The influence of changing costs, grades, and market prices on an upgrading operation

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There are certain ores that can be treated without upgrading (e.g., gold and uranium ores), and upgrading needs to be considered only for fairly low-grade ores of this type. If the grade is very low, treatment will not be economic even with upgrading, and there is therefore a limited range of ore grades for which upgrading is suitable.

Cost analyses have been presented in this Journal[1, 2] for the upgrading of uranium in Witwatersrand gold ore. Clearly, the economics depend upon the efficiency and cost of the concentrating method, the grade of the ore, the cost of further processing, and so on, and the analysis can be further complicated by other factors, among which are changes in market prices and costs of processing. The purpose of this note is to present a simplified method that can be used to determine the feasibility of upgrading and the influence of changing costs and market prices.

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Simplified Cost Analysis for Upgrading

Initially, we shall assume that the cost of subsequent processing (per ton of ore treated) is independent of the degree of upgrading. The following nomenclature will be used:

G	Grade of ore (g/t)
V	Market price of valuable component ($/g)
$R(x)$	Fractional recovery of valuable component during upgrading
x	Mass fraction reporting to concentrate
C_c	Cost of concentrating ($/t)
C_p	Cost of further processing ($/t)
C_m	Cost of mining and other processing prior to upgrading ($/t)
R_p	Fractional recovery of valuable component during subsequent processing.

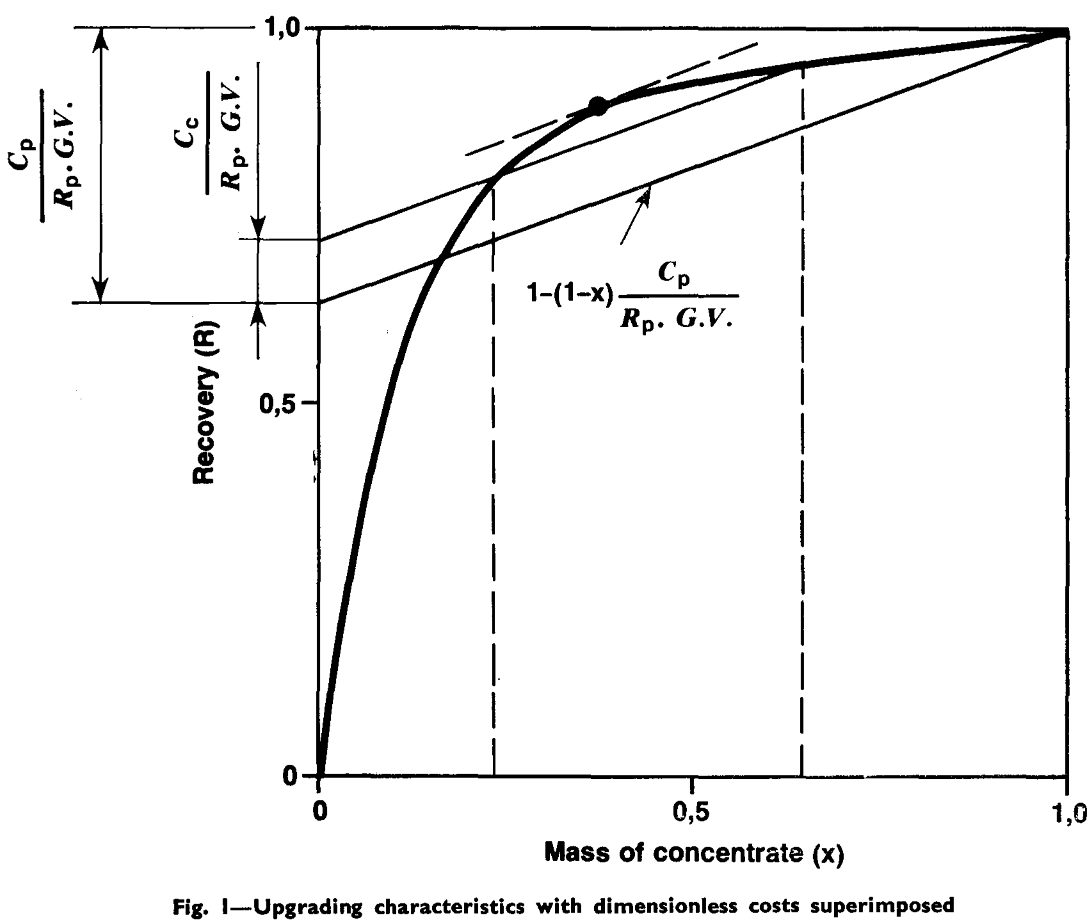

Fig. 1—Upgrading characteristics with dimensionless costs superimposed

Without upgrading,

the profit per ton of ore

$=(R_p.G.V)-C_p-C_m$. . . . . (1)

With upgrading,

the profit per ton of ore

$=(R_p.G.V.R(x))-C_c-(x.C_p)-C_m$. . . . . (2)

Therefore, for upgrading to be economical, (2)−(1) must be positive, i.e.

$(R_p.G.V.R(x))-C_c-(x.C_p)\geqslant(R_p.G.V)-C_p$. . (3)

We note that the cost of prior processing (C_m) need not be considered (which is obvious, intuitively), and that the net value of the ore in the ground ($R_p.G.V$) always appears as a unit. Changes in grade or changes in market price have a proportional effect on the net value per ton. Equation (3) can be rearranged and expressed in the dimensionless form

$$R(x)\geqslant 1+\frac{C_c}{R_p.G.V}-(1-x)\frac{C_p}{R_p.G.V}. \quad . . . (4)$$

Fig. 1 shows the concentration characteristic, expressed as the fractional recovery (R) versus the mass fraction of the concentrate (x). The upper of the two parallel lines shown in Fig. 1 corresponds to the right-hand side of equation (4). The construction is obvious from the notation, and in this case it is economical for a concentrating plant to be operated with a mass of concentrate in the range 23 to 64 per cent. The maximum profit is obtained at the point where a parallel line is tangential to the characteristic curve, i.e., at about 37 per cent by mass. This is determined by differentiation of equation (4) with respect to x, and equating to zero:

$$\frac{dR}{dx}=\frac{C_p}{R_p.G.V}. \quad . . . . (5)$$

Discussion

The simple construction shown in Fig. 1 makes it easy for the influence of changes in costs, grades, and market prices to be understood. For example, if a large proportion of the cost is spent on mining, the ratio $\frac{C_p}{R_p.G.V}$ must be small, and the concentrating process must be very efficient to be considered. The ratios are, in fact, the proportion of net value spent on concentration (C_c) and further processing, i.e., extraction and refining (C_p). An increase in grade or market price will raise the intersections with R, thereby narrowing the range within which upgrading is economical.

In some cases, the unit cost for further processing (C_p) may be a function of the mass of the concentrate. For example, for uranium, the acid consumption per ton of concentrate may be higher than that for the ore. The lines then become curved, but this can be calculated fairly easily.

Finally, the characteristic curve for concentration may be a function of the costs of concentration. For example, the use of more efficient, but more costly, upgrading methods can be considered. This is worth while only if the change in recovery exceeds the fractional increase in costs (i.e., if the movement of R is larger than the movement of the upper line). The lowering of concentration costs and recovery can be analysed in the same way.

Acknowledgement

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References

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