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Oyu Tolgoi Hugo North Lift 1 update: Panel 0 performance and the commencement of Panel 2

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Abstract

The underground operation at the Oyu Tolgoi mine in Mongolia continues to advance with construction completion of Panel 0 block cave, the first of 4 block cave mines that comprise the Hugo North Lift 1 (HNL1) orebody extraction. The 4 block caves are Panel 0 (P0), Panel 2 North (P2N), Panel 2 South (P2S) and Panel 1 (P1). This marks a significant milestone in the ramp-up of one of the world's largest block caving projects.

P0 began its journey with the first undercut blast and first drawbell blast in January and June 2022, respectively. The extraction level construction was completed in October 2024, delivering 124 drawbells and 229 drawpoints, whilst also achieving a maximum drawbelling construction rate of 6 drawbells per month for 10 consecutive months. Current production is exceeding its nameplate capacity of 30 ktpd by upwards of 10%. Building on this success and the extensive lessons gained during the construction and ramp-up phases, P2N commenced its first undercut blast in April 2025 and achieved its first drawbell in August 2025 – also ahead of plan.

P0's development, construction and caving phases are shaping the future of Oyu Tolgoi's underground expansion. Lessons from critical infrastructure readiness, design optimisation, critical path management, undercut quality control and cave health monitoring all form part of the continuous improvement journey for the subsequent panels. Together, they set the stage for early and sustained copper production with a maximised reserve recovery, laying the foundation for the future caves at Oyu Tolgoi.

Keywords: *block cave, ramp-up, performance, critical path, caving*

1 Introduction

Oyu Tolgoi mine is located in the South Gobi Desert of Mongolia and is a joint venture between the Government of Mongolia (34%) and Rio Tinto (66%). It compromises an open pit mine, an underground block cave complex and a concentrator. The underground mine restarted in 2016 after a short hiatus. When at full capacity, Oyu Tolgoi will be one of the 4 largest copper–gold mines in the world and one of the largest underground mines.

Oyu Tolgoi is rapidly advancing towards becoming a world-class underground mining operation as it transitions into a sustained, multiblock cave operation within the Hugo North Lift 1 orebody (HNL1). The operation has already established itself as key to Mongolia's long-term copper production with the completed construction of the Panel 0 Block Cave (P0) and the successful early commencement of Panel 2 North block cave (P2N). This paper presents P0's performance and highlights the achievements and challenges in its cave construction and ramp-up journey. Additionally, this paper discusses the contributing factors to success alongside challenges in constructing the P0 block caving operation (and at speed), and how these conditions can inform future decision-making for design, execution and scheduling. Oyu Tolgoi is

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focused on ensuring undercutting infrastructure readiness, sustainable drawbelling ramp-up and the high quality and speed of the undercut to help construct the foundation of Oyu Tolgoi's world-class block caving operation for the future.

2 Panel 0 mine design and general arrangement

As the first block cave mine at Oyu Tolgoi, a resilient mine design was deliberately chosen, acknowledging the business-critical nature of underground mining to the company, challenging rock mass conditions and that many design assumptions were based on limited rock mass calibration. The design, including undercutting methodology, drawpoint spacing and orepass locations, was predicated on the philosophy of maximising resource extraction by maximising extraction level stability over the life of the block. Further, the design was continuously refined as more orebody knowledge became available from the underground development and construction activities.

Carrying on from the HNL1 2016 and 2020 mine design update (Stegman et al. 2022), the P0 general arrangement was created to include refinements to support rapid development and construction of the 124 drawbells in P0 with a baseline target of 4.7 drawbells per month (maximum) to a 6 drawbell per month actual for a period of 10 months. A notable mention was the detailed pre-undercutting commencement criteria scope of work. This allowed a successful start to the undercutting and supported an uninterrupted advance of the undercut front, significantly reducing the risk of cave construction slowdown because of infrastructure readiness constraints, thereby minimising stress-induced damage to the extraction level (EXL). The mine design and general arrangements also enabled acceleration of the critical path (drawbelling construction rate), the material handling on the undercut level (UCL), and drawpoint development and support on the EXL.

2.1 Panel 0 undercut level mine design and general arrangement

The P0 undercut was constructed using an advanced undercut sequence, where the blasted ring front shadows the drawpoint drives to reduce cave-induced stresses and minimises overall drive deformation as shown in Figure 1. Drawpoints and drawbells are subsequently constructed in the stress shadow. P0 undercutting utilised a UCL and apex level (APL) to maximise breakage above the major apex (Figure 1). The motivation for using this design was to demonstrably eliminate bridges over the major apex and reduce the potential for future point loading onto the EXL drive, thereby improving the long-term stability of the EXL. Whilst this design increased construction costs, it enabled a risk-adjusted design that improved undercutting quality whilst beginning the first cave.

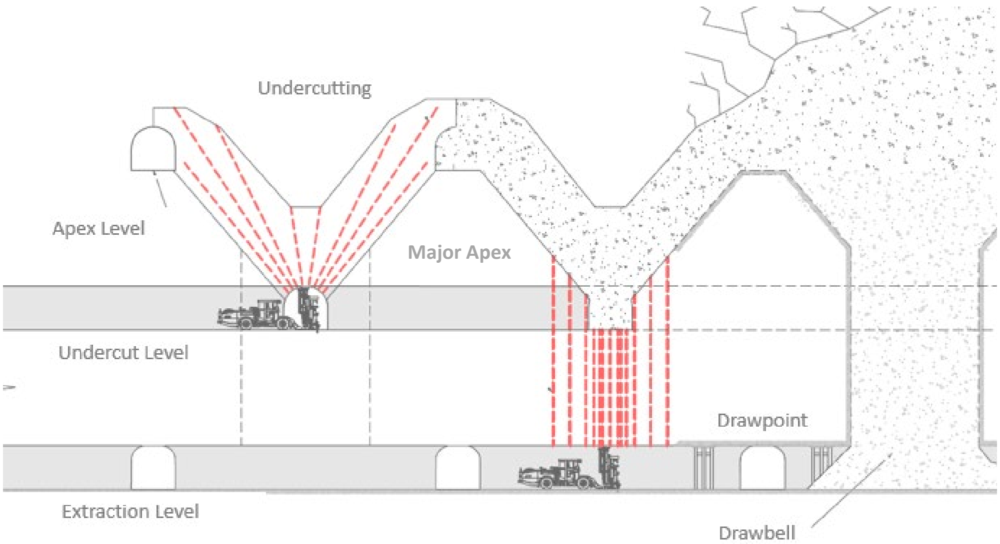


Figure 1 Simplified cross-sectional view of undercutting in Panel 0 showing the apex, undercut and extraction levels with the undercut and drawbell rings (rings shown by the red dashed lines)

2.2 Panel 0 undercut commencement scope and general arrangement

P0's undercutting performance was materially enhanced by comprehensive planning and production readiness activities, which enabled early delivery of critical infrastructure and scope ahead of undercut commencement. This approach emerged as a key lesson from P0's construction, with the completion of construction of infrastructure elements explicitly identified and set as pre-conditions for undercut initiation to reduce the risk of constraining the cave ramp. This was particularly important as it provided flexibility to accelerate the undercut above plan rates to manage cave-induced stress ahead of the undercut front, which was verified in real time through Oyu Tolgoi's extensive drive convergence monitoring systems. Ensuring critical infrastructure readiness before key undercutting milestones (particularly commencement and critical hydraulic radius) avoided artificial limitations on undercutting rates and preserved operational flexibility during early cave establishment. Key call-outs for the critical elements are listed below (not exhaustive):

- shaft 2 production hoist (SH2) and primary crusher 1 (PC1) commissioning
- primary and secondary ventilation circuits to enable multidrive blasting
- two northern undercut orepasses – the first before commencement and the second before critical hydraulic radius was reached
- fully supported drives within high-stress abutment zones (progressively measured as the undercut advances) – 100 m radius
- laydown and staging areas
- steel segregation bays to remove resin bolts and mesh (reducing orepass hang-ups)
- geotechnical monitoring systems.

This scope was managed by measuring schedule float at major milestones throughout the construction phases and working backwards through the schedule to ensure the critical elements were not constraints. It was not practical to complete all outstanding ground support and drives as this was considered to potentially lengthen the critical path, hence careful consideration was given for all scope on the undercutting commencement criteria list. This critical scope can be seen on the general arrangement for P0 undercut level in Figure 2, which outlines the major supporting infrastructure to support the rapid cycling of the 9 undercut drill drives at maximum undercut width.

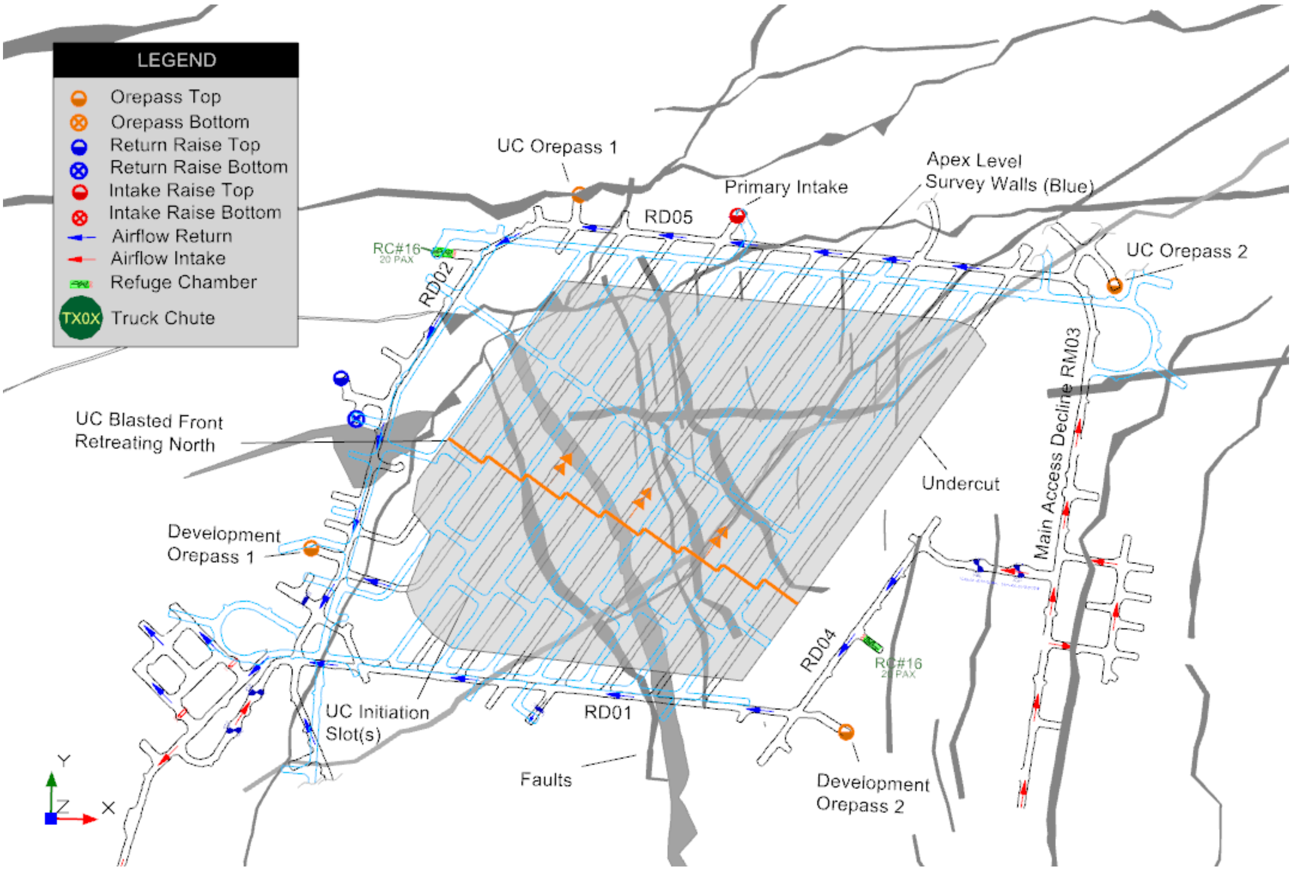


Figure 2 **Panel 0 undercut general arrangement drawing with slot positions, undercut initiation point, major infrastructure, ventilation, fault structures, undercut (black), apex (blue) survey walls (orange line showing staggered undercut blasted front with 2–4 ring lead lag)**

2.3 Panel 0 extraction level general arrangement

Construction of P0 EXL was approached with the mindset of building long-term infrastructure, given the EXL must last for the duration of P0 block cave and allowing for potential mine life extensions, including additional resource recovery on the margins of P0. The EXL shown in Figure 3 was designed to service the 3 phases of cave construction:

1. initial and bulk development with primary access and ventilation infrastructure
2. drawbell construction (alongside undercutting)
3. production mucking (and closure).

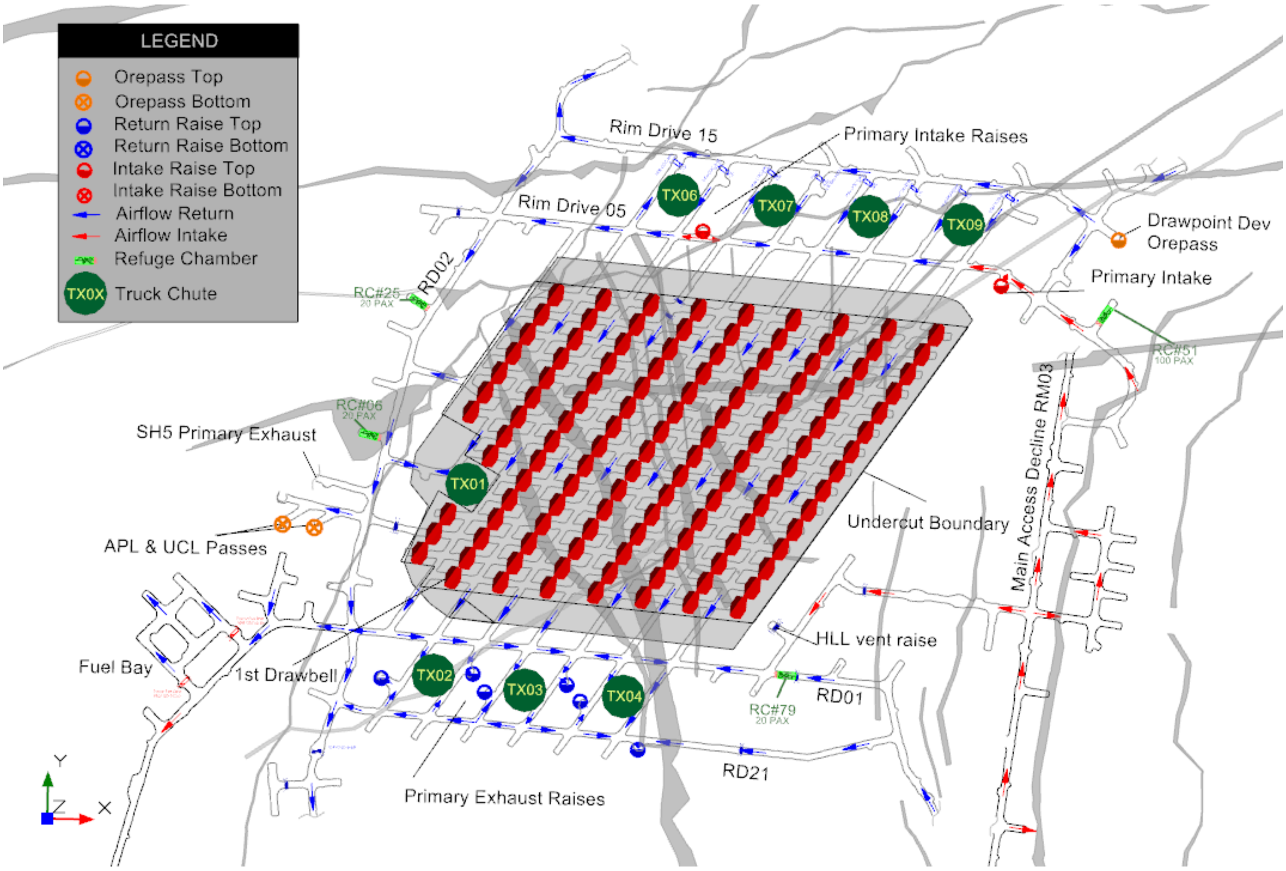


Figure 3 Panel 0 extraction level general arrangement drawing showing drawbells, truck chutes, and major infrastructure and fault structures

Often, the first and final phases are front of mind when designing the extraction level, however, the second phase (drawbell construction, drawpoint drive, steel sets and roadways, drawbell drill and blast) can be argued as most important as cave construction outcomes are directly related to cave health and future productivity outcomes. A slow undercut rate due to a slow drawbell construction rate would result in longer abutment stress loading time on the EXL drives from the undercutting, leading to excessive convergence. Advancing the undercut by pushing the critical path drawbells (driving task) as fast as possible was therefore the priority.

Optimisations included segregating drawpoint development access to the north of the EXL, with steel set and roadway construction crews sharing southern access with production mucking. Additional scope such as a dedicated rehandle orepass for drawpoint development was added to support this process. Roadway and steel set staging and laydowns areas were added to the southern rim drives to allow for quick cycling and delivery of material to support the drawbell construction rate. Opportunities to accelerate the critical path and benefit the operation were continuously evaluated and, once approved, swiftly executed.

This arrangement also supported achieving P0's nameplate capacity, which was initially baselined as 30 ktpd. Included in the basis of design, the EXL material handling configuration consisted of 8 truck chutes, each with dual loading, feeding a fleet of dual tub/tray road trains (~160 t payload), thereby allowing up to 16 loaders to be active on the EXL to execute the cave draw strategy. This equated to an average of approximately 2,000 to 3,000 tonnes per tipple per day, with the aim of having flexibility and dual directional mucking options for an increased output from the production system. The ability to increase output above nameplate capacity was determined to be a significant factor in the success of cave propagation as cave management triggered action response plans (TARPs) balanced EXL production rates to achieve a more robust draw strategy. Designing the mine with uplift potential ultimately provided the flexibility required to sustain good cave health.

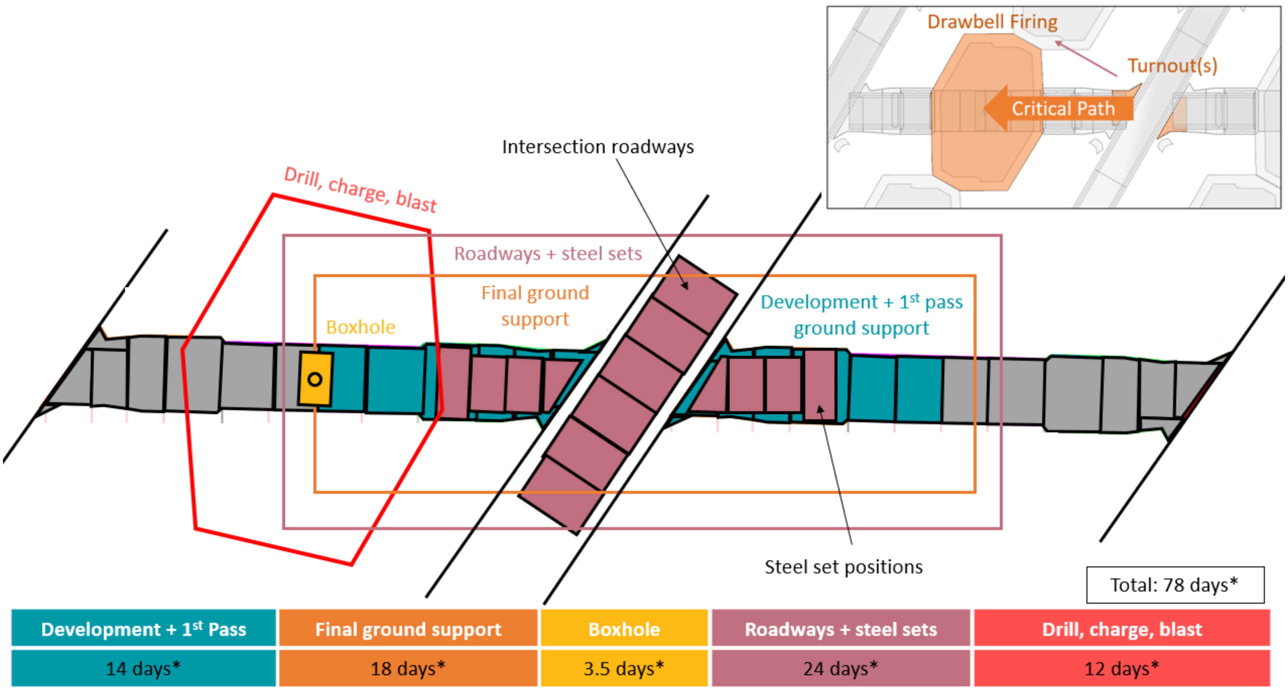
3 Panel 0: undercutting and drawbell construction

3.1 Drawbell construction and critical path management

Simplistically, the approach to constructing drawbells faster included 3 basic approaches where scope on critical path is removed, overlapped or accelerated. In the advanced undercutting sequence, the drawpoint development turnout only starts when it is adequately shadowed by the undercut – for each intersection there is a singular ring known as a ‘releasing ring’. Once this releasing ring has been blasted, the critical path timeline to complete the drawbell construction commences. The drawbell must then be blasted before the undercut reaches an initial maximum distance (60 m) ahead of it – known as the ‘veranda’ length – measured from the drawbell to the undercut blast front. Whilst undercutting will not stop because of an extended undercutting veranda, it is preferable to keep both moving as quickly as possible to prevent potential compaction of blasted material on the undercut level and to minimise potential for hang-ups. Two undercut rings per month per drive was targeted as a minimum.

The drawbell construction cycle was split into the subphases and durations shown in Figure 4 and tracked alongside administrative and handover tasks. This included:

- drawpoint development and final ground support
- boxhole vertical development
- roadways (blinding, subbase, panels) and steel set construction
- drill, charge and blasting.



*Initial planned durations (not actuals). Note durations are for section shown (31 m x 18 m).

Figure 4 Simplified plan view of Panel 0 drawbelling construction sequence and critical path with initial planned durations

Setting clear targets for drawbell construction timelines and closely monitoring them was a major success factor in drawbell construction speed and critical path management. Key performance indicator (KPI) durations for each phase were set and monitored for every drawbell and reported back in daily stand-up meetings to take rectifying actions and assist with reprioritisation of drawbells through resourcing if needed. These were revised in each planning cycle and fed back into the plan as part of continuous improvement principles.

Two key KPIs were monitored:

- drawbell construction total duration (elapsed time)
- individual durations of subphases, handovers and punch lists.

Both metrics were critically important as drawbelling construction practices matured. The primary focus was on productivity increases in each of the subphases whilst ensuring that other activities, including technical tasks and administrative processes, did not detract from the improvements. Every effort was made to reduce these works by simultaneously completing them to align with the mining subphase completions. The main examples of these included hold note ring release for development turnouts, steel set tolerance clash checks, walkdown punch lists and final roadway tolerance checks.

This critical path management was only efficient when targets were effectively cascaded to the operational crews. Simplifying the message of subphase durations to monthly and daily physicals was effective in driving drawbell numbers blasted. A drawpoint required a continuous set of scope items to be completed in advance. This was a 2-3 month journey. To achieve the targeted drawbell number in 2 months, the subphase targets must be met in each month. In simple terms, blasting 'X' drawbells in 2-3 months (average duration) requires the following tasks to be completed each month:

- X drawpoint development metres per month
- X drawpoint total ground support bolts, mesh and cables per month
- X boxholes per month
- X roadways and steel sets installed per month.

Whichever target fell behind would be identified as the bottleneck and flagged for acceleration to ensure the target could be met in the coming months. These effectively became leading indicators and were paramount to the success of an accelerated drawbelling construction rate.

3.2 Panel 0 performance and actuals: undercutting and drawbell construction

The cave construction period commenced when undercutting commenced in January 2022 with the first slot blast in P0 and ceased with the final drawbell construction in October 2024. This was a dual direction undercut as it blasted away from the initial slot positions in each drive and moved towards a staggered undercut face with a 2–4 ring lead lag (shown in Figure 2) before achieving critical hydraulic radius (approximately 20 drawbells). The baselined planned peak drawbell construction duration average was 4.7 drawbells per month. Through multiple continuous improvement initiatives, as shown in Figure 5, a peak 6 drawbells per month was achieved for 10 consecutive months. Notable outliers affecting the undercutting and drawbell achievements, however, occurred in December 2023 and May 2024, with a central heating plant (CHP) surface pipe leakage and winder motor failure limiting ventilation and tonnages extracted during these periods. The final result was undercutting being completed 6–12 months ahead of schedule, with an anticipated corresponding decrease in stress-induced damage to the EXL.

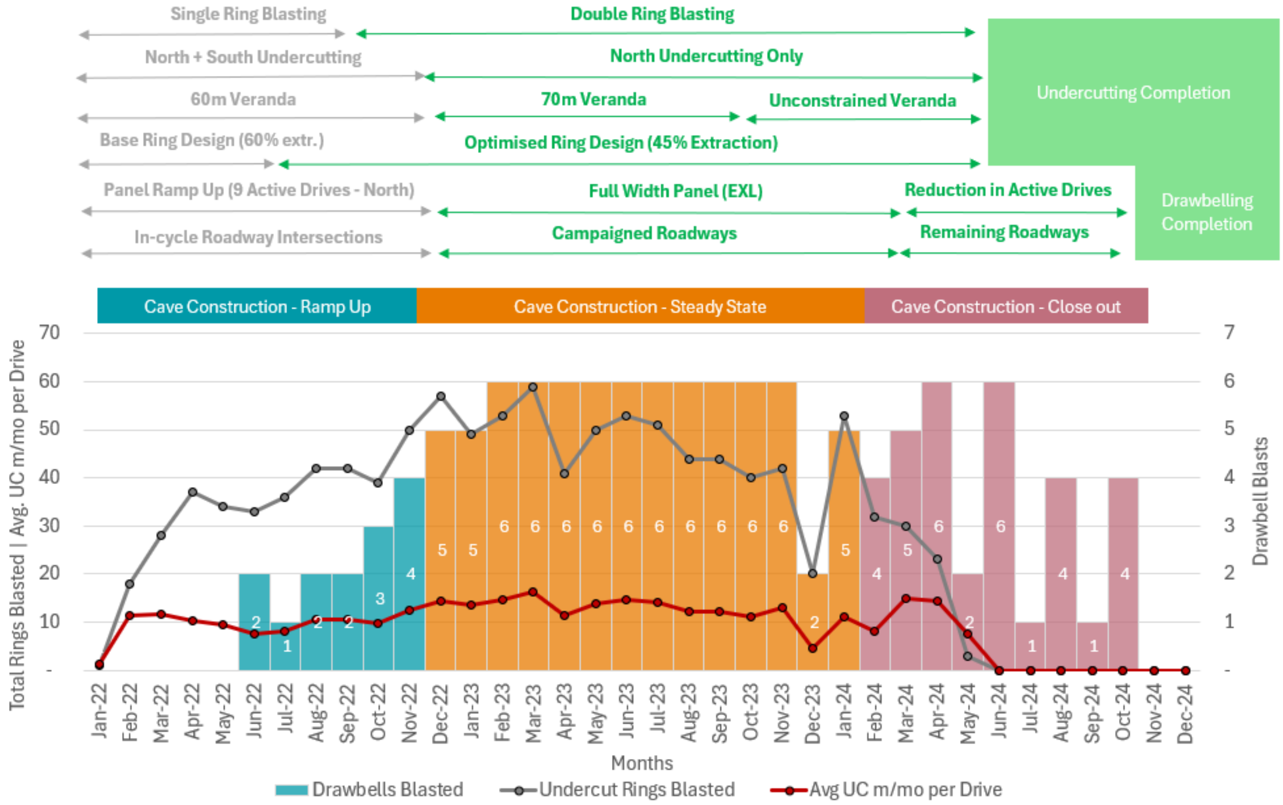


Figure 5 Panel 0 undercutting and drawbell blasting overview graphic (actuals)

3.2.1 Undercutting optimisations

Early undercut blasting and mucking did not consistently expose the apex of the pillars, making it difficult to confirm that clean breakout over the pillars had been achieved. In addition, significant redrill of blastholes was required due to hole closures. The key lessons from the focus on undercut ring blasting speed and quality include:

- Optimised undercut drill design (smaller trough in ring) and double ring blasts increased productivity to support the cycling of 9 active drill drives in various phases of their blasting cycle.
- Refinements in mucking percentages saw 60% extraction down to 45% of a double ring blast.
- Redrilling percentage reductions as 20 to 10 ring drill stocks were reduced down to 6 to limit hole collapse.
- Additional probe holes integrated into the base ring design improved blast confirmation processes without requiring additional probe holes, increasing confidence in blasting outcomes.
- Post-blast inspection practices were enforced and well documented using a mobile application collated by the shift supervisor and blasting engineer.

These combined efforts quickly took effect and set the stage for an undercut speed reaching 12.5–15 m per month across 9 drives against an initial plan of 7.5–10 m per month. In terms of undercut square metres, this equated to an average of 3,765 m^2 for the duration of 2023, peaking at 4,573 m^2 in March 2023.

3.2.2 Development and ground support optimisations

The initial development mine design included a drawpoint drive 4.5 m-wide × 4.5 m-high with key sections including overbreak management with 0–100 mm of allowable underbreak clearance in the steel set area installation (mechanical envelope). This was later converted to a 5.3 m-wide × 4.9 m-high drive to support a larger loader fleet and clearances associated with bullnose and camelback ground support designs. The initial focus was on development and ground support conformance to the initial profile for the best long-term stability outcomes, however, speed and quality were carefully balanced. This acknowledges that all efforts must be made to avoid any stripping during subsequent production mucking phases because of the schedule delays this causes. Therefore, the mine design was revised to ensure that steel set clearances in placement areas and bullnose and camelback support did not encroach on the loader mucking envelope.

Final ground support quantities increased from initial designs, which contributed to longer construction times. Improved ground support productivity did not significantly offset the increased quantities, given the focus on development quality. Improvements then focused on optimising ground support design, which greatly improved installation times without compromising quality. These included:

- removing cable slings from bullnose ground support design.
- removing mesh from the steel set placement areas to improve installation times and clearance.
- reducing cables in the drawpoint drive walls.
- installing fibreglass bolts around the boxhole area, improving boxhole productivities and reducing the likelihood of damage to the reamer head.

3.2.3 Steel set and roadway optimisations

A significant improvement to the drawbelling construction rate included deferring the final completion of the concrete roadways. This delayed the final intersection concrete panel roadway installation in the extraction drive (labelled in Figure 4) after the drawbell was blasted, which removed 8 days from the critical path – roughly 11% of the total drawbell construction duration. Intersection roadways were later installed in 2 adjacent 18 m intersections for increased productivity.

A management of change process was enacted to initiate this updated methodology with an appropriate risk assessment. An identified risk was the prolonged time that the drawpoints would be temporarily closed, as this removes the ability to alleviate stress build-up with mucking and could lead to unwanted convergence. A geotechnical assessment determined that a 14-day window was acceptable, which allowed 2 roadway intersections to be installed. This was then used as the basis for planning and execution. Another risk identified was the reduction in planned drawpoint production because of the deferred final roadway installation. Production targets were updated to recognise the short-term impacts of intersection closures and the deferral of final roadways.

3.2.4 Undercutting blast confirmation practices

Steady state undercutting was achieved when the optimisations became effective and practices were stabilised. It cannot be overstated that the undercut performance, speed and quality were paramount to the long-term success and stability of the footprint. An average peak rate of 12.5 m/month was achieved and maintained with local accelerations of up to 15–20 m/month, as shown in Figure 5. With this speed, excessive cave abutment stress loading times across the EXL were reduced as the undercut front moved at a faster pace.

To maintain this undercutting rate, the mining teams confirmed that a ring was blasted and mucked as per design using a series of checks shown in Figure 6. The purpose of the undercut is to create the initial void for a cave so that propagation of the cave can initiate and continue without stall or remnant pillars being created. It is not required to fully muck out a blasted ring for the purpose of cave initiation (swell mucking only); nor is it practical as it will cause constant rilling as the cave grows, and increase open brow hazards whilst slowing undercutting due to the increased mucking time. Early indicators such as fragmentation, muck throw and brow conditions were used as an indication of a successful undercut blast. However, during mucking activities, earlier-than-expected brow opening prompted a deep dive to understand and fix the reasons for early brow opening (for example, frozen ground).

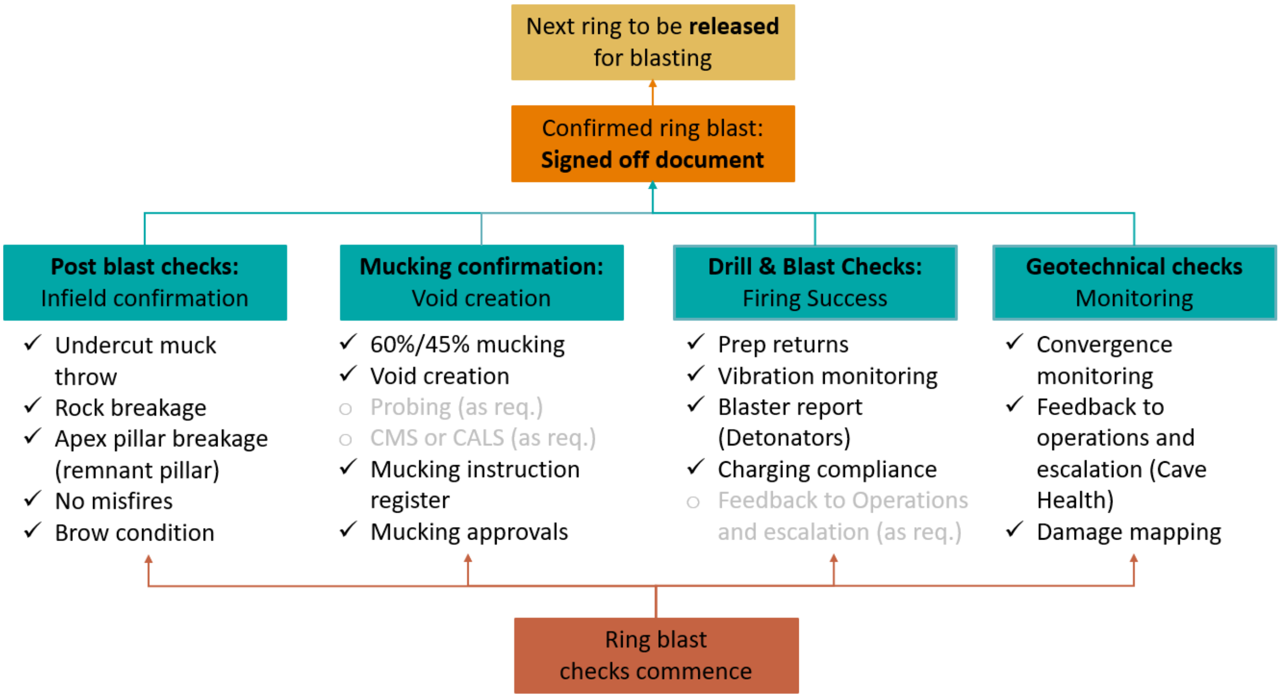


Figure 6 Panel 0 undercut post-blast confirmation checks to confirm successful blasts

The discipline and persistence of ensuring quality at pace allowed the undercut advance in P0 to continue unabated for the entire 2.4 years of undercutting. Undercutting was primarily governed by weekly cave health monitoring, with monthly reviews of progress, where decision-making among key stakeholders was undertaken. Decisions did not necessarily wait for these meetings when excessive convergence was detected on the EXL extraction drive, as an example (a potential lagging indicator of any potential remnant pillars). In this case, areas of concern were monitored through Oyu Tolgoi's integrated cave management system that operates in real time. This allowed for agile management and response through established TARPs, allowing the caving and production team to respond quickly to issues. Responses included accelerating the undercut or holding a blast until probing was conducted.

4 Panel 0 caving ramp-up journey

P0's last drawbell was blasted in October 2024 and with the completion of its eighth and final truck chute, P0's 3-year construction journey was completed. This marked a significant milestone in Oyu Tolgoi's caving journey. P0 subsequently entered its ramp-up phase in full, supported by the concurrent commissioning of the conveyor to surface (C2S) material handling system.

Cave tonnes were drawn as per established production rate curves measured on an individual drawpoint basis from the time of each drawbell blast. Draw was a function of hydraulic radius and height of draw (HOD) within the drawpoint column. In the initial phases of draw (not including blasting volume), approximately 30 tonnes per day per drawpoint were drawn and draw rates progressively increased against a defined draw rate curve to prevent excessive mucking and reduce the likelihood of an airgap forming between the cave back and muckpile. Once the cave matured (function of HOD, undercut completion, hydraulic radius), draw was increased progressively to a set maximum.

The focus for P0 during this period was to pull as many tonnes as possible within the constraints of the PRC, TARPs and triggers, and observations from cave management through the material handling system. In the early stages of 2024, production ramp-up experienced significant headwinds as a result of multiple adverse events, particularly the loss of SH2 due to a winder motor failure and a CHP plant surface pipe failure that reduced heating for the underground operation during winter (Figure 7). Nonetheless, the production ramp-up accelerated significantly after the commissioning of the C2S system, which effectively deconstrained the underground mine. P0 achieved the 1 Mt production milestone in May 2025 at an average daily production rate of > 34 ktpd. During 2025 and 2026, the P0 cave achieved over 45 ktpd as improvements in shift start time, reductions in blasting re-entry delays through ventilation optimisations, and overall productivity improvements were achieved.

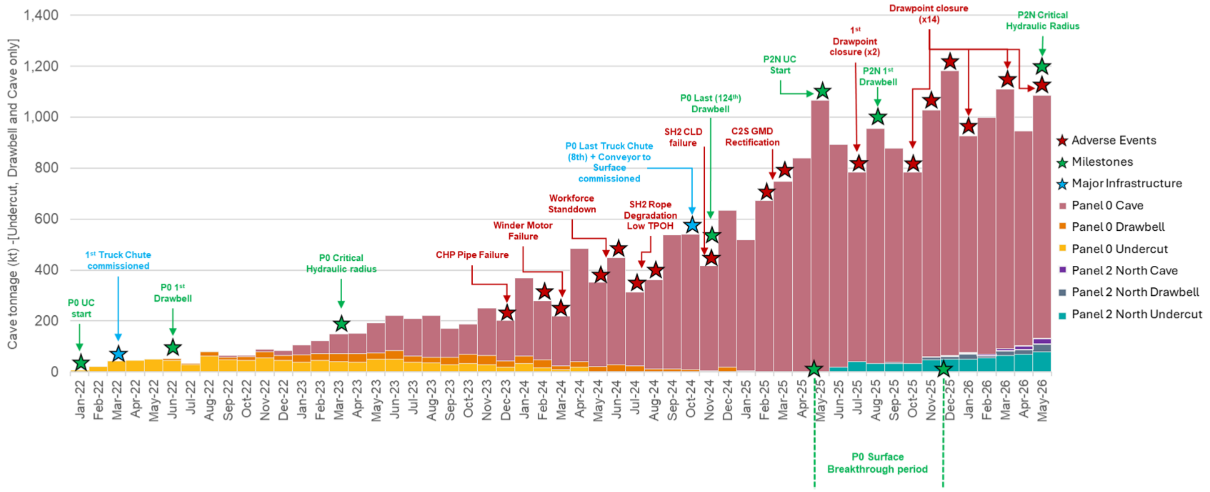


Figure 7 **Caving ramp-up journey for Panel 0 from undercut commencement to May 2026 with Panel 2 North commencement**

P0 cave propagation was tracked in 3D using Oyu Tolgoi's extensive networks of cave trackers, smart markers and open holes. This data showed the P0 cave propagating rapidly in response to cave draw. Arrays of surface sensors combined with InSAR satellite monitoring were established to detect surface subsidence. The P0 cave broke through to surface between May to October 2025 with surface subsidence of 0–2 m above the extraction level, as shown in Figure 8. Surface subsidence primarily followed major faults and structures as observed by installed cave markers and surface measurements. This was a significant milestone as it greatly reduces the principal airgap hazard for P0. As this occurred, the EXL experienced accelerated pillar column loading from the weight of the muckpile loading the pillars. In June 2025 2 drawpoints were closed (or filled with concrete) due to excessive convergence and to preserve the rock mass for future reopening. The drawpoints were located vertically below the point of greatest surface subsidence. This also included partial closure in 2 intersections.

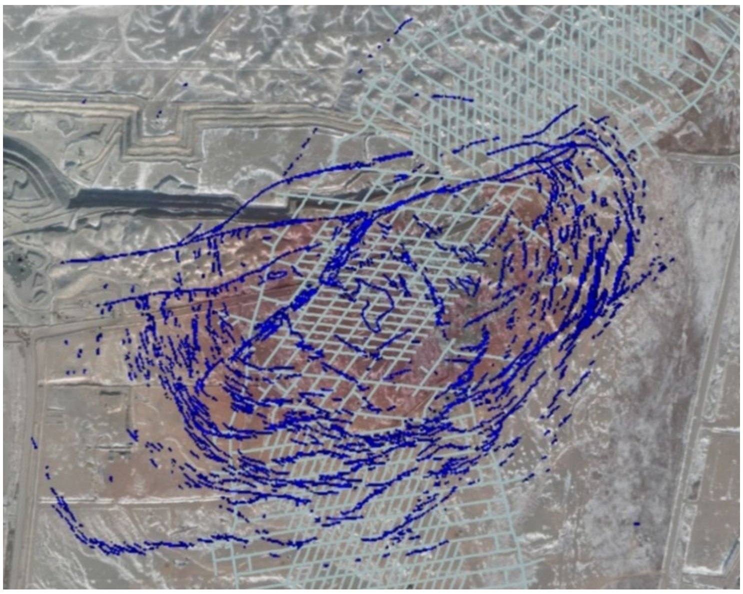


Figure 8 **Panel 0 subsidence zone overlain against the mine design with mapped subsidence cracks (blue lines) and red deformation scaling**

As a result of further progressive surface breakthrough and column loading in Q3 of 2025, the decision was made to close 10 additional nearby drawpoints to manage stress buildup in this area (along with load shedding activities pre- and post-closure). Further work is being undertaken to confirm timing of reopening. The closures have not overly impacted the tonnages from Panel 0 as the current mine design allowed for dual directional mucking to the North and South Truck chutes and the long-term mine plan included forecasts of drawpoint closures. Whilst the number of drawpoint closures are within plan, the location of drawpoint closures differs. Further work is being carried out to calibrate closure mechanisms to improve closure forecasting.

Panel 0 now continues to perform above initial predictions of a 30ktpd nameplate with daily maximums ranging between 30-45 ktpd.

5 The commencement of Panel 2 North and the road to the next caves

Undercutting of Panel 2 commenced with blasting of the first undercut slot in sub-block P2N in April 2025, followed by the first drawbell blast in August 2025. Figure 9 contextualises the challenge ahead: P2N is the second-largest cave in HNL1 under the current mine design, comprising 14 extraction drives compared to the 9 in P0. With P2N now well underway, Oyu Tolgoi's caving journey continues with a deliberate focus on accelerating drawbell execution, and applying the planning, infrastructure readiness and execution lessons from P0 early to support a more efficient and controlled cave establishment phase.

The lessons from P0 have been incorporated into P2 plans. Practices validated in P0 have been adopted in P2 and are being continuously improved. This includes the focus on active cave monitoring and management, high-quality construction and ground support, and rapid undercutting, underpinned by extensive and detailed construction planning and sequencing. P2 mine design includes several improvements, including east–west orientated extraction drives, off-footprint orepasses located on both sides of the block and larger rim drive offsets.

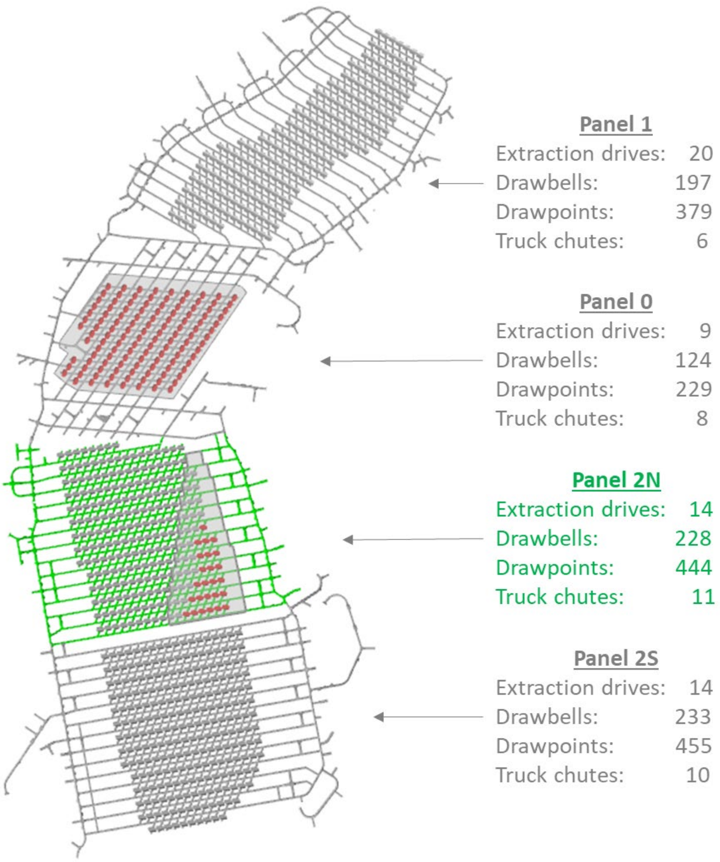


Figure 9 Extraction level of Panel 2 North (green) and the next caves, showing blasted ring cave progression (grey) and blasted drawbells (red) as of end of May 2026

6 Conclusion

Panel 0 (P0) marks a critical step in Oyu Tolgoi's caving journey at Hugo North Lift 1, providing a practical demonstration of how disciplined planning, production readiness and early delivery of critical infrastructure can materially influence undercut execution, cave establishment and ramp-up performance. The experience at P0 demonstrates the importance of the key foundations in mine design and planning, the relentless focus on managing both the quality and critical path of construction and undercutting, and the pursuit of operational excellence built upon extensive monitoring of the cave. P0 also highlights the importance of preserving optionality, including the ability to accelerate caving activities and respond to unforeseen conditions. The overriding lesson is that cave health is linked to mine design, construction quality and disciplined undercut execution.

There is still significant room for improvement and the Oyu Tolgoi team is focused on increased understanding of cave propagation mechanisms to enhance breakthrough predictions and better manage the impacts of loading on the extraction level, thereby reducing premature drawpoint closure.

The transition from P0 to P2N reflects a progression from initial implementation to more deliberate application of established lessons. Increased scale and complexity in P2N place greater emphasis on scheduling methodology, infrastructure readiness and execution sequencing. These considerations are now embedded earlier in the planning and execution process rather than being addressed reactively.

As Oyu Tolgoi advances beyond P2N toward subsequent caves, the insights gained through this journey continue to inform how future panels are planned and executed. The evolving approach supports improved consistency, resilience and efficiency in cave establishment, positioning the operation to build momentum through successive caves with increased confidence and control.

Acknowledgement

The authors acknowledge the Oyu Tolgoi organisation, both employees and contractors – Mongolian and expatriate, underground and surface teams – for their collective effort and collaboration during the underground project.

The underground team's persistence, commitment to continuous improvement and relentless drive for operational excellence in the delivery of Panel 0 development were critical and instrumental in supporting undercutting and drawbell construction practices that have created a strong foundation for future cave establishment.

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