Beach (left), Ryan Weymark (centre), Paul Hughes (right)
5.2.3 Taronga Zoo

As a cultural activity, we visited one of the famed tourist attractions of Sydney: The Taronga Zoo. This zoo is accessed via ferry from the Circular Quay Harbour. The ferry ride provides a view of the city including the Sydney Opera House and the Harbour Bridge. Established in 1916, Taronga Zoo houses animals from all over the world, but most importantly creatures from native Australia. We were able to get a first hand look at the animals that have become the mascots of the country. Koalas, kangaroos and wallabies were observed in natural habitat type settings.

![Figure 10 - Taronga Zoo](image)

The Zoo's exhibits present information about each animal interesting to both children kids and adults alike and animals have been named to help create a more personal relationship. Also, the Taronga Zoo strongly advertises its conservation, research and education efforts. The Taronga Conservation Society Australia fundraises in order to preserve both Australia's endangered species and the rest of the world's various animals.

The Zoo offers several community programs for young children interested in learning more about indigenous culture. Workshops have been set up for teachers to bring their students on excursions and become better acquainted with the natural inhabitants of their country. Taronga Zoo recognizes the importance of the Indigenous students of Australia and offers priority placements for them in the programs as well as volunteer positions in the facility.

The zoo was a highlight for many students. We were fortunate to have the experience of viewing many creatures that are part of Australia’s unique identity.
6.0 Conclusion and Acknowledgements

In conclusion, this research trip to Australia was a rewarding experience for our class as we had the chance to visit many interesting sites, learned more about the mining industry in which we work, and had fun sightseeing. We will remember this trip, the time spent with our peers, and the fun had for a long time.

We would like to thank all of our sponsors and individuals who contributed to this trip. Without your help, the trip would not have been possible. We very much appreciate your generosity in funding and organizational help. Finally, we hope that you enjoyed reading this report and learned a few things about mining and Australia.