Elemental Minerals’ Sintoukola potash deposit

In August 2012, Elemental Minerals Ltd (ELM), a mineral exploration and development company listed on the ASX, announced an updated sylvinitic mineral resource for its Sintoukola deposits, situated on the Republic of Congo coastal plain (Figure 1), containing the Kola potash deposit and Dougo exploration target.

Historically, 26 exploration holes were sunk within the permit area by previous explorers who, subsequently, identified potash seams occurring as both sylvinitic and carnallinitic mineralisation, situated at depths varying from 250 to 1,000 metres. ELM completed 48 vertical diamond drill holes across the Sintoukola project for a total of approximately 17,000 metres, in conjunction with 203 line kilometres of 2D seismic data.

The company announced an updated sylvinitic mineral resource estimate by CSA Global Pty Ltd for the Kola deposit of 264 m tonnes, grading at 21.3% K₂O measured resource, 309 m tonnes, at 20.59% K₂O indicated resource and 475 m tonnes, at 20.39% K₂O inferred resource (Tables 1 and 2). This potash resource is considered to be high-grade, relatively shallow and and comparatively large by global standards.

In addition to the Kola resource, the company recently announced an exploration target for its Dougo prospect of 1-1.4bn tonnes grading between 23% and 25% KCl and having an average thickness of 9.3 metres.

Geology

The Kola potash deposit, and the Dougo exploration target, are hosted by the Aptian-aged Loeme evaporite formation which forms part of the Lower Cretaceous sequence of the coastal Congo basin. The evaporites comprise primarily halite (NaCl), sylvite (KCl), carnallite (K₂MgCl₂·6H₂O), bischofite (K₂MgCl₂·6H₂O) and minor anhydrite (CaSO₄) (Figure 2).

The potash seams are interbedded within the halite layers of the evaporites, which are typically between 400 and 600 metres thick within the Sintoukola permit, and referred to as the salt sequence. The latter is overlain by a 5 to 20 metre thick layer comprised of anhydrite, gypsum, clay and organic material termed the anhydrite sequence which is considered an aquitard.

Within the salt sequence, up to 10 depositional cycles have been identified, comprising alternations of rock salt and carnallinite (carnallite and halite) converted locally to sylvinite (sylvite and halite). Project data indicate that the chemical composition of the salt sequence is exceptional, by the virtual absence of insoluble and other chemical sediments and the high proportion (15%) of carnallite with the primary potash (carnallite) layers (Dorling & Scogings, 2012).

Several potash seams are present (Figure 3). Those of economic importance are named, starting with the uppermost, as the Hangingwall Seam (HWS), Upper Seam (US), Lower Seam (LS), and the Footwall Seam (FWS). The potash seams can be correlated across the deposit extent and are generally sub-horizontal, with localised undulations not exceeding approximately 15° dip.

The thickness of the important seams averages between three and six metres for the sylvinitic and six to ten metres for the carnallinitic. The contact between the salt sequence and the overlying anhydrite sequence is discontinuous and, depending on salt creep and dissolution of the seams relative to this contact, they may be locally removed (see description of ‘washout’ modelling below).

The mineralisation comprises sylvinitic layers, carnallinite layers or less frequently layers containing both sylvinitic and carnallinitic. In the latter, the two mineralisation types are not inter-mixed and sylvinitic is noted to occur above carnallinitic.

Table 1: Kola mineral resource estimate for sylvinitic mineralisation only.

<table>
<thead>
<tr>
<th></th>
<th>Measured</th>
<th>Indicated</th>
<th>Inferred</th>
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<tbody>
<tr>
<td></td>
<td>Tonnes (mt)</td>
<td>% K₂O</td>
<td>% KCl</td>
</tr>
<tr>
<td>HWS</td>
<td>171</td>
<td>22.5</td>
<td>35.5</td>
</tr>
<tr>
<td>US</td>
<td>9.5</td>
<td>19.2</td>
<td>30.4</td>
</tr>
<tr>
<td>FWS</td>
<td>225</td>
<td>17.6</td>
<td>27.9</td>
</tr>
<tr>
<td>Total</td>
<td>264</td>
<td>21.3</td>
<td>33.7</td>
</tr>
</tbody>
</table>

Table 2: Kola mineral resource estimate for sylvinitic and carnallinitic mineralisation (includes sylvinitic resources of Table 1).

<table>
<thead>
<tr>
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<th>Measured</th>
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<tbody>
<tr>
<td></td>
<td>Tonnes (mt)</td>
<td>% K₂O</td>
<td>% KCl</td>
</tr>
<tr>
<td>HWS</td>
<td>245</td>
<td>19.5</td>
<td>30.9</td>
</tr>
<tr>
<td>US</td>
<td>315</td>
<td>13.3</td>
<td>21</td>
</tr>
<tr>
<td>FWS</td>
<td>551</td>
<td>16</td>
<td>25.4</td>
</tr>
<tr>
<td>Total</td>
<td>559</td>
<td>16</td>
<td>25.4</td>
</tr>
</tbody>
</table>

Notes: 1) Sylvinitic density = 2.07 g/cm³ and carnallinitic density = 1.7 g/cm³. 2) Table entries rounded to first significant figure. 3) Mineral resources which are not mineral reserves do not have demonstrated economic viability and may be materially affected by environmental, permitting, legal, marketing, or other relevant issues.
As illustrated in Figure 3, sylvinite at Kola is considered to be a secondary mineral, formed by the leaching of magnesium chloride from primary carnallite and controlled by the vertical and lateral movement of leaching brines originating from the top of the salt sequence (Dorling & Scoeings, 2012).

The uppermost seam modelled to date is the HWS which is known to consist in places of high-grade sylvinite. The main seams of economic interest, about 60 metres below the HWS, are described as the US and LS which are in close vertical proximity and separated by a barren halite interval - 3.6 metres thick, described as interburden Halite, or IBH.

The US consists predominantly of sylvinite, with an increasing proportion of halite towards the upper contact. The LS is either entirely of carnallite or sylvinite, or comprised of sylvinite above carnallitite. The FWS is the lowermost significant potash seam and is approximately 45 metres below the LS. In places where the US and LS have been largely or entirely removed, the FWS consists of sylvinite, elsewhere the FWS is known to consist of carnallitite and bischofite.

On the basis of potash mineralogy, sylvinite and carnallitite domains can be delineated within the US and LS. These are identified as upper carnallite sylvinite (USS) and upper sylvinite carnallitite (USC) and the lower carnallite sylvinite (LSS) and lower carnallitite (LSC).

![Image](Figure 2. Representative coresamples. Macroscopic textures of the salt minerals (Syl = sylvinite, Hal = halite, Anh = anhydrite, Car = carnallite, Bis = bischofite).)

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Genetic interpretation

The Kola potash horizons are the result of a natural chemical process that has its origin in hyper-saline brine that probably originated from sea water evaporation. With increased evaporation the brine becomes saturated in various salt-forming alkaline metals and the salt (chloride) precipitate. The cyclicity within the salt formation and the internal mineralogical cyclicity within each cycle is a record of this process.

Whilst carnallite is a naturally occurring mineral, extensive research (e.g., Warren, 2006; Schleder et al., 2008) shows that sylvite in ancient geological systems is not a primary precipitated mineral, rather, its formation relies on conversion from carnallite.

The sylvitic horizons of the Congo coastal plain are likewise interpreted to be secondary in origin (de Rutter, 1979). The formation of sylvite requires that the precursor carnallite mineral reacted with NaCl-saturated brines according to the reaction: carnallite + water = sylvite + MgCl₂ rich brine.

It is thought that the ingress of water into the carnallitic layers was a consequence of water permeating through pore spaces or fractures in the anhydrite sequence, with the rate of inflow expected to be higher in areas of higher permeability, or if disturbances are present, where the aqutated capacity of the cap rocks (anhydrite) is reduced.

The process of time, flushing that is thought to have affected the salt layers is also likely to be a continuous process that ultimately will lead to the localised complete removal of Mg and K from the system (refer to ‘washout’ in Figure 3).

Resource Modelling

These days, resource geologists have access to a wide range of software packages specifically suited to gridded seam modelling and resource estimation, such as Carbon™, GEOSTA Minex™, Maptek Valcam™ and Ventrix MineScape™. In addition, some of the more traditional 3D block modelling software suppliers, for example Micromine and CAE, have recently developed seam block-modelling packages such as Coal Measure™ and Stera 3D™ respectively. In the authors’ experience, more than one geology software package may be used during a project in order to maximise complementary strengths.

Most gridding software packages produce surfaces using algorithms, including: i) triangulation, ii) inverse distance weighting, iii) kriging or iv) a proprietary algorithm, each of which may have certain benefits or disadvantages. Thus, triangulation strictly honours data, but presents linear interpolation of values between data points which may be nothing like the surface interpreted by a geologist.

Inverse distance weighting techniques may produce surfaces which do not contain estimated values outside of the data limits, thereby producing artefacts in the modelled surfaces (e.g. Waltho et al., 2014). Proprietary surface generation methods may also present technical risks if the algorithm is not clearly documented or understood by the user.

It is highly recommended that whichever software package is used, the resource geologist should ensure the methods used are appropriate for the mineralisation style and that the final model represents the geological interpretation. Validation of the model is key, as is an understanding of the geological and genetic model.

In the particular case of Kola, the gridding method used by CSA Global was Minex’s general (or growth) method of gridding to generate geological surfaces such as Seam Floor (SF) and Seam Roof (SR) in addition to estimating Seam Thickness (ST). As illustrated in Figure 4, the program first calculates values for the grid intersections surrounding each data point.

After the nodes around all boreholes are calculated, the boreholes are removed from further consideration. The program then makes a series of passes over the grid. At each pass it calculates values for any grid node that have not been assigned a value and that are adjacent to an assigned node, therefore
each iteration enlarges the calculated region around the original borehole locations.

Milling seams were set and interpolated using Minex™ Bore Seam Modelling functions so as to complete the stratigraphic sequence and for purposes of applying seam washouts. For the purpose of correctly modelling seam geometries, the interpolated missing seam positions were placed above the logged anhydrite sequence in certain boreholes, in accordance with the genetic model.

This resulted in potash seams being truncated by the anhydrite layer (Figure 6). Drillholes EK21, 30, 34 and 37 were stopped short and were used to model the anhydrite only.

Strings representing the IBH and anhydrite were digitised as reference surfaces in Micromine™ on the basis of seismic reflector patterns and drillhole intercepts (Figure 5). The seismic reflector strings were imported into Minex™ as xyz points which were then assigned the suffix ‘SF’, so that they could be incorporated into the seam floor modelling process (Figure 7). Minor adjustments were made to the seismic strings near some drillholes wherever needed, to enable as close as possible to the IBHSF and ANHYSF with the seam picks.

Where potash seams were interpreted to have been removed by dissolution, the seams were modified by utilising the Minex™ washout function. The washout function takes into account drillhole seam information to estimate the extent of mineralization around drillholes without specific seam intercepts. The function requires inputs of a maximum distance (search distance surrounding all drillholes to ensure complete overlap of the model grid) and a ‘valid distance’ (the maximum washout radius allowed).

The washout valid distance was derived by an interactive process and, in particular, by assessing the...
effort of increased valid distance on interpolated US
positions in the vicinity of adjacent drillholes EK03,
EK11 and EK16. Three barren drillholes (no US
intersections) are between 1,000 and 1,200
metres apart and it was observed that a 1,500 metre
‘valid distance’ resulted in a washout area deemed
appropriate according to the exploration data and
geological model (Figures 8 & 9).

Seam thickness is the underlying control for
Minex™ gridded seam modelling, for which an
east-west grid dimension of 25 x 25 metres was
chosen to honour both the closely spaced seismic
points and drillhole intersections. Subsequent seam
building involved the generation of seam floor and
seam thickness grids, followed by the addition of
seam roof or floor grids according to seam thickness.
Minex™ Grid Arithmetic was used to calculate
interburden between seams, after which the Strata
Build function was applied to build the evaporite
sequence based around the interburden halite
control seam.

Approximately 7% of the area surveyed by high
resolution 2D seismic surveys (~30 km²) contains
geological anomalies (structural lows or disturbance
areas) which may impact the thickness, grade and
potential mineability of the potash mineralisation.
For this season the areas identified as disturbance
areas have been excluded from estimates of mineral
resources.

An assessment of different estimation methods
was completed (including Minex’s growth algorithm
and Ordinary Kriging) from which it was decided
that Inverse Distance Weighting was best suited to
the current data density in the various domains.
Minex’s Modified Inverse Distance Weighting to
the power of 2 (IDW2) along a major axis 328°
and with an anisotropic ratio of 1 (major axis): 0.8
(minor axis) was the selected method for all grade
estimation runs.

Mineral Resource Classification
The classification of mineral resources at the Kola
deposit considered the following factors:

• Level of confidence in geological understanding;
• Area of influence and spacing between drillholes;
• Extent of 2D seismic coverage and interpretation;
• Grade and thickness variation within the seams;
• Quality of assay data and density measurements;
• Structural complexity and structural
interpretation; and
• Geological/mineralogical information outside the
immediate deposit area.

Conclusions

• The gridded seam method was demonstrated to be
suitable for resource modelling of laterally
extensive potash seams such as at Kola;
• Incorporation of seismic data resulted in an
improved seam model;
• The Minex™ washout function catered for the
conveyance of halogen and removal of K and Mg in
areas of higher permeability;
• More than one geological software package may
be desirable for resource modelling, in order to
maximise complementary strengths and
capabilities.

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