# Metallogeny—the search for a rationale behind space-time selectivity of ore deposit formation

Asoke Mookherjee

Department of Geological Sciences, Jadavpur University, Calcutta 700 032, India

**Ore deposits, localized natural concentrations of some metals way above their average crustal abundance, have been forming almost from the beginning of earth's history (~3.8 Ga) to the present day. Global database reflects their strikingly non-uniform distribution patterns which can be region-specific, time-specific and/or metal-specific. Attempts to rationalize such spatial/temporal/compositional selectivity in terms of the broader processes of crustal evolution have been only partially successful so far. However, such efforts have revealed many hitherto unsuspected relationships between mineralization and seemingly unrelated geologic phenomena. A complete understanding—of reasons why ore deposits occur *when* and *where* they do—must await fuller recognition of such nexus.**

THERE is a standing joke among exploration geoscientists that ore geneticists never fail to come up with an erudite explanation about *how*, *when* and *why* a particular deposit was formed at a particular place—but only long after the deposit had been actually discovered; often through routine hard work of field-weary geoscientists and sometimes by sheer chance!

One reason why such pedagogues are indulgently suffered is that they are really trying hard to find a method in the madness of Nature; to understand why an ore deposit is where-it-is, was formed when-it-was-formed, and whether there is any discernible, regionally or globally unifying pattern in their space-time distribution that can be explained in the light of known and emerging facts of the earth's evolutionary history. This in essence is what metallogeny is all about.

*What is an ore deposit*? It is essentially a segment of the earth's crust with a strong positive chemical anomaly in respect of certain element(s) whose *average crustal abundance* (called the Clarke value) is very much lower. Every deposit, large or small, is thus a reminder that something very special must have happened there, so that elements with Clarke values in ppm/ppb range have been concentrated in several million tons within a small volume of rock. The degree of natural enrichment required to be labelled as an ore 'deposit'—even though dependent on technoeconomic factors—is so widely different (Table 1) as to imply that it is either *more difficult*, or *more time-consuming*, or *both*, for Nature to produce deposits of some metals (e.g. Hg, As, Sb), compared to those of some others (e.g. Fe, Cr, Al). A deposit may be a very rich bonanza with a sharp, discrete boundary, or an invisible lean dispersion whose outline is delineated by an arbitrary assay contour cut-off, decided primarily by cost–benefit calculations.

Two endmember earth processes are responsible for diverse genetic types of deposits: *endogenous*, driven by the earth's internal heat engine, and *exogenous*, operated by solar energy. However a large majority of ore deposits are really 'hybrid' products of joint enterprise of the two processes. The same process can give rise to deposits of different metals and different genetic processes can form deposits of the same metal. Quite often, formation of an ore deposit is a multistage operation creating, first, a lean 'protore' and subsequently a further-enriched, smaller and richer orebody(ies).

Interestingly, except Al and Fe (and Mn), metals eagerly sought for are not at all essential for forming the ordinary rocks in the crust. These metals are, so to say, unwelcome stragglers who have to be either grudgingly accommodated by the rock-forming silicate minerals in their lattice or disposed of somehow, somewhere. Seen in that light, formations of ore deposits may be looked upon as Nature's waste disposal arrangement—through its own sewers into its

**Table 1.**

| Element | Clarke (ppm) | 'Cut-off' grade* (ppm) | Required enrichment factor |
|---|---|---|---|
| Al | 81,300 | 300,000 | 4 |
| Fe | 50,000 | 280,000 | 6 |
| P | 1,050 | 100,000 | 95 |
| Cu | 55 | 10,000 | 160 |
| Nb | 20 | 3,400 | 170 |
| Ni | 75 | 1,500 | 188 |
| Mn | 950 | 350,000 | 350 |
| Pt | 0.01 | 4 | 400 |
| U | 1.8 | 1,000 | 500 |
| Zn | 70 | 40,000 | 600 |
| Mo | 1.5 | 1,300 | 867 |
| W | 1.5 | 1,400 | 933 |
| Au | 0.004 | 6 | 1500 |
| Pb | 13 | 40,000 | 3000 |
| Cr | 100 | 300,000 | 3000 |
| Sn | 2 | 10,000 | 5000 |
| Ag | 0.07 | 500 | 7143 |
| Hg | 0.08 | 3,000 | 37,500 |
| Sb | 0.2 | 10,000 | 50,000 |

*Variable technoeconomic parameter.