THE OPTIMIZATION
OF MINERAL EXPLORATION INVESTMENTS WITH
IMPOSED TARGETS BY THE PROGRAM EXIST

by

H.I. DE WOLDE and J.W. BRINCK

1971

Joint Nuclear Research Centre
Ispra Establishment - Italy
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and
Directorate-General Energy
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1. A sufficient capitalized reserve must be always accessible
2. Strong variations in exploration activities are not desirable
3. The expenditures must be minimal while respecting the other conditions
4. Future adaptations of the definition of an exploitable deposit, imposed by the digestion of available reserves have to be incorporated.
The program "EXIST" is strongly related to the already published program "EXILE". Large parts of both programs are identical.
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ABSTRACT

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KEYWORDS

COMPUTERS  PROSPECTING
PROGRAMMING  INVESTMENT
OPTIMIZATION  DEPOSITS
MINERALS  EXPLORATION
EXPLORATION  FORTRAN
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INTRODUCTION *)

The program 'EXIST' is strongly related to the exploration investment optimization program 'EXILE'. Large parts of the both programs are identical and this paper refers accordingly many times to the already published 'EXILE' report.

The computer program 'EXIST' optimizes the mineral exploration investments according to the criterions:
1. A sufficient capitalized reserve must be always accessible
2. Strong variations in exploration activities must be avoided
3. The expenditures have to be minimal, respecting the other conditions
4. Future adaptions of the economic definition of an exploitable ore deposit, imposed by the digestion of available reserves, have to be forecasted and incorporated.

The major difference between 'EXILE' and 'EXIST' is given by the fourth criterion: 'EXIST' constructs a forecast on the development of the definition of an exploitable ore deposit. The name of the program has been derived accordingly from: Exploitation Investments by Size of Target. Large lower grade deposits will become exploitable in future as more and more metal is required and the present reserves are digested. 'EXIST' recognizes a size increase factor and a grade decrease factor which together define a development trend of the quality of the reserves. The time at which these larger lower grade deposits will be economically exploitable depends on the consumption of the reserves. 'EXIST' calculates for each considered year a target deposit defined by a size and a grade. A secondary effect is the reduction of the unit exploration costs as larger deposits are easier to detect. This consequence is also quantitatively represented in 'EXIST'.

The next items are identical for 'EXILE' and 'EXIST':
1. The calculation of the stocktables
2. The capitalization scheme
3. The leveling procedure
4. The calculation of the probability of occurrence of deposits of certain size and grade.

*) Manuscript received on October 29, 1970
A brief description only of these items will be given in this paper since they have been described in full in the 'EXILE' report.

### THE ANNUAL STOCKTABLE

The annual stocktable is calculated on the specified annual requirements, $D_i$, and the requested size of the capitalized reserves expressed as a multiple $c$ on the annual requirements. The capitalized reserves $M_i$ can be calculated by a recurrent relation starting from the capitalized reserve at time zero, $M_0$:

$$M_i = M_{i-1} - D_i \quad \text{if} \quad M_{i-1} - D_i > c \cdot D_i \quad [1]$$

$$M_i = c \cdot D_i \quad \text{if} \quad M_{i-1} - D_i < c \cdot D_i \quad [2]$$

in which $i$ is the year index of the considered period.

The annual capitalized quantities $V_i$ are:

$$V_i = M_i - M_{i+1} + D_i \quad [3]$$

The annual non-capitalized reserves $M'_i$ and the annual discovery rates $M''_i$ are calculated according to:

$$M'_i = M''_{i-1} - V_i + M''_{\text{min}}$$

$$M''_i = \begin{cases} M''_{\text{min}} & \text{if } M'_{i-1} - V_i \geq \sum_{j=i+1}^{i+p} V_j \quad [4] \\ \sum_{j=i+1}^{i+p} V_j & \text{if } M'_{i-1} - V_i < \sum_{j=i+1}^{i+p} V_j \quad [5] \end{cases}$$

in which $M''_{\text{min}}$ is a specified minimum discovery rate and $i_p$ is the minimum time in years between the discovery of a deposit and its capitalization.

More details on the stocktable are given in the 'EXILE' report.
THE PROGNOSIS ON THE ORE QUALITY TREND

The definition of an exploitable ore deposit is related to the grade and to the total amount of metal in the deposit. Suppose that the total presently exploitable world reserves of a metal is \( r \) tons, occurring in deposits with an average grade of \( x \) PPM and an average size of \( z \) tons metal per deposit. Due to the digestion of the present reserves, in future lower grade deposits will become exploitable with a preference for the larger ones. The pattern of the definition development of the average ore deposit can be defined by two factors: a grade decrease factor \( F_x \) and a size increase factor \( F_z \). So one may state that for uranium a potential reserve with a grade of 2/3 times the present median ore-grade should contain at least 2.5 times the amount of uranium. The time at which these potential reserves become available depends on the digestion of the present reserves. The characteristics of the target deposit for each year \( i \) are given by:

\[
x_i = x \cdot F_x \text{ PPM}
\]

\[
z_i = z \cdot F_z \text{ tons of metal per deposit}
\]

in which: \( x, z \) are the characteristics of present exploitable deposits

\( F_x, F_z \) are the specified grade decrease, respectively size increase factor

\( t \) is a factor with the dimension of years, depending on the digestion of the available reserves

The total reserves in the year \( i \) plus the already consumed metal until the year \( i \) are:

\[
r_i = M_i + M_i' + \left[ r-M_o-M_o' \right] + \sum_{j=1}^{i} D_j \text{ tons of metal}
\]

in which:

\( M_i \) is the capitalized reserve

\( M_i' \) is the non-capitalized reserve

\( \left[ r-M_o-M_o' \right] \) is the cumulative consumption before time zero

\( r \) is the originally present quantity of metal of quality \([x, z]\)

\( D_j \) are the annual requirements.
if now $r_i \ll r$, the target deposit specifications for the year $i$ become:

$$x_i = x \text{ PPM}$$

$$z_i = z \text{ tons of metal per deposit}$$

otherwise $x_i$ and $z_i$ must be calculated.

The appropriate $x_i$ and $z_i$ for a requested reserve $r_i$ can be calculated by an iterative procedure. First a guess is made for $x_i$. Then the corresponding size $z_i$ is given by:

$$z_i = \exp \left( \frac{\log F_{z_i}}{\log F_x} \cdot \log \frac{x_i}{x} + \log z \right) \text{ tons of metal}$$

this expression is derived from the relations [6] and [7].

The following expressions are taken out of the theory on the Log-normal distributions of minerals as described in the 'EXILE' report. The linear equivalent of the deposit $x_i, z_i$ can be expressed in the linear equivalent of the present average exploitable deposit $x, z$ by:

$$i = \sqrt[3]{\frac{x_i z_i}{x_i z}} \cdot d \text{ KM}$$

Sequentially the next values are calculated:

$$\gamma_i = \frac{x}{\exp \left[ 0.015 \cdot \log \frac{D}{d_i} \right]}$$

$$\sigma_i = \sqrt{2 \log \frac{x}{\gamma_i}}$$

$$P_i = 0.5 - 0.5 \text{ ERF} \left( \frac{\log \frac{x_i}{\gamma_i}}{\sqrt{2 \sigma_i}} \right)$$

$$r_i = P_i \cdot R \cdot x_i \cdot 10^{-6} \text{ tons of metal}$$

in which the next items are constant for a given metal:

$x$ the average world grade in PPM

$D$ the linear equivalent of the earth's crust = 24 400 KM

$R$ the total weight of the crust = $10^{18}$ tons
The dispersion coefficient

The variables are:

\[ \gamma_i \] the median grade of the collection of all samples of size \( \frac{z_i}{x_i} \times 10^6 \) tons

\[ \sigma_i \] the standard deviation of the same collection

\[ P_i \] the probability of occurrence of deposits of quality \([x_i, z_i]\]

\[ r_i \] the total probable world reserves of quality \([x_i, z_i]\]

The procedure given by the expressions [10] through [15] has to be repeated until a \( r_i \) is found equal to the requested reserves. The corresponding values of \( x_i \) and \( z_i \) are the specifications of the target deposit for the year \( i \).

This approach can be justified by:

1. The development observed of mineral reserves with a long mining history;
2. The fact that the grade of the reserves on which the calculations are made is an average of substantially higher and lower grade ore deposits;
3. The systematic underestimation of the exploitable resources.

However, alternative solutions can be calculated by the program by specifying the target deposits for the consecutive years.

This alternative procedure should always be applied if programs of individual groups are studied (Community, company, etc.).

THE UNIT EXPLORATION COSTS

Supposing the considered metal presently has a market price of \( Q \) $/ton of metal. A fraction \( a \) of this price may be spent on the exploration. Thus the present unit costs are:

\[ U_o = a \times Q \times x \times 10^{-6} \] $/ton of ore \[ [16] \]

in which \( x \) is the average grade of the present reserves. The unit costs for larger, lower grade deposits will be less as they are easier to detect. They are inversely proportional to their total number and their sizes. Once again the linear equivalent \( d_i \) is used to express the sizes. The unit costs become:

\[ U_i = \frac{d_i \times n_i}{d_i \times n_i} \times a \times Q \times x \times 10^{-6} \] $/ton of ore \[ [17] \]
in which $d_i$ is the linear equivalent of the target deposit in year $i$

$n_i$ is the total number of deposits in the earth's crust of the

$target$ deposit type

$d$ and $n$ are respectively the same constants for the present

reserves

The calculation of $d_i$ and $n_i$ by means of the theory on the LOG-normal
distributions, has been described in the 'EXILE' report. The unit explo-
ration costs per ton of metal are:

$$T_i = \frac{d_i \cdot n_i}{d_0 \cdot n_0} \cdot a \cdot Q \$ /ton of metal$$  \hspace{1cm} \text{[18]}

THE EXPLORATION INVESTMENTS

It is assumed that each year an equal amount of $B_i$ $\$ net will be invested
during the exploration period of $i$ years. These investments lead ultimately
to the discovery of $M_i''$ tons of metal in the year $i$. The gross investments in
relation to $M_i''$, increase during $i$ years according to:

\begin{align*}
\text{year:} & \quad \text{gross cumulative investment:} \\
1 & \quad w_{i1} = B_i [1+k] \\
2 & \quad w_{i2} = B_i [1+k] + B_i [1+k]^2 \\
\vdots & \quad \vdots \\
i_e & \quad w_{i_e} = B_i \sum_{j=1}^{i_e} [1+k]^j \quad \text{[19]}
\end{align*}

in which $k$ is the interest rate.

The intrinsic value is estimated as $w_{i_e}$ $\$ on the moment of discovery of
the $M_i''$ tons of metal. Afterwards the gross investments increase only with
the interests until the year of capitalization $i_p'$ with $i_p' \geq i_p$:

$$c_{M_i''} = [1+k]^{i_p'} \cdot B_i \cdot \sum_{j=1}^{i_e} [1+k]^j \quad \text{[20]}
$$

in which $i_p'$ is counted from the year of discovery.

However it may happen that not the whole quantity $M_i''$ will be capitalized in
the same year: $M_i''$ might be capitalized fractionally. A capitalization scheme
may be calculated based on the principle "first in - first out".

The relations for the capitalization scheme are:
\[
\begin{align*}
  v_{io} &= V_i & \text{if } \left[ M'_o - \sum_{j=1}^{i-1} v_{jo} \right] > V_i \\
  v_{io} &= M'_o - \sum_{j=1}^{i-1} v_{jo} & \text{if otherwise} \\
  v_{ij} &= V_i - \sum_{k=0}^{j-1} v_{ik} & \text{if } M''_j - \sum_{k=1}^{i} v_{kj} > 0 \\
  v_{ij} &= M''_j - \sum_{k=1}^{i} v_{kj} & \text{if otherwise}
\end{align*}
\]

in which: \( V_i \) is the annual capitalized quantity in tons of metal, \( v_{io} \) is the part of the original non capitalized reserve \( M'_o \) which will be capitalized in the year \( i \), \( v_{ij} \) is the part of the quantity \( M''_j \) which is discovered in the year \( j \) and capitalized in the year \( i \).

More details on the capitalization scheme and a numerical example are given in the 'EXILE' report.

The allowed gross investments per ton of metal on \( v_{ij} \) are \( T_i \) \$/ton as given in expression \([18]\). Thus:

\[
\sum_{i=1}^{N} \frac{v_{ij} \cdot T_i}{[1+k]^{i-j}} = B_j \cdot \sum_{i=1}^{e} \left[ \frac{1}{1+k} \right]^{i-j}
\]

[23]

The annual net investments equal parts are thus:

\[
B_j = \frac{1}{\sum_{i=1}^{e} \left[ \frac{1}{1+k} \right]^{i-j}} \cdot \sum_{i=1}^{N} \frac{v_{ij} \cdot T_i}{[1+k]^{i-j}}
\]

[24]

thus each year an amount of \( B_j \) \$/net may be invested to discover \( M''_j \) tons of metal in the year \( j \).

With the previous expressions one may calculate the investments at time zero which are of two types:

1. Investments in relation to the non-capitalized reserves at time zero: \( M'_o \)
2. Investments performed before the year zero which will yield the annual discoveries in the years 1, 2, ..., \( i_e - 1 \).

The gross investments on \( M'_o \) at capitalization time is:
\[ C_H' = \sum_{i=1}^{N} v_{10} \cdot T_i \] \[ (25) \]

reduced to the time zero:

\[ I_M' = \sum_{i=1}^{N} \frac{v_{10} \cdot T_i}{(1+k)^i} \] \[ (26) \]

The investments made before time zero on the discoveries of the first \( i_e - 1 \) years are based on the assumption that the net investments for a certain annual discovery are divided in \( i_e \) annual equal parts, \( B \). As has been derived in the 'EXILE' report, the total investments on this type amount to:

\[ I_M'' = \sum_{i=1}^{i_e} \frac{i_e - n}{n+1} B \sum_{i=1}^{i_e} \frac{1}{(1+k)^i} \] \[ (27) \]

Combining the expressions \[26\] and \[27\] the gross investments at time zero become:

\[ I_0' = \sum_{i=1}^{N} \frac{v_{10} \cdot T_i}{(1+k)^i} + \sum_{i=1}^{i_e} \frac{i_e - n}{n+1} B \sum_{i=1}^{i_e} \frac{1}{(1+k)^i} \] \[ (28) \]

The total net investments in the year \( i \) are:

\[ I_i = \sum_{j=i}^{i+1} B_j \] \[ (29) \]

The annual gross proceeds are:

\[ C_i = \sum_{j=1}^{N} v_{ij} \cdot T_j \] \[ (30) \]

The new investments are defined as the total net investments in the year \( i \) minus the value of the produced metal in the previous year:

\[ I_i' = I_i - D_{i-1} \cdot Y_{i-1} \] \[ (31) \]

In which \( Y_i \) is the unit exploration cost of the capitalized reserve from which \( D_i \) is taken. However the capitalized reserve is composed of different types of ore which have been produced at different prices depending on the target deposit specifications. To calculate the unit costs of the capitalized reserve one must know the average grade of the reserve. Then one may calculate \( Y_i \) in $/ton of metal by interpolation in the target grade versus unit costs table, according to the expressions \[10\] through \[15\] and \[18\].
At the end of the year $i$, the capitalized quantity of ore is:

$$\left[ \frac{M_{i-1} - D_{i-1}}{G_{i-1}} + \sum_{j=0}^{N} \frac{v_{ij}}{x_j} \right] \cdot 10^6 \text{ tons of ore} \quad [32]$$

in which: $G_i$ is the average grade of the capitalized reserve in the year $i$
$v_{ij}$ is the quantity of metal discovered in the year $j$ in deposits of average grade $x_j$ PPM and capitalized in year $i$.

Thus the average grade $G_i$ can be calculated by a recurrent relation as $G_0$ is known:

$$G_i = \frac{M_i}{\left[ \frac{M_{i-1} - D_{i-1}}{G_{i-1}} + \sum_{j=0}^{N} \frac{v_{ij}}{x_j} \right] \cdot 10^6} \quad [33]$$

The unit costs of the capitalized reserves are then:

$$Y_i = \frac{T_{i-1} - G_i}{x_i} \cdot \left[ T_i - T_{i-1} \right] \$/\text{ton of metal} \quad [34]$$

the new investments become:

$$I'_i = I_i - D_{i-1} \cdot Y_{i-1} \quad [35]$$

and the cumulative investments are:

$$\hat{I}_i = [\hat{I}_{i-1} + I_i] \cdot (1+k)^{-C_i} \quad [36]$$

in which $I'_o = I'_o$, the gross zero time investments.
### INPUT DESCRIPTION

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>FORTRAN NAMES</th>
<th>RELATED EXPRESSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I₁</td>
<td>IND(1)</td>
<td>not used</td>
</tr>
<tr>
<td>I₂</td>
<td>IND(2)</td>
<td>INPUT [10]-[15]</td>
</tr>
<tr>
<td>I₃</td>
<td>IND(3)</td>
<td>Significant only if I₂ = 1</td>
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<tr>
<td>I₄</td>
<td>IND(4)</td>
<td>'EXILE'</td>
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<td>I₅</td>
<td>IND(5)</td>
<td>= 1 graphical output required according to the next specifications</td>
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<td>K₁</td>
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<td></td>
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<td>= 5 annual capitalization</td>
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<td>= 7 annual gross proceeds</td>
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<tr>
<td></td>
<td></td>
<td>= 8 cumulative investments</td>
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<tr>
<td>r</td>
<td>RSMALL</td>
<td>Tons of metal total presently exploitable world reserves plus already consumed metal</td>
</tr>
<tr>
<td>SYMBOL</td>
<td>FORTRAN NAMES</td>
<td>RELATED EXPRESSIONS</td>
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<tr>
<td>--------</td>
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</tr>
<tr>
<td>z</td>
<td>ZA</td>
<td>[7] Tons of metal average ore deposit</td>
</tr>
<tr>
<td>x_r</td>
<td>XRSM</td>
<td>[6] PPM average grade of the world reserves</td>
</tr>
<tr>
<td>F_z</td>
<td>FZZ</td>
<td>[7] Size increase factor</td>
</tr>
<tr>
<td>F_x</td>
<td>FXX</td>
<td>[6] Grade decrease factor</td>
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<tr>
<td>x</td>
<td>XENY</td>
<td>[12] PPM average grade of the earth's crust</td>
</tr>
<tr>
<td>ρ</td>
<td>RHO</td>
<td>EXILE Specific gravity of the ore</td>
</tr>
<tr>
<td>b/a</td>
<td>BDA</td>
<td>EXILE Dimension ratios of the averageDeposit with a ( a &gt; b &gt; c \neq 0 )</td>
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<td>c/b</td>
<td>CBD</td>
<td>EXILE</td>
</tr>
<tr>
<td>N_y</td>
<td>NYEAR</td>
<td>Number of years of the considered period</td>
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<tr>
<td>i_e</td>
<td>IE</td>
<td>Average number of years between the start of an exploration and the evidence of a deposit</td>
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<td>i_p</td>
<td>IP</td>
<td>Minimum number of years between the discovery of a deposit and its capitalization</td>
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<tr>
<td>M_o</td>
<td>EMO</td>
<td>[1] [2] Initial capitalized reserves in tons of metal</td>
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<td>M'_o</td>
<td>EMAO</td>
<td>[4] [5] Initial non-capitalized reserves</td>
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<tr>
<td>Q</td>
<td>Q</td>
<td>[16] Market price in £/ton of metal</td>
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<tr>
<td>c</td>
<td>CRATIO</td>
<td>[2] Required ratio capitalized reserves/annual requirements</td>
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<tr>
<td>a</td>
<td>ARATIO</td>
<td>[16] Allowed exploration costs as a fraction on the market price</td>
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<td>θ</td>
<td>FINTER</td>
<td>[19] Interest rate as a fraction on 1</td>
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<tr>
<td>x_i</td>
<td>XTRAR(i)</td>
<td>[10] - [15] Only if ( I_2 = 0 ), grades of the target deposits</td>
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<td>d_i</td>
<td>D(i)</td>
<td>[1] [2] Annual requirements in tons of metal</td>
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<td>SYMBOL</td>
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<td>RELATED EXPRESSIONS</td>
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<td>L</td>
<td>NLEV</td>
<td>EXILE</td>
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</table>

Only if \( I_q > 0 \)

= 0 only an automatic leveling is performed

\( > 0 \) \( L \) preference direction coefficients follow; each of them gives raise to an independent leveling

| ai     | ALE(i)       | EXILE               |

Only if \( L > 0 \) : preference direction coefficients for the first interval after the initial period of \( i_e \) years
### Problem: Input Symbols for 'Exist'

<table>
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**EXIST' WORLD LOW URANIUM REQUIREMENTS 1970-1992**

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**NON-LEVELLED STOCKTABLE**

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NEW INVESTMENT

ANNUAL NET INVESTMENT

ANNUAL DISCOVERY RATE

ANNUAL REQUIREMENTS
---PROGRAM EXIST BY HERMAN I. DE WOLDE CETIS-EURATOM FEBRUARY 1970---

EXPLORATION INVESTMENT BY SIZE OF TARGET

EXIST OPTIMIZES THE RAW MATERIALS INVESTMENTS
WITH RESPECT TO THE CRITERIANS
1. A SUFFICIENT CAPITALIZED RESERVE, IN RELATION TO THE
ANNUAL NEEDS, MUST BE ACCESSIBLE AT ANY MOMENT
2. SHOCK EFFECTS DUE TO CONSUMPTION VARIATIONS MUST BE
LEVELLED SMOOTHLY
3. LARGER, LOWER GRADE DEPOSITS ARE CHEAPER TO DISCOVER.
IF THEY BECOME EXPLOITABLE THE REQUESTED
INVESTMENTS DECREASE.
4. MINIMAL COSTS

DIMENSION D(50), EM(50), EMA(50), DINV(50), EMAA(50)
DIMENSION ACDINV(50), DEP(50), S(50), R(50)
DIMENSION V(50), W(50, 20), C(50), DING(50), B(50)
DIMENSION IND(18), ANDEP(50), ILL(50)
DIMENSION VSMALL(50, 50), TOTREQ(50)
DIMENSION RES(10), TOTR(50)
DIMENSION EMAAN(50), ALE(12), HELP(50)
DIMENSION X(50), Y(50), IGRAPH(10)
DIMENSION ITAR(50), RTAR(50), XTAR(50)
DIMENSION G(50), U(50), I(50), DEV(3, 50), TG(50)
DIMENSION TIT(18)
COMMON XRSM, ZA, RSMALL, ALFA, DSMALL, FXX, FZZ, XENV, CUMREO

---BASIC INFORMATION ON THE OCCURRENCE OF THE MINERAL---

READ (5, 98) (TI, T(I), I=1, 18)
98 FORMAT (18A4)
99 FORMAT (/1H, 18A4/)
READ (5,101) (IND(I), I=1, 7), (IGRAPH(I), I=1, 10)
101 FORMAT (7I6, 10I3)
NGRAPH=0
IF (IND(5), EQ, 0) GO TO 1105
DO 103 I=1, 10
IF (IGRAPH(I), EQ, 0) GO TO 1105
NGRAPH=NGRAPH+1
103 CONTINUE
1105 CONTINUE
102 FORMAT (12I6)
READ (5, 104) RSMALL, Z, XRSM, FXX
104 FORMAT (5, 104) RSMALL, Z, XRSM, FXX
C WRITE INPUT DATA

C

WRITE (6,116)
WRITE (6,114) (TITd ),I = 1,18) 59
WRITE (6,116) RSMALL,ZA,XRSM

116 FORMAT (' TOTAL WORLD RESERVES',9X,E12.4,' TONS METAL'/
1' AVERAGE ORE DEPOSIT',10X,E12.4,' TONS METAL'/
2' AVERAGE GRADE RESERVES',7X,E12.4,' PPM'/)
READ (5,104) XENV,RHO,BDA,CDB

CALL PNP (P,ENP,JA)

C

ENP=ENP/SQRT(2.*E2)
GAMENV=(-4.*ENP**2+2.*ALO(XRSM)+4.*ENP*)
SORT(ENP**2-ALOG(XRSM)+ALOG(XENV))
GAMENV=EXP(GAMENV/2.)
ALFA100.*(ALOG(XRSM/GAMENV))**2/(6.*ALOG(24400./DSMALL)*ENP**2)
WRITE (6,118) XENV,RHO,BDA,CDB,GAMENV,ALFA

C

118 FORMAT (' AVERAGE CONTENT IN CRUST',5X,E12.4,' PPM'/
1' SPECIFIC GRAVITY',13X,E12.4,' GR/CM3'/
2' DIMENSION RATIO B/A',10X,E12.4//' 3' DIMENSION RATIO C/B',10X,E12.4//' 4' GAMMA (CALCULATED)',11X,E12.4,' PPM//'
5' ALFA (CALCULATED)',12X,E12.4,' PERCENT//'

READ (5,102) NYEAR,IE,IP
NYE=NYEAR+IE+IP
READ (5,104) EM0,ELAO,ELAMO
READ (5,104) Q
READ (5,104) CRATIO,ARATIO,FIINTER

C

120 WRITE (6,122) NYE,IE,IP,EMAO

122 FORMAT (' TOTAL TIME',27X,I4,' YEARS//'
1' EXPLORATION UNTIL DISCOVERY',2X,8X,I4,' YEARS//'
2' CAPITALIZATION TIME',10X,8X,I4,' YEARS//'
3' MINIMUM ANNUAL EXPLORATION ',12X,E12.4,' TONS METAL//'
FIINTER*100.*FIINTER
WRITE (6,124) Q,ARATIO,CRATIO,FIINTER

C

124 FORMAT (' PRICE OF CAPITALIZED PRODUCT',1X,E12.4,' €//'
1' EXPLORATION FRACTION OF PRICE',E12.4//'
C  --- READ TARGETS IF NOT WORLD RESERVES ---------------
C
150 IF (IND(2) .GT. 0) GO TO 160
READ (5, 104) (XTAR(I), I=1, NYEAR)
ALFX = ALOG(FZZ) / ALOG(FXX)
ALZ = ALOG(ZA)
DO 154 I=1, NYEAR
RTAR(I) = EXP(ALFX * ALOG(XTAR(I)) / XRSM) + ALZ
NK = NYEAR + IE + IP
NZ = NYEAR + 1
DO 158 I = NZ, NK
XTAR(I) = XTAR(NYEARS)
158 RTAR(I) = RTAR(NYEARS)
160 CONTINUE
178 READ (5, 172) (D(I), I=1, NYEAR)
172 FORMAT (6E12.4)
DO 173 I = 1, 50
173 V(I) = 0.
NY = NYEAR + 1
IJ = NYEAR + IE + IP
DO 179 I = NY, IJ
179 D(I) = DD
179 D(I) = DD
200 EM(I) = CRATIO * D(I)
IF (EMO - D(I)) .LT. EM(I)) GO TO 202
EM(I) = EMO - D(I)
V(I) = 0.
GO TO 203
202 V(I) = EM(I) + D(I) - EMO
203 CONTINUE
DO 211 IK = 2, IJ
EM(IK) = CRATIO * D(IK)
IF ((EM(IK-1) - D(IK)) .LT. EM(IK)) GO TO 210
EM(IK) = EM(IK-1) - D(IK)
V(IK) = 0.
GO TO 211
210 V(IK) = EM(IK) + D(IK) - EM(IK-1)
211 CONTINUE
C
EMA(1) = 0.
DO 204 J = 1, IP
EMA(I) = EMA(I) + V(J)
EMA(I) = EMA(I) - EMAO + V(I)
EMA0 = EMA(I) + V(I)
IF (EMA(I) .LT. EMA0) GO TO 205
IF ((EAM0 - V(I)) .LT. EMA(I)) GO TO 206
205 CONTINUE
EMA(I) = EMA0 + EMA0 - V(I)
EMAA(1)=EMAAO
CONTINUE
DO 220 IK=2,II
EMAIK=0.
DO 212 J=1,IP
JJ=IK+J
212 EMA(IK)=EMA(IK)+V(JJ)
EMAIK=EMA(IK)+EMA(IK)-EMA(IK-1)
IF (EMAIK.LT.EMAO) GO TO 219
IF ((EMAIK-1)-V(IK)) .LT. EMA(IK) GO TO 220
CONTINUE
EMAA(IK)=EMAO
EMAIK=EMA(IK-1)+EMAA(IK)-V(IK)
CONTINUE

WRITE THE STOCK TABLE

CUMREQ=RSMALL-(EMO+EMAO)
ILEV=0
DO 247 I=1,II
HELP(I)=EMAA(I)
WRITE (6,230) (TITd),r = 1,II
GO TO 233
WRITE (6,232) (TITd),r = 1,II
WRITE (6,99) (TITd),r = 1,II
GO TO 255
WRITE (6,252) CUMREQ,EMO,EMAO
GO TO 255
WRITE (6,253) EMO,EMAO
CUMREQ=0.0
WRITE (6,254) (EMO,EMAO)
TOTAL=CUMREQ

IF (IND(2).EQ.0) GO TO 251
WRITE (6,252) CUMREQ,EMO,EMAO
GO TO 255
WRITE (6,253) EMO,EMAO
CUMREQ=0.0
WRITE (6,254) (EMO,EMAO)
TOTAL=CUMREQ
DO 254 IK=1,NYEAR
   TOT=TOT+D(IK)
   TOTRE0(IK)=TOT
   RR=EM(IK)/D(IK)
   RRA=(EM(IK)+EMA(IK))/D(IK)
   WRITE (6,256) IK,D(IK),TOT,EM(IK),RR,V(IK),EMA(IK),RRA,EMA(IK)
   1,TOTREO(IK)
254 CONTINUE
256 FORMAT (16,3E14.4,F8.1,2E14.4,F8.1,2E14.4/)

CALCULATE EXPLORATION DEVELOPMENT FOR WORLD RESERVES

IF (IND2J.EQ.0) GO TO 272
IF (ILEV.EQ.0) GO TO 269
IF (IND(3).EQ.0) GO TO 272
269 CONTINUE
216 NYE=NYEAR+IE+IP
217 CUMREO=RSMALL-(EMO+EMA0)
218 TD=0.0
220 DO 270 I=1,NYE
221 TD=TD+D(I)
223 RI=EM(I)+EMA(I)+CUMREO+TD
225 CALL TARGET(RI,ZI,XI,I)
227 RTAR(I)=ZI
229 XTAR(I)=XI
231 CONTINUE
232 M CONTINUE

CALCULATE THE VSMALL-MATRIX

NYE=NYEAR+IE+IP
VSMALL(1,1)=V(1)
SUM=V(1)
DO 281 I=2,NYE
   VSMALL(I,1)=V(I)
   IF (EMA0-SUM).GE.V(I)) GO TO 280
   VSMALL(I,1)=EMA0-SUM
238 IF (VSMALL(I,1).LT.(1.E-20)) VSMALL(I,1)=0.
239 SUM=SUM+VSMALL(I,1)
240 DO 284 JJ=J+1,NYE
242 JJ=J+1
244 SUM=0.
246 DO 288 I=1,NYE
248 VSMALL(I,JJ)=V(I)
250 DO 284 L=1,J
252 IF (VSMALL(I,L).LT.(1.E-20)) GO TO 284
   VSMALL(I,JJ)=VSMALL(I,JJ)-VSMALL(I,L)
254 CONTINUE
IF (EMAA(J).GE.(SUM+VSMALL(I,JJ))) GO TO 286
VSMALL(I,JJ) = EMAA(J)-SUM
286 IF (VSMALL(I,JJ).LT.(1.E-20)) VSMALL(I,JJ) = 0,
SUM=SUM+VSMALL(I,JJ)
288 CONTINUE
290 CONTINUE

C-----CALCULATE THE AVERAGES GRADES OF THE CAPITALIZED RESERVES------

GO=XRSM
NYEE=NYE-1
SUM=VSMALL(1,1)/GO
DO 292 J=1, NYEE
SUM=SUM+VSMALL(1,J+1)/XTAR(J)
292 CONTINUE

G(1)=(EMO-D(1))/GO+SUM)*1.E+6
G(1)=EM(1)*1.E+6/G(1)

DO 296 I=2,NYER
SUM=VSMALL(I,1)/GO
DO 294 J=1, NYEE
SUM=SUM+VSMALL(I,J+1)/XTAR(J)
294 CONTINUE

G(I)=(EM(I-1)-D(I))/G(I-1)+SUM)*1.E+6
G(I)=EM(I)*1.E+6/G(I)
296 CONTINUE

C-----CALCULATE THE UNIT COST DEPENDING ON GRADE/SIZE OF TARGET------

DO 558 IA=1, NYE
ZZZ=XTAR(IA)
GRA=XTAR(IA)
DDP=(ZZZ/GRA)*1.E+6
VD=(DDP/RHO)*1.E-9
AD=(AD)/(BDA**2*CDR)**0.3333333
DD=AD/(1.+BDA+BDA*CDR)
GAMD=ENV/EXP(0.015*ALFA*ALOG(24400./DQ))
SIGD=SQRT(2.*ALOG(ENV/GAMD))
ENP=ALOG(GRA/GAMD)/SIGD
IPP=2
CALL PNP(P,ENP,IPP)
ENDEP=P*1.E+18/DDP
U(IA)=XRSM*VSMALL*RSMDL*ARATIO*0.1.E-6/(DD*ENDEP*ZA)
T(IA)=U(IA)*1.E+6/GRA
558 CONTINUE

C-----CALCULATE THE NETT INVESTMENTS EQUAL PARTS R(I)------------------

SUM=0.
DO 320 L=1,IE
320 SUM=SUM+(1.+FINTER)**L
   FAC=1./SUM
   DO 321 I=1,50
   321 R(I)=0.
   DO 326 J=1,NYE
   326 SUM=0.*
   DO 324 I=1,NYE
   324 SUM=SUM+VSMALL(I,J+1)*T(I)/(1.+FINTER)**(I-J))
   326 R(J)=FACA*SUM

C-----CALCULATE ZERO TIME INVESTMENT-------------------------------------

C
   SUM=0.
   DO 330 I=1,NYE
   330 SUM=SUM+VSMALL(I,1)*T(I)/(1.+FINTER)**I
   FAC=SUM
   IEM=IE-1
   SUM=0.
   DO 334 IN=1,IEM
   334 SUM=SUM+R(IN)*SUMA
   FACA=SUM
   CONTINUE

C-----CALCULATE THE INVESTMENTS------------------------------------------

C
   DO 352 I=1,NYE
   352 C(I)=0.
   DO 349 J=1,NYE
   349 C(I)=C(I)+VSMALL(I,J)*T(J)
   IN=I+IE-1
   DINV(I)=0.
   DO 350 J=1,IN
   350 DINV(I)=DINV(I)+R(J)
   CONTINUE

C-----CALCULATE THE UNIT COST CAPITALIZED RESERVES-----------------------

C
   DO 357 I=1,NYEAR
   IF(G(I).LT.XTAR(1)) GO TO 353
   TG(I)=T(I)
   GO TO 357
   I=1

C
   DO 354 J=1,NYEAR
   IF(G(I).GE.XTAR(J)) GO TO 356
   CONTINUE
   WRITE(6,355)
   355 FORMAT (/// 'ERROR EXIT 4'///)
STOP
356 TG(J) = (XTAR(J-1) - G(I) * (T(J) - T(J-1) / (XTAR(J) - XTAR(J-1))
357 CONTINUE
C
ACDINV(1) = (RINV + DINV(I)) * (1. + FINTER) - C(I)
DINGR(1) = DINV(I) - D(1) * TG(1)
DO 360 I = 2, NYE
ACDINV(I) = (ACDINV(I-1) + DINV(I)) * (1. + FINTER) - C(I)
DINGR(I) = DINV(I) - D(I-1) * TG(I)
C
C------WRITE THE INVESTMENT TABLE-----------------------------
WRITE (6, 362)
WRITE (6, 99) (TIT(I), I = 1, 18)
362 FORMAT (1H1/ TABLE OF INVESTMENTS /' ******************** /)
WRITE (6, 364)
364 FORMAT (' YEAR TARGET DEPOSIT PROB. UNIT COSTS DISC. TOT. N
1 ET RETURN NEW CUM. AV. GRADE')
WRITE (6, 366)
366 FORMAT (' YEAR TARGET DEPOSIT PROB. UNIT COSTS DISC. TOT. N
1 ET RETURN NEW CUM. AV. GRADE')
WRITE (6, 367)
367 FORMAT (' YEAR TARGET DEPOSIT PROB. UNIT COSTS DISC. TOT. N
1 ET RETURN NEW CUM. AV. GRADE')
WRITE (6, 368) RINV
368 FORMAT (15, 2F9.0, F9.2, 4F9.1, F9.0, F9.0)
C
DO 370 I = 1, NYEAR
RES(1) = RTAR(I)
RES(2) = XTAR(I)
RES(3) = U(I)
RES(4) = T(I)
RES(5) = EMAA(I)
RES(6) = DINV(I) * EMI
RES(7) = C(I) * EMI
RES(8) = DINGR(I) * EMI
RES(9) = ACDINV(I) * EMI
RES(10) = G(I)
WRITE (6, 369) I, (RES(J), J = 1, 10)
370 CONTINUE
369 FORMAT (15, 2F9.0, F9.2, 4F9.1, F9.0, F9.0)
C
C------DRAW THE CURVES -----------------------------------
C
IF (IND(5) *.60.0) GO TO 401
CALL FINIM (0., 0.)
START = 0.
SLET = 0.2
SIZX=10.
SIZY=5.0
SIZYY=SIZY+1.0
TEXT=START+SIZY*0.5
TEX=5.0
X(1)=0.
NN=NYEAR+1-IE-IP
DO 379 I=2,NN
379 X(I)=FLOAT(I-1)
DO 399 IGR
NGR=IGRAPH(IGR)
GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16),NGR
1 CONTINUE
Y(I)=0.
DO 381 I=2,NN
381 Y(I)=D(I-1)
CALL SYMBL(0.0,TEXT,SLET,0.0,19HANNUAL REQUIREMENTS,19)
CALL FINIM(TEX,0.0)
CALL DESSIN(X,Y,NN,1,1,0,0,SIZX,SIZY,0,0,5H YEAR,-5,1H ,1,0)
CALL FINIM(-TEX,SIZYY)
GO TO 399
2 CONTINUE
DO 382 I=2,NN
382 Y(I)=EMA(1-1)
CALL SYMBL(0.0,TEXT,SLET,0.0,21HANNUAL DISCOVERY RATE,21)
CALL FINIM(TEX,0.0)
CALL DESSIN(X,Y,NN,1,1,0,0,SIZX,SIZY,0,0,1H ,-1,1H ,1,0)
CALL FINIM(-TEX,SIZYY)
GO TO 399
3 CONTINUE
Y(I)=EMAO
DO 383 I=2,NN
383 Y(I)=EMAI(I-1)
CALL SYMBL(0.0,TEXT,SLET,0.0,24HNON CAPITALIZED RESERVES,24)
CALL FINIM(TEX,0.0)
CALL DESSIN(X,Y,NN,1,1,0,0,SIZX,SIZY,0,0,1H ,-1,1H ,1,0)
CALL FINIM(-TEX,SIZYY)
GO TO 399
4 CONTINUE
Y(I)=EMO
DO 384 I=2,NN
384 Y(I)=EMI(I-1)
CALL SYMBL(0.0,TEXT,SLET,0.0,20HCAPITALIZED RESERVES,20)
CALL FINIM(TEX,0.0)
CALL DESSIN(X,Y,NN,1,1,0,0,SIZX,SIZY,0,0,1H ,-1,1H ,1,0)
CALL FINIM(-TEX,SIZYY)
GO TO 399
5 CONTINUE
Y(I)=0.
DO 385 I=2,NN
385  \begin{align*}
Y(I) &= V(I-1) \\
&\text{CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 21HANNUAL CAPITALIZATION, 21)} \\
&\text{CALL FINIM (TEX, 0.0)} \\
&\text{CALL DESSIN (X, Y, NN, 1, 1, 0, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0)} \\
&\text{CALL FINIM (-TEX, SIZYY)} \\
&\text{GO TO 399}
\end{align*}

6 CONTINUE

\begin{align*}
Y(I) &= 0 \\
&\text{DO 386 I = 2, NN}
\end{align*}

386  \begin{align*}
Y(I) &= \text{DIV} (I-1) \\
&\text{CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 21HANNUAL NET INVESTMENT, 21)} \\
&\text{CALL FINIM (TEX, 0.0)} \\
&\text{CALL DESSIN (X, Y, NN, 1, 1, 0, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0)} \\
&\text{CALL FINIM (-TEX, SIZYY)} \\
&\text{GO TO 399}
\end{align*}

7 CONTINUE

\begin{align*}
Y(I) &= 0 \\
&\text{DO 387 I = 2, NN}
\end{align*}

387  \begin{align*}
Y(I) &= \text{C} (I-1) \\
&\text{CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 13HANNUAL INCOME, 13)} \\
&\text{CALL FINIM (TEX, 0.0)} \\
&\text{CALL DESSIN (X, Y, NN, 1, 1, 0, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0)} \\
&\text{CALL FINIM (-TEX, SIZYY)} \\
&\text{GO TO 399}
\end{align*}

8 CONTINUE

\begin{align*}
Y(I) &= \text{RINV0} \\
&\text{DO 388 I = 2, NN}
\end{align*}

388  \begin{align*}
Y(I) &= \text{ACINV} (I-1) \\
&\text{CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 21HCUMULATIVE INVESTMENT, 21)} \\
&\text{CALL FINIM (TEX, 0.0)} \\
&\text{CALL DESSIN (X, Y, NN, 1, 1, 0, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0)} \\
&\text{CALL FINIM (-TEX, SIZYY)} \\
&\text{GO TO 399}
\end{align*}

9 CONTINUE

\begin{align*}
Y(I) &= 0 \\
&\text{DO 389 I = 2, NN}
\end{align*}

389  \begin{align*}
Y(I) &= \text{DINGR} (I-1) \\
&\text{CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 14HNEW INVESTMENT, 14)} \\
&\text{CALL FINIM (TEX, 0.0)} \\
&\text{CALL DESSIN (X, Y, NN, 1, 1, 0, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0)} \\
&\text{CALL FINIM (-TEX, SIZYY)} \\
&\text{GO TO 399}
\end{align*}

10 CONTINUE

\begin{align*}
&\text{IF (IND(I), EQ, 0) GO TO 391}
\end{align*}

390  \begin{align*}
Y(I) &= \text{M} (I-1, 1) \\
&\text{CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 26HEXPLORATION AREA(AV. DEP.), 26)} \\
&\text{CALL FINIM (TEX, 0.0)} \\
&\text{CALL DESSIN (X, Y, NN, 1, 1, 1, 0, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0)}
\end{align*}
CALL FINIM (-TEX, SIZYY) 501
GO TO 399 502
CALL FINIM (0.0, SIZYY) 503
GO TO 399 504
11 CONTINUE 505
IF (IND(1).EQ.0) GO TO 391 506
Y(1) = 0. 507
DO 392 I = 2, NN 508
392 Y(I) = W(I-1,2) 509
CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 28, EXPL, PRICE PER KM2(AV.DEP.), 28) 510
CALL FINIM (TEX, 0.0) 511
CALL DESSIN (X, Y, NN, 1, 1, 1, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0) 512
CALL FINIM (-TEX, SIZYY) 513
GO TO 399 514
12 CONTINUE 515
IF (IND(3).EQ.0) GO TO 391 516
Y(1) = 0. 517
DO 393 I = 2, NN 518
393 Y(I) = W(I-1,3) 519
CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 28, EXPL, PRICE PER KM2(SPEC.DEP.), 27) 520
CALL FINIM (TEX, 0.0) 521
CALL DESSIN (X, Y, NN, 1, 1, 1, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0) 522
CALL FINIM (-TEX, SIZYY) 523
GO TO 399 524
13 CONTINUE 525
IF (IND(3).EQ.0) GO TO 391 526
Y(1) = 0. 527
DO 394 I = 2, NN 528
394 Y(I) = W(I-1,4) 529
CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 28, EXPL, PRICE PER KM2(SP.DEP.), 28) 530
CALL FINIM (TEX, 0.0) 531
CALL DESSIN (X, Y, NN, 1, 1, 1, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0) 532
CALL FINIM (-TEX, SIZYY) 533
GO TO 399 534
14 CONTINUE 535
Y(1) = 0. 536
DO 395 I = 2, NN 537
395 Y(I) = TOTREQ(I-1) 538
CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 28, CUMULATIVE REQUIREMENTS, 23) 539
CALL FINIM (TEX, 0.0) 540
CALL DESSIN (X, Y, NN, 1, 1, 1, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0) 541
CALL FINIM (-TEX, SIZYY) 542
GO TO 399 543
15 CONTINUE 544
Y(1) = EMO+EMAO 545
DO 396 I = 2, NN 546
396 Y(I) = TOTR(I-1) 547
CALL SYMBL4 (0.0, TEXT, SLET, 0.0, 14, TOTAL RESERVES, 14) 548
CALL FINIM (TEX, 0.0) 549
CALL DESSIN (X, Y, NN, 1, 1, 1, 0, SIZX, SIZY, 0, 0, 1H, -1, 1H, 1, 0) 550
CALL FINIM (-TEX,SIZYY)
GO TO 399
16 CONTINUE
GO TO 391
399 CONTINUE
AS=SIZYY*FLOAT(NGRAPH)
AT=TEX+SIZX+5.
CALL FINIM (AT,-AS)
401 CONTINUE

Cummy PERFORM THE LEVELING -------------------------------

IF(IND(4).EQ.0) GO TO 461
IF (ILEV.GT.0) GO TO 408
READ (5,402) NLEV
IF(NLEV.EQ.0) GO TO 405
READ (5,404) (ALE(I),I=1,NLEV)
402 FORMAT (12I6)
404 FORMAT (6E12.4)
405 ILEV=ILEV+1

C %FIRST INTERVAL-----------------------------------------

410 SUMM=SUMM+EMAA(J)
SUMMA=SUMM/FLOAT(IEE)
DO 411 J=1,IEE
SUMMJ=SUMMJ+FLOAT(2*J-IE)*(EMAA(J)-SUMMA)
411 SUMMJ2=SUMMJ2+FLOAT(2*J-IE)**2
AL=2.*SUMMJ/SUMMJ2
BL=SUMM/FLOAT(IEE)-0.5*AL*FLOAT(IE)
DO 412 J=1,IEE
SUMM=SUMM-(FLOAT(J)*AL+BL)
412 SUMM=SUMM-(FLOAT(J)*AL+BL)
BL=AL+SUMM/FLOAT(IEE)
DO 416 I=1,IEE
EMAA(I)=AL*FLOAT(I)+BL
GO TO 409
408 IF (ILEV.GT.NLEV) GO TO 462
409 CONTINUE
C---FORWARD LEVELING---------------------------------------------

C
ART=ATAN(AL)
IST=1EE
EMST=EMAA(1EE)
420 JIST=IST+1
IF(JIST.GT.(NYE-1)) GO TO 434
IA1=JIST
A1=EMAA(JIST)-EMST
ARTA=ATAN(A1)
JJ=IST+2
DO 426 J=JJ,NYE
SUMM=0.
SUML=0.
DO 424 L=JIST,J
SUMM=SUMM+EMAA(L)
424 SUML=SUML+FLOAT(L)
A2=(SUMM-EMST*FLOAT(J-IST))/(SUML-FLOAT(IST*(J-IST)))
IF(A2.LT.A1) GO TO 426
ARTB=ATAN(A2)
IF(ABS(ARTB-ART).GT.ABS(ARTA-ART)) GO TO 426
A1=A2
ARTA=ARTB
IA1=J
426 CONTINUE
AL=A1
BL=EMST-A1*IST
DO 430 J=JIST,IA1
430 EMAAN(J)=AL*FLOAT(J)+BL
ART=ARTA
IST=IA1
EMST=EMAA(IST)
GO TO 420
434 IF(IST.EQ.NYE) GO TO 440
EMAA(NYE)=EMAA(NYE)
EMAA(NYEAR)=EMAA(NYEAR)
440 CONTINUE
C
EMAA(1)=EMAA(1)
EMA(1)=EMAO-V(1)+EMAA(1)
DO 460 I=2,NYE
EMAA(I)=EMAA(I-1)
460 EMA(I)=EMA(I-1)-V(I)+EMAA(I)
GO TO 248
462 IF(IND(5).EQ.0) GO TO 461
CALL FINTRA
461 CONTINUE
STOP
END
SUBROUTINE TARGET(RI, ZI, XI, IYEAR)

TARGET CALCULATES FOR A REQUESTED TOTAL WORLD METAL
RESERVE THE AVERAGE GRADE AND SIZE OF THE TARGET DEPOSITS

COMMON XRSM, ZA, RSMALL, ALFA, DSMALL, FX, FZ, XENV, CUMREQ
ALFG=ALOG(FX)
R=1.E+18
DLARGE=24400.
IF (RI.GT.RSMALL) GO TO 105
ZI=ZA
XI=XRSM
RETURN

105 XI=XRSM
IWAY=1

110 ZI=EXP(ALOG(FZ)*ALOG(XI/XRSM)/ALFG+ALOG(ZA))
DI=DSMALL*((XRSM*ZI)/(XI*ZA))**0.333333
GAMM=XENV/EXP(0.015*ALFA*ALOG(DLARGE/DI))
SIGD=SQR(2.*ALOG(XENV/GAMM))
ENP=ALOG(XI/GAMM)/SIGD
IPP=2
CALL PNP(P, ENP, IPP)
RIA=P*R*XI*1.E-6
GO TO (115, 120), IWAY

115 CONTINUE
XIB=XI
RIB=RIA
ZIB=ZI
DEL=1.0
DO 135 KK=1, 6
DEL=DEL*0.1
DO 125 J=1, 9
XI=XIB-FLOAT(J)*DEL*XRSM
IWAY=2
GO TO 110

120 IF (RIA.GT.RI) GO TO 130
XIB=XI
RIB=RIA
ZIB=ZI
125 CONTINUE
130 CONTINUE
135 CONTINUE
XI=XIB
ZI=ZIB
RETURN
END
SUBROUTINE PNP, ENP, JA

DIMENSION XLPG%60, YNP%60

DATA 70?

AND

1 XLPG% 1, XLPG% 2, XLPG% 3, XLPG% 4, XLPG% 5, XLPG% 6, XLPG% 7,
2 XLPG% 8, XLPG% 9, XLPG% 10, XLPG% 11, XLPG% 12, XLPG% 13,
3 XLPG% 14, XLPG% 15, XLPG% 16, XLPG% 17, XLPG% 18, XLPG% 19,
4 XLPG% 20, XLPG% 21, XLPG% 22, XLPG% 23, XLPG% 24, XLPG% 25,
5 XLPG% 26, XLPG% 27, XLPG% 28, XLPG% 29, XLPG% 30, XLPG% 31,
6 XLPG% 32, XLPG% 33, XLPG% 34, XLPG% 35, XLPG% 36, XLPG% 37,
7 XLPG% 38, XLPG% 39, XLPG% 40, XLPG% 41, XLPG% 42, XLPG% 43,
8 XLPG% 44, XLPG% 45, XLPG% 46, XLPG% 47, XLPG% 48, XLPG% 49,
9 XLPG% 50, XLPG% 51, XLPG% 52, XLPG% 53, XLPG% 54, XLPG% 55,
10 XLPG% 56, XLPG% 57, XLPG% 58, XLPG% 59, XLPG% 60

DATA

1 YNP% 1, YNP% 2, YNP% 3, YNP% 4, YNP% 5, YNP% 6, YNP% 7,
2 YNP% 8, YNP% 9, YNP% 10, YNP% 11, YNP% 12, YNP% 13, YNP% 14,
3 YNP% 15, YNP% 16, YNP% 17, YNP% 18, YNP% 19, YNP% 20,
4 YNP% 21, YNP% 22, YNP% 23, YNP% 24, YNP% 25, YNP% 26,
5 YNP% 27, YNP% 28, YNP% 29, YNP% 30, YNP% 31, YNP% 32,
6 YNP% 33, YNP% 34, YNP% 35, YNP% 36, YNP% 37, YNP% 38,
7 YNP% 39, YNP% 40, YNP% 41, YNP% 42, YNP% 43, YNP% 44,
8 YNP% 45, YNP% 46, YNP% 47, YNP% 48, YNP% 49, YNP% 50,
9 YNP% 51, YNP% 52, YNP% 53, YNP% 54, YNP% 55, YNP% 56,
10 YNP% 57, YNP% 58, YNP% 59, YNP% 60

IF3JA-102,102,200

THE CALCULATION OF NP AS FUNCTION OF P

102 PP#-ALOG10#P
104 IF#-P-15.0108,108,104
105 JA#3
106 WRITE %6,106# P
107 FORMAT %9H ERROR ARGUMENT TOO SMALL P# E12.5
108 IF#P-7.605689120,110
109 FORMAT %9H ERROR ARGUMENT TOO LARGE P# E12.5
110 IF#P-7.273168465285*PP-0.005688*PP**2
112 JA#2
114 IF#NP-7.0118,118,116
116 JA#1

RETURN
118 JA#0
RETURN
120 IF%PP.GT.XLPG%lnn GO TO 121
JA#4
WRITE %6,107 P
RETURN
121 DO 122 I#l,56
IF%PP-XLPG%lnn124,124,122
122 CONTINUE
GO TO 104
124 IN#1-1
ENP%%PP-XLPG%lnn/%XLPG%lnn&l&-XLPG%lnn&l&YNP%IN&l&YNP%IN&l&YNP%IN&l&
RETURN
C-----THE CALCULATION OF P AS A FUNCTION OF NP-------------------------
C
200 IF%ENP-5.5n202,202,208
202 JA#0
DO 204 I#l,56
IF%ENP-YNP%lnn206,206,204
204 CONTINUE
GO TO 208
206 IN#1-1
PP%%ENP-YNP%IN&l&%YNP%IN&l&-YNP%IN&l&%XLPG%IN%&l&-XLPG%IN&l&XLPG%
RETURN
208 IF%ENP-7.9n214,214,210
210 WRITE %6,212 ENP
212 FORMAT %30H ERROR ARGUMENT TOO LARGE NP#,E12.5
JA#3
RETURN
214 ROOT%2072.51-175.79*ENP
216 PP%40.9006-SQRT%ROOT P
P%10,***-PP
JA#0
IF%ENP-7.0n218,218,220
218 RETURN
220 IF%ENP-7.5n222,222,224
222 JA#1
RETURN
224 JA#2
RETURN
END
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Alfred Nobel
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