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1 Introduction

The contents and presentation of the Geology baseline, impacts and mitigation is dictated by Ministerial Order 863 (M.O. 863/2002) of the Ministry of Waters and Environmental Protection (Annex 2, Part 2, Section 4.4). Components of the geologic condition apply to other regulated Project components, such as the design of facilities described in Section 2 – Technological Processes, and geology-related chemical impacts that effect water quality as described in Section 4.1, Water. In addition, the regulations and permits that relate to mineral extraction also have a geologic component associated with them.

In accordance with the Mining Law 61/1998, the National Agency for Mineral Resources (NAMR) awarded the Mining Licence 47/1998 for mining and processing of gold and silver resource/reserves of Roşia Montană perimeter (Government Decision 458/10.06.1999) to CN MINVEST S.A (MINVEST) as licence holder and to SC RMGC S.A (RMGC) as its licence holder affiliate. The licence was awarded in June 1999 on the date of its publishing in the Official Journal 285/21.06.1999.

In October 2000, the licence was transferred from MINVEST to RMGC according to the NAMR order published in the Official Journal 504/13.10.2000. In addition, MINVEST transferred to RMGC Title Holder rights by means of Additional Deed No. 3 and the NAMR Order No. 310/09.10.2000, and thus, MINVEST became the affiliated company while RMGC became responsible for the completion and funding of all geological detailed investigations and mine development. The applicable licence perimeter for this project was re-defined in Additional Deed No.6, dated 21/06/2004. This amendment substantially reduced the area of the mine licence. The license was granted initially for 20 years and it can be extended five successive years.

The EIA requirements for “Subsoil Geology” associated with M.O. 863 are specifically addressed herein. As required by M.O. 863/2002 the impacts and associated mitigation measures for geology are described in this section. Impacts are generally related to removal of geologic resources and exposures, hydrogeologic impacts, and chemical impacts associated with the geology. Impacts related to surface water and groundwater are presented in more detail in association with Chapter 4.1. Water
2 Baseline Conditions

The baseline geologic conditions of the Roşia Montană Project are presented in this section. The regional, local and Project site geology are described including a discussion of the mineralization that is the basis for the Project (Sections 2.1 and 2.2). Seismic activity in the area is described in Section 2.3. This geologic component is a critical consideration in the design of many of the Project facilities. This is followed by a presentation of the hydrogeology in Section 2.4. The hydrogeology is the geologic component that relates to the presence and movement of groundwater. The geology in the Project area also has potentially chemically reactive lithologies, which can give rise to impacts on soil and water quality by introducing polluants. This component of the geology is discussed in Section 2.5 and largely relates to the generation of acid rock drainage (ARD). Other specific geologic components considered under M.O. 863/2002 are presented in Sections 2.6 through 2.9.

2.1 Regional and Local Geology

Much of the following discussion on the geology associated with the ore deposit has been published in Leary et al. (2004). This section and a portion of the following section liberally cites information in this document, much of which has been developed for RMGC. The following sections discuss both the geology outside of the mineralised area and within the project boundaries.

Romania includes three major Mesozoic aged and older mountainous terrains, namely the Carpathian chain that includes Southern and Eastern Carpathians, the Apuseni Mountains and the Northern Dobrogea terrain. Late Tertiary aged sediments have been deposited in the intervening Pannonian and Transylvanian Basins, and on the Scythian and Moesian Platforms. Two principal areas of Tertiary volcanic rocks, of predominantly calc-alkaline affinity, intrude and overlie these sequences. The first area is in the Eastern Carpathians, from the Baia Mare area in the north (Oaş-Gutăi mountains) to the Călimani-Gurghiu-Harghita mountains in the south, and containing a subvolcanic median sector (Ţibleş-Toroiaga-Rodna-Bârgău mountains). The second area is the Apuseni Mountains in west-central Romania, which is the location of the Roşia Montană Project.

The famous mining districts of the Apuseni and Metaliferi regions of Transylvania comprise a 900 km² area in the Apuseni Mountains, immediately to the north of the city of Deva, commonly referred to as the Golden Quadrilateral. Mineralisation within the Golden Quadrilateral district includes mesothermal porphyry intrusive-related gold-silver, copper-gold and copper deposit types associated with Tertiary (Neogene epoch) volcanic rocks, and associated sub-volcanic intrusive rocks. Three major northwest-trending belts of volcanism and associated mineralisation are identified within the Golden Quadrilateral, with the Roşia Montană Complex representing part of the northernmost belt (Exhibit 4.5.1).

The Golden Quadrilateral has remained Europe’s most important centre of gold production for more than 2000 years since Geto-Dacian (pre-Roman) times. The Roman conquest of Dacia in 105AD-106AD was predicated on gaining control over this important goldfield. The district reached peak production during the period of the Austro-Hungarian Empire, from the end of the 17th Century to 1918.
The geology of the Golden Quadrilateral consists of Mesozoic aged, shallow marine and non-marine sedimentary rocks overlying Palaeozoic and Precambrian sedimentary and metamorphic basement. North-directed thrust faulting during the late Cretaceous resulted in a series of nappes that are unconformably overlain, and intruded, by Tertiary volcanics and intrusions.

The Tertiary (Miocene) volcanism has been subdivided into three cycles. The earliest cycle is interpreted as lower Badenian aged (approx. 15 to 16.5 My) and contains andesitic volcanics and rhyolitic ignimbrite overlain by andesitic and rhyodacitic volcanics. Volcanogenic sediments occur throughout this cycle, and widespread hydrothermal alteration overprints all rock types. Volcanic rocks of the second cycle outcrop extensively and are characterised by andesite and dacite overlain by a very thick sequence of quartz andesite that is, in turn, overlain by pyroxene andesite. This sequence is interpreted to be late Badenian (approx. 13.5 to 15 My) to early Pannonian age (approx. 9 to 11 My). The third and final cycle of volcanism continued into the Quaternary era (2 My to present) and is characterised by pyroxene andesite, basaltic andesite and potassic basalt.

The middle and upper sequence of the second cycle represents the principal host to gold-silver mineralisation currently being mined in Romania. Significant occurrences of copper, lead, and zinc are also present in the sequence.

2.2 Project Geology and Implications to Mine Development

The Roşia Montană volcanic sequence is interpreted as a maar-diatreme complex emplaced into Cretaceous sediments, predominantly black shales, with sandstone and conglomerate beds (Exhibit 4.5.2). The three dimensional geometry of the area is well established due to an extensive network of underground mines that have been developed since the Austro-Hungarian Empire period, and from the extensive drilling conducted from the surface and underground over the last 25 years.

Rock types within the maar-diatreme complex are dominated by breccias, including phreatomagmatic breccias, complexly re-worked and subaqueous breccias and volcaniclastics, intruded by a series of porphyritic dacitic sub-volcanic intrusions, dacitic dykes and later phreatomagmatic breccias (phreatomagmatic breccias form due to explosive eruptions of steam and other gases). The dacitic intrusions are interpreted as Neogene age and are informally named the Cetate Dacite and Cârnic Dacite. The dacite complex is interpreted to have intruded vertically into the maar breccias, sediments and volcaniclastics and to have spread laterally at shallower levels. An alternative interpretation is that only one major dacite intrusion has occurred and that this has been split into the now separate Cârnic and Cetate dacite bodies by a northeast trending strike-slip fault.

The majority of the Roşia Montană volcanic deposit is made up of a lithology locally referred to as the “vent breccia”. This is a diatreme breccia created by numerous phreatomagmatic eruptions produced as hot rising dacitic magma interacted with groundwater. It is of variable composition with clasts of dacite, Cretaceous sediments and basement schist and gneiss. The clast size, degree of rounding, and the proportion of matrix, vary widely. Texturally it exists as both massive breccia units and sub-aqueous reworked breccia indicating the breccia has erupted into a shallow lake or maar. This reworked vent breccia is fine to coarsely bedded and varies from clay-rich, to more common sandy and gravelly beds, to beds containing poorly sorted, cobble sized clasts. Graded bedding is common and cross bedding and ripple marks have also been observed suggesting the presence of a lake or flow water. The vent breccia hosts the dacitic intrusives, as well as multiple later crosscutting phreatomagmatic breccia bodies.
Within the vent breccia a large (1 km by 1 km at the surface) body of breccia has been delineated as a separate phreatomagmatic event. This is composed of generally massive (some sedimentary reworking exists in the upper levels), poorly sorted, matrix-supported breccia, with sub-angular to sub-rounded clasts of dacite, Cretaceous sediments and basement metamorphic rocks. The breccia is distinct because it is the only breccia body at Roșia Montană that still contains significant magnetite. The magnetite is coarse and interpreted to be of magmatic origin. Chlorite also occurs as an accessory mineral in altered clasts. Some sulphide is present as pyrite particles in the matrix or in scattered phyllic-argillic (clay) altered clasts of dacite. It is interpreted that this breccia was emplaced after the main period of sulphide mineralisation, which is supported by a 40Ar/39Ar date on a hornblende separated from juvenile dacite clasts (11.0 ± 0.80 Ma), which is over 1 million years after the youngest date recorded for the mineralisation (12.71 ± 0.13 Ma).

A breccia, locally termed the ‘**Black Breccia**’, forms a sub-vertical pipe in the centre of the diatreme, between the Cetate and Cârnic dacites. The breccia is matrix supported, with clasts of dacite, Cretaceous sediment and basement garnet-bearing schist and gneiss in a matrix of pulverised (rock flour) Cretaceous shale, which gives the breccia its black, clay-rich character.

A number of other intrusive diatreme (phreatomagmatic) breccia bodies crosscut the reworked vent breccia and also the Cârnic and Cetate dacites. Five of these have been identified in the vicinity of the Jig area, where they have a sub-vertical, pipe or lens geometry up to 100m in width. Within the dacites they form multiple broad (up to 100 m wide) to narrow (a few centimetres wide) dykes or breccia pipes. In both locations, the breccias are structurally controlled, with the pipes and broad dyke breccias forming at the intersection of large structures. These are composed of matrix-supported breccias with sub-rounded clasts of dacite, Cretaceous sediment and crystalline schists. The breccia bodies in the Jig area have a high proportion of metamorphic clasts, making them easily identifiable from the surrounding vent breccia and also indicating that the phreatomagmatic eruption originated in the metamorphic basement at depth. Texturally they vary from poorly sorted to moderately sorted with a matrix of fine clay (pulverised rock) in many of the dykes at Cârnic and Cetate to a more sandy matrix in the Jig area breccias.

Andesitic extrusive rocks have been mapped as mantling the northern and eastern parts of the project area, forming a thin to moderately thick cover over the maar complex. The andesitic units are post mineralisation in age and consist of unaltered agglomerates and flows.

### 2.2.1 Structure

The Roșia Montană diatreme is interpreted as being emplaced at the intersection of two sub-vertical structures that trend north-northwest and northeast. The north-northwest trend is interpreted to be the more pervasive of the two structures, and is thought to be a deep seated, basement structure of regional scale that has produced the broad zone of fracturing and veining seen on the surface within the dacites, vent breccia, and Cretaceous sedimentary rocks. The dominant vein orientation strikes parallel to it and is either sub-vertical or dips steeply to the west. A system of large northeast trending sub-vertical faults bound and cut through the Cârnic and Cetate dacites. At Cârnic these have provided a structural path for breccia dykes and also offset the dacite-vent breccia contact.

A system of northwest trending faults has been mapped along the northeast side of Cârnic. These are interpreted as being active during the diatreme formation, as these structures can contain phreatomagmatic breccia dykes, during mineralisation and also post mineralisation, as they can be unmineralised but cut through well mineralised dacite or breccia.
Mapping in the Cârnicel (immediately southwest of Cârnic) and Cetate areas has also identified an east-west fault structure that dips 40-60° to the south. The last phase of movement on the fault post-dates the mineralisation as it offsets the late stage carbonate-base metal sulphide ‘Argint’ vein at Cârnicel. The sense of movement appears to be normal, possibly with some right lateral strike slip. Other east-west structures have also been mapped and interpreted at Cârnic and Cetate, with east-west to west-northwest trending sub-vertical polymictic breccias cutting through the Cetate dacite.

### 2.2.2 Hydrothermal Alteration

An extensive zone of hydrothermal alteration is associated with the Roșia Montană deposits. The distribution of alteration assemblages is complex with five identified assemblages, however, it can be simplified to two key groupings:

- Clay-sericite-pyrite (argillic) assemblages that generally occur peripheral to the core zones of gold-silver mineralisation;
- Silica-adularia-pyrite-sericite (silicic) assemblages, which usually represent the core zones of the various deposits at Roșia Montană. This alteration type is pervasive and associated with precious metal mineralisation.

An additional late stage carbonate-quartz-clay (illite)-sulphide event overprints the main alteration event and forms narrow veins and fracture fill. In addition, chlorite-carbonate-pyrite (propylitic) alteration assemblages are regionally developed within the andesites and the vent breccia in the Corna Valley.

### 2.2.3 Mineralisation

The gold-silver mineralisation at Roșia Montană is interpreted as a mid- to shallow-level, low to intermediate sulphidation epithermal system that may be associated with a porphyry-style system at depth. Gold-silver mineralisation in the Roșia Montană Project area is present in the following types:

#### 2.2.3.1 Dacite-hosted mineralisation:

This type of mineralisation is characterised by wide zones of finely disseminated sulphide (pyrite) hosted within dacite porphyry. Quartz-illite-pyrite and silica-adularia (silicic) alteration are distinctive features of the mineralised dacite and the best indicator of gold and silver grade. Narrow, usually widely spaced stockwork veining is always present but is minor in terms of contained gold and silver. The veins are generally steeply-dipping, discontinuous and less than 1 m wide, in places the veins have blown out into narrow hydrothermal breccia pipes. Significant gold mineralisation of this style occurs at Cetate and Cârnic.

#### 2.2.3.2 Sub-vertical breccia zones crosscutting dacite intrusive bodies:

Breccias are commonly of mixed lithology and are considered to represent structurally controlled phreatomagmatic breccias. Mineralisation occurs within strongly, to intensely, silicified alteration zones and contains low to moderate amounts of disseminated fine-grained sulphide within both the matrix and breccia clasts. Relevant examples of this type are known in Cetate and Cârnic massifs.

A zone of monomictic (single rock type) crackle breccia, with angular blocks of dacite in a fine matrix of rock flour often occurs along the margin of the polymictic (many rock types) breccia bodies that they originated from. These can be fairly localised features and formed as the polymictic breccia events crackle-brecciated the surrounding dacite or caved blocks of the adjacent dacite into the breccia pipes or dykes. These crackle breccia zones often have
a higher permeability and therefore focus the mineralising fluids and become well mineralised. At Cârnic a significant volume of this type of brecciation occurs at the bend in the main breccia body. This is also coincident with a zone of well mineralised hydrothermal brecciation and an area that has been heavily mined by large Corandas (stopes) in the past.

2.2.3.3 Disseminated and vein hosted gold-silver mineralisation within vent breccia:

Significant gold-silver mineralisation is hosted by the vent breccia surrounding the dacitic intrusions. The mineralisation is characterised by silicic alteration and finely disseminated pyrite with infrequent and generally narrow (less than 1 m) veining, as at Jig and Orlea.

2.2.3.4 Diatreme breccia pipe hosted mineralisation:

The sub-vertical diatreme breccia pipes at Jig host this mineralisation. It is characterised by intense, pervasive silicic alteration of both the breccia matrix and the diatreme breccia clasts. Disseminated pyrite is also pervasive within the matrix and clasts and will sometimes completely replace the black shale clasts. Zones of rhodochrosite have also been identified, occurring within the matrix of the diatreme breccia.

2.2.3.5 Cretaceous sediment hosted mineralisation:

This mineralisation occurs directly below the vent breccia-Cretaceous sediment contact and is usually hosted by shale, sandstone and less frequently by conglomerate beds. The mineralisation is characterised by both silicic alteration and pervasive fine-grained disseminated pyrite and in some areas by hydrothermal crackle brecciation that varies from mm-width widely spaced spidery crackle breccia through to more intense mosaic (jigsaw) brecciation. Clasts are always very angular and made up of locally derived sediment. The brecciation can be over 50 m thick and tends to be most intense close to the vent breccia-Cretaceous contact. The breccia matrix is typically vuggy and crystalline, some coliform banding has been observed and up to five phases of mineralisation can be present. Mineralisation is dominated by carbonate (both calcite and rhodochrosite), quartz and pyrite with galena and sphalerite. Only a small portion of the resource is contained by this style of mineralisation.

Gold has been identified as electrum by petrography in numerous samples. Occurrences were noted as minute (4 µm) inclusions in pyrite, as minute grains (up to 25 µm) intergrown with, and overgrowing silver-sulphosalts and tellurides. It has also been observed as coarser grains (up to 100 µm) intergrown with carbonate and barite. The electrum is also associated with quartz, galena, and sphalerite with a fineness ranging from 0.537 µm to 0.763 µm.

The mineralisation will be exploited in the Cetate, Cârnic, Orlea and Jig areas. The dominant lithology at Cetate is the dacitic intrusion, which is bounded by vent breccia and black breccia (see Exhibit 4.5.2 and Figure 2.1). The dacite has been intruded into the core of the maar complex. Strong to intense hydrothermal alteration is typically developed throughout the Cetate Massif and is dominated by silicic and argillic assemblages, along with disseminated fine-grained sulphides.
Gold-silver mineralisation has been strongly developed at Cetate, both within the dacite and the surrounding vent breccias. Wide zones of gold-silver mineralisation, associated with fine grained disseminated sulphides, particularly pyrite, have been identified within a northeast-southwest trending zone, which runs along the southern part of the Cetate dacite and through to the area termed Gauri (Exhibit 4.5.2).

The dacitic intrusion is also the dominant lithology at Cârnic, similar to Cetate (Figure 1.1). The dacite has also been intruded into the core of the diatreme-maar complex. Internal to the Cârnic dacite, several planar to irregular subvertical zones of breccia with clasts of mixed lithologies occur. The breccias contain matrix supported angular to rounded fragments of the dacite and surrounding lithologies.

Within the Cârnic dacite body, gold-silver mineralisation is hosted by both internal phreatic mixed lithology breccias and the dacite body. Some mineralisation is also present within the breccia external to the dacite. The breccia zones are intensely altered, with pervasive development of disseminated sulphides both within the matrix of the breccia and the breccia fragments. Strong silicic alteration is typical within the mixed breccia.

The Orlea area represents a major zone of mineralisation located on the northwestern side of the maar complex. The bulk of the area comprises vent breccia, which is, in part, mantled by a shallow sheet of andesitic volcanics. Underlying the vent breccia at depth are black shales, which dip at a shallow angle towards the east (Exhibit 4.5.2 and Figure 2.2). To the north, the vent breccia is partially overlain by the andesitic volcanics, which are considered to be part of the Roşia Poieni complex located to the east of Roşia Montană.
Gold-silver mineralisation at Orlea occurs both within the vent breccia and to the west, in the Cretaceous shales which surround the boundary of the interpreted maar complex. Data from drilling suggest a strong east-west trend to the mineralisation. The overlying andesites are unmineralised. The quartz vein hosted gold-silver mineralisation at Orlea has been exploited since Roman times. These steeply dipping quartz veins are generally less than 1 m wide.

The Jig area represents a semi-continuous zone of mineralisation located on the northeastern side of the maar complex. The bulk of the area comprises vent breccia, which is, in part, mantled by a thin sheet of andesitic volcanics. A small (probably fault bounded) block of strongly silicified and brecciated dacite occurs at Jig and has been the location for limited historic mining (Exhibit 4.5.2 and Figure 2.3). Underlying the vent breccia at depth, particularly in the east, are Cretaceous black shales, which appear to be dipping at a shallow angle towards the west. To the north and east, the vent breccia is overlain by the Roșia Poieni complex andesitic volcanics. Gold-silver mineralisation at Jig occurs both within the block of altered and brecciated dacite and to the north and west in the vent breccia. The overlying andesites are unmineralised.

In summary, the rock units of economic interest in the Roșia Montană deposit are dacites, mixed breccia, vent breccias, black breccia, brecciated sediments as well as mixtures of these units. Dacites are commonly intensely argilised and silicified. The mineralisation consists of disseminated pyrite locally associated with minor sphalerite, galena and chalcopyrite with economic grades of gold and silver. Vein deposits with gold and silver, that have been mined historically, will also be exploited.
As discussed further in Chapter 2.6, Resources and Conditions for Natural Resources Extraction, the Roșia Montană mineralisation contains approximately 10.1 million ounces of gold and 47.6 million ounces of silver in proven and probable ore reserves based on a variable 0.6 g/t cut off gold grade. The average grade of this ore is 1.46 g/t gold and 6.9 g/t silver. Rock with less than 0.6 g/t gold, which is extracted to access the ore, will be deposited in various waste rock stockpiles. In addition, during the first six years of mining processing will be focused on the highest-grade ore. The stockpiled lower-grade ore, will be processed during the last three years of the Project operations.

2.2.4 Corna Valley Geology

The geology of the Corna Valley contains the Roșia Montană volcanic-hosted mineralization at the head of the valley, and consists of Cretaceous sedimentary rock throughout the rest of the Valley. Local geology in the upper portion of the valley is shown in Exhibit 4.5.2. Overburden in the Corna Valley is soil, colluvium and bedrock residuum comprised of clayey silt and sand to silty clay with varying percentages of gravel and cobble-sized particles. The clasts typically consist of sandstone and/or shale fragments, reflecting the sedimentary parent material. Alluvium, comprising of silty sand and gravel, is present in the valley bottom. Overburden thickness varies from approximately 2 m to 10 m on slopes to 12 m in the valley bottom.

Beneath the overburden the main rock types are as follows:

- Black Shales – This Cretaceous sedimentary sequence, also described as flysch, typically consists of interbedded shale, fine to medium grained sandstone and beds of local thin conglomerates. The rock is characterised by calcite veins within the sandstone, variable bedding orientation, and occasional weak and/or brecciated
zones. This unit comprises the bedrock typical of Corna and surrounding valleys, and forms the foundation of the tailings impoundment embankment.

- **Vent Breccia** – Vent Breccia in the Corna Valley consists of microconglomerates, tuffaceous grits, and medium grained volcanioclastics and is generally massive. The breccia is of Neogene age. It borders the Cârnic ore body on the south side and will underlie the tailings in the upstream portions of the tailings impoundment during the later years of the Project.

- **Andesitic Agglomerate** – This rock type has been mapped in several locations near the head of the Corna Valley and on the ridge between the Corna and Salistei Valleys. It lies outside the tailings basin.

- **Limestone** – Blocks of limestone were observed slightly upstream of the tailings embankment centreline. The limestone units are Cretaceous in age, pelagic and fine-grained and occur as erosional remnants of Late-Cretaceous overthrust nappes.

### 2.2.5 Roșia Valley

In the upper portion of the Roșia Valley, the bedrock is composed of andesitic pyroclastics and flows along the northern and eastern valley ridges. The eastern ridge will contain the Sulei quarry, which will provide andesite construction rock for the project. The lower flanks of the upper portion of the valley and the southern ridge contain the dacite and vent breccias described previously. The mineralised portion of these units will be exploited for the Project. The lower two-thirds of the valley to the west is dominated by upper Cretaceous aged black shales as described for the Corna Valley. The process plant site area is primarily located on shale but will be bound by the proposed Cetate open pit to the east, where outcrops of dacite and volcaniclastic breccia dominate. The Cetate Water Catchment Dam will be located in the area of shale bedrock, and the La Piriul Porcului quarry will be located in sandstone of the Cretaceous black shale sequence which will be excavated for use in construction.

The predominant surface material type encountered in the Roșia Valley is a firm to stiff, plastic residual soil/colluvium comprised of clayey sand and silt with trace to some gravel and cobbles. Colluvial deposits cover the slopes with alluvial deposits covering the valley floor.

### 2.3 Seismicity

#### 2.3.1 Regional Seismicity

The seismicity of Romania and its surrounding bordering regions is shown on Figure 2.4. in the form of a map of epicentre locations for earthquakes that occurred over the past 30 years. The earthquake data were provided by the National Geophysical Data Centre (NGDC) in Boulder, Colorado, and include the epicentre locations with their corresponding magnitudes (on the Richter scale). An extensive catalogue of earthquake events has been maintained in Romania for several centuries, with some recorded large earthquakes dating back over 1000 years.
The level of seismicity within the majority of the Carpathian mountain range of central Romania is moderate, with earthquakes generally occurring at shallow depth. The largest of these shallow earthquakes are in the range of magnitude 6.0 to 6.5. The Vrancea region, which is situated where the Carpathian range curves sharply from north-south to east-west, is the source of high seismic activity that affects more than two-thirds of Romania and parts of Bulgaria, Moldova and the Ukraine. Seismic activity in this region occurs predominantly at intermediate focal depths in the range of about 50 to 170 km. The Vrancea region is situated at about 250 km east of Roșia Montană.

Numerous moderate and large earthquakes have been recorded in Vrancea region over the last several hundred years, several of which were recorded in the last century, including a 1977 magnitude 7.5 event, at a focal depth of about 109 km. The corresponding epicentral Modified Mercalli Intensity (MMI) for this event was measured at Intensity IX. This earthquake caused major damage to the city of Bucharest, located over 100 km from the epicentre. The largest Vrancea earthquake recorded during the last century was a
magnitude 7.7 event in 1940. Other large earthquakes occurred in this region in 1986 and 1990 with magnitudes of 7.2 and 7.0 respectively.

Another area of seismic activity is located to the west of the Roşia Montană project in the county of Timis. Recorded earthquakes in this area and in neighbouring northern Yugoslavia are typically shallow crustal events of small or moderate magnitude of between 4 and 6. A large earthquake occurred in the area of Timis in 1887. An estimated earthquake magnitude of 7.0 has been assigned to this event.

### 2.3.2 Seismic Hazard Analysis

Appropriate seismic ground motion parameters for the Roşia Montană project site have been determined using both probabilistic and deterministic methods of analysis. Both of these methods require an examination of historical earthquake data and the regional tectonics to identify seismic source zones or faults and to estimate the maximum earthquake magnitude for each of these seismic sources. An appropriate relationship defining the attenuation of earthquake ground motion is also required.

### 2.3.3 Ground Motion Attenuation

Both probabilistic and deterministic risk analyses require an appropriate relationship between earthquake magnitude, hypocentral distance (source to site) and ground motion. A review of published attenuation relationships specifically for maximum ground acceleration in Romania was completed.

Seismic data and recorded damage from Vrancea earthquakes indicate that the attenuation of ground motion from these intermediate depth sub-crustal events is slow. Consequently, high levels of ground shaking have been recorded at large distances from the earthquake source. A relationship to estimate the attenuation of effective peak ground acceleration from Vrancea earthquakes was presented by Lungu et al. (1999). For this study, the relationship has been modified to provide estimates of peak acceleration on bedrock. This relationship indicates that for a given earthquake magnitude and hypocentral distance, ground accelerations may be two to three times higher for a Vrancea earthquake compared to shallow crustal earthquakes in Yugoslavia and other areas of Romania. A study by Trifunac et al. (1988) on the attenuation of seismic intensity in the Balkan countries also indicates that the attenuation of seismic shaking from Vrancea earthquakes is much slower compared to other seismic events in the remainder of Romania and neighbouring countries.

For all other seismic sources, including western Romania and Yugoslavia, an attenuation relationship given by Manic (1998) was used. This relationship was specifically derived for estimation of peak acceleration in the North West Balkan region (excluding Vrancea).

### 2.3.4 Probabilistic Analysis

A probabilistic analysis is carried out to define a unique probability of occurrence for each possible level of ground acceleration experienced at a site. The methodology used for the probabilistic analysis is based on that presented by Cornell (1968). The likelihood of occurrence of earthquakes within defined seismic source zones has been determined by examining historical earthquake data.

Seismic source zones were determined from consideration of historical seismicity and the regional tectonics. Using historical earthquake records for the region, magnitude-frequency recurrence relationships are developed for each potential earthquake source zone. A maximum earthquake magnitude and average focal depth were assigned to each potential
source zone, based on a review of the historical seismicity. A minimum magnitude of 4 was used in the analysis for all of the seismic source zones. Earthquakes of lower magnitude are not considered to be a risk to engineered facilities. The seismicity parameters developed for each seismic source zone were incorporated into the computer program EZ-FRISK (McGuire, 1999) to determine the relationship between maximum acceleration and annual frequency of occurrence (and the corresponding return period). The results have been summarised in Table 1-1, in terms of earthquake return period and the probability of exceedance for each return period, for a design operating life of 17 years for the Roşia Montană Project. For a return period of 475 years the corresponding maximum acceleration is 0.082 g. Also included in Table 2-1 is the estimated Modified Mercalli Intensity (MMI) at the Project site, using the relationship between maximum acceleration and MMI developed by Murphy and O’Brien (1977). For the 1 in 475 year earthquake the estimated MMI is approximately VI-VII for firm ground conditions.

Table 2-1. Summary of Probabilistic Seismic Risk Analysis

<table>
<thead>
<tr>
<th>Return Period (Years)</th>
<th>Probability of Exceedance (%)</th>
<th>Maximum Acceleration (g)</th>
<th>MM Intensity (MMI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>28.8</td>
<td>0.035</td>
<td>V</td>
</tr>
<tr>
<td>100</td>
<td>15.6</td>
<td>0.05</td>
<td>VI</td>
</tr>
<tr>
<td>200</td>
<td>8.2</td>
<td>0.062</td>
<td>VI</td>
</tr>
<tr>
<td>475</td>
<td>3.5</td>
<td>0.082</td>
<td>VI-VII</td>
</tr>
<tr>
<td>1000</td>
<td>1.7</td>
<td>0.102</td>
<td>VII</td>
</tr>
<tr>
<td>2000</td>
<td>0.9</td>
<td>0.115</td>
<td>VII</td>
</tr>
<tr>
<td>5000</td>
<td>0.3</td>
<td>0.134</td>
<td>VII-VIII</td>
</tr>
<tr>
<td>10000</td>
<td>0.2</td>
<td>0.151</td>
<td>VIII</td>
</tr>
</tbody>
</table>

Notes:
1) Probability of Exceedance calculated for a design life of 17 years. 
\[ q = 1 - \exp\left(-L/T\right) \]
where, \( q \) = probability of exceedance
\( L \) = design life in years
\( T \) = return period in years.
2) Maximum Accelerations are for values on bedrock/firm ground.

A seismic hazard map of Europe has been published for the Global Seismic Hazard Assessment Program (GSHAP, 1999). This hazard map presents the probabilistic maximum bedrock acceleration with a 10% chance of exceedance in 50 years, corresponding to a return period of 475 years. A part of the seismic hazard map including Romania is shown on Figure 1.5. For the Roşia Montană project the maximum bedrock acceleration determined from this map is in the moderate seismic hazard range of 0.8m/s² to 1.0m/s² (0.08g to 0.10g). This is in good agreement with the maximum acceleration of 0.082g for the 1 in 475-year event determined for this study.
2.3.5 Deterministic Analysis

For the deterministic analysis, seismic source zones are defined and maximum earthquake magnitudes assigned to each source. The resulting deterministic acceleration at the study site for each source is considered to be the maximum acceleration that can occur, on the basis of available geologic and tectonic information. The maximum acceleration produced by this procedure is referred to as the maximum credible acceleration and the corresponding earthquake as the Maximum Credible Earthquake (MCE).

Figure 2.5. Seismic Hazard Map of Romania for Peak Acceleration with 10% Probability of Exceedance in 50 Years (GSHAP, 1999)
Three cases were considered for estimation of the maximum credible acceleration at the Roșia Montană project site. These were chosen as representative of worst-case events, based on a review of the regional tectonics and historical earthquake records.

Two of the cases considered are shallow depth crustal earthquakes with estimated maximum magnitudes of 6.5 and 7.0, at epicentral distances of 75 and 130 km respectively. The magnitude 6.5 earthquake represents an event located in the Carpathian mountain region of central Romania east of the project site. The magnitude 7.0 earthquake represents an event in western Romania, in the high seismicity area of Timiș. The calculated maximum accelerations for these two shallow events are 0.05g for the magnitude 6.5 event and 0.04g for the larger but more distant magnitude 7.0 earthquake.

The third case considered was a large magnitude sub-crustal earthquake in the Vrancea region. Studies by Lungu et al. (1999) and others have suggested a maximum earthquake magnitude of 8.0 for Vrancea earthquakes. Therefore, a maximum earthquake magnitude of 8.0 was assumed at an estimated minimum distance of approximately 250km from the Roșia Montană project. The calculated maximum acceleration for this event is 0.14g.

For the shallow depth crustal earthquakes of western Romania and the Carpathian Mountains region the attenuation relationship of Manic (1998) was used. For the Vrancea region, the ground motion attenuation relationship based on that given by Lungu et al. (1999) was used. The mean plus one standard deviation relationships were used in each case. The results of the deterministic analysis are presented in Table 2-2, including the maximum magnitude, estimated epicentral distance and focal depth and calculated maximum acceleration. Also included in Table 2-2 are the estimated firm ground MMIs at the Roșia Montană project site for each event, using the relationship between maximum acceleration and MMI developed by Murphy and O’Brien (1977).

<table>
<thead>
<tr>
<th>Source Area</th>
<th>Maximum Magnitude (Mw)</th>
<th>Epicentral Distance (km)</th>
<th>Focal Depth (km)</th>
<th>Maximum Acceleration (g)</th>
<th>MM Intensity (MMI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpathian Mountains</td>
<td>6.5</td>
<td>75</td>
<td>20</td>
<td>0.05</td>
<td>VI</td>
</tr>
<tr>
<td>Timiș</td>
<td>7.0</td>
<td>130</td>
<td>10</td>
<td>0.04</td>
<td>V-VI</td>
</tr>
<tr>
<td>Vrancea</td>
<td>8.0</td>
<td>250</td>
<td>100</td>
<td>0.14</td>
<td>VII-VIII</td>
</tr>
</tbody>
</table>

Notes:
1. Maximum Accelerations are for values on bedrock/firm ground.

Based on the results of the deterministic analysis, a Maximum Credible Earthquake (MCE) of magnitude 8.0, causing a maximum bedrock acceleration of 0.14g, was assigned to the Roșia Montană project site. The corresponding Modified Mercalli Intensity for this event has been estimated to be approximately level VII-VIII for firm ground conditions.

### 2.3.6 Seismic Hazard Classification

Consistent with current design philosophy for geotechnical structures such as dams, two levels of design earthquake have been considered: the Operating Basis Earthquake (OBE)
for normal operations; and the Maximum Design Earthquake (MDE) for extreme conditions (ICOLD, 1995). Values of maximum ground acceleration and design earthquake magnitude were determined for both the OBE and MDE.

- The OBE is typically determined using a probabilistic seismic hazard analysis to select an acceptable hazard level, based on the probability of exceedance over the design life of the facility. This is typically chosen as the earthquake that has a 10% probability of exceedance in 50 years, which corresponds to a return period of 475 years.

- The selection of a MDE is based on classification of the tailings dam using criteria given by the Canadian Dam Association’s Dam Safety Guidelines (1999).

The design earthquakes and corresponding design parameters recommended for the Tailings Management Facility are summarised below:

- The OBE was taken as the 1 in 475-year return period event. This corresponds to a maximum bedrock acceleration of 0.082 g. A conservative design earthquake magnitude of 8.0 was assigned to the OBE. This value is based on the historical earthquake record that indicates that several large magnitude events with magnitudes greater than 7.0 have occurred over the last few hundred years, including the magnitude 7.7 earthquake of 1940 and a large earthquake in 1802 that is estimated to have exceeded 7.5. The probability of exceedance for the OBE event is less than 4% for a design life of 17 years. The Tailings Management Facility would be expected to continue to function in a normal manner after the OBE.

- The MDE has been taken as equal to the MCE. The maximum bedrock acceleration for the MCE is 0.14 g. An earthquake magnitude of 8.0 has been assigned to the MDE. For the MDE, damage to the tailings dam is acceptable, provided the integrity and stability of the dam is maintained and release of impounded tailings is prevented.

These design parameters consider that the consequences of a dam failure are classified as “Very High” for the Tailings Management Facility. The maximum accelerations determined for the OBE and MDE are for ground motions in bedrock or firm ground through which ground amplification effects are negligible.

2.4 Hydrogeology and Underground Water Resources Protection

The hydrogeology of the Project site is presented in Section 4.1.1. Water Baseline and Appendix 3 Hydrogeologic Baseline Report. In summary, the occurrence of groundwater is largely limited to the weathered bedrock horizon and the surficial colluvial, alluvial and soil layers. The deeper bedrock units yield little water, and there is no evidence of a significant groundwater system in the bedrock. What bedrock yield does occur is from fracture systems that are not connected over significant distances. Flow in the shallow groundwater system is from the valley ridges toward the valley bottom and then down valley. This results in the occurrence of numerous springs and streams that gain flow from discharging groundwater.

Impacts to groundwater flow are also described in Section 4.1. These impacts will largely be to the surface water system due to the disruption of groundwater discharge to springs and streams. Because the bedrock yields little water and is not used as a groundwater supply, impacts to the bedrock hydrogeology are not predicted. In addition, impacts to valleys adjacent to the Corna and Roșia Valleys are not predicted.
2.5 Quality and Pollutants

The bedrock units of economic interest in the Roşia Montană ore deposit are dacites, mixed breccia, vent breccia micro-conglomerate, black breccia, brecciated sediments as well as mixtures of these units. Dacites occur as intensely altered rock and are argillised and silicified. Mineralisation generally consists of disseminated pyrite, locally associated with minor sphalerite, galena and chalcopyrite. Based on this geology and mineralisation, the ore units and waste rock units appear to have the potential to generate acid rock drainage (ARD), which can impact water quality at mine sites. A detailed assessment of the site environmental geochemistry was conducted and a summary is presented here.

2.5.1 Waste Rock

Waste rock is the rock with sub-economic concentrations of gold and silver (< 0.6 g/t gold) that will be excavated to access the ore. The majority of this waste rock will come from the Cetate and Cârnic mine pits (86 percent), with the remainder originating from the Orlea and Jig-Igre pits. Waste rock produced during the development of the mine will consist of dacite, vent breccia, Cretaceous sediments, black breccia and andesite. Most of this rock will be either unaltered or have undergone dominantly argillic hydrothermal alteration (clay-pyrite), with lesser amounts of quartz-adularia-carbonate-pyrite alteration. Sulphides that may react to form ARD occur in the waste rock associated with the alteration but also can occur as a primary minerals in the black shales that dominate the Cretaceous sediments. Waste rock will be used for construction (e.g. of the tailings and water-retaining structures) and the remainder will be deposited in waste rock stockpiles located adjacent to the main pit complex and Tailings Management Facility as well as in the open pits that are completed while waste rock is still being generated (transfer mining). The stockpiles will be engineered structures designed to minimise environmental impact and facilitate closure.

Waste rock for construction of the tailings dam will be hauled direct from the open pits. Unaltered and competent rocks consisting of andesite and Cretaceous conglomerates and sandstones have been identified and are planned to be used for much of the dam construction. This dam will be raised in successive “lifts” through the project life to allow impoundment of accumulating tailings solids, and waste rock will continue to be deposited on the dam through the construction and operation stages. In the dam construction, potentially acid-generating rock will be selectively placed in deeper sections of the dam shells in order to minimise oxidation and the reaction of sulphides.

As part of an initial evaluation of the possible environmental impacts of the waste rock disposal, the mineralogy of six representative samples was investigated. Optical microscopy was carried out as part of the mineralogical characterisation. This study found that potentially ARD-generating pyrite occurs as free grains, or locked within the quartz, or as inclusions with feldspars. Calcite grains (ARD neutralising) were found in two of the six examples as a minor or trace constituent. Potassium feldspar, muscovite and kaolinite are abundant in most of the samples. The presence of pyrite indicates the rock has some potential to generate ARD. However, since some of the pyrite is encapsulated in quartz, the potential for it to react with water and oxygen is reduced and the full ARD potential of the waste rock may not be realised. Additional data, relative to the major and trace element chemical composition of the forecasted waste rock, has been derived from XRF and additional analytical testing.
2.5.2 **Static Testing**

To specifically evaluate the ARD potential of the waste rock and potential impact on the environment, a total of 161 samples of forecasted future waste rock and 25 samples of historical waste were characterised using the Modified ABA (Acid-Base Accounting) method. The “Modified ABA” method is a standard method routinely used around the world for evaluating the potential for a rock to produced ARD. The results of the “static” ABA analysis are used to evaluate the ultimate potential for a rock to produce ARD assuming that all the chemical reactions are allowed to react to completion. In nature, these reactions can be inhibited, therefore, the ABA results are typically characterised as the potential of a rock to generate ARD. Actual ARD character often requires confirmation with other “kinetic” testing procedures. This testing was also conducted for Roşia Montană waste rock as discussed later in this section. Paste pH was also measured along with the ABA analyses and is selectively discussed in this section. Paste pH is a measure of the acidity associated with a rock or soil sample.

Two separate programmes were completed to collect and analyse samples for their ABA characteristics. The initial ABA programme in 2001 consisted of 46 waste rock and 24 samples of historical waste. This programme provided an initial indication of the ARD potential of the Roşia Montană waste rock.

The second round of ABA data collection from 2003 was more comprehensive and was focused on helping to ensure that a representative number of samples based on industry standards (at least 8 to 12 samples for each waste rock lithology) were collected. Spatial distribution of the samples within the pit design and homogeneity of the waste rock types was also considered in the sampling. Where appropriate, the data from the two programmes (2001 and 2003) have been comparatively evaluated. The ABA data were evaluated against guidelines of the British Columbia Ministry of Employment and Investment of Canada (Price, 1997). For evaluation purposes, the waste rock was separated by lithology and alteration. The lithology classifications include:

- Dacite;
- Vent breccia;
- Black breccia;
- Andesite; and
- Cretaceous sedimentary rocks.

The dacite and vent breccia was further classified by silicified/potassic alteration type (abbreviated as SIK), and non-silicified/non-potassic (NSIK), which is generally argillic but may include unaltered rock or other less intense alteration types. The classifications are based on the geologic and resource model for the project, which was used to project relative percentages of each individual waste rock classification.

A broad range of ABA characteristics are predicted for the waste rock - from rock that has no appreciable potential for ARD generation, to rock that is likely to generate ARD (see Exhibit 4.5.3). It was found that the andesite and Cretaceous sedimentary waste rock types have low to no potential to generate ARD. However, pyritic black shale that occurs in the sedimentary sequence appears likely to generate ARD based on one sample. The black breccia waste rock lithology is consistently characterised as likely to produce ARD. The potential for ARD generation is therefore definable based on lithology for these three waste rock types. However, it is estimated that these rock types will make up less than 25% of the total waste rock volume.
As determined using the geologic block model for the Project, the majority of the waste rock will consist of the vent breccia (57 percent) and dacite (19 percent), with the majority of these rocks belonging to the argillic alteration assemblage (NSIK). A smaller portion is the silicic assemblage (SIK). It is noted that generally the silicic rock is more likely to generate ARD compared to the argillic rock. However, overall there is a large range of ABA characteristics for the vent breccia and Dacite, from no potential to likely to generate ARD. Because the vent breccia will make up the majority of the waste rock, on a weighted basis, the net average ABA character of the waste rock is similar to the average vent breccia characteristic (see Exhibits 4.5.4 and 4.5.5).

Exhibits 4.5.4 and 4.5.5 present the weighted median and mean results of the waste rock analyses, respectively. In this evaluation, the median and mean are weighted by the percentage of projected waste rock so that the vent breccia (57 percent of waste rock) has more effect on the result compared to the andesite (3.6 percent) for example. Both the median and mean can be interpreted as representative of “average” conditions under different scenarios. The median may best reflect the average rock composition of the stockpiles, but the mean may best reflect the average chemical characteristic. Therefore, to address this uncertainty both are presented. As indicated by this analysis, the average potential for the waste rock to generate ARD is low to possible. This indication means that on a bulk-net basis the waste rock mass will have more acid neutralising potential than acid generating potential. However, other factors will affect the character of any water discharging from the waste rock stockpiles.

An example would be the waste rock dumps, where the rock types may not be perfectly blended masses, and the net lithologic composition will vary as they are built. Therefore, individual areas during certain periods of time in the dump development may be more acid generating than others. An additional factor that may result in the waste rock not behaving as predicted by the ABA data is non-ideal weathering behaviour. Rock that has low or possible potential to generate ARD may do so if the neutralising potential is not fully effective. Conversely, a portion that is classified as ARD generating, may not generate its full potential due to silica encapsulation for example, as discussed previously. The kinetic testing (leachate testing) conducted as part of the evaluation is focused on evaluating these possibilities.

2.5.3 Kinetic Testing

Three forms of kinetic testing have been conducted on samples of projected waste rock from the site. The testing procedures included the Synthetic Precipitation Leaching Procedure (SPLP), laboratory column testing, and field column testing. The SPLP test is a short-term leaching procedure designed by the U.S. Environmental Protection Agency (EPA) that uses simulated rainwater as a leaching solution. The procedure best characterises the mobility of metals in the waste rock as it is first extracted and exposed to the surface environment.

The results of the short-term SPLP testing are summarised in Table 2-3. The results are from a limited number of samples collected during the initial characterisation program from the Cetate and Cârnic exploration drilling. All of the samples except HFF24 exhibited neutral to slightly alkaline pH and low concentrations of metals in the SPLP leachate as may be expected for unweathered rock regardless of ARD character.
### Table 2-3. Synthetic Precipitation Leaching Procedure Results

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>CTSD002</th>
<th>CTSD034</th>
<th>CNSD008</th>
<th>HFF24</th>
<th>RMRDO47</th>
<th>RMRDO86</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID</td>
<td>XPO-SSH-SSE</td>
<td>VXB</td>
<td>VDA</td>
<td>CY-LI</td>
<td>VXB</td>
<td>XPO-XBB-XMO-VXB</td>
</tr>
<tr>
<td>Lithology</td>
<td>Vent Breccia</td>
<td>Vent Breccia</td>
<td>Dacite</td>
<td>Waste Rock</td>
<td>Vent Breccia</td>
<td>Vent Breccia</td>
</tr>
<tr>
<td>Depth (m)</td>
<td>130-238</td>
<td>0-160</td>
<td>0-100</td>
<td>0.5-1.0</td>
<td>0-100</td>
<td>0-130</td>
</tr>
<tr>
<td>pH</td>
<td>7.9</td>
<td>7.9</td>
<td>7.7</td>
<td>3.2</td>
<td>8.1</td>
<td>7.8</td>
</tr>
<tr>
<td>Conductivity (μs/cm)</td>
<td>133.7</td>
<td>166.3</td>
<td>162.7</td>
<td>134.8</td>
<td>169.9</td>
<td>183.9</td>
</tr>
<tr>
<td>Aluminium μg/L</td>
<td>1085</td>
<td>1670</td>
<td>201</td>
<td>33017</td>
<td>570</td>
<td>89</td>
</tr>
<tr>
<td>Arsenic μg/L</td>
<td>15</td>
<td>14</td>
<td>17</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Barium μg/L</td>
<td>21</td>
<td>27</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>14</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Cadmium μg/L</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>35</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cobalt μg/L</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>100</td>
<td>&lt;20</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Copper μg/L</td>
<td>&lt;20</td>
<td>20</td>
<td>&lt;20</td>
<td>607</td>
<td>&lt;20</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Iron μg/L</td>
<td>220</td>
<td>986</td>
<td>203</td>
<td>14917</td>
<td>133</td>
<td>60</td>
</tr>
<tr>
<td>Lead μg/L</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Manganese μg/L</td>
<td>25</td>
<td>139</td>
<td>196</td>
<td>24016</td>
<td>141</td>
<td>2718</td>
</tr>
<tr>
<td>Nickel μg/L</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>181</td>
<td>&lt;20</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Silicon μg/L</td>
<td>3087</td>
<td>4340</td>
<td>1338</td>
<td>1197</td>
<td>3012</td>
<td>1404</td>
</tr>
<tr>
<td>Strontium μg/L</td>
<td>48</td>
<td>112</td>
<td>30</td>
<td>94</td>
<td>64</td>
<td>28</td>
</tr>
<tr>
<td>Tin μg/L</td>
<td>&lt;30</td>
<td>&lt;30</td>
<td>&lt;30</td>
<td>&lt;30</td>
<td>&lt;30</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Zinc μg/L</td>
<td>51</td>
<td>140</td>
<td>79</td>
<td>6671</td>
<td>87</td>
<td>59</td>
</tr>
<tr>
<td>Calcium mg/L</td>
<td>9.6</td>
<td>16.8</td>
<td>19.4</td>
<td>191.8</td>
<td>12.6</td>
<td>14.4</td>
</tr>
<tr>
<td>Magnesium mg/L</td>
<td>2.2</td>
<td>2.8</td>
<td>1.3</td>
<td>12.0</td>
<td>3.4</td>
<td>3.9</td>
</tr>
<tr>
<td>Potassium mg/L</td>
<td>16.5</td>
<td>13.8</td>
<td>10.3</td>
<td>0.1</td>
<td>19.8</td>
<td>19.4</td>
</tr>
<tr>
<td>Sodium mg/L</td>
<td>4.4</td>
<td>17.1</td>
<td>1.2</td>
<td>0.5</td>
<td>5</td>
<td>0.6</td>
</tr>
<tr>
<td>Sulphate mg/L</td>
<td>72</td>
<td>64</td>
<td>74</td>
<td>906</td>
<td>95</td>
<td>116</td>
</tr>
<tr>
<td>Chloride mg/L</td>
<td>&lt;5</td>
<td>7</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

Note: Samples were collected from exploration drilling samples from the Cetate and Cârnic pit areas except for sample HFF24, which was collected from the existing Rail Line waste rock dump.

The HFF24 sample was a sample of historical waste rock from the Rail Line waste rock dumps that have been exposed on the surface and weathered. The SPLP results for this sample suggests that the material is currently producing ARD with a low pH of 3.2, and elevated concentrations of many of the metal analytes compared to the other samples. The concentrations of aluminium (33,000 μg/L), iron (14,900 μg/L) and manganese (24,000 μg/L) are indicative of ARD generation.

To address weathering of the waste rock and possible generation of ARD, longer term kinetic testing was also conducted. Based on the initial (2000/2001) ABA testing program, samples from four environmentally significant rock waste components from the Project were...
chosen for laboratory column testing. The samples represented a range of ABA classifications and were lithologies that will be present in the waste rock in significant quantities. The samples tested included two dacite samples, one vent breccia sample and a mixed breccia with black breccia sample from the Cetate and Cârnic pit areas. Three of these samples were identified as likely ARD generators, while one of the dacite samples was identified as not likely to produce ARD.

The initial testing of the three columns with potentially ARD generating rock began in 2001 and ran for 52 weeks ending in April 2002. The column with non-ARD generating rock was run for 11 weeks, and discontinued once the leachate chemistry was established. As part of the on-going ARD evaluations, follow-up testing of the three columns with possible ARD-generating material was started in July 2003, and ran for an additional 26 cycles that ended in March 2004.

During the column leach testing, the columns were flushed with water on one to three week cycles. After flushing, the columns are allowed to dry and be exposed to atmospheric oxygen. Because of the regular wetting and drying cycles, this test is supposed to accelerate conditions observed in the field. The water flushed through the column generates a leachate that was analysed at the end of each cycle for:

- pH,
- conductivity,
- redox potential,
- alkalinity and/or acidity,
- aluminium,
- arsenic,
- calcium,
- iron,
- potassium,
- sodium,
- magnesium, and
- sulphate.

On a monthly schedule, the leachate was also analysed for copper, lead, nickel, silicon, strontium, tin, and zinc. Based on the detailed results of the 79 cycles of laboratory column leach tests, none of the samples has generated any substantial ARD and the pH of the leachate remained alkaline. Low levels of sulphate measured in the leachate indicates that oxidation of sulphide minerals is very limited or not occurring. A potential explanation for this behaviour, which is counter to the ABA results, is that either the pyrite is locked within the silicates (and therefore non-available for reaction) or that the pyrite is otherwise non-reactive. If significant sulphide oxidation reactions were occurring, which were being neutralised, higher levels of sulphate and calcium would have been observed.

Field-based leaching tests of the waste rock have also been conducted at the site. These tests were designed to monitor the rate and timing of acid rock drainage generation under actual site conditions and were initiated in August 2003. These tests will continue for an extended time into Project implementation to provide additional data. The field-based leaching evaluation of the waste rock includes 26 barrels filled with waste rock representative of each of the primary waste rock types, which are exposed to climatic conditions at the site. The majority of samples were collected from excavations in the Cârníc...
and Cetate areas (11 samples each), but several samples from the Orlea (1 sample) and Jig (2 samples) areas were also included. A single sample of existing waste was also included. The number of barrels for each waste rock type is weighted based on the percentage of waste rock projected to be produced for each lithology.

These field-testing barrels are open topped with holes in the sides for ventilation. A sampling portal at the base for each barrel allows for sampling of fluid that has contacted waste rock in the barrels on a regular basis dependent upon rainfall. The initial sampling of the barrels was completed in October and November 2003 with subsequent sampling in June, August and November 2004. More frequent monitoring of pH and specific conductivity also occurred.

The results of the field column testing indicated that the waste rock is mostly behaving as predicted by the ABA results. The pH of the field column leachate from the initial October/November 2003 sampling event is presented in comparison to the column rock ABA characteristics in Exhibit 4.5.6. Leachate was not produced from six of the columns during the sampling period. Data from over one year of weathering in field conditions indicate that of the ten field columns classified as likely to produce ARD only nine actually became ARD generating. Of six columns with rock classified as having low or possible ARD potential, one column generated ARD. Ten columns were classified as having no potential to generate ARD with one these columns generating ARD from initiation of the testing and one becoming ARD generating after over a year of weathering. This behaviour is highlighted on data tables presented as Exhibits 4.5.7 and 4.5.8.

The majority of columns behaved as predicted but there were exceptions in all categories of ARD potential. Combined with the laboratory columns, about an equal number of samples performed contrary to their ABA classification. In review of the data, it appears that the behaviour of the samples with contradictory results may be because the small (approximately 200 gram) composite ABA samples were not representative of the large mass (approximately 300 kilogram) tested in the columns. This type of error is more likely to produce a random outcome with similar numbers of samples becoming ARD generating or not counter to the ABA results. This is in contrast to a significant chemical effect that would tend to bias result in one direction.

The column testing has confirmed the conclusions of the static ABA testing in that some waste rock will become ARD generating while a large portion will not. Based on the ABA testing it is expected that the non-ARD generating rock mass will be larger than the ARD generation mass, and a net neutral water quality is a likely result. However, because of the heterogeneity of the waste rock mass, some periods and areas of ARD generation are possible and mitigation to prevent water quality impact is required.

The water quality associated with the field columns is presented in Exhibits 4.5.7 and 4.5.8. The non-ARD producing samples yield water quality that is relatively low in metals but may produce water with elevated concentrations of calcium, sulphate and TDS because of internal ARD neutralisation reactions. This is the most likely net waste rock water quality from the Roșia Montană waste rock mass. The ARD that is generated in the columns has relatively depressed pH and elevated concentrations of sulphate, TDS, and many metals including, arsenic, cadmium, cobalt, copper, iron, nickel, and zinc. The black breccia produces some of the highest ARD concentrations. It should be noted that in the waste rock mass, ARD will be blended with non-ARD water and react with neutralising rock along the flowpaths in most cases. Therefore, it is not expected that concentrations as high as those observed in the field columns will ever be observed issuing in leachate flowing from the waste rock stockpiles.

In summary, based on the geochemical data collected for the waste rock, the preliminary conclusion is that the neutralising potential is greater than the acid generating potential on a
net basis, and therefore large scale ARD generation is not likely. However, because the sulphide content of the rock is relatively high, some sulphide oxidation and ARD generation will occur. It appears that the majority of the ARD generated will be neutralised within the waste rock mass near its source. The most probable water quality for seepage and runoff from the waste rock is therefore that of neutralised ARD. This water would likely have elevated concentrations of sulphate and other major ions, but with neutral pH and concentrations of most heavy metals that are not significantly elevated. However, local areas with greater concentrations of ARD producing rock are likely to occur, because the waste rock will not be a homogeneously blended mass. If runoff or seepage from these areas directly enters the environment, then local ARD may be observed. Similarly, areas with low sulphides may result in water with neutral pH and low metal content. The overall ARD character of the waste rock will be improved by specific strategies for handling the black breccia, andesite and sedimentary rock (i.e. consistent potentially ARD and non-ARD generating rock types). However, the majority of the waste rock will be vent breccia that has variable ARD potential and presents no clear visual indication of its ARD character. Therefore it is proposed that ABA testwork is continuously carried out during the production process, so that waste rock may be appropriately stored in the stockpiles according to its likely environmental performance, i.e., potentially ARD generating rock is placed within encapsulating cells of non-ARD generating waste.

2.5.4 Mine Pit Walls

A subset of the waste rock ABA data was collected near the projected mine pit walls. This included 27 samples from a range of lithologies similar to those discussed above. These data generally reflect the distribution of the waste rock data with ABA characteristics ranging from likely to generate ARD to no potential to generate ARD. Similar to the overall characteristic of the waste rock, sedimentary rock and andesite exposed in the pit walls are indicated as not likely to produce ARD. However, much of the exposure in the pit walls will be dacite, vent breccia and black breccia with variable ARD potential and some ARD generation is likely. This ARD has the potential to contribute to an overall acidic pit water quality, as also discussed in Chapter 4.1 Water and in the Mine Rehabilitation and Closure Management Plan and this is significant for closure planning, requiring adoption of a range of mitigation measures including minimisation of ARD generation in the walls and ongoing treatment of any acidity.

2.5.5 Low-Grade Ore

Low-grade ore will be stockpiled on the site during the first six years of mining and then milled during years 15 through 17, after mining is completed. Of the 26 low-grade ore samples collected and analysed for ABA characteristics, only three were not classified as likely ARD generators. In addition, paste pH was measured and 65 percent of the samples exhibited pH less than 5.0. From these data and the field column data for waste rock with similar ABA results, it is concluded that the low-grade ore stockpile is likely to become a potential source of ARD shortly after material is placed.

The predication of the acid generating characteristics of the low grade ore material is consistent with ARD runoff currently observed at the site. Due to the relatively limited grade control on the existing mining operation, waste rock stockpiles are expected to contain materials similar in characteristic (grade and therefore geochemistry) to that tested as low grade ore material. Therefore, ARD runoff from these materials would be expected.
Again, prediction of geochemical performance has allowed design of stockpiling arrangements for low grade ore that will minimise ARD generation and allow interception, storage and treatment of any contact water in line with the Water Management Plan.

2.5.6 Possible On-Site Construction Materials

Grab samples from five potential construction materials were collected from near the site for ABA analysis. Samples of non-mineralised vent breccia and conglomerate from the upper Corna Valley, sandstone from the proposed La Piriuil Porcului quarry in Roșia Valley, and two types of andesite from the Sulei quarry were collected and analysed. On this basis, these samples were classified as having no potential for ARD generation. The sulphide concentration of these samples was less than 0.1 percent with Neutralising Potential Ratios (NPRs) greater than 10 (10 times more neutralising potential than acid generation potential). Compared to the waste rock from the mineralised area, these samples are classified as among the most net-neutralising rock in the Project area. The paste pH of each of these samples was greater than 8.0.

In addition, samples of the excess cut materials within the Process Plant Site were obtained and tested. It is expected that a substantial volume of cut material will be generated as part of the construction for the plant. This material will be stockpiled at the upper end of the Corna Valley. At least some of this material is planned to be used as soil cover for the waste rock stockpiles and the tailings impoundment as part of closure and rehabilitation activities during the later part of the mine life. The results of the ABA testing on this material indicate it will be strongly net neutralising.

2.5.7 Process Tailings

Tailings from the processing of the ore, as described in Section 2, will also represent a geologic material extracted from the mine pits and (following processing) deposited as a waste material on the surface. Similar to the waste rock, the geochemical characteristics of the tailings can give rise to impacts on water quality; however, because the tailings originate from the mill, some of the chemistry associated with the tailings is derived from the processing and process reagents. A detailed evaluation of tailings is presented under Sections 2 and 4.1, as well as in the Tailings Facility Management Plan and the Waste management Plan. The geological (geochemical) components that will impact water quality are discussed here.

Tailings deposited in the Corna TMF impoundment will consist of process plant (CIL) solid and liquid residues, discharged, via a pipeline as slurry at average 48% solids. The tailings solids are forecast to contain mainly sands and silts and a minor clay component. Testing indicates vertical permeability in the range of $2 \times 10^{-4}$cm/s to $2 \times 10^{-5}$cm/s for settled tailings that will reduce with further consolidation to $1 \times 10^{-7}$cm/s.

The chemical composition of the tailings solids is determined by the mineralogy of the host rock, the ore, the mineral processing operations, and the composition of reagents and conditioners. The ore has been classified into ten different types for process development purposes. A mineralogical study indicates that the ten types have a consistent gangue mineralogy (comprising of quartz, K feldspar, sericitic muscovite/plagioclase and sulphides). The average non-weighted sulphide content of the tailings was 1.63 percent with a high percentage of 4.10 and a low of 0.63. The gangue includes a small percentage of carbonates of a rather complex range of compositions with high manganese levels. The sulphides are 90% pyrite with minor amounts of marcasite.
As part of process design work, ABA testing (Modified ABA) was carried out on the 10 composite ore samples. A later testing programme conducted ABA testing on six additional composite tailings samples. The tailings samples resulting from the ten different ore types and the composite samples were classified as likely to generate ARD (see Exhibit 4.5.8). Further testing in 2004 on three new composite samples representative of the first seven years of mining verified this characteristic (Exhibit 4.5.8). However, 26 weeks of humidity cell testing used to evaluate the weathering characteristics of the future tailings, did not produce ARD. The material tested was simulated tailings produced by bench scale process testing and cyanide detoxification.

Other available data relating to the tailings composition include XRD and XRF mineralogical data. Two samples representative of the tailings from the Cetate existing pit and Cârnic siliceous dacite composites were characterised by XRD and XRF which allow the chemical elements and mineralisation of the rock type to be determined. Tables 2-4 and 2-5 show the results of the characterisation.

### Table 2-4. XRD Results for Two Samples Representative of Tailings

<table>
<thead>
<tr>
<th></th>
<th>Cetate Existing Pit</th>
<th>Cârnic Siliceous Dacite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>Major</td>
<td>Major</td>
</tr>
<tr>
<td>K Feldspar</td>
<td>Major</td>
<td>Major</td>
</tr>
<tr>
<td>Muscovite</td>
<td>Accessory</td>
<td>Accessory</td>
</tr>
<tr>
<td>Chlorite</td>
<td>Accessory</td>
<td>Accessory</td>
</tr>
<tr>
<td>Pyrite</td>
<td>Accessory</td>
<td>Accessory</td>
</tr>
<tr>
<td>Carbonate</td>
<td>Trace</td>
<td>Trace</td>
</tr>
<tr>
<td>Goethite</td>
<td>Trace</td>
<td>Trace</td>
</tr>
<tr>
<td>Rutile</td>
<td>Trace</td>
<td>Trace</td>
</tr>
</tbody>
</table>

Major = 20-50%, Accessory = 1-10% and Trace = <1%

### Table 2-5. XRF Analysis Results for Two Samples Representative of Tailings (wgt %)

<table>
<thead>
<tr>
<th></th>
<th>Cetate Existing Pit</th>
<th>Cârnic Siliceous Dacite</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>66.7</td>
<td>67.3</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>14.3</td>
<td>15.2</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>4.38</td>
<td>3.0</td>
</tr>
<tr>
<td>K₂O</td>
<td>9.93</td>
<td>9.76</td>
</tr>
<tr>
<td>MgO</td>
<td>0.25</td>
<td>0.4</td>
</tr>
<tr>
<td>MnO</td>
<td>0.2</td>
<td>0.15</td>
</tr>
<tr>
<td>Na₂O</td>
<td>0.2</td>
<td>0.18</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.34</td>
<td>0.32</td>
</tr>
<tr>
<td>SO₃</td>
<td>3.57</td>
<td>3.23</td>
</tr>
<tr>
<td>LOI</td>
<td>3.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Total</td>
<td>103.1</td>
<td>102.3</td>
</tr>
</tbody>
</table>
The results presented above suggest that the tailings have limited but some neutralisation potential due to a trace concentration of carbonate. However, the neutralisation potential is smaller than the acid generation potential associated with pyrite. Quartz, the main constituent of the tailings samples, releases no (or very little) alkalinity. K-feldspar has very slow dissolution kinetics and therefore a large quantity is required before it can provide any significant neutralisation capacity.

As noted above, kinetic testing consisting of humidity cell testing has been conducted on three tailings samples produced in the laboratory to evaluate the rate and timing of acid production. The testing was conducted on composite samples of freshly generated tailings that resulted from bench scale testing of the planned process and that had been subjected to the cyanide detoxification process. The tailings were produced from ores representative of the first seven years of mining. Paste pH and ABA testing was performed on each set of samples which indicated the samples had neutral to alkaline pH but had a likely potential to generate ARD. Results from 26 humidity cell cycles indicate ARD generation had not occurred. It can be concluded from these results that tailings ARD, if it occurs, will be delayed for an extended period of time, and as discussed below, actual ARD generation is not likely to occur.

Based on the existing ABA data, mineralogy of the ore and the ABA character of the low-grade ore which will be processed, it appears likely that the tailings have the potential to generate ARD and may do so if exposed to favourable conditions for an extended period of time. However, ARD generation was not demonstrated in humidity cell testing designed to simulate weathering. During operation it is unlikely that ARD will be generated given the rate of tailings accumulation in the TMF, which will be approximately 4 to 8 metres of depth cover per year. The initiation and perpetuation of sulphide oxidation will be limited by the rapid accumulation of tailings, which will keep the level of water saturation high, limit oxygen diffusion, and limit the time individual tailings accumulations are exposed on the surface. In addition, humidity cell testing has indicated that the onset of ARD generation would be delayed for months or years. The associated water quality expected from the TMF and the tailings is discussed in detail in Chapter 4.1 and the Tailings Facility Management Plan.

### 2.6 Resources and Conditions for Natural Resources Extraction

The objective of the Project is to extract the geologic resource at the site at a profit, which will provide economic and other benefits to the company developing the property and the surrounding region and communities. The geologic resource is present due to the mineralisation previously described. Mineralisation styles identified for precious metal and targeted for extraction at Roșia Montană are previously described in Section 2.2, but generally include:

- disseminated gold-silver mineralisation, and
- vein hosted gold-silver (and minor base metals) mineralisation.

The resource associated with this mineralisation, which has been identified for exploitation through extensive exploration, includes proven and probable ore reserves comprising 215 million tonnes of ore containing 10.1 million ounces of gold and 47.6 million ounces of silver. This is based on an average grade of 1.46g/t gold and 6.9g/t silver and a 0.6g/t cut off grade for gold. The Cetate and Cârnic areas contain approximately 79% of this reserve, with the quantity of ore by deposit as follows:
Based on the results of the exploration program, a block model was created for the entire gold resource at Rosia Montana. The results are presented in Figure 2.6.

**Figure 2.6. Resource location**
The total resource, including measured, indicated and inferred classifications at a 0.6 g/t cut off grade may be as much as 380 million tonnes of ore. The resource has not been wholly defined in some areas, and it is possible that an expansion of the reserves could occur in the future. Changes in the price of gold and silver can also affect the cut off grade and increase or decrease the size of the resource in the future.

A portion of the reserve to be mined during the first six years of mining is defined as low-grade ore. Processing during these first six years will focus on the higher-grade ore. The lower grade ore will be stockpiled and processed during the last three years of the operation when mining has ceased. The low-grade ore will have an average gold grade greater than 0.6g/t but has an upper cut off grade based on economic criteria related to the cost of processing.

To profitably extract the ore reserve, low cost mining and beneficiation methods are required. Description and assessment of alternatives evaluated for the extraction of the mineral resource is provided in Section 5. Additional details on the mining and ore processing methods are discussed in Section 2. Extraction of the resource will be through the open pit mining method. To extract the ore, unmineralized and uneconomic mineralised waste rock will need to be excavated and stockpiled on site. The production of waste rock will be 1.2 parts waste rock to 1.0 part ore for the Project. The footprint of the pits and waste rock stockpiles is shown on Exhibits 2.2 through 2.8 and further described in Chapter 2. The areas of the existing open pit mining are also shown.

2.7 Protected and Recreational Areas and Landscapes

Alba County Council Decision No. 20 issued on October 27, 1995, established and nominated as protected areas certain complex landscape, geological, speleological, palaeontological and botanical reserves, as well as flora and fauna species protected within the County. The only monuments of nature, which lie within the Project Area are two rock outcrops, as follows:

- Piatra Despicata - a block of andesite rock located in between Roșia and Comă Valleys; and,
- Piatra Corbului - an outcrop of dacite and polymict breccia on Cârnic.

These rock outcrops appear to be relatively small in the overall landscape and their aesthetic quality is minimised by their situation on the degraded slopes of Cetate and Cârnic. Site development will result in the approved relocation of Piatra Despicata and in-place conservation of Piatra Corbului. The landscape features as well as the natural monument of the area are further described in the Chapter 4.7. Landscape. Exhibit 4.7.3 and Photos 4.7.13 and 4.7.14 provide additional detail.

2.8 Conditions for Carrying Out the Geological Engineering Works

Extensive studies have been conducted to address the geologic conditions in the Project area. A key component of these evaluations is the selection of the mining method. The geologic conditions are a significant factor in determining how the ore reserve can be economically extracted. As described in Chapter 5, the open pit method was determined to be the only economic method. Underground mining is not economically viable.
Detailed geotechnical investigations have been conducted in the area of the proposed facilities and excavations to facilitate correct design. The major geotechnical studies evaluated in detail the processing plant area, the Cârnic Waste Rock Stockpile, Tailings Management Facility, Secondary Containment Dam and Cetate Water Catchment Dam, the quarried dam construction materials, as well as the stability of Project excavations (the open-pit mines).

The geotechnical investigations addressed the soil and sub-soil geologic conditions so that foundations and structures could be correctly designed to reduce settlement and potential damage to structures. The subsurface geology in the area of all of the key project structures was determined to contain significant shale. For the water management facilities, this is beneficial due to the low-permeability. However, the lower strength of this rock type and the associated weathered rock and soil, requires consideration when engineering Project structures.

The plant site is underlain by variable thicknesses of clayey silt soil derived from the weathering of the underlying Cretaceous sedimentary rock. The rock consists of mostly shale with sandstones and conglomerate. The contact between the weathered and unweathered rock is not always clearly defined, and the near surface weathered material and soil is not suitable for direct support of heavily loaded, settlement sensitive structures. Such structures will be founded on suitable rock material or engineered fill consisting of imported clean, free draining, well-graded durable aggregate from one of the quarry sources.

Sub-soil geology in the Corna Valley and Roşia Valley beneath the significant waste rock, tailings and water retention facilities was found to consist of weathered rock overlying unweathered Cretaceous sedimentary bedrock. The weathered rock is overlain by alluvium, colluvium and soils. The sedimentary rock geology consists of predominately black shale with interbedded sandstone and conglomerate. The geology of these areas was described previously in Section 4.5.1. The geotechnical properties of these materials are similar to the ones found at the plant site and have been evaluated and used in the basic engineering studies. They will be carefully reviewed and will be a key consideration in the final design of all the structures at the detailed engineering stage.

Geotechnical investigations have also been completed for the Cetate and Cârnic open pits comprising the completion of core oriented drill holes, packer permeability testing, surface mapping of existing pit benches and road cuts as well as field strength and laboratory testing. The purpose of this work was to provide site-specific geotechnical data for a feasibility level open pit slope design for the Cetate, Cârnic, and the smaller Jig and Orlea open pits.

The main rock types that are expected to form the final pit walls will comprise dacite, vent breccia and black breccia. The dacite is generally moderately fractured and competent. Local argillaceous zones are present that are of weak strength. The rock quality of the dacite can generally be described as being “GOOD” using common rock quality classification criteria (e.g., Deere, 1963). The rock quality of the vent breccia and black breccia can generally be described as being “FAIR”. The uniaxial compressive and triaxial strength testing results have indicated generally consistent data on the intact and shear strength of the dacite and vent breccia rock types of the deposit.

Rock mass structural orientation data from surface and underground drilling as well as underground mapping were thoroughly reviewed and evaluated as part of the pit wall stability evaluation. This information was found to be in general agreement with structural orientation data from the geotechnical drill holes and surface mapping. The orientations of the main joint sets for each of the rock types were selected from stereonet projections of the structural orientation data for use in the pit slope design. Site-specific structural orientation data were considered for the Cetate and Cârnic pit areas from geotechnical investigations.
Site-specific structural orientation data were considered for the Orlea and Jig pit areas from completed core-oriented exploration drilling.

Based on the geotechnical program data, pit design parameters were recommended and are reflected in the mine pit designs described in Chapter 2.3.2. Highwall stability analyses, using a limit equilibrium computer program, were carried out for the overall slopes within the open pit sections where poor to fair quality vent and black breccia rock are expected to form the overall final walls, to confirm that the recommended pit bench geometry is acceptable over these entire highwalls. The results of these analyses indicate that the highwalls formed in these poor to fair quality rock conditions will be required to be developed at shallower overall slope angles than those determined from the kinematic stereonet analyses that account only for failure along the rock mass structure.

As described in Chapter 2.3.2, as a result of drainage provided by the old underground workings, mine dewatering requirements are expected to be negligible down to an elevation of approximately 720 metres above sea level (mASL). However, some potential exists for impounded bodies of water to be encountered in old underground workings. Below 720 mASL, a dewatering requirement has been assumed. The dewatering system will consist of vertical dewatering wells and sub-horizontal gravity drains. Conventional practice will be employed using in-pit sumps to collect these gravity drains.

2.9 Geological Processes

Geological processes associated with the subsurface geology in the project area are minor. The seismicity of the area was previously discussed in Section 2.3., Seismicity. Landslides are documented processes in the Project area that can involve some of the bedrock and is a consideration in the design and operation of the Project. In general a landslide is triggered by the presence of a low-strength geological formation (such as shales). The impacts of historical landslides on Project structures have been evaluated as part of geological investigations such as the investigation of the process plant site area. The risks associated with landslide processes within the mine area have been reviewed and were found to be minimal, as presented in detail in Chapter 7. Management of the process plant and pit development will prevent any slides that may impact the area, as detailed in the Water Management & Erosion Control Management Plan and the Mine Closure Plan.
3 Assessment of Impacts

In the assessment of impacts, both the local impacts and impacts outside the Project boundaries (transboundary) are considered. Because the geology is relatively immovable the impacts are largely local as described below. However, transboundary impacts can occur as the result of secondary impacts that result from altering the geologic conditions. This is discussed most thoroughly in association with the media that are primarily impacted, which in this case includes water (Chapter 4.1). Specifically, the geochemistry of the rocks to be exposed during the Project, which is described in this section, can result in generation of ARD. While this is a geological characteristic, the impact is to water and is appropriately described in Chapter 4.1 Water.

3.1 Impact to the Local Geologic Environment

Impacts are discussed for the three phases of the Project: construction, operation and closure, where appropriate. Impacts to the geology will begin during the construction phase, although they will become more extensive in the operational phase. The effect of the impacts will still be present in the closure phase, although most will be reduced by the closure procedures. The specific impacts to the area subsoil geology are described below and summarised in Table 3-1. Measures for mitigating the impacts discussed in this section are described in Section 4, below.

3.1.1 Depletion of Sandstone and Andesite Reserves from Quarrying

Appropriate quality rock will be needed for construction of various Project facilities with most being used in the Tailings Management Facility starter dam. The Cetate Water Catchment Dam will also require quarried rock. The rock will be quarried from the Sulei and La Piriul Porcului quarries (Exhibits 2.3 and 2.4). Andesite will be excavated at the Sulei quarry removing a large andesite outcrop. The impact of the sandstone quarrying from La Piriul Porcului will be less visible. These reserves of good quality construction rock will be utilised, depleting a portion of the reserve in the Roșia Montană area. However, sufficient reserves will be available in the area for future projects. In addition, once the Project enters the operational phase, waste rock will be used for some construction, minimising the subsequent need for the quarried material. Overall, this is considered a minor impact.

3.1.2 Covering of Geologic Outcrop and Material with Waste Rock and Tailings

Beginning in the construction phase, some geologic exposures will be covered by the waste rock stockpiles and tailings management facility. However, the loss of this geologic information will not be significant. The areas covered by waste rock and tailings have been evaluated for their economic potential and no potential resource areas, under future foreseeable economic conditions, will have been sterilized by waste rock disposal. The final pit will be retained, in a rehabilitated condition, as a possible access point to resources that are currently uneconomic to recover. In addition, exposures covered by tailings and waste rock do not have high visibility. Overall, this impact is minor.
3.1.3 **Removal of Geologic Outcrops and Geologic Monuments**

Natural geologic outcrops will be removed within the pit and quarry areas. However, there will be a net gain in geologic exposure due to the excavation of the mine pits. The geologic information will not be lost and in fact a greater understanding will be developed as a necessary part of the Project. The Piatra Despicata and Piatra Corbului natural monuments are located within the mine boundary. Piatra Corbului will remain in-place and approval has been granted to relocate Piatra Despicata. These monuments were previously discussed in Section 2.7, above.

3.1.4 **Depletion of the Geologic Ore Resource**

Extraction of ore and realisation of the associated benefits of the geologic mineralization is the primary objective of the project. However, mining activities will be subject to precise planning to ensure that extraction is limited only to reserves that are economically recoverable with best available technologies. This impact is limited to the operational phase and is considered minor in that a geologic ore reserve is only present if it can be economically mined. As presented in Sections 2.6 and 4.2, mineral resources in the Project area will not be completely depleted, and major Project components have been designed and laid out in such a way to minimize the loss of remaining resources.

As part of closure and rehabilitation activities that will start during the later part of the mine life, substantial volumes of soil will be required for construction of covers that will retard water infiltration. Covers are planned for the waste rock stockpiles as well as the tailings facility. Without proper planning during the initial phases of the project, substantial new borrow areas may be required. However, the current project plans include stripping and stockpiling of all recoverable topsoil materials for re-use during closure and rehabilitation. In addition, excess soil and rock materials excavated as part of the plant site construction will be stockpiled for re-use. This will avoid additional new disturbance and additional impacts to subsurface geology.

In summary, the primary impact from the proposed development is the disturbance of land within the pit footprints, as well as that of the ARD that may occur once mineralised rock is exposed at the surface. Impacts that result from ARD are to water, and as such, are described in Section 4.1, *Water*.

3.2 **Transboundary Impacts**

There are no expected transboundary impacts directly related to the subsurface geology. Impacts to geology by their nature are localised. However, the geologic conditions can affect water quality and quantity. Those impacts that may transgress boundaries are described in Section 4.1, *Water*.
4 Mitigation Measures for Subsoil Geology (Bedrock Geology)

The impacts presented in Subsection 3, above, will be mitigated to various degrees by procedures that are also necessary for economic extraction of the ore resource. However, the most significant mitigation measures are those associated with water quality and quantity that are affected by disturbance of the subsoil geology. These are discussed most thoroughly in the text associated with water, Chapter 4.1, Water. Mitigation measures associated with alternative locations and technological applications are described in this section, as well as some measures to address the cultural and education aspects associated with geology.

Table 4-1 provides a summary of the geologic impacts and their proposed mitigation measures.
Table 4-1. Geology Impact Summary Table

<table>
<thead>
<tr>
<th>Potential Impact</th>
<th>Mitigation Measures</th>
<th>Applicable Management Plans</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depletion of sandstone and andesite reserves from quarrying operations</td>
<td>Precise sizing and planning of quarrying operations to limit extraction of construction materials to the quantities necessary to support construction.</td>
<td>Annual Mining Plan (see Section 4.6 of the Roşia Montană Project Environmental and Social Management Plan)</td>
</tr>
<tr>
<td>Covering or removal of geologic outcrops and other surficial features in construction of new roads, process plant site, stockpiling of topsoil and quarried materials</td>
<td>None; the impact is minor, and the geologic understanding of the area that will result from the development of the geologic resource will far exceed the geologic knowledge lost from any coverage of surficial geology.</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Operation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Removal of geologic outcrops and geologic monuments</td>
<td>Removal of geologic outcrops will be mitigated by exposure of new outcrops and subsurface geology in the mines. The exploration and mining of the ore deposit will increase geologic knowledge and provide opportunities for the training of new geologists. Geologic &quot;monuments&quot; will either be preserved or relocated. Additionally, public access to geologic information will be improved by public displays of educational materials related to geology and the mining history of the Roşia Montană area.</td>
<td>Annual Mining Plan (see Section 4.6 of the Roşia Montană Project Environmental and Social Management Plan) and Cultural Heritage Management Plan</td>
</tr>
<tr>
<td>Covering geologic outcrops with waste rock and tailings</td>
<td>None; the impact is minor, and the geologic understanding of the area that will result from the development of the geologic resource will far exceed the geologic knowledge lost from any coverage of surficial geology.</td>
<td>N/A</td>
</tr>
<tr>
<td>Depletion of geologic ore reserve</td>
<td>Extraction of ore and realisation of the associated benefits of the geologic mineralisation is the primary objective of the project; however, mining activities will be subject to precise planning to ensure that extraction is limited only to reserves that are economically recoverable with best available technologies. &quot;Sterilisation&quot; of the reserves (e.g., limitation of future access to the reserves) ill be limited by the placement of waste rock stockpiles and other Project components on top of non-mineralised or marginally mineralised areas.</td>
<td>Annual Mining Plan (see Section 4.6 of the Roşia Montană Project Environmental and Social Management Plan)</td>
</tr>
<tr>
<td><strong>Decommissioning and Closure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact to hidrogeologic conditions and groundwater flow from decommissioning and closure activities</td>
<td>Some loss of groundwater discharge to surface water streams is predicted and will be mitigated through flow supplementation. Impacts are predicted to decrease as hydrology returns to natural conditions. Detailed discussion is provided in Section 4.1, Water.</td>
<td>Water Management and Erosion Control Plan; Tailings Facility Management Plan; Mine Rehabilitation and Closure Management Plan</td>
</tr>
<tr>
<td>Potential Impact</td>
<td>Mitigation Measures</td>
<td>Applicable Management Plans</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
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</tr>
<tr>
<td>Development of borrow areas for closure covers and revegetation</td>
<td>Due to careful material management during construction, it is expected that the majority of topsoil and overburden required for closure will be developed and stockpiled during construction. Therefore, no new borrow areas will be required at closure and no geologic resources will be lost.</td>
<td>Mine Rehabilitation and Closure Management Plan</td>
</tr>
</tbody>
</table>
4.1 Alternative Locations

The location of the mine is fixed by the in situ mineral resource. In all mining operations, the locations of excavations must be optimised in order to make a project economically viable. In addition, other alternative sites would have similar impacts to the bedrock geology as part of the Project development. Therefore, other sites were not investigated as part of the mitigation measures for the geology.

The availability of suitable construction rock is an important economic consideration for the success of the Project. The selection of quarries for andesite and sandstone construction material is based on the identification of suitable rock within an economical distance from the mine. Several locations were evaluated with the two locations selected as described in Chapter 5.8. Other locations did not contain suitable material, had larger impacts, or were economically not viable.

4.2 Technological Measures

Ore extraction will be planned in such a way to minimise the footprint of the excavations and creation of waste rock. This is both an important consideration in reducing the impact and creating an economically viable project. Similarly, placement of mined waste will be done so that geologic ore reserves not viable under current economic conditions are not covered and left inaccessible should economic conditions or technology change.

In addition, careful planning will enable minimization of subsurface impacts related to caverns, adits or openings that are encountered during open pit excavations. Currently, the ore body is very well defined in a three-dimensional space, and the presence of underground mine workings is well known. It is expected that excavation work in selected pits will remove most of the existing underground caverns, and the project is designed to deal with these situations when they arise. Mitigation measures will be in place to keep the mine site safe and properly rehabilitate the area, including backfilling and/or sealing any remaining openings.

Impacts to the hydrological conditions will be mitigated through flow supplementation to impacted surface water streams to provide acceptable minimal flows to support biological conditions. This mitigation is described in more detail in Chapter 4.1, Water. The mitigation measures designed to address the impacts of ARD, which results from exposure of the geologic material, are also addressed in the water section. As described in the water section, to address pollution that may be generated from exposure of reactive geologic materials, the project will largely rely on avoidance of exposure of ARD materials in the first place and also the collection and treatment of water that does contact these materials. These measures will also address existing sources of pollution in the Roșia Valley and Corna Valley.

The principal strategy for the mitigation of impacts on land resources is to develop a closure plan to re-establish appropriate land uses. The impacts of the removal of the geological resource are considered secondary impacts to biodiversity and land-use and therefore such measures for mitigation will be dealt with in other sections of this report. The closure plan that is presented in Chapter 2.4 and in the Mine Rehabilitation and Closure Management Plan sets out the concepts for re-establishing stable landforms and productive vegetation in the project development area.
4.3 Other Measures

Removal or covering of geologic outcrops in the quarry and mining areas will be mitigated by exposure of new outcrops and subsurface geology. The exploration and mining of the ore deposit will increase geologic knowledge of the area and the type of ore body mined, and will provide opportunities for the training of new geologists, engineers and technologists in the mining sector. Such geologic knowledge and skills will be important for Romania and for the development of similar ore deposits, which will provide future economic benefit to the region. Any loss of geologic "monuments" will be mitigated by public displays of educational materials related to geology and the mining history of the Roșia Montană area. The pit walls will expose subsurface geology which, if accompanied by displays, will provide future visitors with a unique opportunity to visualise the geology associated with the rich mining history of the area.
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