BOWDENS SILVER

Response to Earth Systems Review – Acid and Metalliferous Drainage

State Significant Development No. 5765

October 2022

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Bowdens Silver Project

Response to Earth Systems Review – Acid and Metalliferous Drainage

State Significant Development No. 5765

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1. Introduction

1.1 Scope

This document has been compiled to provide a response to the eight recommendations made in the *Independent Review – Acid and Metalliferous Drainage*, prepared by Earth Systems and hereafter referred to as Earth Systems (2022). This review was commissioned by the Department of Planning and Environment (DPE) to independently review acid and metalliferous drainage risks associated with the Bowdens Silver Project (the Project). The review was provided to Bowdens Silver Pty Limited (Bowdens Silver) on 8 June 2022.

1.2 Background

With regards to the Project's characterisation, classification and proposed management of acid generating material, the DPE commissioned Earth Systems to review the following documents that were prepared to support the Project's Development Application (SSD 5765) and placed on public exhibition from Tuesday 2 June 2020 until Monday 27 July 2020.

- *Environmental Impact Statement – 2020* (EIS). Prepared by R.W. Corkery & Co. Pty Limited (RWC, 2020) on behalf of Bowdens Silver Pty Limited.

- *Materials Characterisation Assessment – 2020*. Prepared by Graeme Campbell & Associates Pty Ltd (GCA, 2020) on behalf of Bowdens Silver Pty Limited and presented as Part 3 of the *Specialist Consultant Studies Compendium* which accompanied the EIS.

- *Tailings Storage Facility Preliminary Design – 2020*. Prepared by ATC Williams Pty Ltd (ATC Williams, 2020) on behalf of Bowdens Silver Pty Limited and presented as Part 16a of the *Specialist Consultant Studies Compendium* which accompanied the EIS.

- *Preliminary Design of PAF Waste Rock Emplacement, Oxide Ore Stockpile and the Southern Barrier – 2020*. Prepared by Advisian – Worley Group (Advisian, 2020a) on behalf of Bowdens Silver Pty Limited and presented as Part 16b of the *Specialist Consultant Studies Compendium* which accompanied the EIS.

- *TSF and WRE Closure Cover Design – 2020*. Prepared by Advisian – Worley Group (Advisian, 2020b) on behalf of Bowdens Silver Pty Limited and presented as Part 16c of the *Specialist Consultant Studies Compendium* which accompanied the EIS.

Following public exhibition, a comprehensive response to the matters raised in submissions responding to the EIS were presented in the *Submissions Report* for the Project (RWC, 2021) that was provided to DPE in June 2021. DPE also provided the *Submissions Report* and individual submissions on the EIS prepared by Dr Haydn Washington, a former scientist at CSIRO, to Earth Systems for review.

1.3   Summary of Matters Raised

Key matters raised by Earth Systems principally concerned the level of sampling and analysis undertaken to inform the waste classifications and the use of a Total (%S) cut-off value of 0.3% for identification of non-acid forming (NAF) waste rock for use as a construction material or resource and the effect this approach has on the Project's overall acid and metalliferous drainage (AMD) risk classification system. Earth Systems also provided commentary on the Project's proposed strategies for managing potentially acid forming (PAF) and NAF waste materials, such as:

- the design, development and progressive rehabilitation of the proposed waste rock emplacement;

- the management of seepage from the tailings;

- the management of runoff and water quality risks from NAF waste rock stockpiles and landforms constructed with this material; and

- the proposed closure and rehabilitation strategies presented in the EIS.

1.4   Approach to the Response

The level of detail presented in the EIS and supporting documents has been sufficient to satisfy NSW Government agencies such as the Environment Protection Authority, NSW Resources Regulator, Department of Regional NSW – Minerals, Energy and Geoscience and DPE Water regarding waste material management. It is also noted that these agencies raised no concerns relating to the classification or proposed management of waste materials. Detailed information was presented within and appended to the EIS that established a conservative characterisation of the materials within the proposed open cut pits. The review undertaken by Earth Systems has queried the underlying assumptions and therefore the outcomes of the information presented in the EIS. It is acknowledged that some of these assumptions may have been better justified in the documents provided and this would have assisted the Earth Systems review. In addition, since the publication of the EIS, Bowdens Silver has continued to investigate and refine its understanding of the geological and geochemical setting of the deposit providing important context for the Project's waste classification.

This document has been structured to provide information on:

- the geological and geochemical setting of the Project;

- the outcomes of the additional investigations undertaken since the publication of the EIS including discussion of the waste classification strategy; and

- the work that would continue following commencement of the Project.

This is followed by a detailed response to the matters raised by Earth Systems considering the information presented in preceding sections. A summary of actions that would occur prior to commencement of mining and over the life of the Project is also provided.

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This response is supported by information presented in two appendices. **Appendix 1** provides information relating to the geological context, evolution and mineralogy of the Bowdens Silver Deposit, while **Appendix 2** provides additional information on the environmental geochemistry for the Deposit. The following are presented in the appendices.

- *A note on Bowdens Deposit Mineralogy* prepared by Dr Ian Graham (2022) and presented in **Appendix 1**.

- A copy of the article *Hydrothermal Alteration at the Bowdens Silver Deposit, NSW* prepared by J. Elliot, T. Leach and I Pringle presented at the Minerals of the Pacific Rim Conference in 2004 and presented in **Appendix 1**.

- A memo prepared by GCA with the subject *Clarification of Key Items in GCA (2020) Report on Environmental Geochemistry and Implications for Mining-Stream Management* and presented in **Appendix 2**.

- A second memo prepared by GCA with the subject *Computational Approach Employing %S, %Ca, and %Mg Assays in Geological- Database for Mining-Stream Classification* and presented in **Appendix 2**.

1.5   Summary of Outcomes

1.5.1   Geological and Geochemical Setting

The preparation of this response has relied upon a geological database developed over many years and from 650 mineralogical samples examined using a range of structural and optical techniques, multi-element assay data from almost 100,000 metres of drilling samples and over 11,500 hyperspectral data points. Sampling and analysis in 2003 led to initial definition of the geological context of the Bowdens Silver deposit[1] (the "Deposit"), with additional work continuing to support and enhance Bowdens Silver's understanding. This information continues to support the current hypothesis regarding the evolution and mineralogy of the Deposit and allowed Bowdens Silver to confidently plan and design mining infrastructure including the waste rock emplacement (WRE) and tailings storage facility (TSF). In summary, the Deposit:

- is an epithermal, low temperature and low to intermediate sulphidation deposit hosted principally within the felsic Rylstone Volcanics;

- is the product of multiple alteration phases, driven by a dacitic intrusive, that pervasively altered primary mineralogy whilst spatially constraining alteration products; and

- is within a ground mass of quartz and potassium feldspar Rylstone Volcanics containing reactive carbonates, but is largely devoid of jarosite, alunites or other calcium or magnesium bearing minerals.

For the purpose of waste classification, GCA (2020) separated the Deposit into weathered waste zones (WZ) and primary waste zones (PZ) whose geochemical characteristics are closely tied to the above hydrothermal alteration phases. An important consequence of such hydrothermal

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[1] See Elliot et al (2004) provided in **Appendix 1**.

alteration is the absence of a distinct lithological control on $\%S_{total}$ occurrences within the primary waste zone of the Deposit. GCA developed waste material classifications based on $\%S_{total}$ reflective of the Deposit's geology, including primary, clay and secondary (weathered) mineralogy, and outcomes from the static and kinetic testing programs. Importantly, waste classifications based on $\%S_{total}$ determined via XRF assaying during grade control activities will directly guide separation, handling and placement of the mined materials.

1.5.2 Waste Classification System

In summary, the hydrothermal alteration phases have resulted in the Bowdens Silver deposit being characterised by four zones, namely:

- An (uncomformably) overlying zone comprising the sediments of the Snapper Point Formation and un-mineralised Rylstone Volcanics with trace sulphide minerals that is classified as NAF waste rock (WZ1).

- An outer zone within the Rylstone Volcanics with negligible sulphur or manganese alteration and a late carbonate (dolomite / ankerite) over-printing event comprising NAF waste rock (PZ1 and PZ2 [low-Mn sub-variant]).

- A low temperature peripheral zone within the Rylstone Volcanics with trace sulphide (low concentration), manganese minerals and silver rich ore. Interfingered benches of waste material in this zone are classified as NAF (PZ2 [high-Mn sub-variant]) and PAF (PZ3).

- A core high temperature zone within the Rylstone Volcanics comprising ore (base metals) and trace sulphide (higher concentration) minerals. Waste material within this zone is classified as WZ2 and PZ3 (PAF) corresponding to location within the weathered zone and primary zone, respectively.

Further drilling and sampling since the publication of the EIS has clarified the geological boundaries of the waste zones. Key outcomes for the classification system based on the understanding of the effects of the hydrothermal alteration zones are that:

- sulphur enriched areas are classified as PAF waste (WZ2 and PZ3);

- weathered zone PAF waste material (WZ2) is located at the periphery of the core hydrothermal zone;

- NAF waste occurrences within the core hydrothermal zone are isolated and irregular and would not be suitable for separation during mining; and

- the spatial off-set from the dacitic intrusion generally accord with the high-Mn areas with $\%S_{total} <0.3$.

For the classification of NAF waste material, the key outcomes for the classification system are as follows.

- NAF waste material in the weathered zone (WZ1), consists of material with $\%S_{total}$ <0.3% where potential soluble aluminium acidity associated with locally occurring traces of alunite are immobilised and buffered by co-occurring high activity clays (see GCA, 2022a).

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- NAF material in the primary waste zone consists of material with $\%S_{total} < 0.1\%$ (PZ1) as well as material with $\%S_{total} \geq 0.1\%<0.3\%$, that is, within the range 0.1-0.2 (PZ2). For practical purposes, the PZ1 and PZ2 classifications are restricted to the primary waste zone within the northern section of the open cut pit.

- Further consideration of PZ2 has identified that this classification may need to be classified into two sub-variants based on Manganese (Mn) content ($\%Mn_{total}$), with high Mn material potentially requiring some specific handling, stockpiling and management prior to use as a construction material (where leaching is constrained).

1.5.3   Waste Material Balance

In response to the peer review comments from Earth Systems, re-evaluation of the materials balance was undertaken using a higher resolution geological model developed from the geological database and a probabilistic approach to defining $\%S_{total}$. This re-evaluation reflects the improved geological understanding of the Deposit since EIS submission. This approach conservatively assumed all waste within the $\%S_{total} > 0.3$ boundary (i.e. the core hydrothermal zone) is PAF. GCA (2020) had identified possible isolated occurrences of PZ1 or PZ2 within this area. However, where they occur, they are unlikely to be separately mineable and therefore are considered PZ3 (PAF) for operational purposes. This also removes any uncertainty around $\%S_{total} > 0.1$ and <0.3 in the primary waste zone. The result of this approach has been that a small volume of material in the primary (unweathered) zone that was previously classified as NAF is now classified as PAF. However, a greater understanding of boundary conditions supports a higher volume of NAF overall. In summary, it has been identified that:

- 24,061kt or 52% of all waste material is classified as PAF (reduced from 57% in EIS); and

- 22,338kt or 48% of all waste material is classified as NAF (increased from 43% in EIS).

This represents an overall increase in NAF waste rock material compared to what was presented in the EIS and the volumes of construction material assumed in designing key site infrastructure such as the WRE. Therefore, the Project as presented in the EIS has sufficient NAF to support proposed construction and rehabilitation measures and the WRE has sufficient capacity to accommodate and encapsulate all PAF waste rock material.

As part of the additional work undertaken since submission of the EIS, and to further justify the classification system developed by GCA (2020), the Project's extensive lithochemical database for the primary waste zone has been interrogated. There has been a focus on the northern section of the proposed open cut pit where reactive carbonate alteration (dolomites / ankerites) is pervasive, in accordance with the spatial distribution and nature of hydrothermal alteration events. Specifically, Bowdens Silver has assessed the buffering capacity of the primary (unweathered) zone in terms of %Ca and %Mg assays with corresponding calculation of $\%S_{residual}$ (see GCA, 2022b – provided in **Appendix 2**). The use of $\%S_{residual}$ for classification is only relevant in the primary (unweathered) zone where calcium and magnesium occur chiefly as reactive carbonates (e.g. dolomites and ankerites) (see Graham, 2022). This lithochemical-based estimation of $\%S_{residual}$ supports the PZ1 and PZ2 classifications as defined in the GCA (2020) study based on $\%S_{total}$. It is nevertheless important to note that whilst estimation of $\%S_{residual}$

supports the primary zone waste classification and the material balance re-evaluation, the actual waste classification system for the Project is based on $\%S_{total}$ as determined via XRF during grade control activities.

1.5.4   Investigations and Data Sources

Bowdens Silver is confident that sufficient sampling, analysis and test work has occurred to date to represent and quantify AMD risks. This confidence is based on the following as presented in this response.

- Sampling and analysis presented in GCA (2020) is supported by work since that time that has defined boundary conditions and refined the understanding of the geological context.

- The current understanding of the deposit is supported by numerous lines of evidence including structural and optical techniques (e.g. XRD, SEM, petrography), multi-element assay, hyperspectral scanning and detailed electron optical and mechanical studies.

- The analysis undertaken to define and refine the geological setting has not identified evidence of any geological event, other than those previously identified, that may have resulted in unexpected mineralogy and therefore waste classification requirements.

- Mining activities would not actively classify waste based on $\%S_{residual}$ but rather continue to rely on $\%S_{total}$, which removes any uncertainty relating to the buffering capacity in the primary zone.

- GCA has also correctly identified isolated and irregular occurrences of NAF material within the core hydrothermal zone, however, it is confirmed that this material was not considered NAF for Mine planning given the likely difficulty in separating this material from PAF in practice.

A feature of the Deposit is the occurrence of multiple phases of hydrothermal alteration throughout its geological history which imparts a degree of spatial uniformity in terms of the environmental geochemistry of the waste zones. Importantly, the latter necessarily constrains how much sampling and testing is needed for AMD risk assessments, and especially so where the geological, mineralogical and lithochemical databases of the waste zones are comprehensive, as is the case for the Bowdens Silver Project.

1.5.5   Post-Approval Actions

Regardless of the above, review and refinement of the waste classification strategy would occur over the life of the Project. Prior to the commencement of mining activities, Bowdens Silver would develop a Mine Waste Rock Management Plan that would describe the ongoing program of data collection, assessment and review to inform waste rock management. This Plan would be prepared by a suitably qualified and experienced person and submitted to DPE for approval. The Plan would provide a practical guide to waste management including the approach to classification, handling and long-term storage of waste rock materials. The approach to waste rock management would be refined over the life of the Mine and would be informed by ongoing

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data collection and analysis. This would ensure that AMD risks would be identified and managed over the life of the Project and ultimately, the Mine closure objectives of the Project would be satisfied.

1.5.6   Response to Matters Raised

Responses to the recommendations presented by Earth Systems has relied upon this information in formulating replies to the matters raised. In summary:

- Bowdens Silver and GCA do not agree that the geochemical characterisation work undertaken to date is preliminary. The significant geological database compiled from drilling, assay, hyperspectral analysis and optical techniques, demonstrates the geochemical validity and conservatism of the initially proposed waste classification scheme. The absence of distinct lithological control in terms of $\%S_{total}$ occurrences within the waste zones is reflective of influences from hydrothermal alteration phases which has been made clear from the testwork undertaken by GCA (2020). Valid demarcation of NAF and PAF waste material for the Deposit is **not** lithology based. Operationally, the overriding influences from hydrothermal alteration phases simplifies waste classification via use of the $\%S_{total}$ criteria that is independent of lithology. However, the PZ2 waste classification has been refined to classify materials as sub-variants, based on $\%Mn_{total}$. This sub-variant approach to classification would continue to be tested and updated as mining progresses.

- Assessment of 'lag-phases' of PAF waste materials was undertaken in GCA (2020) via kinetic testing which provided a good understanding on which management decision making could be based (see GCA, 2022a). It is important to note that the sulphide mineral suite within the waste rock does **not** include forms which are intrinsically hyper-reactive, reflective of the non-sedimentary nature of the Deposit.

- The reliability of GCA's (2020) AMD risk classification has been tested and confirmed through further investigations since publication of the EIS. The Project's materials balance has been re-evaluated via the geological database and knowledge of $\%S_{total}$ occurrence. This has identified that more NAF construction materials are likely to be available than previously expected. This re-evaluation is supported by additional indications of the buffering capacity of PZ2 waste material in the northern section of the main open cut pit when likely $\%S_{residual}$ outcomes are considered.

- It is noted that the Project, as presented and assessed for the EIS does not assume that runoff collected from NAF material stockpiles would be suitable for discharge without treatment / management. Locally, NAF PZ2 waste material may be characterised by manganese in reactive carbonates (high-Mn PZ2 sub-variant) which may be a source of Neutral Mine Drainage. However, these occurrences have been identified as minor and would be easily managed through specific handling, placement and storage. It is also noted that this material would be subject to interaction with high activity clays with a corresponding suppression of acidity. Identification of the NAF waste materials with their well understood geochemical characteristics therefore permits their use in construction activities within the Mine Site such that resulting contact waters do not have an impaired quality.

- The preliminary cover design for the WRE and TSF (Advisian, 2020b) does not call for PAF material to be placed near surface. Rather it is proposed that fine oxide PAF waste material is placed to provide a bedding layer for a geosynthetic clay liner (GCL). This GCL would provide a barrier that limits oxygen and moisture ingress to the underlying PAF waste material. The GCL would then be covered by between 1.8m to 3.0m of NAF/subsoil and topsoil material (store and release). The proposed approach and alternative options for the cover system of the WRE would be tested during development of the WRE to inform Mine closure (e.g. running of field cover system trials). Alternative options may include a greater depth of NAF waste rock applied to the surface or additional liners such as the GCL. Nevertheless, based on the nature of the PAF waste and the climate of the Mine Site, the current cover design is considered most appropriate for the Project and reflects current industry guidance.

- It is acknowledged that AMD risks may arise from TSF development. Whilst seepage rates for the preliminary design of the TSF (ATC Williams, 2020) were within the bounds specified by the NSW EPA, Bowdens Silver elected to include a bituminous geomembrane liner over the entire TSF impoundment subject to detailed design outcomes. Bowdens Silver would also undertake trials and monitoring on sections of the TSF to assess the effectiveness of proposed rehabilitation measures, including the effectiveness of the GCL in limiting oxygen ingress. This monitoring would inform any adaptive management measures to ensure the proposed rehabilitation outcomes are achieved.

- Whilst there is a store and release component, the preliminary design of the closure capping described in Advisian (2020b) does not rely solely on this component as the means for controlling AMD. Rather the store and release component is intended to limit percolation of rainfall into the encapsulated PAF waste material. Another critical aspect of this component is to provide soil water storage for vegetation that then removes stored water via evapotranspiration whilst stabilising the surface. However, the proposed cover system also includes a GCL that would provide an additional barrier to (primarily) limit oxygen ingress to the underlying PAF waste material. The GCL would be placed above the PAF waste material and then covered by between 1.8m to 3.0m of NAF/subsoil and topsoil cover material (store and release).

- A detailed understanding of AMD risks associated with final void lake water quality and a management strategy for this structure are not considered necessary given that the final landform would be constructed to create terminal sink conditions, that may include passive mitigation, to limit transmission of this water to downstream/down-gradient receptors.

This review confirms that the Project as presented in the EIS has sufficient NAF to support proposed construction and rehabilitation measures and the WRE has sufficient capacity to accommodate and encapsulate all PAF waste rock material. Further, the design and management of WRE and TSF, including plans for closure remains appropriate.

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2.　Geological and Geochemical Setting

2.1　Geological Setting of the Bowdens Silver Deposit

2.1.1　Description and Evolution

The Deposit is an epithermal, low temperature carbonate-silver-base metal low to intermediate sulphidation deposit (Wang et al, 2019). The Deposit is hosted principally within the mid-Carboniferous Rylstone Volcanics (between 327 to 324-327 million years old) that unconformably overlie a sequence of Ordovician aged metasediments (approximately 460 million years old). Mineralisation has been dated at approximately 321 million years old (AuScope initiative: National Argon Map). Within the deposit, the Rylstone Volcanics are composed of a sequence of rhyolitic to dacitic composition volcanics commencing with a basal crystal tuff that passes up to welded tuff then to a mixed rhyolite breccia/flow banded rhyolite. The highest stratigraphic unit of the Rylstone Volcanics consists of interbedded laminated ash tuff with crystal (lithic) tuff horizons. An intrusion of dacitic composition (Graham, 2022) intrudes into the crystal tuff of the Rylstone Volcanics and Ordovician age metasediments and is located immediately beneath the centre of the proposed pit. These volcanics range in thickness from 10m to >200m and are partially overlain (unconformably) by quartzose sediments of the Snapper Point Formation which belongs to the Permian Shoalhaven Group (a basal group of the Sydney Basin).

Lithologies within the open cut pits are silica and potassium-feldspar (felsic) volcanics which have undergone substantial wallrock and open space filling hydrothermal alteration. The dacite intrusion formed as a sill during the collapse of the volcanic structure (forming a caldera) and represents the final magmatic influx (pulse) in the evolution of the Rylstone Volcanics at the Deposit. This intrusion represents the core of a decaying thermal convection cell that was the dominant influence on the distribution of mineralising fluids within the Deposit. Therefore, due to the varying temperatures at which different hydrothermal minerals precipitate, this intrusion was also the key driver of the type and spatial distribution of alteration minerals within the Deposit.

Hydrothermal fluids initially migrated along major caldera structures (ring faults) before being localised into the Deposit through a network of extensional type faults. These fluids then predominantly permeated along lithological contacts within the Rylstone Volcanics and into the underlying basement. The hydrothermal alteration zones created by these fluids present a mineralogy that is principally characterised by quartz, pyrite, carbonate and clay minerals (discussed in more detail below).

The bulk of the mineralisation within the proposed open cut pits occurs as a thick zone extending from surface, and near surface, to vertical depths of at least 180 metres (m). Drilling completed to date has identified mineralisation to depths exceeding that of the main open cut pit floor, to approximately 600m below surface. Across the open cut pit, the Snapper Point Formation and upper sections of the Rylstone Volcanics display a weathering (oxidized) horizon of varying but shallow depth. As the Snapper Point Formation is comprised of sediments, oxidation has little

effect on this lithology. However, weathering within the Rylstone Volcanics has resulted in a distinct but limited horizon (zone) of oxidation. Beneath this weathered zone within the proposed open cut pits lie unaltered and altered Rylstone Volcanics.

2.1.2   Mineralogy

The Rylstone Volcanics and deposit mineralogy have been the subject of multiple studies (published and unpublished) which have utilised a range of structural and optical techniques including: powder x-ray diffraction (XRD), scanning electron microscopy (SEM) (including QEMSCAN, quantitative SEM), microscopy on petrographic thin sections and HyLogger hyperspectral analysis. This HyLogger methods use visible and infrared light to characterise selected minerals and confirm observations made in thin section. The qualitative analysis performed by HyLogger has been validated by both point and quantitative XRD. The following summary has generally been developed using the information presented in Elliot et al (2004) and provided by Dr Ian Graham of the University of New South Wales (Graham, 2022). These documents are provided as **Appendix 1**.

Hydrothermal alteration events within the Rylstone Volcanics occurred over multiple phases via fluids of varying composition. These phases are described in detail by Elliot et al (2004) with an overview of the sequence and resultant alteration mineralogy as follows:

1.   Quartz phase: quartz (± adularia), illite, carbonate, disseminated sulphides (pyrite, arsenopyrite, sphalerite and marcasite).

2.   Sulphide phase: quartz, pyrite, arsenopyrite, sphalerite, carbonate, galena, chalcopyrite, illite, tennantite, silver (sulphosalt), marcasite.

3.   Carbonate phase: carbonate, illite, quartz, pyrite, galena, sphalerite, tennantite, silver (sulphosalt), marcasite, silver (sulphide, native).

4.   Clay phase: illite, carbonate, kaolinite, quartz, marcasite, galena, tennantite, silver (sulphosalt, sulphide, native).

Except for the major minerals that define each phase (e.g. quartz and sulphide), the occurrence of minor and trace alteration minerals is not a constant throughout the respective phase. It is noted however that mineral dominance of the sulphide phase is shared by pyrite and quartz. Each phase in the sequence resulted in alteration of primary minerals (e.g. potassium-feldspars) as well as intergrowth with (in-filling), and overgrowth / replacement of alteration minerals.

The pervasive alteration has leached all primary feldspars of potassium and calcium. This results in illite/muscovite/carbonate (± adularia) alteration with Graham (2022) noting that all calcium is present as complex sequence of secondary (reactive) carbonates. These secondary carbonates are present as calcite, ankerite with lesser kutnahorite, siderite, rhodochrosite and magnesite with extensive solid solution throughout. Whilst early phase carbonate minerals are manganiferous (e.g. kutnohorite, rhodochrosite), latter phase carbonates are iron rich (e.g. siderite, ankerite). Furthermore, later phase carbonate events result in a finer-grained groundmass. A key aspect of this is the overprinting of pyrite by a late-carbonate rich phase in the northern section of the main open cut pit.

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Clay alteration is the dominant wall rock replacement in the Rylstone Volcanics, although there are some occurrences as fracture fill. Clay mineralogy ranging from crystalline illite is present in the high temperature zone and transitions toward poorly crystalline, interlayered smectite/illite in the lower temperature zone. However, Graham (2022) also notes that illite consistently transitions to muscovite between 150m to 200m depth.

Minor montmorillonite, chlorite and kaolinite are present within the weathered zone of the Rylstone Volcanics, the latter particularly in the northeastern section of the open cut pit. Minor occurrences of iron (e.g. jarosite) or aluminium (e.g. alunite) hydroxysulphate minerals are also observed locally within the weathered zone. As the Snapper Point Formation sediments were deposited post-mineralisation they are generally quartz rich and lack extensive clays.

2.2   Geological Information Used for the EIS

As noted in Section 2.2 of the EIS, the Bowdens Silver Ore Reserve Statement was prepared by AMC Consultants Pty Ltd (AMC, 2018). This statement was prepared using information from drilling by Bowdens Silver and previous drilling undertaken by Kingsgate Consolidated Limited, Silver Standard Australia Pty Limited, GSM Exploration Pty Limited and CRA Exploration Pty Limited. In total, this represented approximately 83,815m of drilling in 653 drill holes (70% reverse circulation holes and 30% diamond drill holes).

AMC (2018) used a multiple indicator kriging model, prepared by H&S Consultants Pty Ltd based on a silver equivalent cut-off grade, to develop a three-dimensional mining block model for the Project. This mining model also utilised ordinary (linear) kriging techniques to estimate the lead, zinc, total sulphur ($\%S_{total}$), manganese, arsenic, antimony, cadmium and copper concentrations for each $391m^3$ mining block. In total, the mining model utilised a total of 281,961 assay data points to inform the approximately 86,000 mining blocks. A summary of the data points is presented in **Table 1**.

Table 1
Mining Model Assay Data

Element	Measurement	Samples
Silver	Parts per million (mg/kg)	41,076
Lead	Percent (%)	41,078
Zinc	Percent (%)	41,078
Total Sulphur	Percent (%)	19,505
Manganese	Percent (%)	23,070
Arsenic	Parts per million (mg/kg)	41,027
Antimony	Parts per million (mg/kg)	24,704
Cadmium	Parts per million (mg/kg)	20,234
Copper	Percent (%)	30,189
Total		**281,961**
Source: AMC, 2018		

The mining model was then used to optimise design of the Project's open cut pits and develop the mining schedule and materials balance. This materials balance (and mining schedule) was based on four classifications:

1.   Primary Ore: Unweathered material with a silver equivalent exceeding the nominated cut-off grade.

2.   Low Grade Ore: Unweathered material with a silver equivalent marginally below the nominated cut-off grade.

3.   Oxide Ore: Weathered material with a silver equivalent exceeding a nominated cut-off grade.

4.   Waste Rock: All other material.

The mining schedule and materials balance was then used to inform the design and development of a range of mining-related infrastructure such as the tailings storage facility (TSF) and waste rock emplacement (WRE). However, it is noted that the techniques adopted by AMC to develop the mining model were conservative and did not account for dilution at the edges of individual mining blocks. In addition, whilst AMC identified the depth of weathering (oxidation) as averaging approximately 9m across the deposit, the mining model assumed a nominal weathering depth of 35m and applied this throughout.

2.3   Geochemical Information Used for the EIS

The mining model utilised the waste material classifications developed and presented in GCA (2020) to identify waste mining blocks within the materials schedule and balance. Following an initial static testing program (15 samples) and prior to further testing, the Project's geologist team inspected drill core for physical properties (porosity, friability and alteration (manganese and sulphur)) and assay data (including sulphur, manganese and zinc) from all lithologies within the deposit (refer Appendix 3 of GCA (2020]). GCA was also involved in the review of the extensive set of multi-element assays within the geological data base. Following this review, GCA (2020) identified that sulphide mineral occurrences were common at the metre-scale, reflective of sulphide pervasiveness, though of varying abundance, within the Rylstone Volcanics. It was also readily apparent that $\%S_{total}$ occurrences typified all lithologies, such that there is no lithological control on $\%S_{total}$ within the primary waste zone of the Deposit. Where $\%S_{total}$ was >0.3 in the weathered zone, it was generally associated with secondary products of primary sulphide mineral weathering (e.g. alunites / jarosites).

Based on the above information review, a further 113 samples of waste rock material from drill holes (54 samples with $\%S_{total} < 0.3$ and 73 samples with $\%S_{total} >0.3$) was selected by GCA in 2013 for a program of static testing to classify waste material according to its acid forming potential. This static testing program was followed by one of kinetic testing on selected, representative samples. Discussion with the Project's geologists prior to sample selection indicated that logging during drilling investigations generally indicate that within the primary waste zone carbonates occur typically in trace amounts only. This information was taken into account when selecting the 113 samples for the static testing program.

A further program of static testing, targeting low $\%S_{total}$ primary zone waste material in the western and northeastern sections of the proposed main open cut pit was undertaken in 2017. Of the 15 samples with $\%S_{total}$ <0.3, 13 were classed as non-acid forming (NAF). Whilst the

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remaining two samples were classed as low capacity, potentially acid forming (PAF), it must be noted that these samples were drawn from a two-metre section of drill core. Therefore, the results do not consider dilution and/or the buffering capacity provided by carbonates in material above and below this two-metre section that would occur during mining (e.g. a five-metre vertical mining block).

Kinetic testing was undertaken on selected samples representing the various deposit lithologies from the weathered and primary waste zones, and a range in $\%S_{total}$ values to assess the weathering behaviour over time. Kinetic testing of waste rock samples with $\%S_{total}$ <0.3 utilised seven weathering columns and was conducted over varying durations (up to 30 weeks). The duration of a weathering column test was determined by trends in leachate analysis results. However, three columns ($\%S_{total}$ between >0.1 and <0.2) were recommenced and another ($\%S_{total}$ >0.2) was added for an extended program that ran up to 162 weeks. The waste rock material for the kinetic testing program was obtained from drill core in the northern and western sections of the main open cut pit (i.e. focused on the location of materials classified as NAF). Major and minor minerals for all samples, identified by XRD, were either quartz or clays (kaolinite, illite/smectite) although some potassium feldspar was present. Accessory iron-carbonates were a characteristic of the $\%S_{total}$ <0.1 samples whilst trace alunites and jarosites were a characteristic of the $\%S_{total}$ samples between >0.1 and <0.3.

Based on the outcomes of the static and kinetic testing programmes, GCA (2020) developed a waste material classification based on $\%S_{total}$, reflective of the Deposit's absence of lithological control on $\%S_{total}$ occurrence. A summary of this classification is provided in **Table 2**.

Table 2
Waste Material Classifications (GCA, 2020)

Name	Acid Forming Potential Classification	$\%S_{total}$ Content	Comment
Weathered Zone			
WZ1	Non-acid Forming (NAF)	<0.3%	Material class devoid of pyrite with some trace alunites and jarosites (Al/Fe hydroxysulphate minerals) and rhodochrosite locally present. Also includes clays (smectite and illite) that are capable of buffering weak (aluminium) acidity. Suitable for use in construction without geochemical constraints.
WZ2	Potentially Acid Forming (PAF)	≥0.3%	Geochemically reactive, pyrite bearing material requiring selective handling, placement and storage.
Primary Zone			
PZ1	NAF	≤0.1%	Material class devoid of pyrite and suitable for use in construction without geochemical constraints.
PZ2	NAF	0.1%-0.3%	Material containing trace pyrite and/or trace alunites and jarosites in a groundmass that is variously calcareous. Situated chiefly in northern section of the main open cut pit (volcanic breccia). Local occurrences of this material also noted within primary waste zone (PZ3), though may not be mineable. Potential for sub-classification based on manganese concentration.
PZ3	PAF	≥0.3% and Total-S = 0.10-0.30% in areas distant from the northern section of the proposed main open cut pit.	Geochemically reactive, pyrite bearing material requiring selective handling, placement and storage. Occurrences of PZ1 or PZ2 in the core hydrothermal zone are considered PAF or PZ3 for the purposes of management given that they are isolated and irregular and would be difficult to separate in mining.

2.4   Materials Balance Presented in the EIS

As noted in Section 2.3, AMC (2018) applied the $\%S_{total}$ values of the waste classifications developed by GCA (2020) to the waste blocks of the mining model. This resulted in the waste materials balance that informed the preliminary design of the WRE, the staged development of the tailings storage facility and volumes of material available for rehabilitation. In summary, waste rock classified as PAF (WZ2 and PZ3) accounted for approximately 26.6 million tonnes (Mt) (57% of all waste rock) whilst waste rock material classified as NAF (WZ1, PZ1 and PZ2) would account for approximately 19.8 Mt (43% of all waste rock). The approximate quantity and percentage of each classification, as derived from the mining model of AMC (2018) and presented in the EIS is as follows.

- WZ1 .... 10 Mt (21.6%)
- WZ2 .... 4.1 Mt (8.7%)
- PZ1 .... 3.5 Mt (7.6%)
- PZ2 .... 6.3 Mt (13.6%)
- PZ3 .... 22.5 Mt (48.5%)

3. Additional Investigations and Outcomes

3.1 Geological Information Collected Since the EIS

Since exhibition of the EIS, Bowdens Silver has continued with its extensive program of geological investigation to enhance its understanding of the deposit within and around the proposed open cut pits (one main and two satellite pits). This program has employed a range of methods to ensure this understanding is supported by multiple lines of evidence. The following information has been collected from this program.

- 5,150m of additional diamond drilling within the proposed open cut pits that has been geologically logged and subjected to multi-element assay at roughly 1m intervals.

- 5,500m of diamond drilling within the proposed open cut pits that has been the subject of hyperspectral scanning (9,922 data points).

- 42,500m of diamond drilling both beneath and adjacent to the proposed open cut pits.

- More than 157 petrological observations, 143 SEM analysis and 189 XRD samples have been undertaken across the Deposit.

- A further 35 samples within the northeastern pit areas are also awaiting XRD analysis.

- The locations of diamond drill traces within the proposed open cut pit that have been subjected to multi-element assay and hyperspectral analysis are shown on **Figure 1**.

This information has been entered into Bowden Silvers' geological database alongside the data used for the EIS. This database has then been used to develop an updated geological model in LeapFrog Geo[2].

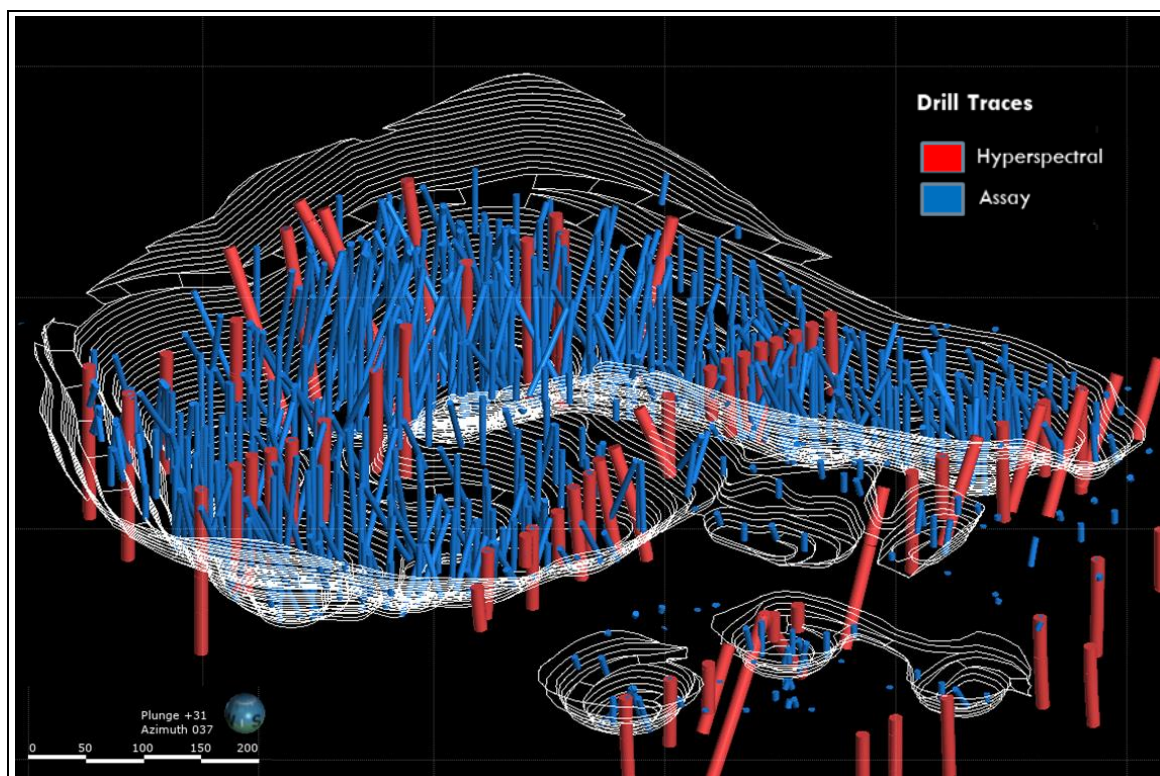
[2] See https://www.seequent.com/products-solutions/leapfrog-geo/

Figure 1
Diamond Drill Traces Used for Elemental Assay and Hyperspectral Analysis

3.2   Summary of Investigations and Data Sources

Bowdens Silver continues to collate a substantial geological database to inform its understanding of the deposit's geochemical evolution, alteration styles, zonation and mineralogy. Within and adjacent to the open cut pits that inform the materials balance, the database includes:

- Over 662 mineralogical samples examined via a range of structural and optical techniques (e.g. XRD, SEM, petrography) to characterise the entire mineralised system. Including the northern sections WZ1, PZ1, PZ2(NAF) of the proposed main open cut pit.

- Within the pits some 46,748m of drilling samples with multi-element assay data at 1m intervals (average) and a further 52,066m adjacent to the proposed open cut pits.

- 7,106m within the proposed open cut pits that has been the subject of hyperspectral scanning (11,527 data points).

- Detailed electron optical and mechanical studies on ore zones material comprising well over 4 tonnes of sample materials, characterising the nature and occurrence of sulphide bearing mineralogy. Including the Main Zone North Ag (MNAG) metallurgical sample in the north of the pit using various size fractions comprising ~180kg concentrated and subjected to detail mineralogical analysis by CSIRO, using QEM-SCAN.

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- Two geological (petrological and mineralogical) studies[3] undertaken since the EIS was finalised using the latest electron optical techniques, in addition to ongoing research in the northern section of the Deposit and an additional five historical studies[4] specific to the Rylstone Volcanics including XRD analysis undertaken by Terry Leach in 2003, the conclusions of which underpinned the work of Elliot et al (2004).

Based on the substantial datasets, analysis and technical studies, Bowdens Silver confirms that the geological setting of the deposit, including alteration styles and mineralogy are well defined and characterised.

3.3 Confirmation of GCA (2020) Waste Classification

In summary, the hydrothermal alteration phases have resulted in the Bowdens Silver deposit being characterised by four zones, namely (from top or side edge to centre):

- An (uncomformably) overlying zone comprising the sediments of the Snapper Point Formation and un-mineralised Rylstone Volcanics with trace sulphide minerals that is classified as NAF waste rock (WZ1).

- An outer zone within the Rylstone Volcanics with negligible sulphur or manganese alteration and a late carbonate (dolomite / ankerite) over-printing event comprising NAF waste rock (PZ1 and PZ2 [low-Mn sub-variant]).

- A low temperature peripheral zone within the Rylstone Volcanics with trace sulphide (low concentration), manganese minerals and silver rich ore. Interfingered benches of waste material in this zone are classified as NAF (PZ2 [high-Mn sub-variant]) and PAF (PZ3).

- A core high temperature zone within the Rylstone Volcanics comprising ore (base metals) and trace sulphide (higher concentration) minerals. Waste material within this zone is classified as WZ2 and PZ3 (PAF) corresponding to location within the weathered zone and primary zone, respectively.

These zones are clearly defined in the geological model sections through the main open cut pit that are presented on **Figures 2** and **3**. These figures also provide insight to the spatial relationship of the hydrothermal sulphide alteration zone with the dacitic intrusive that, whilst not shown is beneath the southwestern section of the main open cut pit.

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[3] See Keothammavong S. (2018) and Lay A (2019)
[4] See Leech (2003), Kuoni J (1991), Cranney, D (2012), Marshall G (1990) and Perry, B (1998)
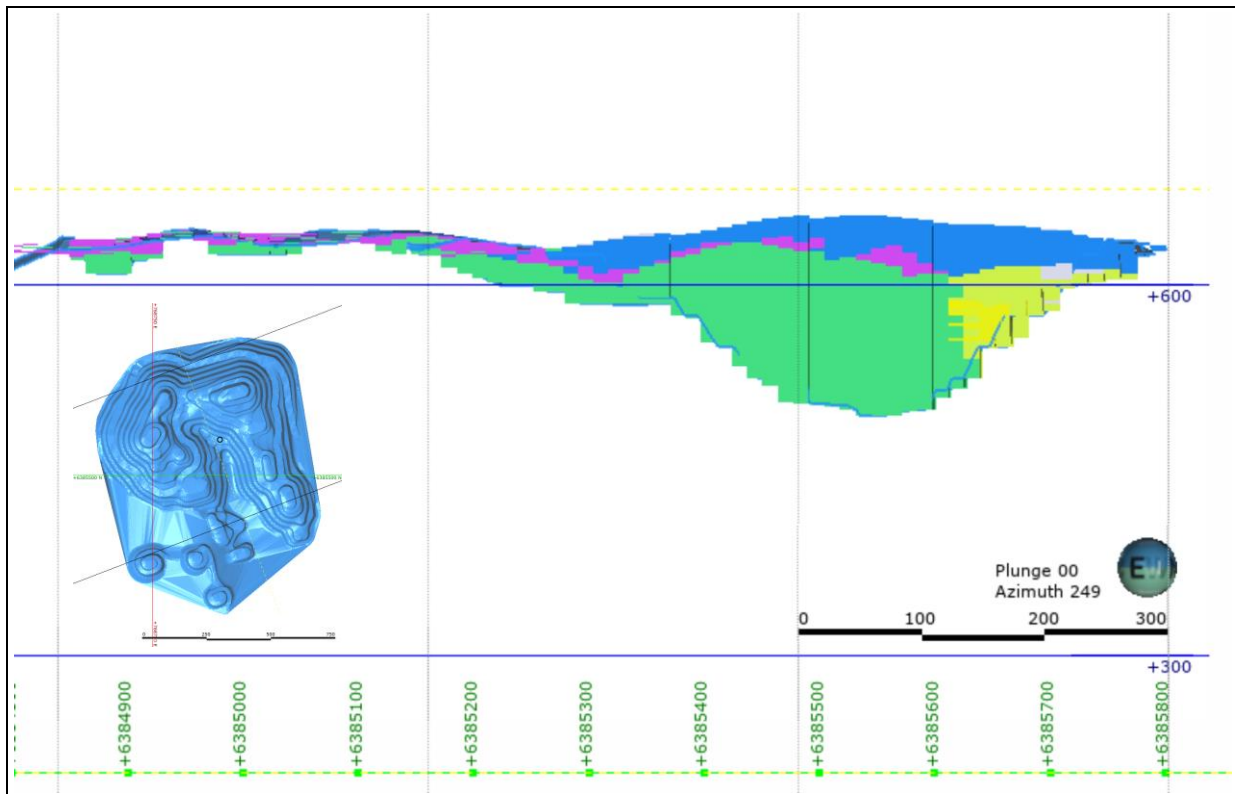
Figure 2
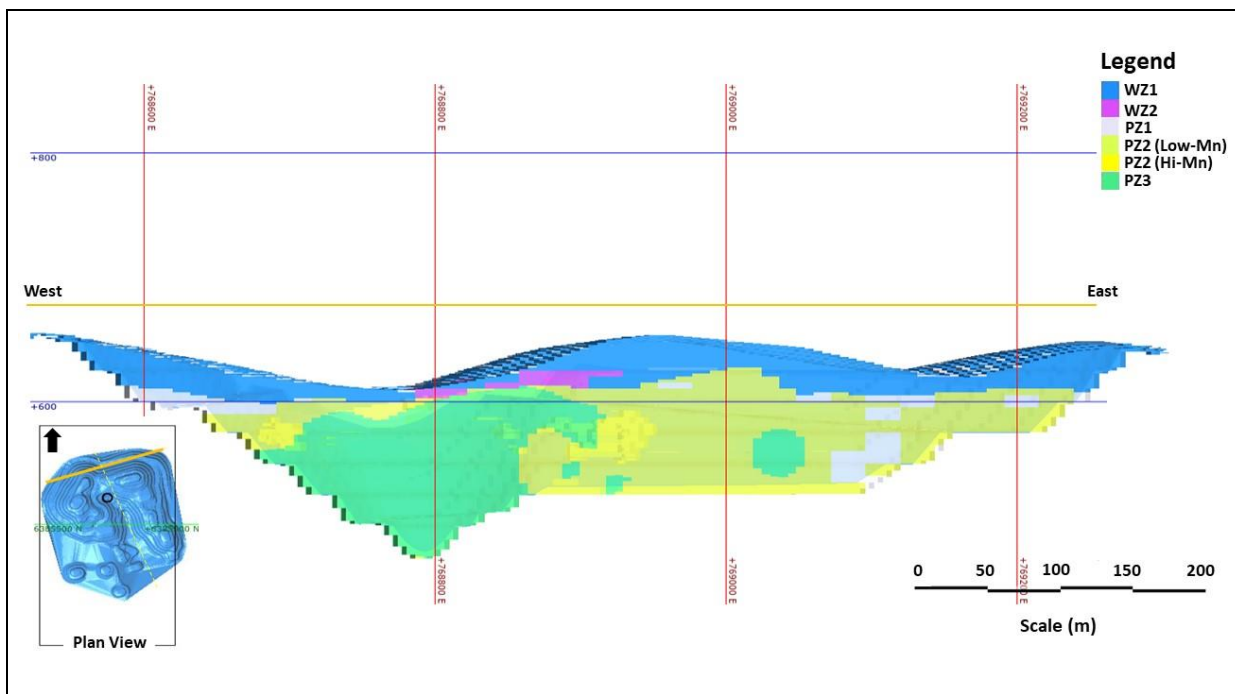**South-North Section of Geological Block Model Showing Waste Material Classification**

Figure 3
West-East Section of Geological Block Model Showing Waste Material Classification

Furthermore, continued drilling and sampling to refine the boundary of the $\%S_{total} > 0.3$ mineralisation (refer **Figure 2**), confirms accuracy and robustness of the EIS materials balance as well as its suitability for waste classification, noting:

- sulphur enriched areas align with PAF waste (WZ2 and PZ3) in the EIS materials balance;

- weathered zone PAF waste material (WZ2) is located at periphery of the core hydrothermal zone; and

- the spatial off-set from the dacitic intrusion generally accord with the high-Mn areas with $\%S_{total} > 0.3$.

- the zoning of hyperspectral illite crystallinity (temperature of crystal formation) data align with the spatial off-set from the dacitic intrusion and areas with $\%S_{total} > 0.3$.

The boundary of the hydrothermal sulphide alteration zone has been well constrained by drilling, the periphery of which can be described as a transition zone from $\%S_{total} > 0.3$ to <0.3. Therefore, geologically, the findings of the work undertaken by GCA (2020) correctly reflect the hydrothermal alteration phases, not lithology, as the key drivers of the Deposit's ore and waste material's geochemical characteristics and ensuing behaviour when exposed to conditions at surface (i.e. water, air and rock interactions).

3.4 Update to Waste Classifications of GCA (2020)

3.4.1 Introduction

GCA (2020) indicated that soluble manganese concentrations of waters in contact with locally manganese enriched PZ2 NAF waste material may, on occasion be within the low mg/L range. Therefore, GCA (2020) considered the future demarcation of sub-variants of PZ2 waste material based on manganese content would be useful to ensure effective management and application of this material within the Mine Site. Provisionally, GCA (2020) proposed a manganese cut-off value of 1,000mg Mn/kg to demarcate low-Mn and high-Mn sub-variants of PZ2.

3.4.2 PZ2 Sub-variants

Increased mineralogical and lithochemical understanding from geological logging, assays, petrology and hyperspectral analysis work has allowed the demarcation of two PZ2 sub-variants, namely:

1. High-Mn PZ2 sub-variant ($\%S_{total} < 0.3$ and $\%Mn_{total} > 0.1$) with reactive manganese carbonate minerals present as thin intercepts (<1 metre); and

2. Low-Mn PZ2 sub-variant ($\%S_{total} < 0.3$ and $\%Mn_{total} < 0.1$) with reactive carbonate minerals (calcite, dolomite, ankerite) commonly present as fine veins within the groundmass.

3.5   Updated Material Balance

3.5.1   Materials Balance Using Total Sulphur Calculations

Bowdens Silver has re-evaluated waste material volumes using the geological model built using the higher resolution dataset and by applying $\%S_{total}$ boundaries based on the waste classification values presented in **Table 2**. To spatially constrain the extent of a given $\%S_{total}$ boundary, a 50% probability of the $\%S_{total}$ value occurring at that point was adopted as the test condition. By adopting this approach, all mining blocks within the $\%S_{total}$ boundary are conservatively assigned the waste classification defined by the $\%S_{total}$ boundary, thus removing all uncertainty in material volumes. The use of a $\%S_{total}$ < or > 0.3 boundary is therefore appropriate, as it assumes any occurrences $\%S_{total}$ <0.3 waste material within the broader $\%S_{total}$ >0.3 shell is PAF. Therefore, the various waste rock classifications are delineated with high confidence, volumes re-calculated and the materials balance updated. As noted in previous sections, alteration zones within the Deposit, when tested by drilling, prove distinct and reliable boundaries. This proves that not only is the geological model reliable and robust, but that waste classification based on $\%S_{total}$ is entirely appropriate in the absence of lithological controls on sulphide abundance.

In addition, as recommended by GCA (2020), the materials balance re-evaluation included consideration of the PZ2 sub-variants introduced in Section 3.4 via the adoption of a $\%Mn_{total}$ >0.1 boundary.

A comparison of materials balances, as presented in the EIS and from re-evaluation of the geological model is presented in **Table 3**.

Table 3
Comparison of EIS and Updated Materials Balance Based on $\%S_{total}$

Acid Forming Potential	Waste Classification	Materials Balance				
		EIS (2020)		Updated (2022)		
		Kilotonnes (kt)	Percent (%)	Kilotonnes (kt)	Percent (%)	% Change
NAF	WZ1	10,009	21.6	9,917	21.4	-0.2
NAF	PZ1	3,516	7.6	3,234	7.0	-0.6
NAF	PZ2 (low-Mn)	6,292	13.6	7,617	16.4	2.8
NAF	PZ2 (high-Mn)	0	0	1,570	3.4	3.4
PAF	PZ3	22,524	48.5	21,478	46.3	-2.3
PAF	WZ2	4,058	8.7	2,583	5.6	-3.1
	Totals	**46,400**	**100**	**46,400**	**100**	**-**

Review of **Table 3** identifies that re-evaluation of the geological model results in a 5% reduction of total PAF waste material volumes (57% to 52%). Much of this reduction can be attributed to defining the PZ2 / PZ3 boundary condition which also constrains PZ2 to the northern section of the main open cut pit. However, the increase in PZ2 waste material and decrease in WZ2 waste material is also the result of additional drilling that refines the geological model and proves the absence of sulphur in the northern section of the open cut pit. Closer inspection of PZ2 waste material volumes also identifies:

- PZ2 waste material increases from 13.6% to 19.8% of all waste material;

- Hi-Mn sub-variant PZ2 is a minor (3.4%) component of all waste material;

- 28% (2,572kt) of PZ2 material has $\%S_{total}$ <0 .1;

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- 54% (4,961kt) of PZ2 material has $\%S_{total}$ between 0.1 and 0.2; and

- 18% (1,654kt) of PZ2 material has $\%S_{total}$ between 0.2 and 0.3.

In summary, re-evaluation of the materials balance using the geological model confirms that:

- sufficient capacity for all PAF waste material is provided by the preliminary design of the WRE (Advisian, 2020b); and

- sufficient NAF waste material is available to meet the Project's construction and rehabilitation requirements.

Therefore, re-evaluation of the materials balance confirms the conservatism and suitability of the EIS materials balance that informed design and development of Project infrastructure and rehabilitation measures.

3.5.2 Alternate Materials Balance Using Residual Sulphur Calculations

Since the publication of the EIS, multi-element assay data (calcium and magnesium) and mineralogical observations (e.g. Graham (2022)) have been applied to identify the PZ1 and PZ2 waste material's potential for carbonate buffering. Use of such assay data to calculate this buffering potential allows further analysis of the geological model to quantify waste material volumes. While Bowdens Silver considers there has been sufficient analysis of the northern section of the main open cut pit to justify this approach, it is noted that Earth Systems has raised concerns regarding the lack of physical sampling and analysis (viz. QXRD and static geochemistry test work). However, as Bowdens Silver would apply $\%S_{total}$ values for waste material classification during grade control activities as part of normal operations, the following information is provided as a means of demonstrating the robustness of the re-evaluated materials balance.

The Rylstone Volcanics are strongly felsic (i.e. silica and potassium-feldspar rich) and have been subjected to carbonate alteration events. This means that calcium and magnesium assay data may be used to assess the carbonate buffering capacity of waste material via the calculation of molar ratios to derive a $\%S_{equivalent}$ (GCA 2022a). The $\%S_{residual}$ of the assayed interval is then calculated by subtracting the $\%S_{equivalent}$ from the $\%S_{total}$ and whereby:

- negative $\%S_{residual}$ (≤ 0.0) identifies materials with surplus alkalinity (carbonate buffering) and classified as NAF;

- $\%S_{residual}$ between 0 and 0.1 identifies materials with a negligible alkalinity deficiency, negligible amounts of relic sulphides (typically surface-armoured from weathering), and thus classified as NAF; and

- $\%S_{residual} > 0.1$ identifies materials with an alkalinity deficiency and non-negligible amounts of sulphides, and thus classified as PAF.

GCA (2022b) recommends a conservative approach to this process to allow for trace calcium and magnesium bearing mineral species that may not occur as carbonates. Full details of the computational approach and its geochemical foundations are provided in GCA (2022b, refer **Appendix 2**).

It should be noted that for $\%S_{residual}$ <0.1, the relic pyrite which this represents is derived from pyrite which is not intrinsically hyper-reactive (GCA 2020). Together with its surface-armoured state developed during weathering, the resultant rate of oxidation is weak, and of no consequence environmentally. In reality, a $\%S_{residual}$ value of < 0.1 parallels a $\%S_{total}$ of <0.1 (as seen in WZ1, noting that additional buffering capacity exists in PZ1) both of which correspond to negligible oxidation rates.

It is however recognised that $\%S_{residual}$ may only be employed in the primary (unweathered) zone where mineralogical analysis identifies that calcium and magnesium occurs as reactive carbonates (e.g. dolomites and ankerites). Multiple lines of evidence indicate that, on a Deposit scale, most calcium and magnesium occurs within the Rylstone Volcanics as reactive carbonate species (Graham, 2022). This is demonstrated by the following:

- Visual observations of reactive carbonates (ankerites, dolomites etc.) within primary zone waste material that is substantiated via petrography and XRD analysis.

- Apart from reactive carbonates, calcium or magnesium bearing minerals, such as mafics, are absent from the strongly felsic Rylstone Volcanics.

- Primary feldspar minerals are either alkali (e.g. potassium) or calcium poor end-members of the plagioclase series.

- Where present, clay minerals occur as:

  – trace chlorite (confined to occasional fracture coating);

  – minor montmorillonite (with $\%S_{total}$ >0.1); and

  – dominant illite with minimal calcium or magnesium substitution, as demonstrated by the lack of correlation between illite zones (from hyperspectral analysis) and assay results.

When the calculated $\%S_{residual}$ is applied to assay data from the primary (unweathered) waste zone of the geological model, significant changes to the material balance are observed and whereby:

- 19,162kt or 41% of all waste material is PAF

- 27,238kt or 59% of all waste material is NAF

Whilst this approach does not change weathered zone waste material volumes, NAF material increases to 59% of all waste rock. This occurs via an increase to PZ2 material from 13.6% of the EIS waste materials balance to 30.5%. Again, this analysis constrains PZ2 occurrence to the northern section of the main open cut pit where the groundmass is characterized by reactive carbonate minerals. It is noted that 8.2% of the total waste rock material is the high-manganese sub-variant of PZ2, which may require some specific handling, stockpiling and management prior to use as a construction material. Notwithstanding this, re-evaluation of the materials balance using this method supports Bowdens Silvers position that the Project can meet its construction and rehabilitation requirements using waste material generated during mining and that the capacity of the WRE, as presented in the EIS is sufficient to contain all PAF waste material.

4.   Response to Earth Systems' Recommendations

4.1   Introduction

The information relied upon for the responses provided below has been drawn from Project-related documentation placed on public exhibition, industry guidance on the management of AMD risks including storage and rehabilitation of landforms containing PAF materials. In addition, Dr Graeme Campbell has also provided a detailed clarification on many matters raised by Earth Systems, this document is provided in **Appendix 2** and referred to hereafter as GCA (2022b).

4.2   Geochemical Characterisation

Recommendation

Geochemical characterisation work conducted to date is considered to be preliminary only. Much more static geochemistry data are required to establish a reliable and practical AMD risk classification system for the Project.

Response

Bowdens Silver and Dr Graeme Campbell (GCA) do not accept the statement that the Project's geochemical characterisation work to date is "preliminary". Dr Campbell commenced work in 2012 and progressed until 2020 using a representative set of waste rock samples to allow an appropriate level of materials characterisation to inform the Project's waste classification, materials balance and mining schedule. The level of information compiled by Bowdens Silver aligns with that required by Commonwealth (leading practice and sustainable development) and International (international network for acid prevention) guidance for the planning, design development and feasibility phase of a mining project.

As identified in Section 3.3, the reliability of GCA's (2020) waste classification system has been tested and confirmed using further investigations undertaken since publication of the EIS. The following matters are relevant regarding the individual classifications and NAF waste materials balance.

- Within the weathered zone, WZ1 NAF waste material is defined by the Sydney Basin Sediments which, having been formed post-mineralisation, has trace (if any) sulphur. The occurrence of alunites and/or jarosites in WZ1 material is restricted locally, as shown by the findings of the hyperspectral work.

- Within the primary (unweathered) zone, PZ2 NAF waste material, simply described, represents the transition zone from the negligible sulphur ($\%S_{total}$ <0.1) of PZ1 NAF waste material to the sulphur bearing PAF waste material classed as PZ3 ($\%S_{total}$ >0.3). This transition zone is spatially off set (between 200m-250m) from the dacitic intrusion that has a strong spatial correlation with the extent of hydrothermal alteration in the deposit. The multiple lines of evidence presented in Section 3 support Bowdens Silvers interpretation of the deposit's geochemical evolution, hydrothermal alteration zonation and mineralogy.

The work undertaken by GCA (2020) correctly identified the hydrothermal alteration phases as the key drivers of the ore and waste material's geochemical behaviour when exposed to conditions at surface (i.e. water, air and rock interactions). This imparts a degree of spatial uniformity in terms of the environmental geochemistry of the waste zones which actually simplifies waste classifications for operations via the use of 'across-lithology' $\%S_{total}$ criteria. Importantly, the spatial uniformity in environmental chemistry constrains how much sampling and testing is needed for AMD risk assessments, and especially so where the geological, mineralogical and lithochemical databases of the waste zones are comprehensive, as is the case for the Bowdens Silver Project. GCA's waste material classification, based on $\%S_{total}$ values, conservatively defines the chemical reactivity of minerals within the Deposit (i.e. primary sulphides in the unweathered zone or sulphide oxidation products in the weathered zone) and remains an entirely appropriate and "mature" approach to classifying the AMD risk of materials.

Notwithstanding this, to inform operational waste rock management during operations, Bowdens Silver would develop a Mine Waste Rock Management Plan, prepared by suitably qualified person in consultation with DPE. More detail on this Plan is presented in Section 5. However, if the presence of other reasonably hypothesised mineral assemblages were proposed and further test work identified, then Bowdens Silver would commission this work to test such a hypothesis and ensure the robustness of the waste classification strategy. The results and the outcomes of analytical programs that would be implemented during mining would be used to continually update the geological model, re-evaluate the materials balance and the suitability of the waste classification system.

As with any scientific analysis, more data generated through sampling, testing and analysis may not materially change the outcomes; provided the original sampling was representative. In this case the significant geological database compiled from drilling, assay, hyperspectral analysis and structural and optical techniques, demonstrates the suitability and conservatism of the initially proposed waste classification scheme. While the precision in outcomes required at the time of mining demands greater accuracy at a local scale, any geological risk to the waste classification scheme can, with confidence and weight of evidence, be considered highly unlikely or implausible. The sampling regime used to inform GCA (2020) has been demonstrated as being representative of the alteration zones that are not controlled lithologically, but rather by spatial association with the dacitic intrusive and the timing of alteration. This is supported by all additional investigations that clearly establish the spatial and paragenetic sequence of the setting. In this manner it is considered that the information presented in Section 2 and Section 3 satisfy best practice (such as that described in DIIS, 2016) and strongly support Bowdens Silver's confidence in seeking to proceed to develop the Project.

4.3   Behaviour of Sulphidic Mine Waste

Recommendation

The behaviour of sulfidic mine waste materials over time is poorly understood and additional kinetic test work is required to address this. From the test work conducted to date, it has not been possible to quantify the rate of pyrite oxidation / acidity generation processes, the "lag time" before acid conditions will develop, or the longevity of AMD generation from PAF waste rock or tailings.

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Response

A detailed response to this recommendation is provided in GCA (2022b, refer **Appendix 2**). As noted in GCA (2022b), in kinetic testing undertaken for GCA (2020), the PAF samples which were circum-neutral at the commencement of testing had estimated lag phases ranging up to approximately 12 months. This was based on weathering conditions in a laboratory setting (i.e. moist, fully oxygenated and thus favourable to biogeochemical oxidation of sulphides). Where sphalerite oxidation was also appreciable (e.g., in low-grade primary ores), the lag phase would be extended (and possibly indefinite), due to the NAF character of sphalerites. However, a number of PAF samples in the kinetic-testing programme were also acidic at the commencement of testing. GCA (2020) also noted that the geochemical behaviour of all PAF waste material was essentially identical thus requiring similar management strategies for handling and long-term storage.

All waste material classified as PAF would be selectively handled, transported and stored in storage facilities (i.e. the TSF or WRE) with specific design measures to manage possible reaction products. This means the TSF would be underlain by a constructed liner to limit seepage and the WRE would be underlain by a HDPE liner. Leachate generated WRE cells would be collected and transferred to a dedicated, lined Leachate Management Dam. Therefore, irrespective of the reaction rate or acid generation process, reaction products from exposure of PAF material to conditions at surface would be prevented from entering the downstream environment.

As described above, Bowdens Silver would develop and implement a Mine Waste Rock Management Plan. This plan would include field trials and testing to determine lag phases, and oxidation rates under field conditions and in a controlled environment to manage potential environmental impacts. More detail on this Plan is presented in Section 5. The data collected by such a program would be used to assess the effectiveness of proposed handling, placement and long-term storage measures and inform ongoing adaptive management to ensure proposed rehabilitation outcomes are achieved.

4.4   AMD Risk Classification

Recommendation

The AMD risk classification system is considered inappropriate for this Project, resulting in inaccurate predictions of PAF and NAF material tonnages. This will affect waste rock dump design and the availability of non acid forming (NAF) materials for construction / rehabilitation requirements. The mine block model and materials schedule will need to be updated to better quantify tonnages based on geochemistry / water quality risk and suitability for construction or rehabilitation.

Response

As identified in Section 3.3, the reliability of GCA's (2020) waste classification system has been tested and confirmed through further investigations since publication of the EIS. The Project's materials balance has been re-evaluated using two separate methods (refer Section 3.5) which were applied to the geological model that relies upon the substantial geological database compiled by Bowdens Silver (refer Section 2 and Section 3).

Irrespective of the method applied, this re-evaluation of the materials balance identifies:

- sufficient capacity for all PAF waste material is provided by the preliminary design of the WRE (Advisian, 2020a); and

- sufficient NAF waste material is available to meet the Project's construction and rehabilitation requirements.

In fact, it is anticipated that more NAF waste material than previously predicted (and consequently less PAF waste material) would be available for construction activities at the Mine Site.

Finally, the $\%S_{total}$ criteria defining the WZ1, WZ2, PZ1, PZ2 and PZ3 classifications feed directly into grade control activities via use of XRF assaying for delineation and ground mark-up in advance of actual mining.

4.5 Acidic, Neutral of Metalliferous Drainage

Recommendation

There appears to be a significant potential for acidic drainage (associated with alunite and jarosite) or neutral and metalliferous drainage (NMD) from mine materials that have been classified as "NAF". The EIS appears to assume that "NAF" waste rock is benign and drainage water quality will be suitable for discharge without treatment / management. A clear strategy is required to address these potential water quality risks from "NAF" waste rock.

Response

As the deposit is a low temperature, low to intermediate sulphidation deposit alunite occurs as a trace mineral only (where present at all). Jarosite is a weathering product of sulphides that does not occur in significant quantities within the deposit due to its geological setting. For example, just nine alunite intervals and seven jarosite intervals were identified from 9,922 hyperspectral measurements of 5,500m of drilling. These occurrences were principally constrained to waste material classed as PZ3 (PAF) which would be encapsulated within the WRE. This frequency clearly justifies their designated occurrence as "trace". XRD analysis of drill core obtained from PZ1, PZ2 and WZ1 waste materials also confirm the relative absence of alunites and jarosite. Where sufficient sulphides are present in the weathering horizon for weathering to produce jarosites or alunites, they are restricted in vertical extent and, based on $\%S_{total} > 0.3$, this material is classified as WZ2 (PAF). Further justification for use of WZ1 waste material in construction activities without the need for specific management measures (e.g. runoff collection) is provided in GCA (2022b).

Further support for directly using most NAF waste material in construction is provided by petrological observations from across the deposit which confirm it contains next to no alunite (Graham, 2022). This is expected as the deposit is not a high-sulfidation system but an intermediate low sulfidation system that lacks accessory alteration mineral assemblages likely to form with alunites.

Bowdens Silver acknowledges that other potential sources of NMD relating to the presence of manganese in reactive carbonate forms do occur in waste material classed as NAF. However, they predominantly occur as carbonate minerals, such as kutnohorite (Graham, 2022). As shown

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in **Table 3** the presence of high-manganese minerals within PZ2 waste material is limited to a small proportion of this material's overall volume. Based on the re-evaluated materials balance presented in **Table 3**, even if all of this material was excluded from use as a construction material and placed within the WRE, there would be no implications for Project-related construction or WRE capacity. Notwithstanding this, it is recognized that the high-manganese PZ2 sub-variant, may require specific handling, stockpiling and management prior to use as a construction material.

The Project, as presented and assessed for the EIS does not assume that runoff collected from NAF material stockpiles would be suitable for discharge without treatment / management. Rather, the Project's Surface Water Assessment (WRM, 2022) assumes all runoff from NAF material stockpiles is captured in appropriately sized dams with no release unless water quality meets the requirements of the Project's Environmental Protection Licence.

4.6   Waste Rock Emplacement Design

Recommendation

The waste rock dump design is unproven and appears substantially problematic, with initial indications that the site could be establishing the need for water treatment in perpetuity. Large-scale laboratory test work and/or field trials with appropriate instrumentation are needed prior to construction, to demonstrate that waste rock placement methods will sufficiently limit air entry to PAF waste rock and allow water quality objectives to be achieved. Additional management measures are required for the outer layer of PAF waste rock (e.g. 10-metre oxygen diffusion front as reported) that remains exposed to air entry during operations / post closure. Additional measures are required to manage other water quality risks from "NAF" rock. Near-surface PAF material in the final waste rock dump landform should be avoided.

Response

As described in Section 3.1, Bowdens Silver considers its understanding of the geology and geochemistry of the waste material is sufficient for the planning and design development of the Project. The level of this information aligns with that required by Commonwealth and International guidance.

It is important to note that Earth Systems (2022) also states:

"*It is positive to note that the proposed method of PAF waste rock placement is consistent with current leading practice (e.g. INAP, 2020)*".

The preliminary design of the WRE (Advisian, 2020a) has been developed in accordance with industry best practice and describes its progressive development and rehabilitation. Specific design measures have been incorporated into the WRE to manage leachate generated from active cells and that emanating from rehabilitated cells. This leachate would be directed to a dedicated Leachate Management Dam from where it would be recycled in processing operations.

The preliminary cover design for the WRE and TSF (Advisian, 2020b) does not call for PAF material to be placed near surface. Rather it is proposed that fine PAF waste material is placed above stored PAF waste material to provide a bedding layer for a geosynthetic clay liner (GCL). This GCL would provide a barrier that limits oxygen and moisture ingress to the underlying PAF

waste material. The GCL would then be covered by between 1.8m to 3.0m of NAF/subsoil and topsoil cover material (store and release). It is also pertinent to note that the preliminary design of the cover system (Advisian, 2020b) accords with current industry best practice (MEND, 2017) which states:

> *"The use of geosynthetic materials within cover systems can dramatically reduce NP* (nett percolation) *of water and oxygen ingress."*

The proposed approach and alternative options for the cover system of the WRE would be tested during development of the WRE to inform Mine closure. Alternative options may include a greater depth of NAF waste rock applied to the surface or additional liners such as the GCL, however based on the current understanding of the local setting and the materials to be encapsulated the current approach is considered the most appropriate. The testing of cover options for the WRE and triggers for the implementation of alternative approaches would be described in the Mine's Rehabilitation Management Plan with commitments to testing and the presentation of outcomes described in the Forward Program and annual Rehabilitation Report.

Regarding management of water quality risks arising from placement of NAF waste material, this matter was addressed in Section 4.5.

4.7　　Tailings Storage Facility

Recommendation

More detailed assessment of potential AMD impacts from tailings during operations and post-closure is warranted. AMD from the tailings (surface water and seepage) could become a particularly significant issue post-closure as the tailings are progressively drained. Kinetic test work and a strategy for management of PAF tailings is required.

Response

As described in the *Water Supply Amendment Report*, Bowden Silver will install a paste thickener to produce tailings with a 63% w/w solids content. Whilst this measure is primarily designed to reduce the Project's overall water demands, it will also reduce water discharged to the TSF and potential seepage. However, it is recognised that the TSF would receive rainfall and runoff with much of this water returned for processing operations. Modelling undertaken by WRM (2022) also identifies no discharge of water stored from within the TSF.

Whilst seepage rates for the preliminary design of the TSF (ATC Williams, 2020) were within the specific bounds stipulated by the NSW EPA, Bowdens Silver elected to include additional design elements for seepage mitigation. These design elements were then subjected to refined modelling for assessment of potential impacts from thickened tailings. The results of these assessments, presented in Section 3.3 of the *Submissions Report*, identified the inclusion of a bituminous geomembrane liner over the entire TSF impoundment area provided the most effective reduction in seepage. When solute transport, mixing and dilution was considered, predicted changes to water quality at Lawsons Creek from seepage were substantially limited. Bowdens Silver has committed to installing a bituminous geomembrane liner over the entire TSF impoundment unless detailed design of the TSF justifies reduced coverage can achieve the same outcomes presented in the Section 3.3 of the *Submissions Report*.

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Should the Project be approved, further assessments would be undertaken to confirm the detailed design of the liner for the TSF. This includes a commitment to undertake reactive transport modelling of possible seepage from the TSF. Bowdens Silver would also undertake further kinetic testing of tailings samples, generated from its ongoing metallurgical test work program, to assess potential acid generation within tailings and any seepage implications for downstream water quality. These assessments are standard engineering practice and would further refine understanding of seepage flux and water quality risks. The outcomes would be used to determine the most effective design elements for mitigation that would also be informed by detailed geotechnical investigations.

Further to the ongoing field trials described in Section 4.4, Bowdens Silver would also undertake trials and monitoring on sections of the TSF to assess the effectiveness of proposed rehabilitation measures, including the effectiveness of the GCL in limiting oxygen ingress. This monitoring would inform any adaptive management measures to ensure the proposed rehabilitation outcomes are achieved. The effectiveness of all measures would be routinely assessed using data collected from a comprehensive groundwater monitoring program that would be implemented for the Project.

4.8   Store and Release Cover

Recommendation

Store-and-release covers are used widely, but almost never in recent years for the purposes of AMD control. The proposed store-and-release cover systems are not considered an appropriate strategy for PAF waste rock or PAF tailings management.

Response

INAP (2017) identifies that cover system functionality and performance is a continuum with store and release systems being a component to limit infiltration of water into the stored PAF waste material. The other components of this continuum being oxygen ingress and erosion.

Whilst there is a store and release component, the preliminary design of the closure capping described in Advisian (2020b) does not rely solely on a store and release system as the means for controlling AMD. Rather the store and release component is intended to limit infiltration of rainfall into the encapsulated PAF waste material. Another critical aspect of this component is to provide soil water storage for vegetation that then removes stored water via evapotranspiration whilst stabilising the surface. The incorporation of such a component is therefore critical to achieving the Project's rehabilitation objectives for the final landform and is entirely suitable for the prevailing climatic regime, as identified in INAP (2017). The depth of the proposed store and release cover system and its effectiveness in limiting infiltration to stored PAF waste material was tested using numerical modelling and climate data obtained from SILO.

However, as identified in Advisian (2022b), the proposed cover system also includes a GCL that would provide an additional barrier to (primarily) limit oxygen ingress to the underlying PAF waste material. The GCL would be placed above the PAF waste material and then covered by between 1.8m to 3.0m of NAF/subsoil and topsoil cover material (store and release). Again, this accords with the continuum described by INAP (2017) which also identifies GCLs can dramatically reduce oxygen ingress.

As noted in previous sections, the effectiveness of the proposed capping strategy would be the subject of ongoing field trials to determine the most effective configuration. As identified in Section 3.5, the Project has identified additional NAF during re-evaluation of the materials balance that provides surplus rehabilitation materials as contingency.

4.9   Final Void

Recommendation

Pit lake water quality issues associated with AMD generation within the pit wallrock, including floor rock and highwall materials, have not been considered for the operations or post-closure phases of the Project. Potential AMD impacts on pit water quality should be assessed and a management strategy developed.

Response

Bowdens Silver commissioned a detailed Uncertainty Analysis of the final void lake's behaviour in terms of its interaction with the groundwater setting. This type of analysis is used to assess the potential future behaviour of the final void across a range of probabilities, with predictions providing an detailed understanding of potential environmental risks. This assessment has identified that at higher pit lake levels, through flow conditions may develop in some sections of the void. Given that the final void lake would be present in perpetuity and that evapoconcentration of salts, acids and metals may occur over time, Bowdens Silver has committed that the final landform would incorporate passive controls that limit or remove the occurrence of through flow.

As Bowdens Silver is at the start of its development of the Mine, it is confident that such controls can be successfully applied. Measures that have already been considered by the Company's consultants include the following.

- Constructing wetlands that artificially recharge the groundwater setting at key locations adjacent to the final void, thus locally reversing hydraulic gradients to prevent outflow from the final void.

- Amending final void geometry to increase the evaporative surface of the pit lake, thus depressing lake levels and reducing likelihood of through flow conditions developing.

- Applying grouting at select locations within the final void to provide a barrier to groundwater flow.

Assessment of constructed wetlands and the benefits from changing final void geometry support their potential adoption for passive mitigation measures[5]. In addition, grouting is also a well-known mitigation measure with numerous established practical applications. Bowdens Silver has also committed to the progressive review of the groundwater model developed for the Project to provide for model updates as mining progresses and more data is collected. This approach would provide the means for continuous improvement that ensures modelling assumptions are

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[5] See the *Uncertainty Analysis of Final Void Closure Risk for the Bowdens Silver Project* (RWC, HydroAlgorithmics, WRM and Jacobs, 2022)

progressively tested and validated through physical results. This would then allow robust testing and assessment of all proposed closure strategy(ies) such that any measure (if required) could be adopted with confidence.

On this basis, a detailed understanding of final void lake water quality and a management strategy are not considered necessary.

5.   Proposed Post-approval Actions

The identification and separation of NAF waste rock material would be a day-to-day operational requirement for the Project. An initial testing program comprising detailed material characterisation would be undertaken and would be used to develop a procedure for routine monitoring as part of grade control activities. This would guide ongoing mine development planning and management/separation of waste rock material. This is standard practice for mining developments and was referred to in Section 5.3 of the *Submissions Report*.

Large-scale field testing and trials would commence post-approval when sufficient waste material volumes are available and the initial stages of the WREs have been constructed. Data collected from the field testing and trials would be used to assess the performance of proposed management and rehabilitation measures and inform adaptive waste rock management practices (where and if required). This would ensure that the proposed AMD management and closure measures would effectively manage risks associated with placement of PAF waste material in the final landform.

Section 2.5.4 of the EIS Project Description describes the progressive development of the WRE in eight cells that would be constructed over the life of the Project. Each of the cells would be constructed in 10m lifts with progressive compaction occurring every 2m and a covering layer of finer/clayey material over each lift. Bowdens Silver would take a continuous improvement approach to WRE construction and waste rock management to enhance closure outcomes. Reliance would be placed on technical guidance such as that provided in *Rock Placement Strategies to Enhance Operational and Closure Performance of Mine Rock Stockpiles* (INAP, 2020). That document in particular describes opportunities to improve closure performance by reducing lift heights, improving layering density of materials and the use of methods to improve encapsulation, incorporate oxygen consuming materials and incorporate sulfide passivation.

Prior to the commencement of mining activities Bowdens Silver would develop a Mine Waste Rock Management Plan that would describe the ongoing program of data collection, assessment and review to inform waste rock management. This Plan would be prepared by a suitably qualified and experienced person and submitted to DPE for approval. Bowdens Silver anticipates that this plan would include (but not be limited to) the following.

- A description of the plan's objectives.

- A description of the geological and geochemical setting of the Mine.

- A description of waste material characteristics.

- A description of the environmental risks posed by waste materials.

- The waste material classification strategy, including:

    – A description of protocols for the operational identification, handling and placement of waste materials (including destination, compaction and pre-treatment).

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- A description of protocols for the WRE development and progressive rehabilitation.

- A description of ongoing validation of testing procedures and data management.

- A description of the ongoing field-testing programs to be undertaken, including testing to determine lag phases, and oxidation rates under field conditions and in a controlled environment.

- A description of triggers for reactive management based on the results of ongoing field-testing.

- Identification of the persons responsible for implementation of the plan.

- Periodic review of plan implementation including review of results of the field-testing program against the plan objectives and closure strategies.

6. Concluding Statement

Bowdens Silver considers that the geochemical test work presented in GCA (2020) and the additional analysis presented in Section 3 provides a clear and appropriate understanding of the geology and geochemistry of the setting to enable an understanding of AMD risks and inform ongoing classification and management of NAF and PAF waste material. The inclusion of additional investigations and data collection supports the waste classification system proposed in GCA (2020) with additional refinement of PZ2 classification (into sub-variants) and the consideration of the %$S_{residual}$ providing further support for the materials balance, waste classification and use of waste material in construction activities.

In summary, it has been identified that:

- 52% of all waste is classed as PAF; and

- 48% of all waste is classed as NAF.

This review confirms that the Project as presented in the EIS has sufficient NAF to support proposed construction and rehabilitation measures and the WRE has sufficient capacity to accommodate and encapsulate all PAF waste rock material. Further, the design and management of WRE and TSF, including plans for closure remains appropriate. Testing and analysis of the material characteristics, local setting constraints and approach to revegetation would be tested and refined over the life of the Project to ensure that rehabilitation objectives are satisfied.

The implementation of a detailed Mine Waste Rock Management Plan, as described above, would guide the progressive development of the Mine, including the ongoing testing, analysis and management of waste materials generated. This would ensure that AMD risks would be identified and managed over the life of the Project and ultimately, the Mine closure objectives of the Project would be satisfied.

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Appendices

Appendix 1   Note on Bowdens Deposit Mineralogy –
Dr Ian Graham

and

Hydrothermal Alteration at the Bowdens
Silver Deposit – Elliot et. al.

Appendix 2   Clarification of Key Items in GCA (2020)
Report on Environmental Geochemistry
and Implications for Mining-Stream
Management

and

Bowdens Silver Project: Computational
Approach Employing %S, %Ca and %Mg
Assays in Geological-Database for Mining
Stream Classification

Appendix 1

Note on Bowdens Deposit Mineralogy

prepared by Dr Ian Graham
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and

Hydrothermal Alteration at the Bowdens Silver Deposit

prepared by Elliot et. al.

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A note on Bowdens Deposit Mineralogy as of 15-9-22:

The mineralogy of the deposit has been studied using quantitative XRD in conjunction with detailed petrographic analysis in thin-sections in both transmitted and reflected light. In addition, selected mineralised samples have been analysed in further detail using scanning electron microscopy, electron microprobe analysis (including some element mapping) and for the trace elements in sulfides, laser ablation inductively coupled plasma mass spectrometry . In addition, the sources of C and O in the carbonates and S in the sulfides have also been examined using isotopes analysis across the deposit.

Studies on the Bowdens deposit include those of Perry (1998) from UNSW on the surface geology around the deposit, Cranney (2012) from the University of Canterbury on the silver mineralogy and geochemistry and Keothammavong (2018) from UNSW on comparison of the alteration and mineralisation within the Rylstone Volcanics and underlying Coomber Formation. In addition, as part of her PhD project on silver mineralogy and geochemistry of selected silver-rich deposits from NSW, Lay (2019) from UNSW also looked at the mineralogy, associated alteration and geochemistry of silver-rich mineralisation from the Bowdens deposit. Currently, I have on ongoing project looking at alteration across the deposit (using quantitative XRD and petrographic analysis on the same samples) and a current Honours student, Rory Carter, is investigating the alteration and mineralisation within the Northwest and Aegean zones.

Considering these studies and ongoing petrological observations I have the following comments:

The Lower Permian Sydney Basin cover sequence contains no mineralisation, is quartz-rich and lacks extensive clays. In terms of clay species, kaolinite is confined to the oxide zone and illite transforms to muscovite at a relatively consistent depth of 150-200 metres.

The limited oxidised zone at Bowdens contains minor montmorillonite-chlorite and jarosite. In the oxide zone, some of the Mn occurs in complex manganese oxides/oxyhydroxides though on a deposit scale, most is in Mn and Mn-bearing carbonates. In the oxide zone most of the Fe is in various iron oxides/oxyhydroxides, jarosite and chlorite, on a deposit scale most of the Fe is in disseminated pyrite. Pyrite is an early alteration phase throughout the deposit as disseminated grains.

Most of the Ca and Mg on a deposit scale occurs within cross-cutting veinlets of various carbonate species. The entire deposit is pervasively altered with all primary feldspars being leached of K and Ca and replaced by illite-muscovite-carbonate and/or adularia, all Ca can be accounted for in a complex sequence of secondary carbonates (dominantly calcite and ankerite with lesser kutnahorite, siderite, aragonite (at depth), rhodochrosite and magnesite and with extensive solid solution throughout.

As chlorite is rare (and mostly clinochlore in composition) within the primary zone, it should cause no processing problems. Biotite and especially amphiboles (in the case of Bowdens, ferroactinolite and tremolite) are rare in the volcanic sequence and largely replaced by illite-chlorite-carbonate assemblages. They are certainly more prevalent in the underlying Coomber Formation.

To date, fluorite and baryte (both of rare and very patchy occurrence) have only been found within the primary zone in contrast to abundant secondary carbonates, particularly calcite that occurs throughout the primary zone.

From my previous 15 years of experience working on epithermal systems including the Busai, Woodlark King and Kulumadau epithermal Au-Ag deposits on Woodlark Island, PNG; the Ojolali

epithermal Au-Ag deposit of Sumatra, Indonesia; the Strauss, Kylo, Gladstone Hill, All Nations, Silver King, Red Rock, White Rock, White Rock North and Lady Hampden deposits of the Drake Goldfield, NE NSW and current work on epithermal Au-Ag systems of the Georgetown Inlier of North Queensland, I am reasonably confident that we have a good understanding of alteration and mineralisation across the Bowdens epithermal Ag deposit.

X

Ian Graham
Senior Lecturer

Dr Ian Graham

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Hydrothermal Alteration at the Bowdens Silver Deposit, NSW

J Elliot[1], T Leach[2] and I Pringle[3]

ABSTRACT

The Bowdens Silver Deposit is a low sulfidation epithermal silver-base metal deposit that has formed on the northern margin of a hydrothermal system within air-fall breccias, ignimbrites and crystal tuffs of rhyolitic composition. The deposit lies near the north-eastern margin of the Lachlan Fold Belt and the rhyolitic host rocks are of Early Permian age. The silver mineralisation occurs as flat-lying zones of disseminations and silicic fracture-filling within the Rylstone Volcanics and is closely associated with sulfides of iron, arsenic, lead and zinc. High-grade silver mineralisation is also found in steeply-dipping fracture zones which host banded sulfide veins. Studies of the alteration products indicate that high temperature fluids, flowing from south of the current project area, resulted in quartz (±adularia) – illite/sericite alteration. Cool, low pH steam-heated waters on the northern and eastern margins of the prospect area resulted in siderite – smectite-illite clay – Fe-carbonate – marcasite – kaolinite alteration. Mixing of the two fluid types resulted in the deposition of iron and base metal sulfides, a decrease in both sulfur activity and pH of the mineralising fluid, and subsequent silver mineralisation.

LOCATION

The Bowdens Silver Deposit is located in the Central Tablelands region of New South Wales, (NSW), Australia, 29 km by road south-east of Mudgee and 23 km north-west of Rylstone. The deposit is on the eastern margin of the Lachlan Fold Belt and the mineralisation is hosted by silicic pyroclastics of Early Permian age (Rylstone Volcanics).

EXPLORATION HISTORY

The deposit was discovered in 1988 by CRA Exploration (CRAE), during regional stream sediment sampling. Between 1988 and 1992 follow up drilling defined the extent of outcropping mineralisation. The property was originally called Bowdens Gift but is now known as the Bowdens Silver Deposit (BSD), or simply Bowdens. Golden Shamrock Mines acquired the ground in 1994 and in 1997 the property was purchased by Silver Standard Resources Inc of Vancouver and is currently held under Exploration Licence 5920.

Drilling since 1994 has extended the mineralised sequence down dip towards the north from the discovery outcrops. On the basis of topography and inferred faulting the deposit has been divided into four zones. The original Bowdens Gift zone defined by CRAE has been renamed Main Zone South and the northern extension, beneath sandstone cover, is called Main Zone North. Further drilling some 400 m west of the Main Zone has defined another prominent zone of mineralisation, extending N-S for 600 m, which has been divided into Bundarra North Zone and Bundarra South Zone. All these zones comprise the Bowdens Silver Deposit.

A pre-feasibility scoping study which included metallurgical testwork and environmental studies was completed in 1997. In 1998 further extensive drilling, metallurgical studies, and

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geological mapping were completed. Environmental baseline studies continued and included surveys on flora, fauna, archaeology, meteorology, noise control and water. Further drilling and metallurgical work have been undertaken since 1998.

Since discovery of Bowdens 403 holes totalling 43 764 m have been completed at an average drillhole spacing of approximately 30 m.

LOCAL GEOLOGY

Alteration and mineralisation at Bowdens is hosted in a sequence of rhyolite pyroclastic units of the Rylstone Volcanics, that unconformably overlie fine grained Ordovician meta-sediments, which crop out in the southeast corner of the prospect (Figure 1). Post-mineral sandstones of the Shoalhaven Group (Permian) unconformably overlie the pyroclastic sequence in the northern project area (Figure 1, Pringle and Elliot, 1998).

The rhyolite pyroclastic sequence comprises four distinct, relatively flat lying units. A lower thick unit of fine-grained crystal to crystal lithic tuff is overlain by a thinner ignimbrite unit, which in turn is overlain by a unit of coarser lapilli tuff and tuff breccia. A thin (few metres) vitric tuff unit locally occurs in the uppermost portion of the pyroclastic sequence. The basement meta-sediments consist of very fine-grained meta-siltstone that alternates with lenses of coarser grained meta-sandstone.

The Main Zone of mineralisation is bounded to the east by a north to NNW trending structure, whereas mineralisation at Bundarra North and South are aligned along another north/NNW fault zone in the western part of the prospect area (Figure 1). The pyroclastic sequence has been downfaulted within a graben-like feature associated with these fault zones. A series of ESE faults are subsidiary to the N/NNW structures.

ALTERATION AND MINERALISATION

Style

The silver-base metal mineralisation is mainly hosted within air-fall breccias, ignimbrites and crystal tuff units, with minor mineralisation extending into the underlying sediments. The ignimbrites, and to a lesser degree the tuffs, are frequently welded and therefore are excellent hosts to crackle, mosaic and rotational breccia-style mineralisation, in which ore minerals are deposited within the matrix and the siliceous fill cementing the breccias. The crystal tuffs, however, display less brecciation and locally, the mineralisation may be finely disseminated within the altered matrix. A later stage of mineralisation is represented by crustiform veining, up to 100 mm in width, often within subvertical shear or fault zones, and comprising quartz-carbonate-sulfide assemblages. The zones of strong silicification and fracturing, notably within the ignimbrite units, are considered to have been the loci of mineralising fluids.

The mineralisation occurs as stacked lenses within a 20 - 80 m thick zone extending from surface, and near surface, to vertical depths of about 200 m and dipping northwards at less than 30 degrees. However, this zone is not uniformly mineralised and irregular barren intervals are present. The BSD, as delineated at present by drilling, extends 600 m east-west and 700 m north-south. In the east and north the mineralisation is terminated by inferred steeply dipping faults. The southern and western limits have not yet been clearly determined.
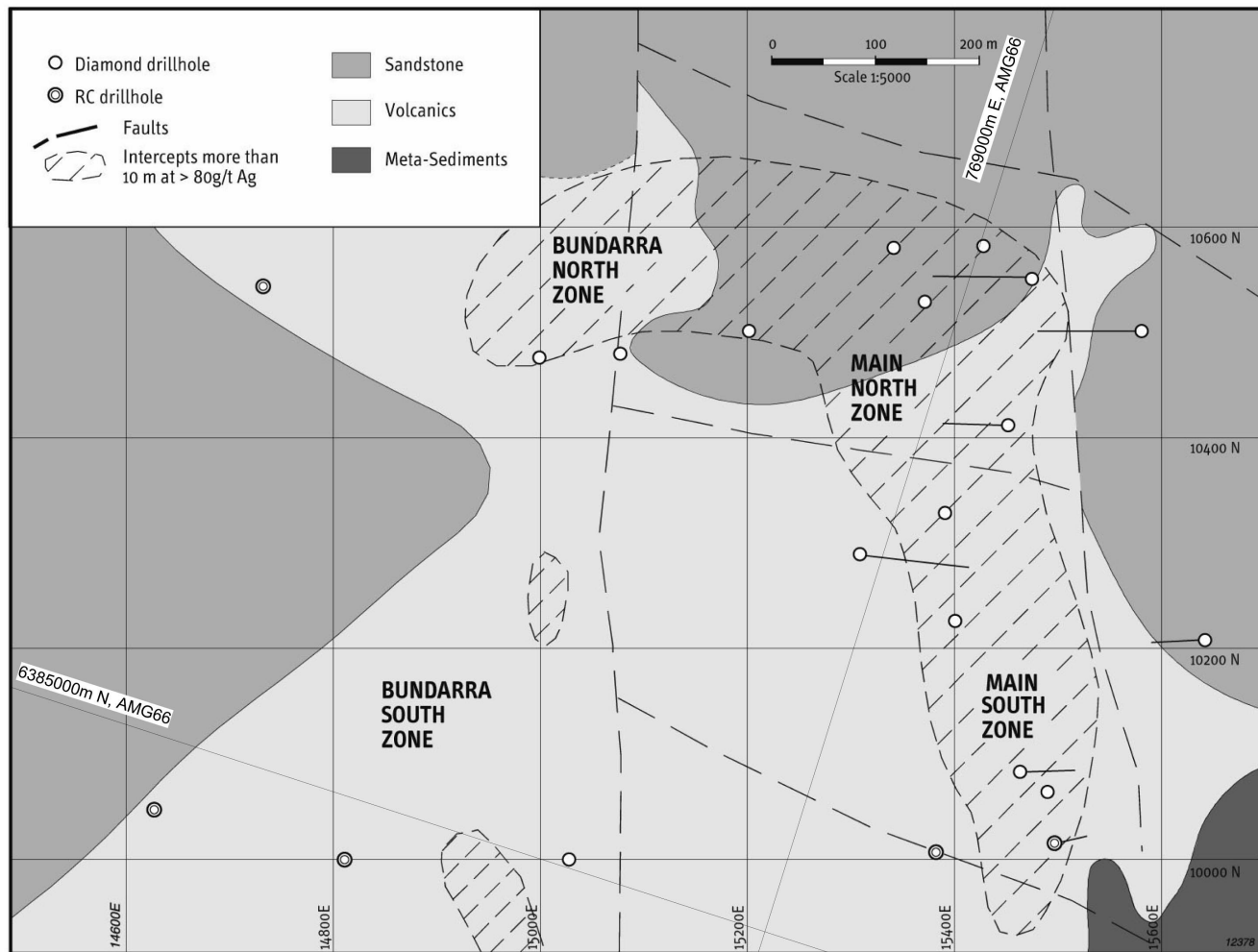
FIG 1 - Geology plan of Bowdens Silver Deposit.

Sequence

The sequence of hydrothermal events at Bowdens is initiated by an early stage of fluidised brecciation in which pyroclastic fragments have been transported, milled and sealed in a quartz-illitic clay-pyrite altered comminuted matrix (Figure 2).

The breccia event was followed by a polyphasal event that grades from early to late stages of wallrock replacement and cavity, fracture and breccia fills dominated by: quartz → sulfides → carbonate → clay. In some samples this sequence is repeated, indicating a periodically pulsating hydrothermal system. This sequence of events is identical to that recognised in the South-West Pacific carbonate-base metal-gold systems (Corbett and Leach, 1998).

Quartz replacement and deposition took place throughout all hydrothermal events, but dominated in early events that post-dated the formation of fluidised breccias. Early stage quartz is fine grained and intergrown with illitic clay + pyrite, whereas later quartz is coarser grained, clear and contains intergrowths of illitic clay, pyrite, arsenopyrite and/or sphalerite. Primary feldspar has undergone initial alteration to adularia, which also lines some fractures and cavities, and is replaced by later illite clays or sericite. Traces of hydrothermal apatite are locally intergrown with the quartz.

The abundance of sulfides increases during later quartz events and continues into subsequent carbonate-dominated events. In many of the open spaces, quartz is overgrown by sulfide minerals that exhibit an overall depositional sequence of pyrite →

arsenopyrite → sphalerite → galena → tennantite (±chalcopyrite) → silver minerals, although there is considerable overlap in this sequence. In most cases the sulfide minerals are deposited in open spaces; however they are also the product of the replacement minerals, especially mafic crystal fragments and to a lesser degree feldspar fragments and vitric ash.

Sphalerite is the most abundant base metal sulfide mineral, and exhibits an overall change from Fe-rich (red-orange in thin section) cores to Fe-depleted (pale yellow to yellow) rims, indicative of progressive cooling during mineralisation. However these zonations are polyphasal, again illustrating multiple pulses of hydrothermal activity. Chalcopyrite occurs in only trace amounts and reflects the copper-poor content of the hydrothermal fluids at this level in the system.

Carbonate minerals are intergrown with, and commonly overgrow the quartz and sulfide minerals. The early carbonate species are manganiferous, whereas later carbonates are more iron-rich. The carbonate becomes progressively finer grained during later depositional events, and locally forms very fine grained multiple colloform banding.

Clay minerals are the dominant wallrock replacement minerals and are also deposited in fractures and breccias with quartz, sulfide and carbonate minerals. Clay minerals also commonly fill open spaces and overgrow all other depositional minerals. Depositional kaolinite overgrows and partially replaces illitic clay, and locally contains marcasite and traces of galena and silver minerals.

Mineral \ Event	Fluidised Breccia	POLYPHASAL FRACTURING ± BRECCIATION			
		Quartz	Sulphide	Carbonate	Clay
Quartz					
Adularia					
Illitic Clay					
Kaolinite					
Carbonate					
Apatite					
Pyrite					
Arsenopyrite					
Marcasite					
Sphalerite					
Galena					
Chalcopyrite					
Tennanite					
Ag-Sulphosalt					
Ag-Sulphide					
Native Ag					

FIG 2 - Interpreted paragenetic sequence at Bowdens.

Silver mineralisation

Silver mineralisation took place mainly during the carbonate event and extended into the clay-rich depositional events. Silver occurs in tennantite (McConachy, 1989), as silver sulfosalts (pearceite-polybasite > pyrargyrite – proustite), silver sulfide (argentite, acanthite) and native silver. Microprobe analyses (McConachy, 1989; Pontifex, 1995) also identified stephanite/argyrodite, plagionite and cerargyrite. The silver content of the galena has not been determined. The overall sequence of deposition of the main silver minerals is: (?Ag-galena) → Ag-tennantite/freibergite → native silver → argentite/acanthite → pyrargyrite-proustite → pearceite – polybasite.

Distribution in alteration and mineralisation

The distribution in illitic clay minerals in plan view at the 500 m level is illustrated in Figure 3, as identified by x-ray diffraction (XRD) analyses. Illite and well-crystalline sericite define a relatively high temperature, N-S trending regime that coincides with a major fault in the western portion of the prospect area and broadens to the south. The clay minerals grade to interlayered smectite – illite (high smectite content) over short distances to the west, suggesting rapidly cooling conditions in that direction. To the east however, the broad zones of interlayered illite-smectite, with a progressive increase in smectite content, to the east is interpreted to reflect slowly cooling conditions, possibly associated with an outflow zone. The smectite content of the interlayered clays increases with depth in the northeastern drillholes, suggestive of temperature reversals associated with the postulated outflow zone.

Based on XRD data, Fe-rich carbonate minerals (siderite, mangano-siderite) dominate in the eastern portion of the prospect area, whereas manganese ± magnesium (rhodochroiste, kutnahorite, ankerite) are the main carbonate minerals identified in the western drillholes (Figure 3).

From polished thin section analyses, arsenopyrite occurs mainly in the south and west, whereas abundant marcasite is closely associated with Fe-carbonate formation in the north and east. The distribution in the Fe-content of the sphalerite (based on colour index in thin section) follows that of the illitic clays, and is indirectly related to the temperature of mineralisation (Simmons et al, 1988). Fe-poor sphalerite indicative of cooler conditions occurs mainly in the northeastern drillholes and at shallower levels, whereas darker, Fe-rich sphalerite is overall restricted to the western drillholes. Galena (and higher lead assays) dominates over sphalerite (and Zn-assays) as the main base metal sulfide at shallower levels, especially in the northeastern drillholes. Silver minerals are mainly restricted to samples selected from the north and east drillholes, as would be expected from the distribution in ore zones. Overall tennantite (Cu-rich silver sulfosalt) occurs at deeper levels, whereas Sb-As-Ag ore minerals (pearceite, pyrargyrite, argentite/acanthite, native silver) occur in the northeast and at shallow levels.
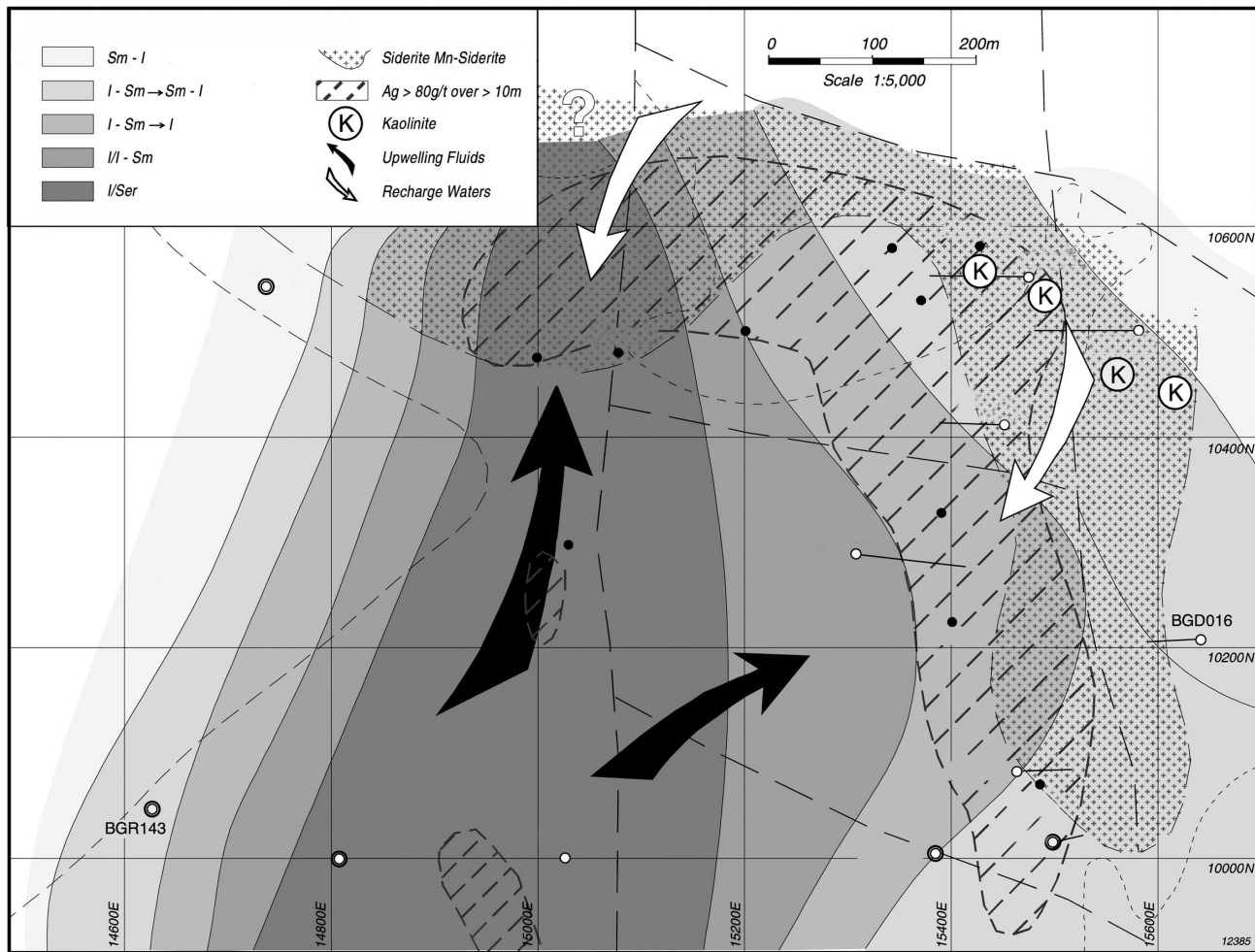
FIG 3 - Distinction in clay minerals and siderite at 500 m level.

MINERALISATION MODEL

The above distribution of the mineralisation and alteration indicates the following:

1. The Bowdens Silver Deposit formed on the northernmost margin of a hydrothermal system. High temperature fluids originating south of Bowdens flowed northwards along a major structure on the western side of the deposit and northeast along open structures or fracturing. This resulted in quartz (±adularia) – illite/sericite – pyrite – arsenopyrite assemblages.

2. Cool, low-pH steam heated waters, comparable to that encountered around the margins of many active geothermal systems (eg Broadlands; Simmons and Brown, 2000), permeated the volcanic units in the north and east, and resulted in an alteration assemblage comprising siderite – smectite-rich illite clays – Fe-carbonate – marcasite ± kaolinite.

3. The mixing of the two fluid types resulted in deposition of iron and base metal sulfides, a subsequent decrease in both sulfur activity and pH of the mineralised fluid, and subsequent silver mineralisation. The clay minerals associated with the ore zones indicate that silver – base metal mineralisation took place at less than 150 - 200°C.

The almost total absent of gold at Bowdens is enigmatic, and may reflect a geological environment comparable to that associated with silver-base metal provinces in southern USA and Mexico (Simmons et al, 1988).

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Appendix 2

Clarification of Key Items in GCA (2020) Report on Environmental Geochemistry and Implications for Mining-Stream Management

and

Bowdens Silver Project: Computational Approach Employing %S, %Ca and %Mg Assays in Geological-Database for Mining-Stream Classification

Prepared by Dr. Graeme Campbell

(Total No. of pages including blank pages = 15)

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ATTENTION: Anthony McClure

FROM: Graeme Campbell

SUBJECT: Bowdens Silver Project: Clarification of Key Items in
GCA (2020) Report on Environmental Geochemistry and
Implications for Mining-Stream Management

NO. PAGES (including this page):   9   DATE: 6th July 2022

Anthony,

The discussion below relates to the following documents:

- Graeme Campbell and Associates Pty Ltd, 2020, "Bowdens Silver Project: Materials Characterisation", May 2020, report prepared for R.W. Corkery & Co. Pty Limited

- Earth Systems, 2022, "Bowdens Silver Mine: Independent Review - Acid and Metalliferous Drainage", 31st May 2022, Technical Memorandum prepared for NSW Department of Planning and Environment

To facilitate discussion, extracts of text from the GCA (2020) report are included below, where appropriate.

1.0   WZ1 CLASSIFICATION

1.1   General

The WZ1 classification corresponds to waste-rock materials derived from the Weathered-Zone (nominal uppermost 20-30 m of the geologic-profile) characterised by

a Total-S values less than 0.3 %, as to be determined via XRF assaying during grade-control activities.

Though trace amounts of hydroxy-sulphate minerals (e.g. alunites) locally occur within the Weathered-Zone of the Bowdens Pit, these are admixed *in situ* with clays (especially illites / smectites) within the groundmass. Via various mechanisms, the latter are important 'sinks' for soluble-Al forms which is the chief source of the 'weak-acidity' associated with alunite dissolution. Furthermore, kinetic-testing programme showed that the initial weak acidity associated with leaching of 'trace-alunites' abates over time as alunite is depleted.

In addition, save for the initial weeks of weathering, leachate-Al concentrations for the tested 'alunite-bearing' WZ1 samples were consistently less than 0.1 mg/L (refer Table 9 in GCA (2020) report), reflective of the effectiveness of the illites / smectites at the Bowden site as ultimate 'sinks' for hydrolysed soluble-Al forms . This contrasts with leachate-Al concentrations within the 1.0-1.5 mg/L range reported by Linklater *et al.* (2012) for kinetic testing (undertaken by GCA) of 'alunite-bearing' waste-rock samples from Pilbara iron-ore mines with an essentially 'inert' groundmass (i.e. lack of 'high-activity' clays) in terms of sorption of hydrolysed soluble-Al forms.

That leachate-SO_4 concentrations of a few tens-of-mg/L for the weathering of 'alunite-bearing' samples were similar between the GCA (2020) testwork, and the Linklater *et al.* (2012) study, shows conformity to the (expected) near-equilibrium-type dissolution behaviour of 'trace-alunites' for all samples. Yet, the fate of the associated 'alunite-derived-Al' is totally contrasting: (re)immobilisation for WZ1 at Bowdens, versus remaining soluble for the samples from Pilbara iron-ore site.

In brief, during weathering of 'trace-alunites in the WZ1 mining-stream, any released soluble-Al forms are transients, due to interactions (including intercalation reactions) between Al and 'high-activity' clays with corresponding suppression of acidity *per se*.[1]

1.2   Manganese Solubility

As shown in the kinetic-testing programme, weathering of the WZ1 mining-stream may be a source, albeit constrained, of soluble-Mn forms.

The source of the soluble-Mn may include *inter alia* desorption of Mn(II) forms from the clay-cation-exchange complex through sorption (competitive) of soluble-Al forms derived from 'trace-alunite' dissolution. The GCA (2020) showed that Mn(II) occurs in exchangeable forms on the exchange-complex of the clays, reflective of pervasive "Mn-dispersion" at Bowdens generally.

1.3   Conclusion

Given the above, in terms of environmental geochemistry, GCA is adamant that the WZ1 mining-stream is suitable for use in construction applications, and for practical purposes may be classified as a NAF lithotype for the Project.[2]

---

[1] Though the above discussion is couched in terms of the weathering of 'trace-alunites', the same mechanisms and outcomes apply to the weathering of 'trace-jarosites' where they locally occur within the WZ1 mining-stream.

[2] NAF = Non-Acid Forming

However, depending on the specific construction application concerned, there may be a need to provide control measures for the weak source of soluble-Mn accompanying weathering of WZ1 variants containing 'trace-alunites', at least until such are depleted. Any control measures would only need to be "low-key", as indicated in Section 6.2 of the GCA (2020) report as follows:

> "Site wide application of agricultural lime (i.e. crushed limestone), or equivalent, is one option for restricting Mn solubility via precipitation reactions (e.g. Zachara *et al.* 1991). Broad scale surface dressing with crushed limestone is an integral method for controlling Mn solubility in PAF waste rock at the Martha Mine, New Zealand (Miller 2014).
> Use of agricultural lime within the Mine Site for controlling Mn solubility would require the establishment of agricultural lime stockpiles on site for use, as required. Methods and rates of application should be developed with site experience, and periodically reviewed and revised, where required."

As indicated below (from Section 6.2 in the GCA (2020) report), segregating "negligible-S" sub-variants of the WZ1 mining-stream <u>may</u> prove beneficial for site decommissioning and rehabilitation:

> "Ideally, rock material (Total-S <0.1%) should be separately stockpiled, where practicable within the southern barrier. As an added safeguard, agricultural lime should be applied both to the outer surfaces of the southern barrier, and the ground in the immediate vicinity of this barrier, in order to constrain Mn concentrations in runoff. Ensuring that the outer-most section of the southern barrier has a Mn content less than c. 1,000mg/kg should ensure that Mn concentrations in 'contact waters' are within the sub-mg/L range initially, and steadily decreasing over time."

Though the GCA (2020) testwork allows preliminary assessment of Mn-solubility behaviour for the WZ1 mining-stream, further kinetic testing of WZ1 samples needs to be undertaken on the forward-works programme for the Project to cross-correlate *inter alia* Mn tenor and solubility strength.

Operationally, in addition to %S values determined by XRF during grade-control activities, criteria need to be developed to accurately indicate where the depth of 'Weathered-Zone' locally "terminates" at the time of mining.

2.0   INDICATIVE 'LENGTH-SCALES' FOR O_2-PENETRATION INTO PAF-PROFILES AND 'LAG-PHASE' WEATHERING

2.1   'O_2-Diffusion-Front'

Construction of the PAF-profiles, for both waste-rock and LG-ore, within the Cells of the <u>Waste-Rock Emplacement (WRE)</u> via the "bottom-up" method of paddock-dumping and dozing-over will generate a reasonably well-mixed profile of clasts and 'rock-fines' broadly resembling a moderately consolidated "conglomerate-like" profile.[3]   In addition, this profile will be characterised by regular (e.g. every vertical 2 m nominal) 'traffic-layers' which are 'fines-enriched' from the dozing-over works.

In terms of O_2 supply for pyrite oxidation, the resulting PAF-profile is conducive to 'O_2-diffusion' control, save for the outermost couple of metres where convective mass-transfers locally play a role reflective of temporal (e.g. diurnal, seasonal, etc.) variations in surface-temperatures and barometric-pressures.

---

[3] PAF = Potentially-Acid Forming

As a broad indication of the reach of the 'O$_2$-diffusion-front' into an <u>uncovered</u> PAF-profile (e.g. in an active working area during WRE-Cell operation), use was made of O$_2$-Consumption Rates (OCRs) determined during the GCA kinetic-testing programme, and simple, steady-state, 1D models for O$_2$-diffusion into porous media. Such models in the global mining industry are well established since the 1990s (Morin and Hutt 1997; Gibson *et al.* 1994; Scharer *et al.* 1991).

The measured OCRs after 30 weeks of weathering of PAF waste-rock samples (1-3%S) in the kinetic-testing programme ranged from 1.4E-11 kg O$_2$/kg/s, to 6.3 E-11 kg O$_2$/kg/s, corresponding to weathering-pH values of *ca.* 3-6 (p. 3-24 in Section 3.3 in GCA (2020)). Given the %S and weathering-pH values, these OCR values indicate that <u>the intrinsic reactivity of the 'accessory-sulphides' (pyrites and sphalerites) is relatively modest</u> (cf. hyper-reactive).[4]

Assuming conformity to an ideal reaction stoichiometry for the complete oxidation of pyrite by O$_2$, these OCR values correspond to <u>Pyrite-Oxidation Rates (PORs)</u> within the range 10-60 mg SO$_4$/kg/week which translate into an 'O$_2$-diffusion-front' penetration estimation 'of-the-order' 3-10 m.

The above is the basis of the following in Section 3.3 of the GCA (2020) report:

> "Where sulphide oxidation is controlled by the diffusive supply of O$_2$ (e.g. waste rock profile within WRE constructed by the bottom-up method [Section 5.3.1]), the measured OCRs suggest that the 'O$_2$-diffusion-front' would range up to c. 10m."

It is noted that with both more detailed kinetic-testing programmes of samples of PAF waste-rock and LG-ores, and recourse to more elaborate models of O$_2$-diffusion dynamics, the above estimation of the 'O$_2$-diffusion-front' would be refined. Its provision in the GCA (2020) report was made in the spirit of indicating 'order-of-magnitude' estimations of the diffusive penetration of O$_2$ for pyrite oxidation in an uncovered PAF-profile in the WRE, constructed as per above.

2.2 'Lag-Phase'

In the kinetic-testing programme undertaken in the GCA (2020) study, the PAF samples which were circum-neutral at the commencement of testing are estimated to have 'lag-phases' ranging up to around 12 months or so, corresponding to laboratory-weathering conditions (viz. moist and fully oxygenated favourable to **bio**geochemical oxidation of sulphides via mixed consortia of autotrophic and heterotrophic microbes). Where sphalerite oxidation is appreciable (e.g. in LG-Fresh-Ores), the 'lag-phase' will be extended (possibly indefinite), due to the NAF character of sphalerites which are "non-ferroan" (or at least weakly ferroan).

A number of PAF samples in the kinetic-testing programme were acidic at the commencement of testing, corresponding in practice to waste-rock which is acidic 'ex-pit'.

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[4] This statement is based on GCA's experience since the late-2000s with the determination of OCRs and Acid-Generation Rates (AGRs) for waste-rock and tailings samples derived from a wide range of hard-rock mines in terms of commodity, geology, and S-tenors.

3.0   PZ2 CLASSIFICATION

3.1   General

The PZ2 classification corresponds to waste-rock materials derived from the Fresh-Zone characterised by a Total-S values greater than 0.1 %, but less than 0.3 %, as to be determined via XRF assaying during grade-control activities.

As part of the sample-selection programme in 2012 for the main testing programme described in the GCA (2020) report, inspection of multi-element assays continuous, downhole profiles (1m-intervals) was undertaken. It was apparent that, for the multi-element assays available at the time, the Fresh-Waste-Zone was characterised by:

      (a)   limited occurrences of Total-S values of either less than, or equal to, 0.1 % (i.e. corresponding to the PZ1 classification)

      (b)   limited occurrences of Total-S values, as defined above, for the PZ2 classification

Furthermore, where Total-S values corresponding to the PZ1 and PZ2 classifications occurred, they were restricted spatially to no more than a few metres generally. Such spatial variations in S-tenor, irrespective of lithology, reflects the style of mineralisation within the large-scale, low-grade silver deposit at Bowdens.

No PZ1 or PZ2 samples were accordingly included in the main testing programme undertaken in the GCA (2020) study.

3.2   2017-2018 Static-Testing Programme of PZ1 and PZ2 Samples

A follow-up programme of static testing on PZ1 and PZ2 samples derived from the northern end of the proposed pit was undertaken during 2017-2018, as described in Section 4 of the GCA (2020) report. This static-testing programme was initiated following a review by Bowdens Silver geologists of S assays in the geological database (expanded since the initial inspection of multi-element assays in 2012, as indicated above).

The key findings of this follow-up programme of testing were summarised in Section 4 in the GCA (report) as follows:

> "Summarising, the 2017-2018 testing program on Low-S (< 0.3%) samples from the fresh rock zone has shown that down-hole runs up to some tens-of-metres of Low-S volcanic breccia occurs in the northern end of the proposed open cut pit, located chiefly along the western edge and across the northeast corner. The tested samples represent NAF variants of Low-S rock from the fresh rock zone. The corresponding groundmass commonly contains at least traces of carbonates which includes reactive carbonates such as ankerites and dolomites. However, rhodochrosites also occur, and thus where they are active neutralisers for acid produced from the oxidation of 'trace pyrite', soluble-Mn forms would result locally."

The above work thus shows that there are mineable blocks of both PZ1 and PZ2 waste-rock derived from the northern-end of the pit suitable for construction applications, though needing to have Mn-solubility behaviour assessed through a kinetic-testing programme with possible demarcation of 'Low-Mn' and 'High-Mn' variants (e.g. Mn cut-off value of 0.1 %) for specific applications.

The need for additional work to fully characterise the PZ1 and PZ2 classifications was made in footnote-30 in Section 6.1 in the GCA (2020) report:

> "Further work would be needed as the Project progresses to more completely assess options for use of PZ2 rock (mostly volcanic breccia) to take as much advantage as possible of its desirable physical stability."

Since the PZ1 and PZ2 classifications will not begin to be intersected until around Mining-Year 4, there is time to undertake the additional work to refine these classifications for site decommissioning and rehabilitation.

Finally, in light of the expanded geological data-base and refined pit-shell design and geological modelling, domains of mineable blocks of the PZ1 and PZ2 classifications in specific regions of the bulk-fresh-waste-zone may be able to be defined, and delineated. If this proves to be the case, then static- and kinetic-testing programmes on samples from such domains stand to be of benefit to refining volume estimates and schedules for the PZ1 and PZ2 classifications.

3.3   Rhodochrosite Geochemistry

In terms of the role played by rhodochrosites (and siderites) during weathering of PAF mining-streams at Bowdens, the following from Section 2.1.1 in the GCA (2020) is pertinent:

> "Siderites are ineffective in circumneutral buffering under aerated conditions, save for the dissolution of 'trace' amounts of Mg, Ca and Mn that may be incorporated into the crystal structure of this mineral. Rhodochrosites are generally effective at circumneutral buffering, due to the sluggish aerobic oxidation kinetics of soluble-Mn(II) at circum-neutral-pH."

An important corollary here is that the dropwise addition of peroxide during the back-titration step with dilute NaOH solution for the determination of Acid-Neutralisation Capacity (ANC), variously under-estimates the effective-ANC, as governed by the proportion of rhodochrosites in the total-suite of carbonate-minerals. Importantly, at Bowdens, the nature of alteration and mineralisation is such that, where carbonate-minerals occur, rhodochrosites are often prominent, and locally may dominate.

In terms of the environmental geochemistry of waste-rock and LG-ore weathering, rhodochrosites, in effect, play a "dual-role": they are valuable neutralisers of acid generated from pyrite oxidation, but in so doing they are a source of soluble-Mn forms. This "dual-role" of rhodochrosite has long been known for waste-rock weathering generally, and for the mining-streams to be produced at Bowdens was abundantly evident early in the testing programmes performed in the GCA (2020) study.

In assessing the findings of the 2017-2018 testwork conducted on PZ1 and PZ2 samples for the GCA (2020) study, the following is cited in the Earth Systems (2022) review in the context of effectiveness of carbonates in circum-neutral buffering:

> "While some neutralising carbonate was identified (eg. dolomite), other carbonate forms (eg. siderite and rhodochrosite) will not neutralise acidity from the PAF materials …"

The above point that rhodochrosite will not neutralise acidity during weathering of PAF materials is geochemically incorrect.

4.0   SUB-RANGES OF TOTAL-S VALUES

Inspection of multi-element assays for continuous, down-hole profiles (1m-intervals) in 2012, and discussions with Project geologists at this time, indicated that alteration and mineralisation within the Bowdens deposit generally exhibit subdued S- and carbonate-tenors which spatially co-vary (anti)sympathetically within all chief primary-rock lithologies (viz. ignimbrites, volcanic breccias, cystal tuffs, and laminated tuffs).

Such geology meant that %S 'cut-off' values for demarcating NAF and PAF variants for waste-rock and LG-ore management would be tightly constrained (i.e. for waste-rock from the Primary-Zone to classify as NAF, pyrite occurrences at the metre-scale would likely correspond to 'trace-S' [e.g. <0.3%S], etc.). This was the basis for assessing the environmental geochemistry of samples of the major lithologies grouped according to Total-S values (viz. < 0.1%S, 0.1-0.3 %S, 0.3-0.5 %S, and > 0.5% S) derived from the Weathered-Zone and Primary-Zone, as appropriate.

The initial ('desk-top' / 'pre-testing') projection of indicative %S thresholds applicable across all chief lithologies within the Primary-Waste-Zone at Bowdens was confirmed by the GCA (2020) study. In addition, the established %S (and %Mn) thresholds feed directly into assessing XRF determinations undertaken during grade-control activities for 'typing' mining-streams with ground mark-up for selective handling.

5.0   MISCELLANEOUS

5.1   Net-Acid-Generation (NAG) Testing and Hydoxysulphate-Minerals

In assessing the GCA (2020) findings for samples of waste-rock from the Weathered-Zone, the following is cited in the Earth Systems (2022) review in the context of 'trace-alunite' / 'trace-jarosite' occurrences:

> "Also, at least one of the four "Uncertain though likely NAF" samples would be regarded as PAF by Earth Systems, based on a NAG pH value of 4.2."

The sample in question is GCA10664 (Sandstone, 17.9 m bgl) which had a NAG-pH value of 4.2, and a pH-(1:2) value of 4.1.

Mechanistically, the "reaction" between peroxide (H_2O_2) and hydroxy-sulphate minerals (e.g. alunites / jarosites) has no meaning (Jennings *et al.* 2000).

The reported "NAG-pH" value above simply reflects the net outcome of the effect of boiling during the NAG-testing procedure on enhanced hydrolysis/ dissolution of alunites / jarosites, and enhanced hydrolysis/dissolution of groundmass components (especially clays), in sample GCA10664.[5]

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[5] In addition to the research by Jennings *et al.* (2000), this statement is based on GCA's 'in-house' research as part of a project whose geology was characterised by pervasive alunites within the Oxide-Zone.

5.2 Limestone and Manganese

In assessing the GCA (2020) recommendation for the application of crushed limestone to assist in abating soluble-Mn in drainage-waters derived from weak Mn-sources (e.g. WZ1 mining-stream [refer citation from GCA (2020) report in Section 1.3 above]), the following is cited in the Earth Systems (2022) review:

> "Limestone would not produce a high enough pH to remove all manganese from solution. Additional treatment may be required."

Agriculturally, calcareous soils often require periodic Mn-fertilizer supplements to "correct" a Mn-deficiency reflective of the **bio**geochemical oxidation of Mn by soil micro-biota.

Broad-scale application of crushed limestone at Bowdens stands to play a useful role in constraining soluble-Mn forms derived from "weak-sources" such as the WZ1 mining-stream.

5.3 Oxide-Ores

No oxide-ore samples were tested in the GCA (2020) study, so that samples of this mining-stream need to be characterised in the Project's forward-works programme.

Save for Ag, etc., the geochemistry of the oxide-ores should be similar to that of the tested WZ1 samples. However, it is conceivable that 'trace-alunites' / 'trace-jarosites' may be more prevalent within the oxide-ores.

6.0 REFUTATION

In the later sections of the Earth Systems (2022) review, the following statements are made:

> "Geochemical characterisation work conducted to date is considered to be preliminary only."

> "The behaviour of sulfidic mine waste materials over time is poorly understood …"

GCA refutes these statements outright.

GCA fully acknowledges the need for additional sampling and testing to further refine assessment of mine-waste, LG-ore and tailings geochemistry. Such is a given for the forward-works programme for any mining project which, during operations, builds-on, expands, and integrates the data-base on environmental geochemistry generated during the approvals phase.

However, the investigatory work undertaken since 2012 for the Bowdens Silver Project is **not** "preliminary", and has identified the "key drivers" mechanistically underpinning rock-water-air interactions controlling weathering behaviour and quality of 'contact-waters' with ensuing implications for mining-stream management.

GCA would suggest that the "tables are turned" with use of "poorly understood" more aptly reserved for critiquing selected content in the Earth Systems (2022) review itself, as applied to various fundamental geochemical misconceptions identified above.

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7.0 CLOSING

The intent of the above is to clarify various points raised in the Earth Systems (2022) review of the geochemical-testing programmes, interpretation of results, and ensuing implications for waste-rock and LG-ore management, as documented in the GCA (2020) report.

I trust the above is useful to you.

Regards,

Dr GD Campbell
Director

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2213/1

COMPANY: Silver Mines Limited

ATTENTION: Anthony McClure

FROM: Graeme Campbell

SUBJECT: Bowdens Silver Project: Computational Approach Employing **%S**, **%Ca**, and **%Mg** Assays in Geological-Database for Mining-Stream Classification -

Input to Modelling of Sulphur Occurrences in Context of Carbonate-Alteration for Refining Volume Estimations

NO. PAGES (including this page): 5 DATE: 11th August 2022

Anthony,

The calculations presented herein are aimed at making use of the %S, %Ca, and %Mg assays in the geological database to assist mining-stream classification. This applies especially to the **PZ1 (<0.1%S)** and **PZ2 (0.1-0.3%S)** classifications which reside chiefly within the <u>northern-end, and north-western-flank, of the Bowdens Pit</u> where carbonate-alteration is pervasive.

In turn, the outcomes of the computation approach below usefully serve as input to refine volume estimations of the various mining-stream categories for the Project.

1.0 GEOLOGY AND LITHOCHEMISTRY

The major lithologies within the Bowdens pit are highly felsic volcanics rich in K-feldspars and silica with rare (if any) mafic-minerals. The lower crystal tuff unit and underlying basement is intruded by a dacitic sill with a porphyritic felsic texture.

In addition to intense silica alteration, the deposit has experienced multiple sulphide-mineralisation and carbonate-alteration events (e.g. four separate pyrite events have been interpreted with the initial pyrite event strongly associated with silica). The peripheral extent of these events has been defined by hyperspectral analysis.

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Carbonates (dolomites, ankerites, and calcites) occur in the groundmass, both with and without pyrite, and include *inter alia* a late carbonate overprint often as overgrowths to sulphides. Co-occurring Mn-carbonates include kutnohorites (Ca-bearing) as opposed to solely rhodochrosite ($MnCO_3$).

Given both the strongly felsic nature of the "source-geology", and the subsequent carbonate-alteration overprints, the %Ca and %Mg assays (typically for 1m-intervals) in the geological database may be put to good use in assessing the capacity for circum-neutral (pH 6-8) buffering during **bio**geochemical weathering following waste-rock generation. Employing this quantitative approach has benefited greatly from the increased drilling and assaying undertaken since the GCA (2020) study, and the resulting increased understanding of geology, alteration, and mineralisation within the Bowdens deposit.

2.0 Ca AND Mg ASSAYS IN TERMS OF PYRITE ABUNDANCE

2.1 General

2.1.1 Ca- and Mg-Bearing Carbonates

In terms of the amount of 'reactive-carbonates' (e.g. calcites) needed to maintain circum-neutral (pH 6-8) conditions during weathering of pyrite-bearing rock, the required $Ca:H_2SO_4$ mole:mole needs to be at least 2:1 (mole:mole) [MEND 2009]. This bound for the mole:mole ($Ca:H_2SO_4$) ratio reflects the typical predominance of bicarbonate (HCO_3) ions, as distinct from carbonate (CO_3) ions, during the dissolution of calcite at circum-neutral-pH. There is a degree of embedded conservatism in requiring this mole:mole ratio to be at least 2.0.

The above $Ca:H_2SO_4$ mole:mole ratio applies to Ca residing within the cation sub-lattices of calcites, dolomites, ankerites, and kutnohorites.

The corresponding $Mg:H_2SO_4$ mole:mole ratio has an identical numerical bound, as applied to Mg residing within the cation sub-lattices of dolomites and ankerites.

2.1.2 Acidity from Pyrite Oxidation

For the complete-oxidation of pyrite by atmospheric-O_2 to H_2SO_4 and "$Fe(OH)_3$", converting the %S value (assuming all S occurs as pyrite-S) to an 'acid-loading' (as kg H_2SO_4/tonne) uses a conversion-factor of 30.6.

> Example: 1.00%S as pyrite-S corresponds to an 'acid-loading' of 30.6 H_2SO_4/tonne.

This 'acid-loading' calculation corresponds to the Maximum-Potential Acidity (MPA) derived from pyrite oxidation.

2.1.3 Groundmass-Carbonate Status: %S-Equivalent Value

Since the Ca and Mg in the fresh-zone lithologies at Bowdens occur predominantly within carbonates, the Ca% and Mg% assays may be used in computations to define a %pyrite-S-equivalent, or more simply, a %S-equivalent ($\%S_{eq.}$) value corresponding to a weathering-pH regime that is circum-neutral.

Such computations comprise calculation of:

> (a)   the moles of Ca and Mg per tonne of rock from %Ca and %Mg assays

> (b)   the moles of H_2SO_4 per tonne "accommodated" by (a), subject to the above bound on the $Ca:H_2SO_4$ (and $Mg:H_2SO_4$) mole:mole ratios

> (c)   the corresponding $\%S_{eq.}$ value

The computational logic involved is presented below.

2.2   Transformation of %Ca and %Mg Assays

2.2.1   %Ca Assays

- 1.00 % as Ca = 10.00 kg Ca/tonne
  = 249.5 moles Ca/tonne (Ca $_{Atomic-Weight}$ = 40.08)
  = 124.7 moles H_2SO_4/tonne for 2:1 $Ca:H_2SO_4$ (mole:mole) ratio
  = 12.25 kg H_2SO_4/tonne (H_2SO_4 $_{Molecular-Weight}$ = 98.22)
  = 0.400 % $S_{eq.}$ (as pyrite-S using 30.6 conversion-factor)

2.2.2   %Mg Assays

- 1.00 % as Mg = 10.00 kg Mg/tonne
  = 411.5 moles Mg/tonne (Mg $_{Atomic-Weight}$ = 24.30)
  = 205.7 moles H_2SO_4/tonne for 2:1 $Mg:H_2SO_4$
  = 20.20 kg H_2SO_4/tonne
  = 0.660 % $S_{eq.}$

3.0   IDENTIFICATION OF PYRITE-BEARING WASTE-ROCK WITH EITHER SURPLUS OR DEFICIENT ALKALINITY RESERVES

3.1   Computational Approach

3.1.1 $\%S_{eq.}$ Values

The %Ca, %Mg, and %S assays in the geological database typically correspond to <u>1m-intervals</u> (i.e. "fine-resolution" spatially).

The first step is to determine of $\%S_{eq.}$ value for a given interval based on the %Ca and %Mg assays for that interval.

One $\%S_{eq.}$ value is calculated from the %Ca assay, and a second $\%S_{eq.}$ value calculated from the %Mg assay; both values are summed to give **the** $\%S_{eq.}$ value for the interval concerned.

3.1.2   Estimation of Alkalinity Reserves

In estimating the alkalinity reserves, relative to pyrite-S abundance, the %-Residual-S (%S$_{res.}$) value is first obtained by subtracting the $S_{eq.}$ value from the %S assay for each interval, i.e.

$$\%S_{res.} = \%S - \%S_{eq.} \qquad \text{Eq. (1)}$$

The possible outcomes for the %$S_{res.}$ values (as %S) calculated from Eq. (1) are:

(a)   %$S_{res.}$ ≤ 0.00

Negative %$S_{res.}$ values correspond to intervals with an <u>alkalinity surplus</u> (i.e. intervals classify as <u>Non-Acid Forming, NAF</u>).

(b)   0.00 < %$S_{res.}$ < 0.10

Whilst these positive %$S_{res.}$ values reflect an alkalinity deficiency in theory, the corresponding 'residual-pyrite' represents a negligible acidification risk in practice.[1]   <u>Intervals with such %$S_{res.}$ values are thus lumped with the NAF intervals in (a)</u>.

(c)   %$S_{res.}$ ≥ 0.10

These %$S_{res.}$ values correspond to intervals with an <u>alkalinity deficiency</u> (i.e. intervals classify as <u>Potentially-Acid Forming, PAF</u>).

The above approach for classifying intervals as either NAF or PAF then permits input to modelling for delineation of waste-blocks, and estimations of volumes (and ultimately schedules) as NAF and PAF categories.

3.1.3   Low- and High-Mn Sub-variants

For the NAF classification above, 0.10%Mn could also be incorporated to demarcate Low-Mn and High-Mn sub-variants, as proposed in the GCA (2020) study for the PZ2 classification.[2]

3.1.4   Geochemical Benefit of "Mixing" During Mining

Since the assays in the geological database typically correspond to 1m-intervals, and since ground marked-up for mining from grade-control activities will correspond to larger spatial-scales of some metres, adjoining 1m-intervals with a surplus (NAF) or deficient (PAF) of alkalinity reserves will be locally 'taken' together when mined. Thus, the 'fines-fraction' of a 1m-interval of the PZ2 stream which classifies as PAF stand to have surplus alkalinity nearby following mining, dumping, and dozing of waste-rock.

Based on the computations above for the 1m-intervals, such geochemical benefit of "mixing" may be able to be captured during modelling for volume estimations where spatial-scales larger than 1m are employed.

3.2   Added Level of Conservatism

In terms of an added level of conservatism to the computational approach above, one option could be to first subtract 0.10%Ca from the %Ca assays, and 0.05%Mg from the %Mg assays, in the geological database (i.e. not all Ca and Mg taken to occur as 'carbonate-Ca' and 'carbonate-Mg'). And, then to proceed as outlined.

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[1] Importantly, the 'trace-pyrite' within the PZ1 (<0.1%S) and PZ2 (0.1-0.3%S) streams is **not** intrinsically hyper-reactive (GCA 2020), as is the case for framboidal forms associated with sedimentary provenances (e.g. pyritic horizons of acid-sulphate soils).

[2] As noted in the GCA (2020) report, this Mn 'cut-off' value of 0.10%Mn for PZ2 is provisional, and subject to be confirmation (or refinement) through testing.

4.0   CLOSING

As indicated in the recent GCA (2022) review, on-going drilling and other technical work since the GCA (2020) investigation has meaningfully added to the geological understanding of the Bowdens Deposit, thus allowing refined assessment of mine-waste management in terms of environmental geochemistry.   The computational approach presented herein utilising %S, %Ca, and %Mg assays for mining-stream classification is a clear case in point, and through incorporation into modelling, usefully refines volume estimations for the Project.

I trust the above is useful to you.

Regards,

Dr GD Campbell
Director

Acknowledgement: *Discussions with Mr David Biggs (Geological Data Scientist) concerning geological details of the Bowdens deposit, especially the improved understanding gained from drilling and other investigations since the GCA (2020) work, are gratefully acknowledged.*

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