Australian Workshop on Acid and Metalliferous Drainage

2020 AMD Workshop

Notes for the Field trip on Wednesday 25 March

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Edited: Peter Scott

The 2020 AMD Workshop Field Trip will be to the mining and exploration leases owned and operated by Alkane Resources Limited located between Parkes and Dubbo in Central West New South Wales. The Alkane properties include 2 gold mines – Peak Hill located 200m east of the Peak Hill township; and Tomingley Gold Operation (TGO) located 1km south of Tomingley township; as well 440km^2 of Exploration Licence area that include advanced exploration prospects. The Peak Hill Mine is currently in care and maintenance and has been rehabilitated. It is the main focus of the field trip. The Tomingley Gold Operation is an operating mine with limited access for buses. TGO is currently an underground operation having commenced in 2014 as an open cut operation. These field notes are based on published papers by Ian Chalmers (Technical Director, Alkane Resources Ltd and others (e.g. Chalmers et al, 2006, 2007 etc.), and Alkane Resources reports (curtesy of Mike Sutherland, Manager NSW Operations Alkane Resources Ltd).

Alkane has focused on a single geographic area, the Central West of New South Wales that includes the geology of eastern belt of the Lachlan Orogen and has been an active gold explorer in the region since the late 1970s. This has given the company an understanding of the geology and a place within the local community. The work over this time has resulted in identifying prospective exploration land, acquiring the Peak Hill Mine, discovery of the Wyoming gold deposits implementing an extensive gold exploration program with a key objective of sourcing additional ore for the gold processing facility at Tomingley, and the development of two significant gold resource projects: the Peak Hill Gold Mine that commenced in 1996 and is now in care and maintenance pending commissioning underground mining of identified gold resources; and the commissioning of the Tomingley Gold Operations to mine the Wyoming gold deposits which started production in February 2014. In addition Alkane have discovered and are developing the Dubbo Project which will be a strategic and significant supply of zirconium, hafnium, niobium and the full suite of rare earths.

Dubbo is located in the Central West mining region of New South Wales. The Central West mining region lies within the Eastern Lachlan Orogen which hosts several world-class late Ordovician porphyry gold–copper deposits such as Cadia, Ridgeway and Northparkes, as well as epithermal carbonate-base metal gold deposits such as Cowal. Dubbo is also close to the eastern part of the Hunter Valley coal mines such as Ulan and Moolarben. Historically, most gold production came from relatively small, high-grade quartz vein gold deposits. **Figure 1** shows some of the mines near Dubbo.

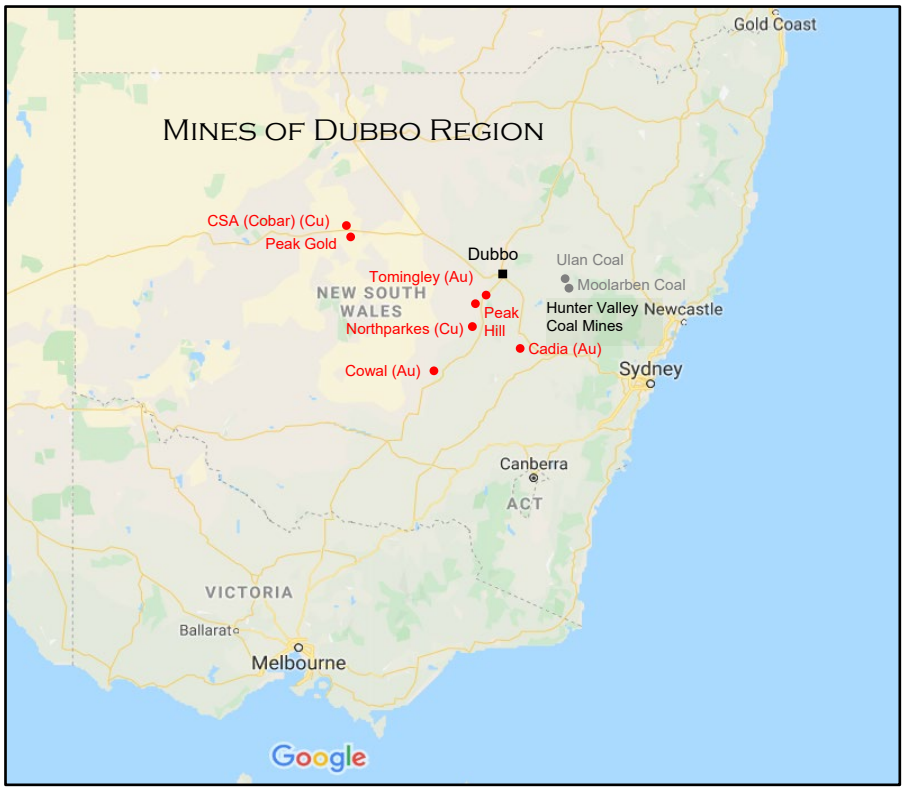

Figure 1: Mining operations in the Dubbo area

STOP 1: Peak Hill Mine

Discovery History

Alluvial gold was discovered in 1889 in drainage channels on the slopes of a prominent hill. Mining of outcropping lode was commenced the following year. A substantial hard rock mine, both open cut and underground, operated from 1904-1917 and produced over 60 000 oz Au (Alkane). From 1964 onwards, a number of companies explored the deposit. Alkane Exploration NL drilled out the deposit in the 1990s and commenced mining in 1996. Operations in the main open cut ceased in 2001 but continue in two satellite pits.

Physical Features and Environment

The deposit is located on a prominent hill some 80 m above surrounding residual soil and alluvium plains. There is some remnant natural vegetation on the hill, mainly cypress pine (Callitris spp) and ironbark (Eucalyptus sideroxylon), but surrounding areas have been extensively cleared for agriculture. The climate is semi-arid with summer temperatures 18-33°C and in winter 5-15°C. Average annual rainfall is 550 mm pa, distributed through the year but with a slight peak in summer.

Geology

The Mingelo Volcanics (Goonumbla Volcanics equivalent) host the Peak Hill deposit (**Figure 2**). At Peak Hill, these rocks occur in a high strain zone between the Parkes Thrust to the West and the Narromine-Tumut Fault to the East. Strong shearing, brecciation and hydrothermal alteration has largely destroyed primary rock textures. An extensive advanced argillic core of pyrophyllite alteration grades out through kaolinite-alunite, sericite and illite-montmorillonite assemblages. Silicification is also prominent.

High pyrite concentrations, a Cu sulphide assemblage dominated by enargite and tennantite and extensive advanced argillic alteration characterises the Peak Hill deposit as a high-sulphidation porphyry system.

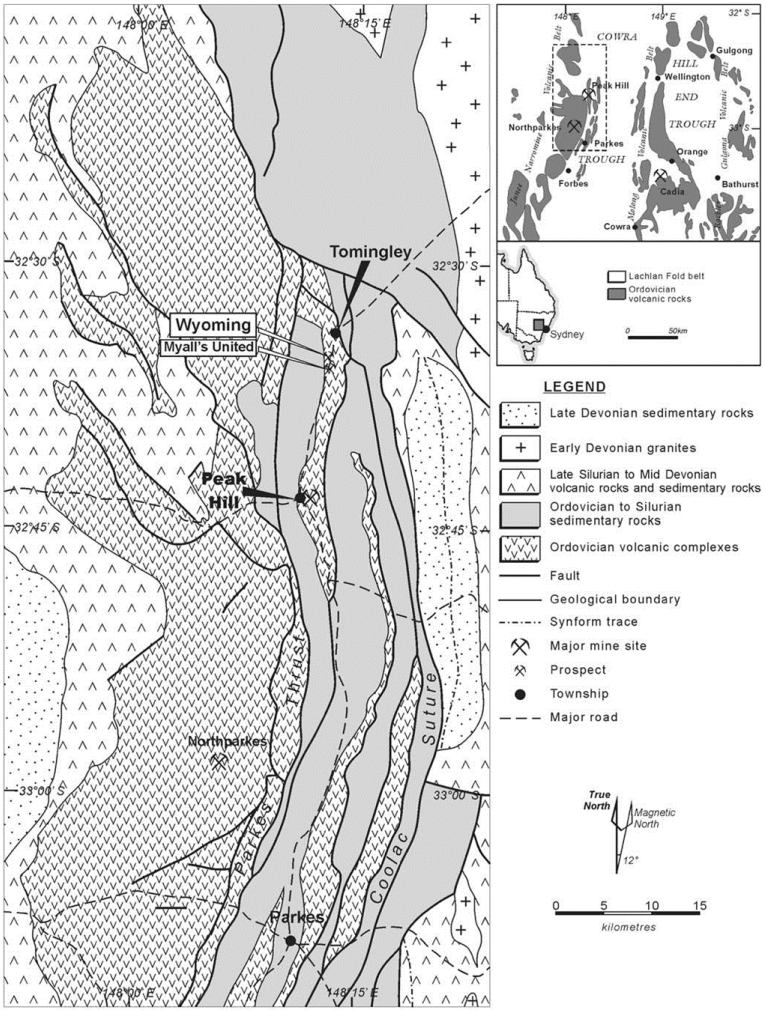

Figure 2: Regional geological interpretation of the Wyoming area; figure is a simplified lithostratigraphic map with the overlying cover sequences removed (Source Chalmers et al 2007)

Regolith

Locally, the regolith comprises mostly thin, skeletal soil over saprolite and saprock. Siliceous gossans and soft, powdery, pyrophyllite-rich material are typical of the upper parts of the oxidized ore. Oxidation has extended to >90 m. The redox boundary between oxidised and unoxidised rock is very irregular

due to peaks, tongues and residual pods of primary sulphides extending into overlying oxidised material (as evident in Figure 3). High sulphide contents and structures promote oxidation, influencing the topography of the redox surface. The water table in the main Proprietary pit is around 245m RL and the monitoring bores to the north and northeast have SWL between 210-222m RL.

Oxide mineralization

The main oxide orebody was some 300 m long, 50 m wide and extended from the surface to 90 m. It contains both of primary and secondary Au grains. Residual primary Au grains have cores with up to 4% Ag and Ag-depleted margins about 5 µm thick. However, most grains are Ag poor and could be secondary. Some Au occurs as fracture fillings in botryoidal goethite and is clearly secondary. Copper has been almost completely removed from the oxide zone. Primary grades commonly are 0.2-0.6% Cu, but grades in the oxide zone are mostly less than 25 ppm. Secondary Cu minerals, that might normally be associated with this type of copper deposit, are absent. Mining was commenced on a reserve of 1.8 Mt at 2.0 g/t Au.

The oxide zone is dominated by goethite (FeOOH), hematite (Fe O), jarosite ($KFe_3(SO_4)_2(OH)_6$) and some barite. Groundwater collecting in the base of the Proprietary Pit has a pH of 1.5. Here dissolved Cu remains in solution unless precipitated by evaporation. Wall faces of sulphide ore, exposed by mining, commonly developed blue to green surface coatings of chalcanthite ($CuSO_4.5H_2O$) and cuprian melanterite ($(Fe,Cu)SO_4.7H_2O$).

Supergene enrichment

The distribution of Au in the oxide zone, compared to primary mineralisation, suggests some mobilisation and possible supergene enrichment during weathering. This includes greater widths of ore in the upper parts and enhanced grades in the lower parts. There is only minor enrichment of Cu below the redox boundary, predominantly as covellite, chalcocite and non-stochiometric phases varying between digenite and yarrowite. There is no well-developed, flat lying, supergene blanket of secondary Cu sulphides.

Primary mineralisation

Gold mineralisation at Peak Hill is hosted by Late Ordovician Mingelo Volcanics which consist mainly of andesitic lavas and andesitic pyroclastic rocks with minor interbedded sedimentary rock types. The rock sequence has been tightly folded so that the sequence dips steeply to the east.

The recent Au mining by Alkane was in the oxidised zone. Beneath the oxide zone the primary mineralisation comprises Au, Cu sulfides and pyrite associated with extensive advanced argillic alteration and silicification in a steeply plunging lenticular zone. Pyrite contents commonly exceeded 15% and barite is a prominent accessory mineral. Gold is mainly free milling with a low Ag content (0-4%) and occurs with minor calaverite (Au telluride). Tennantite and enargite are the dominant primary Cu minerals with lesser chalcopyrite. A preliminary resource estimate was 11.27 Mt at 1.29 g/t Au and 0.11% Cu.

The gold resource for the heap leach operation was largely contained within the zone of oxidation which extended from the surface to an irregular base of moderate oxidation, (BOMO), 10 to 100m below

surface (averaged 40m). It was the irregular boundary of oxidation that has led to some contamination of the heap leach and waste rock emplacements with pyritic material.

Limited processing of the primary ore was undertaken by Alkane due to its refractory nature, presence of cyanide soluble copper and poor recoveries. Advances in metallurgical processing suggests that the sulfide ore can be processed and an underground resource at Peak Hill is being drill tested.

Acid and Metalliferous Drainage Potential

Pyrite contents of the ore and waste immediately adjacent to the ore commonly exceed 15%. The primary mineralisation component of the Peak Hill ore body has one of the highest sulphide concentrations in deposits in Australia with some of the fresh ore containing 50% pyrite. The bulk of the sulfide waste was separated out from oxide waste by the 110 tonne excavator used on site and separately stockpiled and ultimately encapsulated in the waste rock emplacement (WRE). The acid mine drainage potential of the Peak Hill waste rock is on clear display in the lake of the main Proprietary pit (**Figure 3**). Pods of grey sulfides can be seen in the open cut batters and the indigo-coloured pit lake (ground water table supplemented by rainfall). In October 2004 the pit lake had a pH of 2.3, 15, 300 mg/L TDS, 10,800mg/L SO4, 163mg/L Cu and 2.59mg/L As.

The high sulphide content of the primary mineralisation resulted in extremely acid conditions during oxidation. The advanced argillic alteration assemblages offer few cations capable of removing H+ acidity and thus have limited buffering capacity on the acid ground water. 815,000t of sulfide waste (ore) was mined but could not be processed for economic recovery of gold and was placed in the waste rock emplacement for storage. Limited quantities of sulfidic material was mined and placed in the dump leach facility. Small areas of acid scalding can be seen on the surface of the dump leach. Runoff and seepage is captured and tested and returns near neutral pH and low metal and sulfate concentrations.

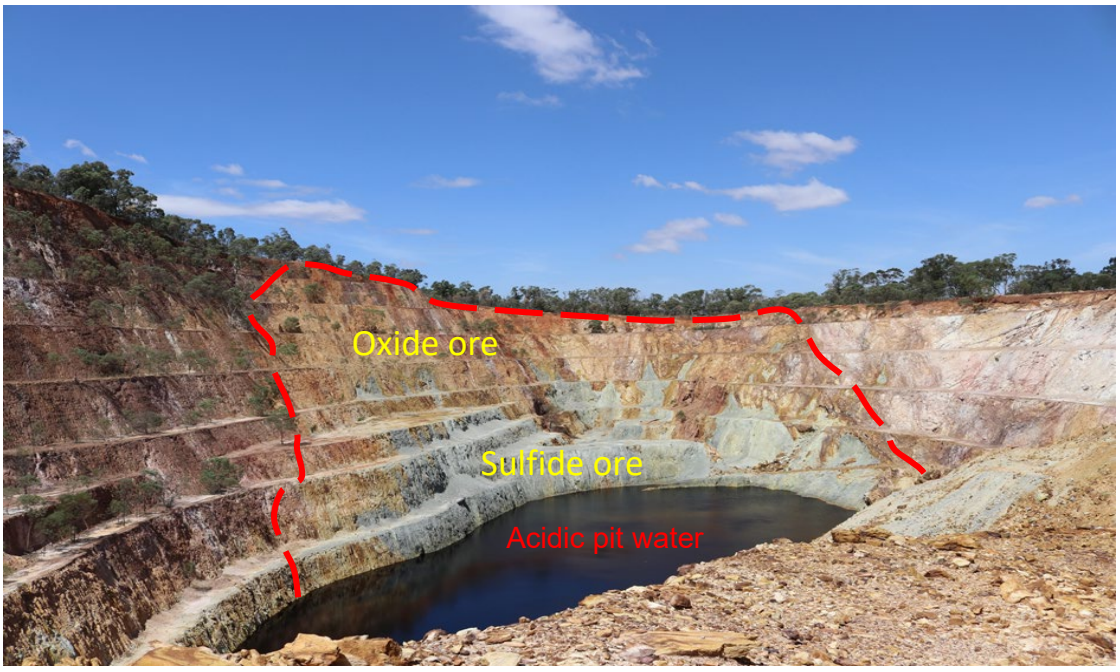

Figure 3: Proprietary Pit Peak Hill Mine

Project Description

The project comprised a drill and blast operation extracting approximately 1.8 million tonnes of ore and 3.0 million tonnes of waste rock over a 4-5 year mine life. The aerial image showing the rehabilitated mine landforms is shown in **Figure 4.** The project developed 1 main pit (Proprietary-Parkers) and 3 satellite pits (Bobby Burns, Crown and Great Eastern), a Heap-Dump leach facility and 5 leaching ponds, a waste rock emplacement (WRE), a ROM pad, mine office and roadways. **Figure 5** shows the construction of the WRE. **Figure 6** shows the rehabilitated WRE.

Mining ore in the open cut was extended to the base of oxidation only because the fresh rock contained sulphides including sulfide ore hosted gold and copper which are moderately refractory by standard metallurgical processes.

Figure 4: Aerial image of rehabilitated Peak Hill mine site (Source Google Earth).

Figure 5: Peak Hill Waste Rock Emplacement under construction (Source Alkane Resources)

Figure 6 Rehabilitated waste rock emplacement

The crushing plant consisted of a primary jaw crusher and a secondary cone crusher to take the ore down to <7 mm particle size prior to agglomeration with cement and stacking to 10 metres high on an HDPE lined heap leach pad. The heap leach facility was irrigated with a low concentration of sodium cyanide with gold to be recovered from solution through carbon adsorption, elution and electrowinning to produce 2,400 kg of gold bullion. Good returns from low grade ore prompted construction of the dump leach facility on top of the spent heap leach facility (**Figure 7**).

Figure 7: Dump leach construction on top of Heap Leach facility

STOP 3: Tomingley Gold Operation (TGO)

The TGO is located 1km from Tomingley and 50km southwest of the city of Dubbo , the TGO was based upon four deposits with a total near 1Moz of gold. The Tomingley Gold Operation (TGO) includes the Wyoming 1 and Wyoming 3, and the Caloma and Caloma 2 deposits and is located ~40 km NNE of the Northparkes porphyry Cu-Au deposit, 52 km SW of Dubbo and ~15 km north of Peak Hill in the Lachlan Fold Belt of New South Wales, Australia. Mining commenced in 2014. **Figure 8** shows the mine layout comprising 4 pits, 3 Waste rock emplacements, tailings dam, ROM and Plant site.

Figure 8: Tomingley mine site layout (Source Google Earth)

Discovery History

The Au mineralization in the Tomingley district occurs in a N-striking belt extending 12 km S of Tomingley. It and was worked from 1883 to 1914 and yielded 2.1 t of Au, 97% of which was from the McPhail's (Myall United) Mine, 500 m SSE of the Wyoming deposit (Figure 2).

More recent exploration by Alkane in the region around Peak Hill focussed on a potential porphyry source for the epithermal mineralisation, but success was limited by the extensive Cretaceous to Quaternary cover. Exploration was also directed at the Myall's United area but was again limited by the extent of the transported cover, which restricted the use of traditional surface geochemical techniques.

Drilling by Alkane through the widespread transported cover sequence (>30 m) immediately to the north–northwest of the Myall's United mine in 2001 to follow up the trend of historically reported mineralisation, discovered extensive alteration and gold mineralisation within an andesitic feldspar porphyry intrusion and adjacent volcaniclastic sandstones and siltstones. Subsequent reverse circulation and core drilling has identified a resource of 600,000 oz of gold to a depth of about 300 m. Subsequent detailed resource definition drilling has identified a substantial mineralised body at Wyoming One comprising a number of distinct zones, associated with sericite–carbonate (ankerite)–

albite–quartz-(±chlorite ± pyrite ± arsenopyrite) alteration. A smaller but similar body was identified at Wyoming Three about 500 metres to the north.

In 2006-07, following several years of drilling and compilation of the geological data, Alkane tested a new target called Caloma located about 500 metres to the east of the Wyoming deposits which shows similar characteristics to the Wyoming deposits and has similar resource potential as the Wyoming One deposit (500,000 ounces) bringing the total resource inventory at the project site to plus 1 million ounces of gold.

Wyoming Geology

The immediate Tomingley area is almost entirely covered by alluvial sequences of clays, sand and gravel (regolith) of Quaternary to Cretaceous age that are up to 50 m in thickness (**Figure 9**).

Figure 9: Wyoming One Pit showing cover and depth of oxidation (Source Alkane Resources)

The Wyoming gold deposits are hosted within late Ordovician volcaniclastic rocks, rare lavas and shallow intrusive porphyritic rocks. The volcanic units are of trachy-andesite to basaltic trachy-andesite in composition, with very rare detrital quartz in the volcaniclastic rocks. These volcaniclastic rocks are dominated by well-bedded sandstones and siltstones with minor breccias, lithic conglomerates and black mudstones. The dominant sandstones and siltstones have a primary composition of plagioclase and augite, but are now largely altered to sericite, carbonate, chlorite, and albite, with rare primary quartz. The sequences that host the Wyoming gold deposits show textural and compositional affinities to rocks that host the Peak Hill high-sulphidation epithermal gold–copper deposit.

Gold mineralisation at Wyoming One is distributed both around and within a sub-vertical, south plunging, feldspar ± augite porphyritic sill. The deposit has been separated into distinct mineralised zones: the porphyry zone; contact zone; hangingwall zone; the ‘376’ zone and the ‘831’ zone.

Gold mineralisation is characterised by strong quartz ± carbonate (ankerite) ± albite ± pyrite ± arsenopyrite veins within intense sericite–carbonate (ankerite)–albite–quartz-(± chlorite ± pyrite ± arsenopyrite) alteration of the feldspar ± augite-porphyritic intrusion and the volcaniclastic sediments.

The hangingwall zone appears stratigraphically controlled by a fine-grained carbonaceous mudstone and the '376' and '831' are high grade east west zones truncating and transecting the porphyry. Gold mineralisation at Wyoming Three also shows a strong spatial relationship with feldspar porphyritic rocks however pervasive alteration is limited or absent with mineralisation hosted within structurally controlled quartz ± carbonate ± chlorite ± pyrite ± arsenopyrite veining striking about 105°.

Acid and metalliferous drainage

In stark contrast to Peak Hill deposit the Wyoming deposits at Tomingley are low sulfidation mineralisation with minor accessory pyrite and arsenopyrite.

It is understood that sulfides are closely associated with the gold mineralisation and that there is limited sulfides in the waste rock and therefore limited potential for acidic leachate generation from the WREs.

Operations

Construction of the 1Mt pa plant and associated infrastructure commenced soon after the mining lease was granted in February 2013 and was commissioned in January 2014. Total expenditure came in under the budget of A$116 million, which included the EPCM and contingencies. The Project had no debt and was financed internally from existing shareholder funds.

The plant comprises a standard two stage crushing and grinding circuit, with gravity and carbon in leach gold recovery (**Figure 10**). Total ore feed is approximately 25% oxide and 75% fresh with an average 93% recovery. Power is supplied through the State electricity grid at Peak Hill and water sourced from a company bore near Narromine , 45km north of the mine site. The workforce of 180 staff and contractors have been recruited locally and there are no fly in, fly out personnel. First gold was poured in February 2014. Contract pre-stripping of waste commenced in December 2013, and mining through a 'dry hire' contract was underway in January 2014. To date the mine has produced 200,000 ounces of gold.

The Project had a base case start up life of 7.5 years developed upon an initial open pit and underground operation. The output of the 1Mt pa operation is expected to be approximately 400,000oz over the base case life, i.e. : 50,000-60,000 ounces of gold per year. An active exploration program, further underground resources and testing of regional target could see the mine life extended.

Open cut mining has been completed and the WREs have been decommissioned and rehabilitated with construction of final landform, placement of the final cover, and installation of water management structures. **Figure 11** shows the WRE 3 rehabilitated landform. Surfaces of the WRE have been reshaped and recontoured, topsoil and seeded and surface drainage structures installed.

Figure 10: Tomingley Processing Plant (Source Alkane Resources)

Figure 11: Rehabilitated Waste Rock emplacement-WRE3. (Source Alkane Resources)

Exploration

The Tomingley deposits are located near the eastern margin of the Ordovician Junee-Narromine volcanic belt of the early Palaeozoic Macquarie Arc, in the Lachlan Orogen of eastern Australia, and is close to the interpreted Parkes Thrust. The Junee-Narromine volcanic belt extends north-south for several hundred kilometres and includes the 450.9±4.2 my aged Goonumbla Volcanic Complex which hosts the nearby Northparkes porphyry Cu-Au system.

The north-south arc parallel Parkes Thrust separates the Goonumbla Volcanic Complex from the Mingelo Volcanics, a thin slice of north-south trending andesitic volcanics identified by regional aeromagnetic data and interpreted to be equivalents of the Goonumbla Volcanics.

This thin volcanic belt, which hosts the Tomingley and Peak Hill gold deposits, has a strike length of ~35 km varies from 2 km in width in the north, to ~500 m in the south and is an exploration target for Alkane Resources. The Tomingley Gold Project (TGP) covers an area of approximately 440km^2 stretching 60km north-south along the Newell Highway from Tomingley in the north, through Peak Hill and almost to Parkes in the south. **Figure 12** shows Alkane tenements in the Tomingley mineralised belt. The TGP contains Alkane's currently operating Tomingley Gold Operations (TGO), and the Peak Hill Mine.

Over the last year Alkane has conducted an extensive regional exploration program with the objective of defining additional resources that have the potential to be mined either via open pit or underground operations and fed to TGO. The program has yielded broad, shallow high grade intercepts that demonstrate potential for material project life extension and show that a return to open pit mining and / or underground extension is possible with appropriate resource confirmation, landholder agreement and regulatory approvals.

Exploration drilling in the last twelve months has focussed on the Roswell, San Antonio and El Paso prospects which are all located within 7km of the TGO processing facility.

Significant broad high grade results have been reported for the Roswell prospect , San Antonio and El Paso prospects 3 to 4km south of TGO. To date approximately 200 RC and 30 diamond core holes have been completed in this target corridor with a cumulative strike length of 2.5km.

References

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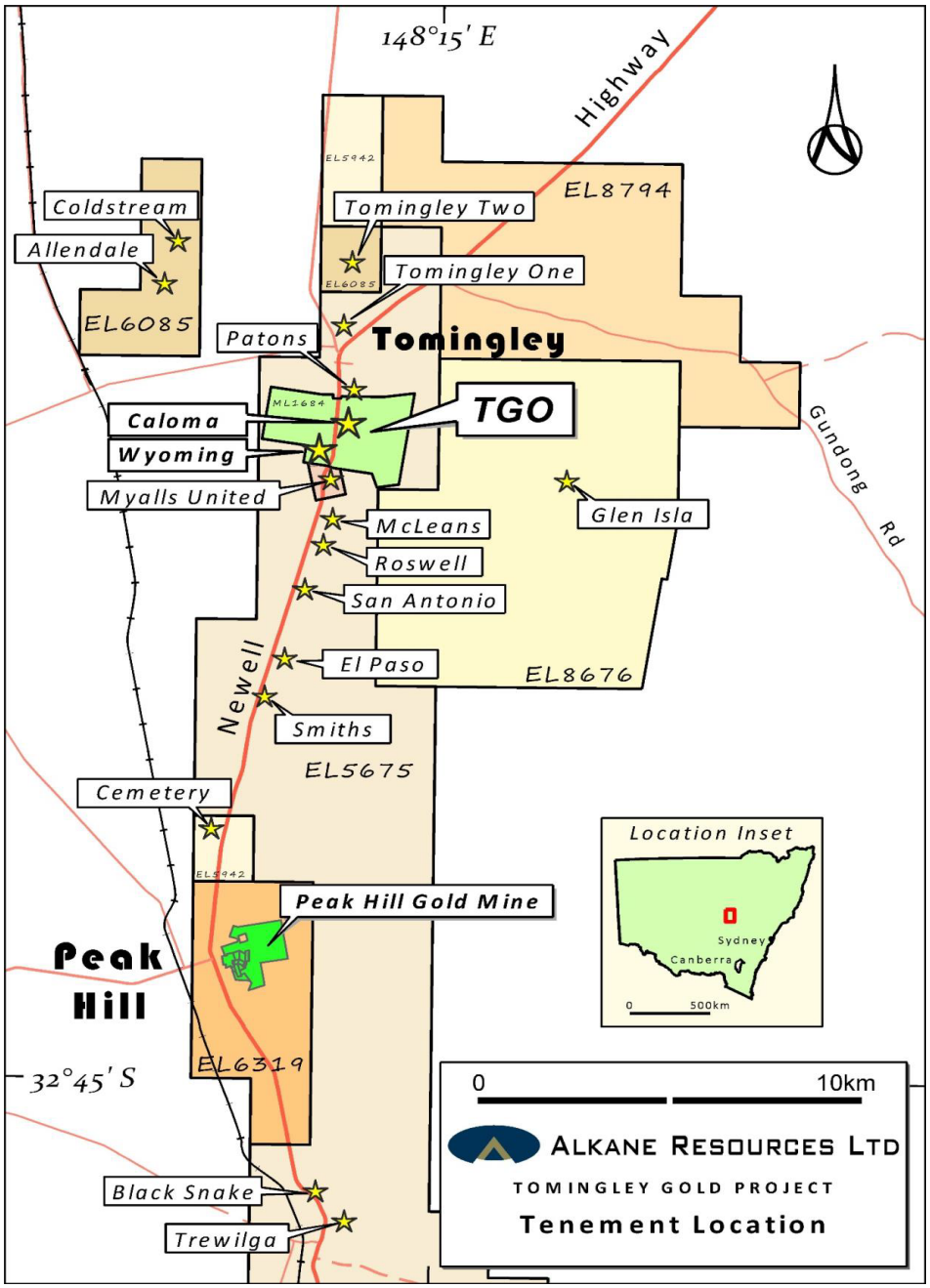

Figure 12: Alkane tenements in the in the Tomingley-Peak Hill area (Source Alkane Resources)