GIANT METALLIC DEPOSITS UNDER COVER: MAIN SOURCE OF METALS IN THE 21st CENTURY

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Abstract

The majority of existing mineral deposits has been discovered in surface exposures or under shallow unconsolidated overburden. The first concealed orebody was found by drilling in 1899, so ore finding under cover goes back only 110 years yet at least 67 major concealed deposits have been found by 2009. Giant deposits under deep cover are going to be the main source of metals in this century, but finding them will increase the costs. Even so, with increasing depth under the present surface many important ore types will disappear. Placers and lateritic deposits will disappear at the 100 m depth level; most epithermal deposits will peter out at 1000 m; porphyry coppers in depth will lack zones of supergene enrichment and will be gone completely by the 3000 m depth. Only orogenic gold, Bushveld type and anorthosite Ti-Fe-V deposits will likely persist to greater depths, although there are numerous exceptions due to structure (e.g. Witwatersrand reefs intersected at 5000 m depth).

Orebodies discovered in the past at exposed surface account for the majority of giant deposits found so far, but by now this source has been severely depleted, especially for ores with conspicuous appearance (e.g. outcrops of oxidic Cu minerals stained green, strong gossans).

Orebodies buried under shallow unconsolidated overburden like gravel, sand, glacial drift and in-situ tropical regolith have, in the past, been discovered in accidental excavations (e.g.during water well sinking, foundation excavation, railway construction; e.g. Sudbury and Cobalt) and only in the last century as a result of systematic exploration. The noninstrumental prospecting techniques (e.g. ore boulder tracing in glacial drift, panning for heavy minerals) have been joined by exploration geochemistry (pioneered by the Soviets in the 1930s; e.g. Fersman and Vernadsky) and geophysics. The targets were excavated or drilled. Since about the 1980s the various reverse circulation, air blast and similar rapid techniques of soft overburden drilling greatly accelerated discoveries under shallow cover.

The first major concealed orebody in solid rocks was found by mining in 1859 and the first drilling discovery, indicated by primitive geophysics, was made in 1899 at Falconbridge in the Sudbury district, Canada, so ore finding under cover has a little more than 110 years of history yet at least 67 major concealed deposits have been found by 2009 (Laznicka, 2010).

Major ore deposits under cover discovered by 2009

It is estimated that about three quarters of metallic deposits in outcrop and shallow subcrop have already been found worldwide so the future will rely on discoveries under increasingly deeper cover. First, let's review the concealed ore finds of the past.

New major orebodies are occasionally found in active mines where they are intersected by mine workings (a) or by exploration drilling from underground (b). The 1859 discovery of the Neues Lager at Rammelsberg (Germany) that multiplied the magnitude of this deposit is an example of (a), discovery of the Borska Reka porphyry Cu under Bor (Serbia) workings exemplifies (b). Additional "giant" (a) examples include the Butte porphyry Cu-Mo (Montana); Mount Emmons-Mo (Colorado); Goldcorp bonanza Au (Red Lake, Ontario) and others. Examples of (b) include Climax Lower Orebody-Mo (Colorado), Kalamazoo-Cu,Mo (Arizona), Magma (Superior) Deep-Cu,Mo (Arizona), Alemăo-Cu,Au (Brazil), Rico-Mo (Colorado) and others. Although some early blind ore discoveries were made by direct mining from surface or from hillsides (e.g. Ballarat Deep Leads-Au under basalt flows; Australia), most concealed orebodies have been discovered by drilling based on geological interpretation (c) or, increasingly, on geophysical evidence (d). Examples of (c) include discovery of the Central Tennessee (Elmwood) MVT field intersected during a "random walk" (=a drilling traverse), Admiral Bay Zn-Pb (Western Australia), Lubin Cu (Poland), and others. In many cases there was some inconclusive geophysical evidence anyway. Geophysics-assisted drilling begun in the Kursk Magnetic Anomaly (Russia) and in the Norrbotten Fe ore provinces (Sweden) in late 1800s (based on magnetics), whereas the 1899-1901 finding of the blind Falconbridge (Sudbury) Ni orebody in Canada is credited to T.A. Edison's electrical experiments. Perhaps the highest credit for application of an early geophysics to locate deeply buried ores is due to Rudolph Krahmann (Robb and Robb, 1998) whose magnetic exploration technique in the 1930s succeeded to trace westward the week response given by the Contorted Bed marker (in the West Rand Group, South Africa). This suggested subsurface continuation of Central Rand Reefs away from their outcrop area. Follow-up drilling then discovered the deeply buried West Wits (Carletonville) goldfield, the most productive one in the Witwatersrand. Subsequent deep drilling in the Witwatersrand (down to 5 km depth) succeeded in finding and outlining the Vaal Reef in Klerksdorp (1942), Welkom goldfield (1946) and Evander goldfield (1950). More recent holes drilled at fringe of known goldfields and into gaps between goldfields intersected the Beatrix, Oryx, Sun, Oribi and the 5000+ m deep Western Ultra Deeps (resource of 1705 t Au; Anglogold) deposits. Outside of Witwatersrand the drilled depths to orebodies have been more modest, although the recent discoveries of Cu-mineralized Weissliegende dune sandstone (associated with the Kupferschiefer) under the Polish Plain are a close match to the Rand (Sulmierzyce, 1500m; Kaleje, 3000m). Drilling for concealed orebodies is now a standard technique in well mineralized areas that lack outcrop (e.g. the Olympic Dam IOCG province in South Australia), or in mature ore districts with no more outcropping orebodies to be likely found (e.g. the southern Urals VMS province, Russia). Major mineralized provinces have recently been outlined without a single outcrop showing (the southern Kazakhstan-northern Uzbekistan uranium province, especially the Chu-Sarysu Basin). It is evident that concealed orebodies are the near future of exploration geology: now, how much is there?

Do all metallic deposits persist into greater depths?

Opinions have been expressed that, say 500m or 1000m depth levels (that is "moderate" depths that could be reached by the present drilling technology and then economically mined) might contain the same frequency of mineralization as experienced in the present outcrop. With this I strongly disagree. Fig. 1. shows the range of depths of formation of selected ore types. Those formed at the (paleo)surface do not last long unless they are soon buried and preserved which is the normal case with most marine sedimentary deposits (e.g. bedded Fe, Mn, phosphorites) deposited in subsiding basins and buried by continuous sedimentation, and then preserved in slowly eroding platformic sequences or in "miogeoclinal" orogens. This applies to many VMS and sedex deposits as well. Continental sedimentary deposits (alluvial placers, playa lake sediments and brines) have a much shorter lifespan unless they are soon buried by what are mostly episodic, irregular events (e.g. flood basalts, pyroclastics, prolific sedimentation e.g. in alluvial fans or landslides). The usual (normal) evolution of surface and near surface deposits and their tendency to soon perish is not proven invalid by one of a kind or rare exceptions, no matter how productive (e.g. Witwatersrand as a paleoplacer). Metalliferous regoliths (e.g. Ni, Fe, Co laterite/saprolite), shallow infiltrations (sandstone-U, Cu), MVT-style ores, are also preserved poorly in geologically old sequences, although some have survived around unconformities. Fig. 2. shows the interpreted persistence of various ore types with depth, in relation to the present surface. The graph is based on predictions supported by geological information now available for more than 50,000 deposits worldwide. The graph suggests that the 100 m deep level under the present surface would preserve only the deepest (basal) horizons or roots of alluvial placers or laterites with only few exceptions where the material filled anomalously deep (fault or karst) depressions. This might eliminate up to 70% of the presently available global Ni endowment and a significant proportion of the past gold supply derived from placers. The 400 m exploration depth level would lack placers and laterites altogether. Geologically older sandstone-U deposits formed at about that depth in basinal sequences undergoing uplift now appear directly at the present erosional surface, partly oxidized and impoverished by leaching (e.g. the first generation of Colorado Plateau carnotite deposits). Geologically younger U infiltrations or older ones in still subsiding actively sediment-filling basins will be still there in depth, perhaps drill intersected at their most productive levels (Chu-Sarysu Basin).

High-level hydrothermal deposits predominantly situated in settings that undergo (and have undergone) rapid uplift will also be gradually decimated with increasing depth. At the 100m depth level hot spring deposits will have only their roots left, although these can support major orebodies (McLaughlin Au-Sb-Hg in California). At the 400m level even these roots will disappear despite the few geologically older exceptions known (Devonian Drummond Basin-Au, Queensland, or Ordovician McGee-U, South Australia; not “ore giants”). At the same depth (~400m) porphyry Cu-(Mo,Au) will still be present, perhaps slightly reduced in quantity, but they will be without their supergene enriched (oxidic and secondary sulfides) blankets. Unconformity-U, mesothermal Pb-Zn veins and replacements will likely be rarer at 400m to substantially reduced in frequency at 1500m: all without oxidation zones (although at Tsumeb oxides persisted to 1600 m under present surface).

Frequency of VMS and sedex deposits will likely change only slightly with depth, if at all. The IOCG deposits are a mixed bag, still poorly understood. Their magnetite or hematitedominated high-level equivalents and relatives interpreted as lava flows, ore dikes or lowpressure replacements like El Laco or Cerro de Mercado will likely be gone or degraded in a 400m depth, but those interpreted as mid-crustal replacements associated with feldspathization will likely persist to a considerable depth. Of still other ore types Carlin gold will likely diminish at the 400m depth and disappear at 1500m, perhaps to be substituted by deep-seated equivalents (skarn?). Reduced scheelite skarn and orogenic (“mesothermal”) gold lodes will likely persist to a considerable depth (viable at 2500 m but without oxidized tops). High-grade metamorphic ores (Broken Hill Pb-Zn, Thompson Ni) will likely persist to the lower limit of supracrustal sequences, accompanied by metamorphosed BIF. Bushveldtype mafic-ultramafic systems and Fe-Ti-V oxides in anorthosites may reach the greatest depths, perhaps even increasing in frequency. Modern exploration technology and accumulated information make it increasingly possible to detect, then intersect, many orebodies that are outside the reach of the traditional prospector, but quality people have to provide ideas, manage the process, and control the gadgets.

References

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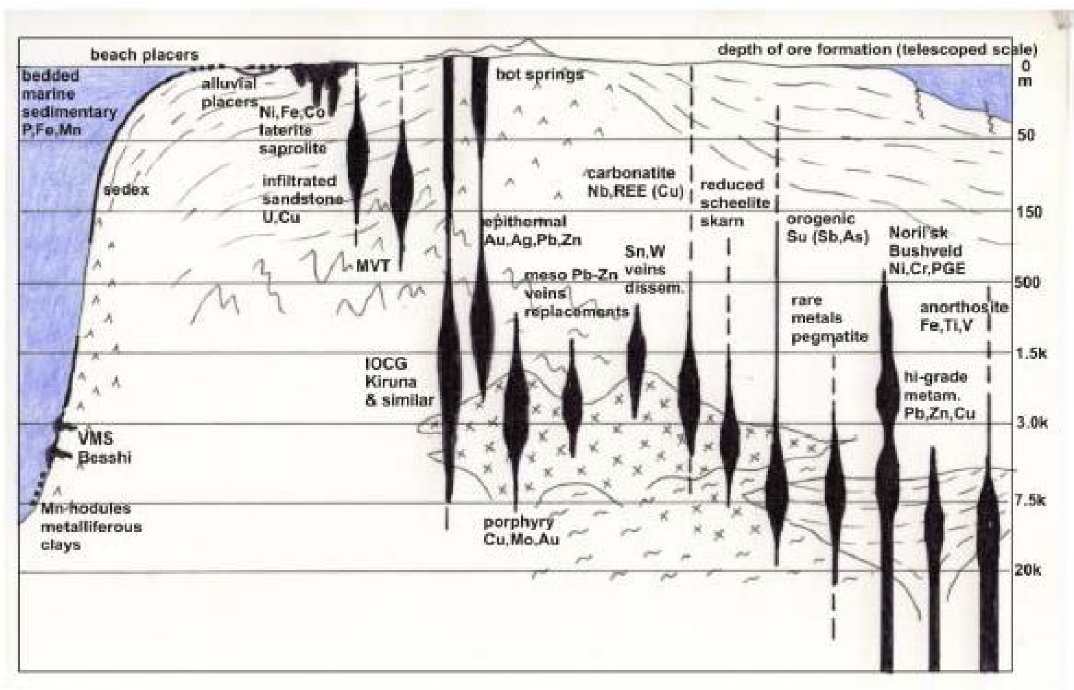

Figure 1. Depth (range) of selected ore type in the time of formation. From Laznicka (2009).

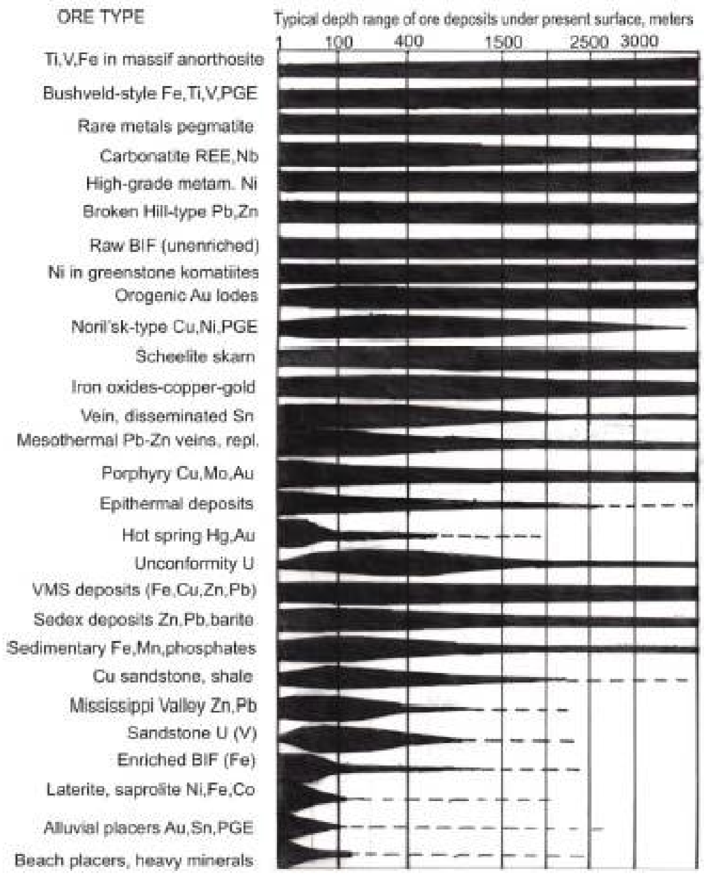

Figure 2. Estimated depth and range of selected ore types presently exposed at dry land surface (not depths of original ore formation). From Laznicka (2009).