Economic Aspects of Planning Exploration Programme

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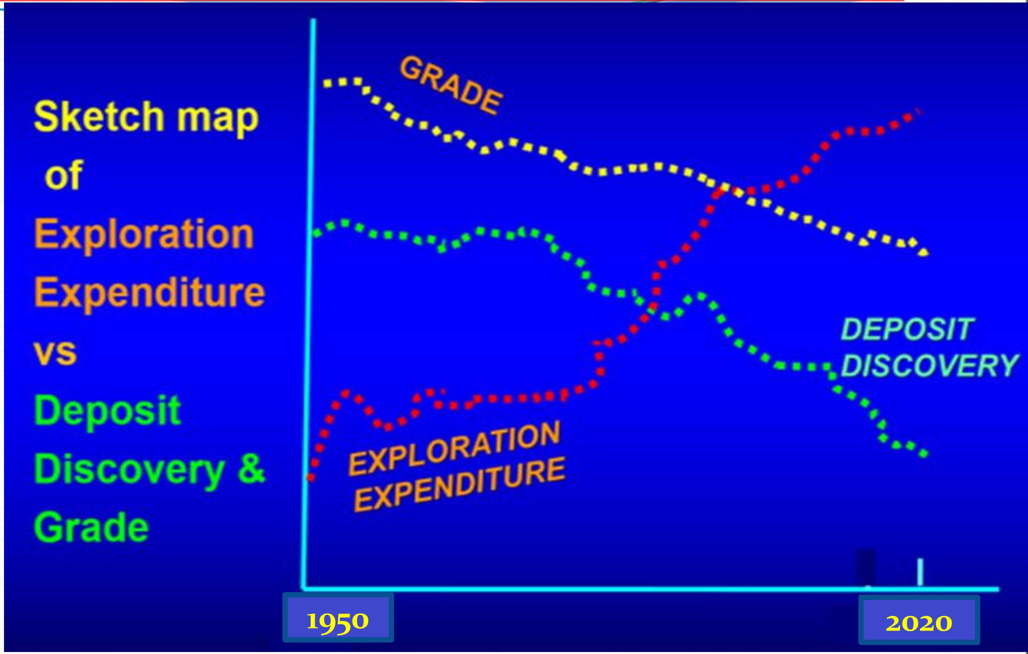
GLOBAL CRISIS FACED BY EXPLORATION ORGANISATIONS

1. **Discoveries are harder to make; *exploration costs have risen dramatically over the last few decades.* Drilling has become an expensive component *(But if we do not drill, we would not discover any resource)***

2. **Rate of world-class/large deposit discoveries is on a *declining trend* with terrain maturity *(existing mines are getting depleted fast and we need to replace them)***

3. **Recent undue emphasis has been on 'brownfields' exploration, whereas bigger discoveries tend to be in 'greenfields' exploration.**



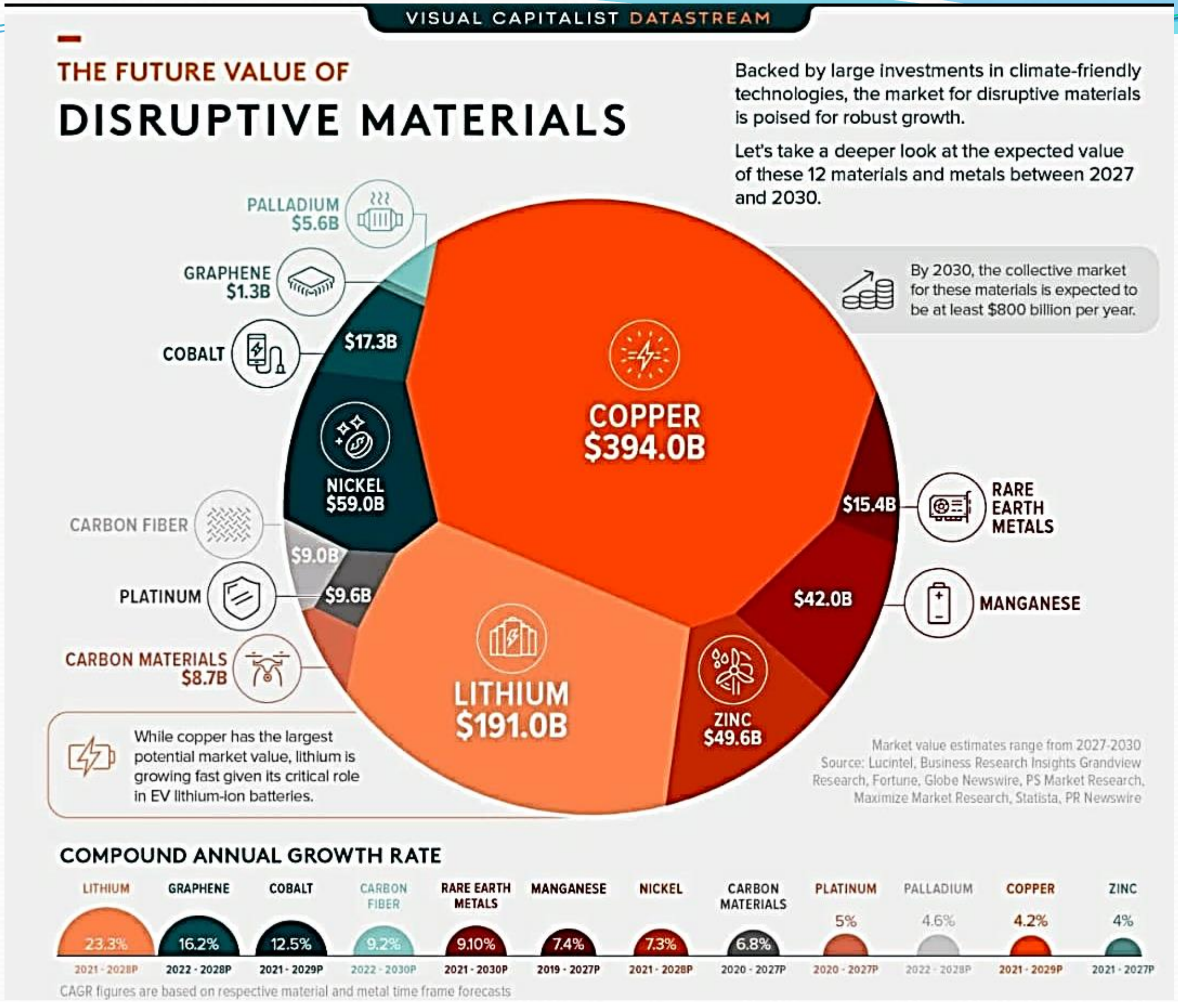
STATISTICS OF WORLDWIDE DISCOVERED DEPOSITS

~30% were discovered "by chance/ by accident"
(Sudbury , Cobalt Ag, Kalgoorli , Broken hill, Erstberg, Rampura-Agucha, Sukinda etc.)
~32% due to combined exploration efforts by Private and multinational exploration companies/Corporations
~20% due to unsophisticated prospecting
~18% due to Govt. enterprises or agencies

CHALLENGES IN MINERAL EXPLORATION

- Mineral exploration is potentially a high risk and high reward activity
- With almost all ‘easy’ deposits near surface have been found and mined out, focus is more and more on discovering deep-seated deposits
- Exploration spending has increased but number of Tier I and Tier II discoveries has not increased
- Cost of collecting geo-scientific data is becoming quite an expensive aspect of mineral exploration
- Success rate of finding new deposits has become low, as low as 0.5% for finding a new economic deposit and that near a known deposit as 5.0%

FUTURE VALUE OF DISRUPTIVE MINERALS



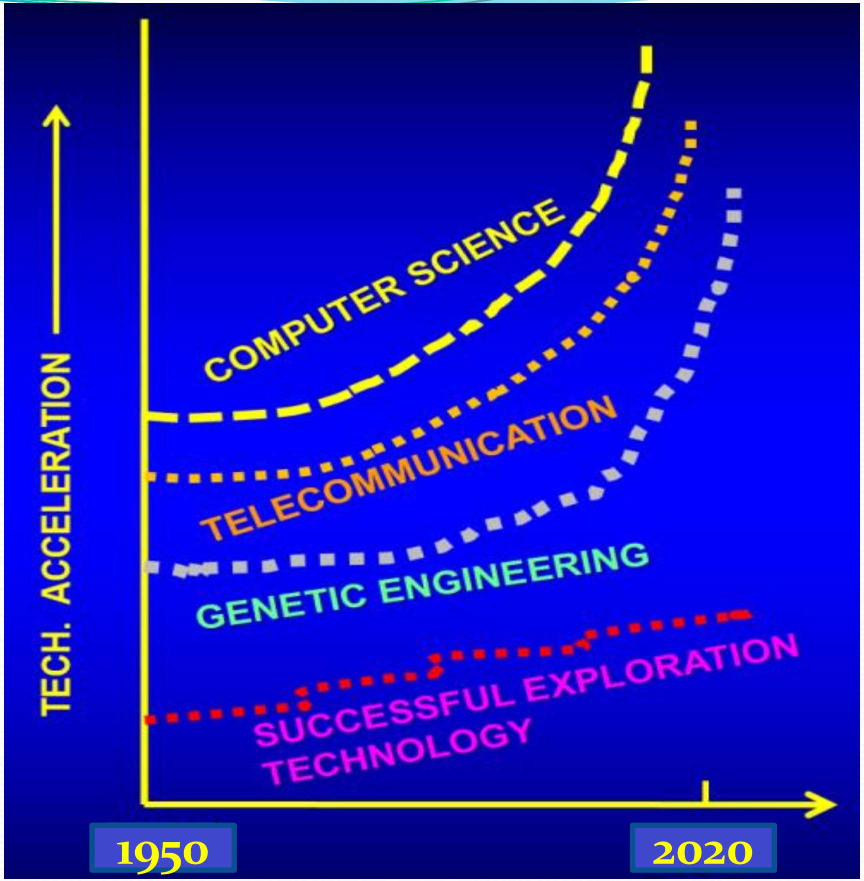
TECHNOLOGY ACCELERATION IN EXPLORATION TECHNOLOGY

1. In the Past 70 years, Technological acceleration in other sciences have doubled more than the Domain Knowledge in shorter time span. But same is not the case in Mineral Exploration Technology (it's a very slow pace)

2. Technology Acceleration in Mineral Exploration depends on:

   (i) Increasing demand for metals that were not sought earlier for growth of industrial output;

   (ii) New ore types and greatly improved geological knowledge and exploration technology



INDIA'S MINING PERSPECTIVE – POTENTIAL VS REALITY

McKinsey study on India's mining industry indicates that there is potential to create 6.5 million jobs and add US$22 billion to the country's GDP by 2024 through increased exploration and mining

Status/Perception[1]	India Status	Global Benchmark
Mining contribution to GDP	1.64%	4.3% (Australia)
Time Taken to Process an Exploration/Mining Right	24-36 months	1 month (Columbia)
Exploration spend per km^2	US$17	US$827 (Chile)
Number of Companies with Planned Exploration	11	566 (Canada)
Fraser Institute[2] Ranking on Investment Attractiveness	97/104	1/104 (Canada)
Fraser Institute[2] Ranking on Policy Perception	88/104	1/104 (Ireland)
Fraser Institute[2] Ranking on Best Practice Mineral Potential	94/104	1/104 (Australia)

CONCEPT OF PROBABILITY & RISK IN EXPLORATION

Exploration cost can be mathematically expressed as,

$$E = (C/P_s) \text{ where,}$$

C is the cost of discovering a mineral occurrence

P_s is the probability of discovering an economic deposit

So, Lower the probability of discovery, higher is the risk

P_s = P1 x P2 x P3, where

P1: Probability of occurrence of a deposit in a prospect;

P2: Probability of its actual discovery;

P3: Probability that it would have sufficient economic worth to compensate investment in exploration, mining and processing cost.

- **These probabilities are interdependent on each other. If any of these individual probability values is zero, net result is a Failure, *i.e.* $P_s = 0$**
- **These probabilities, among others, are largely influenced by:**

(i) Selection of proper geological environment

(ii) Exploration technology used

(iii) Identification of minimum acceptable economic target

(iv) Monetary and time cost of exploration

EXPLORATION PHASE IN MINERAL SUPPLY CHAIN

- Mineral resources being depleting assets, a continuous search is essential to maintain even the existing levels of supply

- In a mineral supply chain, exploration phase carries highest geological and economic risk

- The risk could be minimized within given limitations by evolving an EXPLORATION STRATEGY, which judiciously combines GENESIS oriented GEOLOGICAL MODELS with ECONOMIC and COMMERCIAL JUDGEMENT at each stage of discovery and delineation process

ECONOMIC MODEL EXPECTED VALUE OF A MINERAL OPPORTUNITY

EXPECTED VALUE (EV) in Exploration may be expressed as:

$$EV = R - E \text{ , where}$$

R is **Average Return** associated with an economic deposit after **Discounting Cost of Development and Production**, and

E is **Average Exploration Cost** required to Discover and Delineate an economic deposit

Any investment in exploration, which would yield satisfactory return on capital should satisfy the following inequalities:

$$EV > 0 \text{ or } R > E$$

ECONOMIC MODEL EXPECTED VALUE OF A MINERAL OPPORTUNITY

Break-even Economic Condition is given by the following equation:

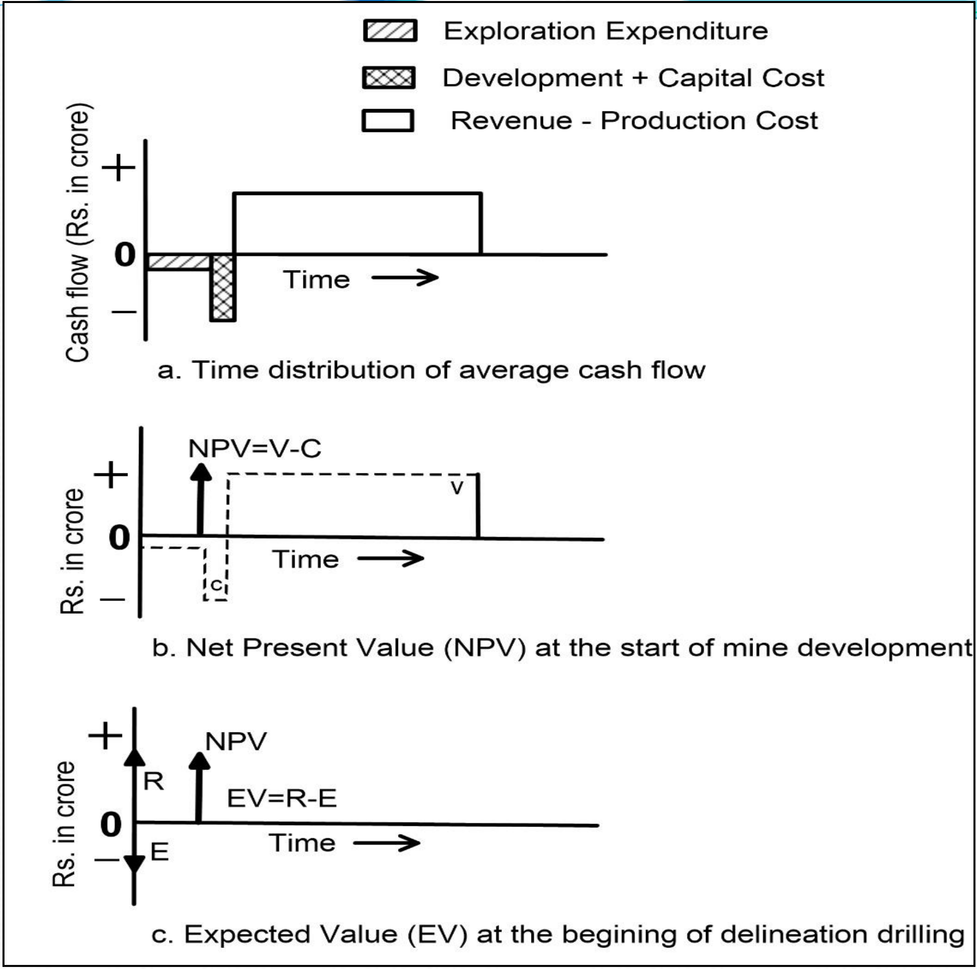
$$V = C + E$$

where, V is the cumulative PRESENT VALUE of annual profits*

C is the cost of development *
E is the cost of exploration *

*all read at a COMMON POINT OF TIME

ECONOMIC MODEL



ECONOMIC EVALUATION PROCESS

Gross in-situ value = (Geological reserve x Geological grades x Metal prices)

Less:

- Mining and Milling losses
- Smelting and Refining charges
- Concentrate transportation costs

Revenue at mine site

Less:

- Capital expenditures
- Operating costs

Before tax cash flow

Less: taxation payments

After tax cash flow

Less: Cost of Capital

Net present value at the start of mine development

MINIMUM ACCEPTABLE ECONOMIC TARGET

An Economic Target has two parameters:

- **Size as measured by ore reserves, and**
- **Profitability condition as determined by Rate of Return (RoR) or average grade of ore.**

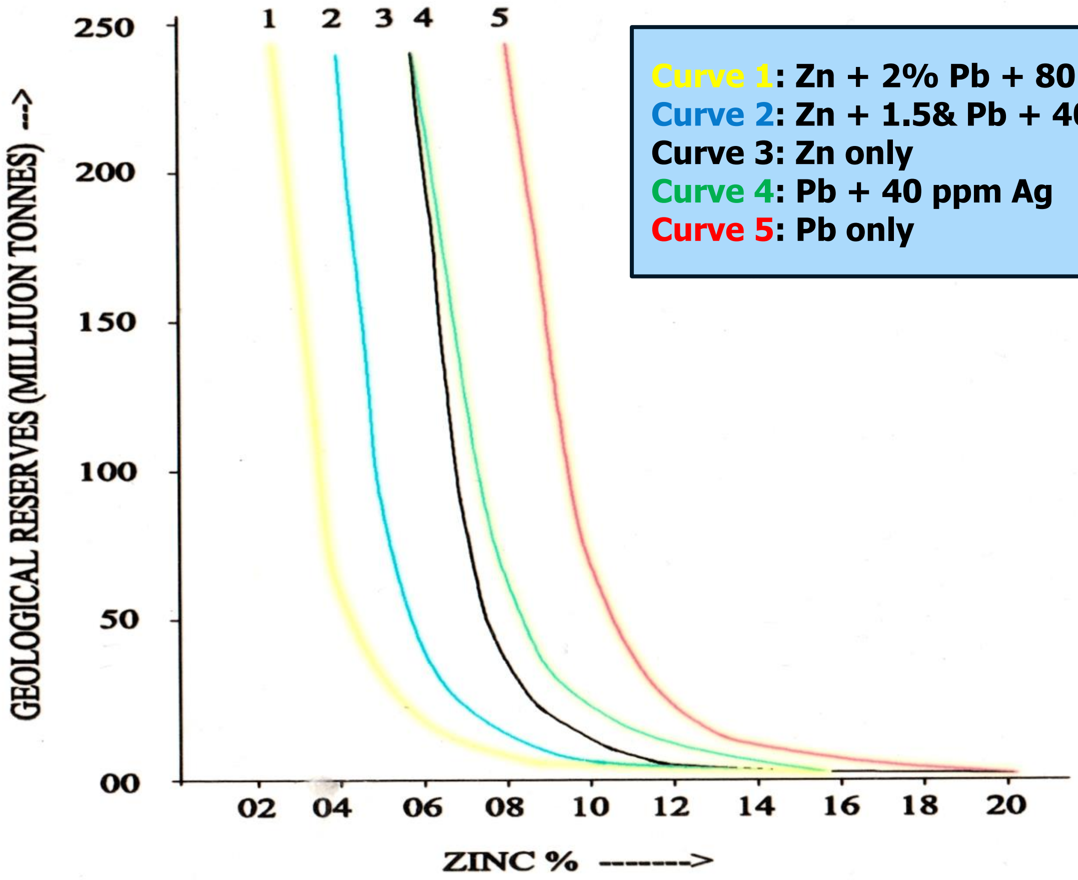
Break-even Economic condition is given by the following equation:

V = C + E, where

V is the cumulative present value of annual profits*
C is the cost of development *
E is the cost of exploration *

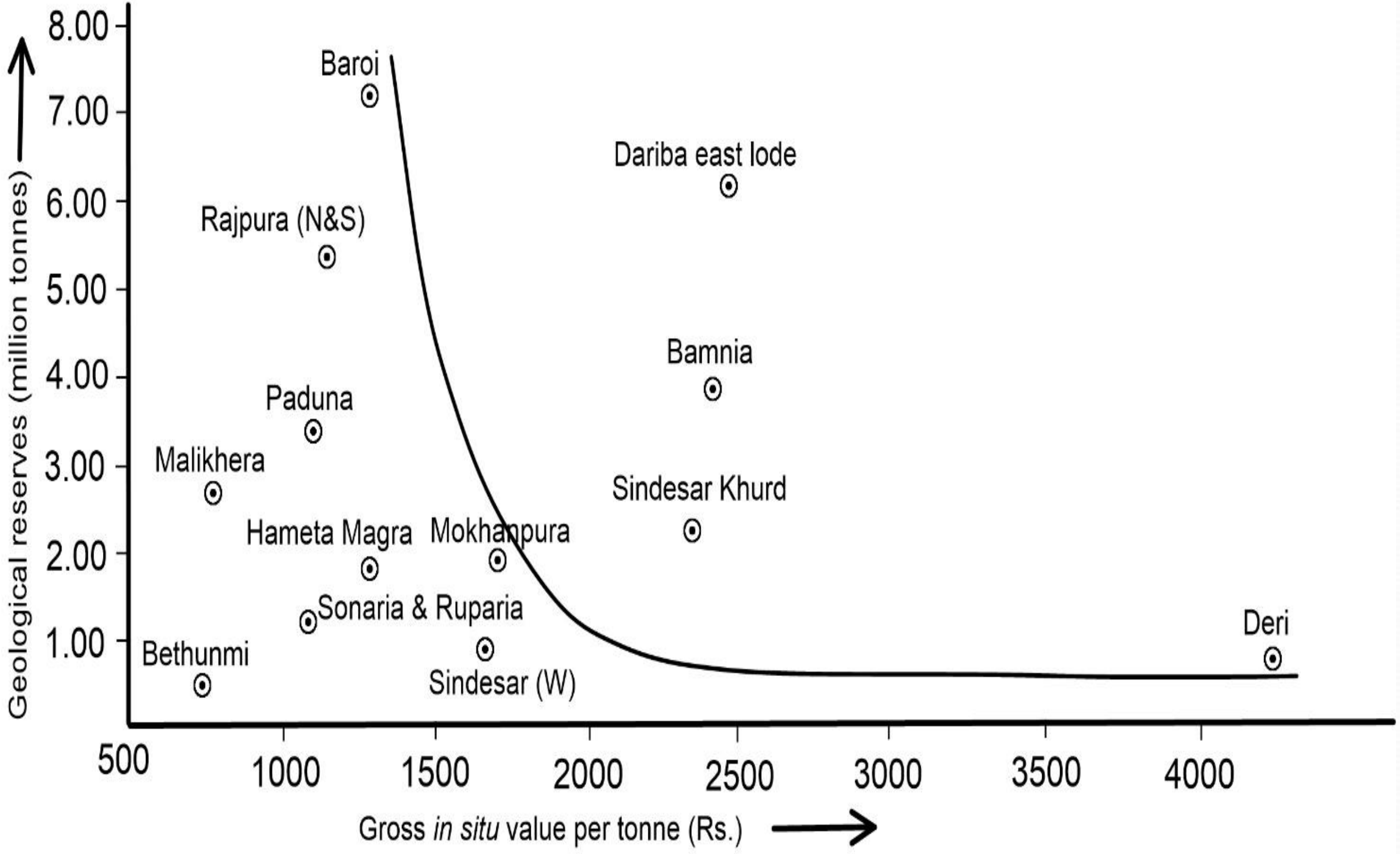
***all read at a common point of time**

MINIMUM ACCEPTABLE ECONOMIC TARGET GRADE-TONNAGE CONDITION FOR DIFFERENT TYPES OF ZINC-LEAD DEPOSITS

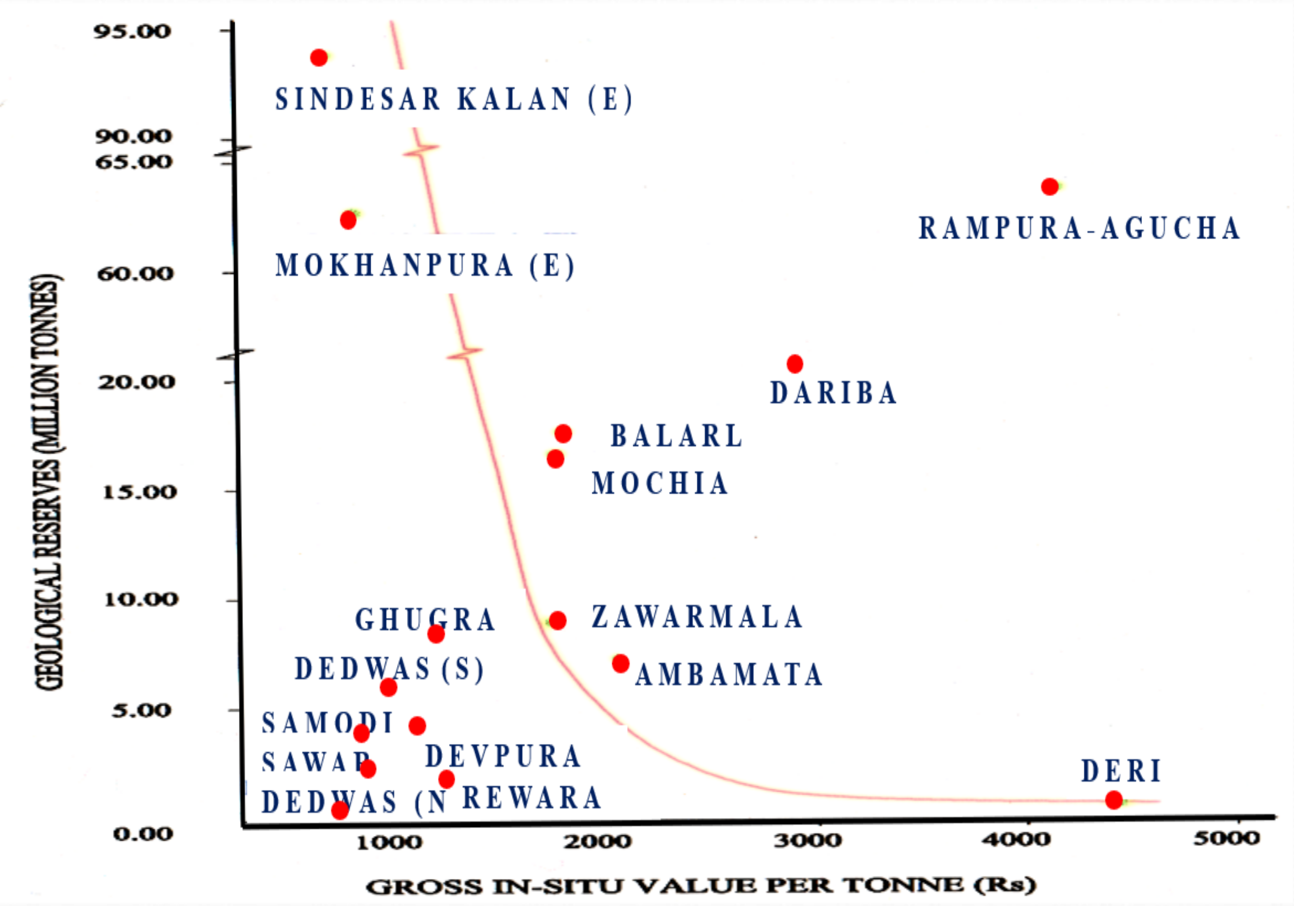


Curve 1: Zn + 2% Pb + 80 ppm Ag
Curve 2: Zn + 1.5& Pb + 40 ppm Ag
Curve 3: Zn only
Curve 4: Pb + 40 ppm Ag
Curve 5: Pb only

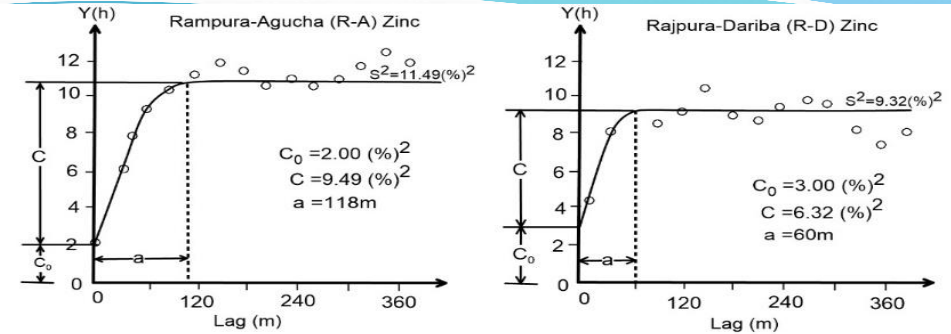
MINIMUM TARGET CONDITION FOR ZINC-LEAD DEPOSITS WITH REGIONAL MILLING FACILITY



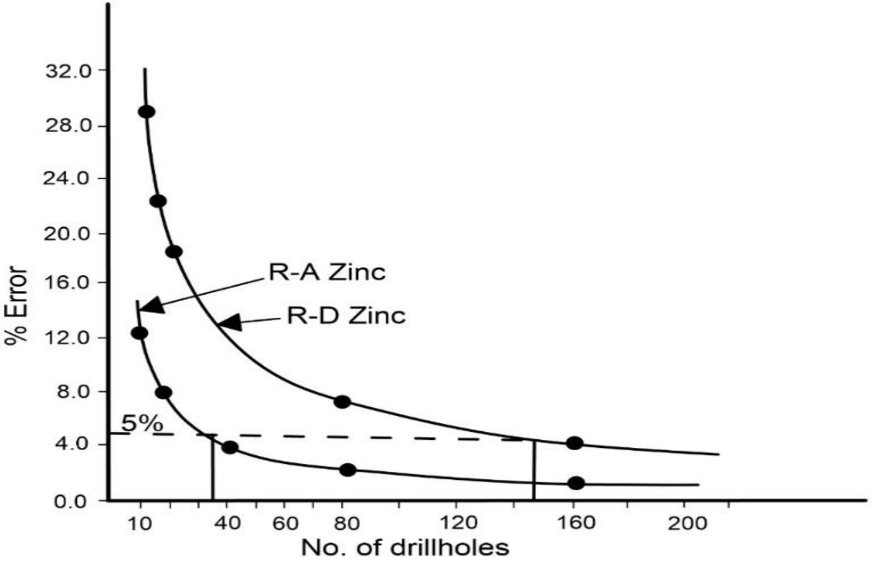
MINIMUM ACCEPTABLE ECONOMIC TARGET BREAKEVEN CONDITION FOR ZINC-LEAD DEPOSITS



OPTIMIZATION OF DELINEATION INVESTMENT USING GEOSTATISTICS

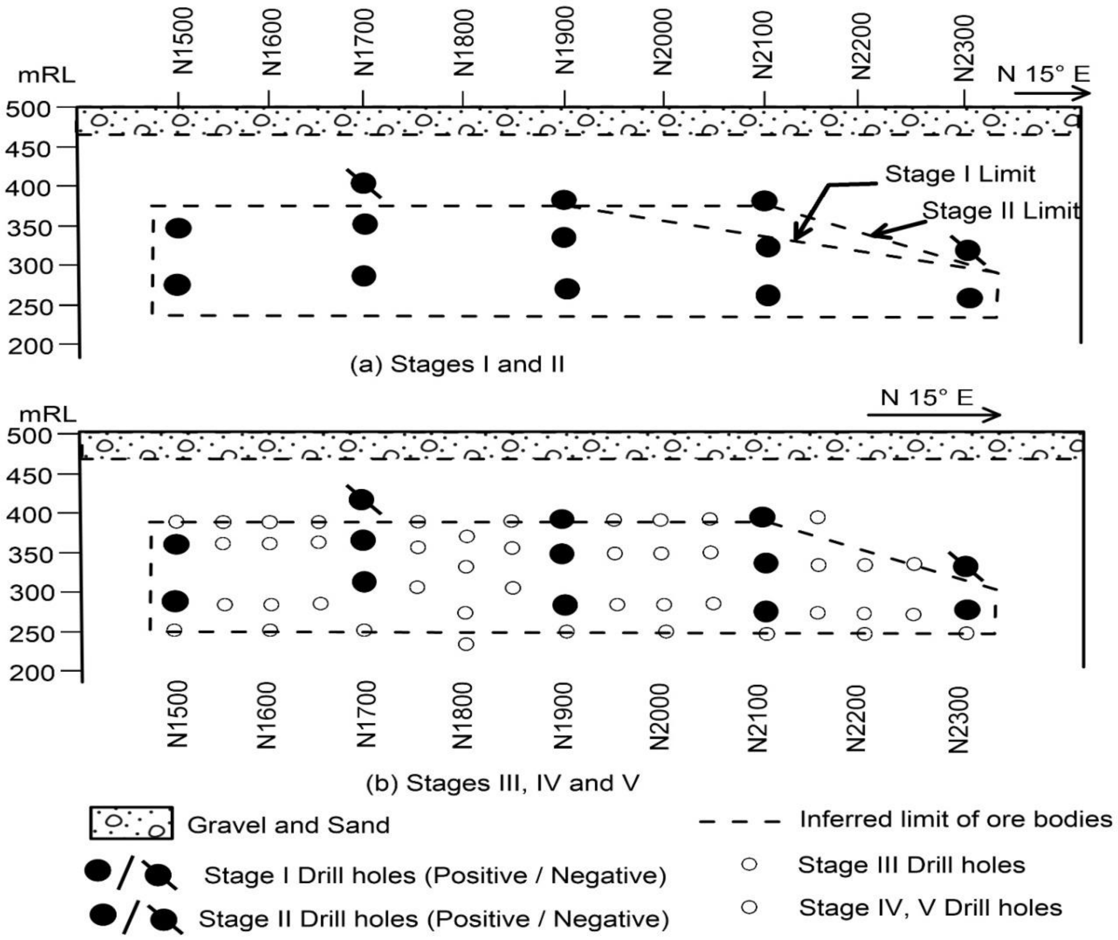


a. Semi-variogram models



b. Optimization curves

SEQUENTIAL DELINEATION PROGRAMME



SEQUENTIAL DELINEATION PROGRAMME

Stages	Drilling Grid (m)	Cumulative Schedule			
		No. of Holes	Drilling (m)	Cost (Rs in Crores	Time (years)
I	400 x 50	7	2270	0.34	0.6
II	200 x 50	13	4183	0.63	1.1
III	100 x 50	30	9800	1.47	2.7
Projected					
IV	100 x 50 (part 50)	40	12800	1.92	3.5
V	50 x 50	57	18200	2.73	5.0

ORE RESERVE ESTIMATES

Stages/ Drilling Grid (m)	No. of Holes	Reserves (mt)		Average content			
				Lead (%)		Zinc (%)	
		T	LLT	X	LLX	Y	LLY
I/400 x 50	7	4.39	2.54	2.54	2.24	5.34	4.81
II/200 x 50	13	4.42	3.01	2.55	2.23	5.41	5.02
III/100 x 50	30	4.42	3.49	2.55	2.34	5.41	5.15
Projected							
IV/100 x 50 (part 50)	40	4.42	3.61	2.55	2.37	5.41	5.19
V/100 x 50 (part 50)	57	4.42	3.72	2.55	2.39	5.41	5.21

MINE DEVELOPMENT SPECIFICATIONS

Mine capacity (t/d)		750t
Pre-production period (Years)		4
Mining method		Cut and Fill
Mine recovery%		80
Dilution%		10
Mine Life (Years)		17
Mill recovery%	Pb	90
	Zn	87
Capital cost (Rs. crores)		30
Mine sustaining capital cost (Rs. crore/year)		1
Operating cost (Rs/t)		450
Smelter recoveries%	Pb	90
	Zn	85
Smelting and refining charges (Rs/t) of Concentrate	Pb	5200
	Zn	4400
Realisable metal prices (Rs/t)	Pb	15000
	Zn	25900

RESULTS OF ECONOMIC MODELLING

Rs in Crores							
Bore holes (Nos)	Delineation Cost (E)	Expected Profitability			Lower Limit Profitability		
		NPV	R	EV	NPV	R	EV
7	0.32	28.14	26.62	26.30	7.78	7.36	7.04
13	0.56	26.59	23.59	23.39	10.88	9.80	9.24
30	1.24	26.59	20.57	19.33	16.67	12.90	11.66
Projected							
40	1.55	26.59	19.06	17.51	18.36	13.17	11.62
57	2.08	26.59	16.51	14.43	20.41	12.67	10.59

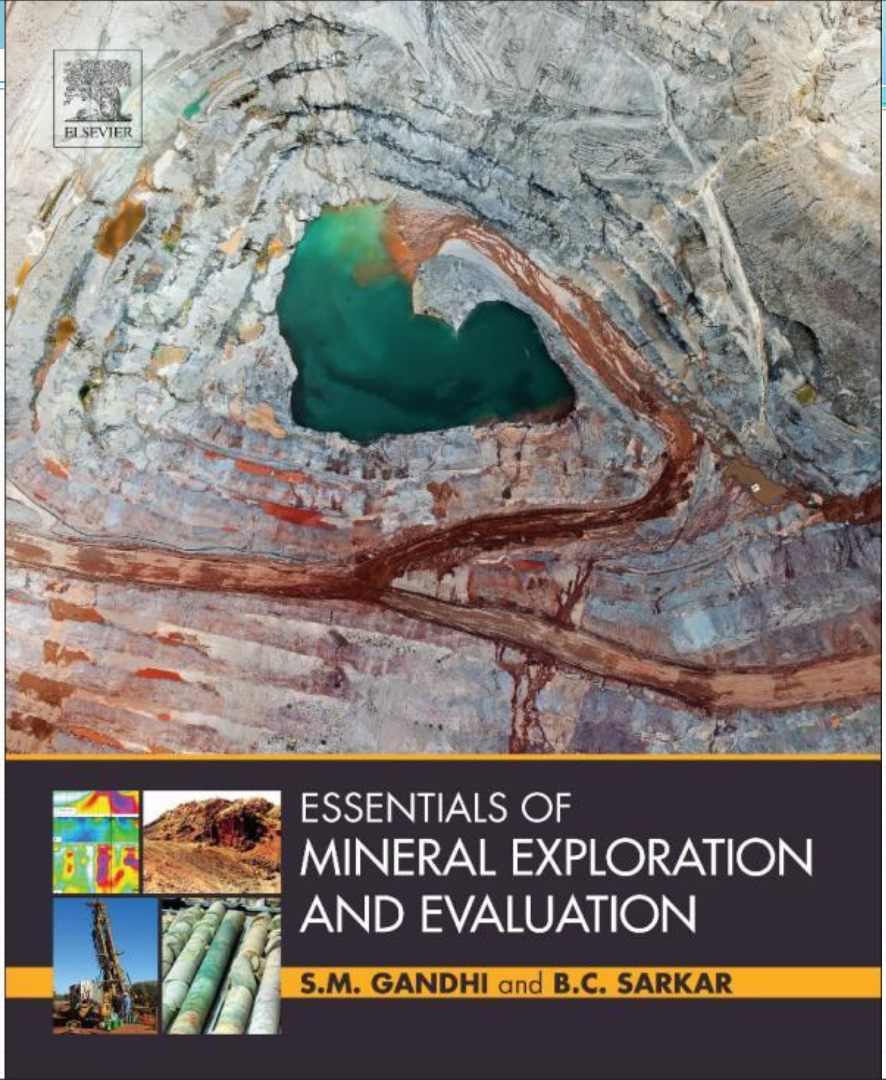
CONCLUDING REMARKS

- Exploration agencies incur substantial expenditure and time in delineation of mineral deposits

- The presented analyses of exploration results provide an effective means for defining economic sampling limit and optimization of delineation expenditure

- The model can be used DYNAMICALLY to understand the effect and significance of successive levels of delineation on Expected Profitability and Associated Risk

- Such information is gradually achieved as delineation progresses to keep an exploration agency appraised about economics of exploration investment


ELSEVIER
ESSENTIALS OF
MINERAL EXPLORATION
AND EVALUATION
S.M. GANDHI and B.C. SARKAR

Thank you &

Queries PLEASE?