The KOIDU VERTICAL PIT

Design & Implementation

Joubert, J.S.C., Freeman, L., Terbrugge, P.J. & Venter, J.
Koidu Holdings S.A. is a wholly owned subsidiary of BSG Resources.

Koidu Holdings S.A.
Koidu Kimberlite Project
- 330 km east of capital Freetown
- 25 year Mining Lease
- Area - 4 km²

Tongo Diamond Field Project
- 68 km south of Koidu
- 25 year Mining Lease
- Area - 88.5 km²

Exploration
- Kangama
- Upper Sewa River
- Middle Sewa River
- Matemu
Vertical Pit Mining

- New mining technique – previously used at Nyala chrome deposit in Zimbabwe in the 1990s
- Koidu Holdings has refined this technique on the No. 1 Pipe kimberlite at Koidu
- Koidu vertical pit is the largest diameter open air shaft with a vertical depth of 74m from collar
- Dimensions: 90m x 48m x 74m
Why Vertical Pit Mining at the Koidu Kimberlite Project?
Koidu Kimberlite Project – No. 1 Pipe History

- 1953 – 1984: Drilling, sampling and mining of No. 1 Pipe and No. 2 Pipe by SLST & NDMC
- 1984 – 1997: Dormant
- 1997: DiamondWorks to start sampling, disrupted by war
- 1997 – 2002: Civil war
- 2002 – 2003: Redevelopment of KKP
- 2004 onwards:
  - Q1 2004 – Initial bulk sample using conventional open pit
  - 2004 to 2008 – Interim mine plan whilst assessing economic feasibility of under ground mine
Mining Options for No. 1 Pipe as at 2004

- **Open Pit**
  - Initial planning allowed for 3 cuts over 4 years
  - High stripping ratio on 3rd cut
  - Social Impact

- **Underground**
  - Limited drilling and bulk sampling information available
  - Insufficient information to justify underground mining expenditure

- **Vertical Pit**
  - Never been attempted on kimberlite
  - Technical and operational challenges
Factors considered in selection of mining method

- Continuous Operation/Cash Flow
- Social and Environmental Issues
  - Proximity to residential area
  - Impact of blasting procedures
  - Restrictions on blasting frequency
  - Ongoing resettlement program
  - Size of environmental footprint

No. 1 Pipe Open Pit – March 2005
Factors considered in selection of mining method

- Geological/Mining/Geotechnical factors
  - Size and shape of pipe
  - Condition of host rock
  - Grade
  - Limited drilling at depth
- Operational and Economic Trade-off Study

No. 1 Pipe surface mapping and drillholes – December 2003
Design Criteria

- Design by SRK Consulting
  - Also involved at Nyala
- Geotechnical
  - Hoek-Brown Failure Criteria
  - Rock mass strengths
  - Structures
  - Ground water
  - Lateral support
- Operational
  - Production target 26,000 tonnes ore per month
From open pit ... to vertical pit...

Open Pit – March 2005
Vertical Pit development – May 2005
Vertical Pit – November 2005
Implementing the mine plan involves several key components:

- Regulatory framework
- Site establishment
- Infrastructure
- Drilling and blasting
- Loading and hoisting
- Support
- Monitoring
- Dewatering
- Mine Planning/scheduling
Infrastructure

- A-Frame headgear
- Winder
- Generators
- Compressors
- Fuel storage
- First aid station
- Stores
- Pump station and services
- Lighting plant
- Safety wall and ladderways
- Drainage system
- Survey beacons
- Offices
- Safety and security systems
Drilling and Blasting

- Blast design
- Scheduling
- Constraints
Loading and Hoisting

- **Shaft Sickers** – contracted to supply and operate hoisting arrangement
- Loading from muck pile
- Hauling to kibble
- Hoisting
- Cycle time/capacity

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Cycle time (min)</th>
<th>Tonnes / hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>9.3</td>
<td>80</td>
</tr>
<tr>
<td>60</td>
<td>10.4</td>
<td>72</td>
</tr>
<tr>
<td>90</td>
<td>11.7</td>
<td>64</td>
</tr>
</tbody>
</table>
Lateral Support Specifications

- **Cable Anchors**
  - 20 m long cable anchors tensioned to 40 t at a 5 m by 5 m spacing
  - Fixed end 5 m long leaving 15 m free for tensioning and grouting

- **Dowels (Rockbolts)**
  - Fully bonded grouted dowels with an ultimate tensile strength of 14 tonnes at a 1.5 by 1.5 m spacing

- **Weldmesh**
  - Wire diameter of 4 mm
  - Aperture size of 150 mm

- **Wetcrete**
  - Compressive strength of 30 MPa
  - Minimum thickness of 75 mm
Cable Anchor Installation

- Fully prepared 20m anchor rope - bulbed with grout guide and base plate
- SPX Power Team Hydraulic Pump with Stress Tech RAM 500KN Hydraulic Jack
- FEMCO Electric_Hydraulic Bulbing rig
- Anchor tensioning
- ICTUS 2000 Grout Pump with Air Grout Mixer and Mixing Drum
Slope Monitoring Programme

- To detect early signs of impending fall of ground
- Regular visual inspections of surrounding rock mass
- Regular monitoring of ground water levels
- Regular survey of targets on side walls and beacons on collar
Dewatering

- Ground water
  - Geohydrological investigation
  - Vertical and inclined boreholes
  - Pumping arrangement
- Surface water
  - 4,000mm rainfall per annum
  - Drainage systems
  - Sump
  - Pumping arrangements
Mine Planning/Scheduling

- **Sequencing** (drilling, blasting, anchor installation, wire mesh, rock bolts, wetcreting, loading and hauling, hoisting, maintenance)
- **Constraints** (blasting, drilling capacity, hoisting capacity, logistical support)
### Financial Analysis

<table>
<thead>
<tr>
<th>Activity</th>
<th>Capital Cost</th>
<th>Operating Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Pit</td>
<td>$4.3 million</td>
<td>$2.50/t</td>
</tr>
<tr>
<td>Underground</td>
<td>Approx $50 million</td>
<td>$40/t</td>
</tr>
<tr>
<td>Vertical Pit</td>
<td>$3.1 million</td>
<td>$15.2</td>
</tr>
</tbody>
</table>

### Cost comparison OP vs VP from 345 – 265m amsl

<table>
<thead>
<tr>
<th>Activity</th>
<th>Open Pit Cost (US$)</th>
<th>Vertical Pit Cost (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open pit phase</td>
<td>15,856,250</td>
<td>1,348,000</td>
</tr>
<tr>
<td>Vertical pit phase</td>
<td>15,856,250</td>
<td>14,430,591</td>
</tr>
<tr>
<td>Waste development</td>
<td>15,856,250</td>
<td>15,778,591</td>
</tr>
<tr>
<td>Total</td>
<td>15,856,250</td>
<td>17,892,591</td>
</tr>
</tbody>
</table>

Budget requirement 25,000 tonnes processed per month
Vertical pit mining has been shown to be an economically viable alternative to open pit and underground mining methods on small kimberlite pipes.

The factors critical to the successful implementation of this technique are the following:

- **Geology** – The geometry of the orebody must be known;
- **Host rock** – An imperative for the design is a full geotechnical appreciation of the host rock and the groundwater conditions
- **Size and Shape** – Variances in size and shape can be problematic particularly with the development of overhangs;
- **Economic factors** – required depletion rate, cost per tonne, revenue per tonne
- **Implementation** – Design specifications should be strictly adhered to with efficient quality control; and
- **Geotechnical** – Ongoing geotechnical input including mapping and logging is a pre-requisite for success.