

LITHOTHEQUE knowledge system about world's mineral deposits supported by miniaturized sample sets: call for international adoption, networking and exchange

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Abstract

Our civilization is based on metals, among other life supports. The existing ore deposits are becoming rapidly depleted by almost exponentially increasing demand and production and major new ore discoveries are needed. Mineral exploration is supported by modern tools and scientific ideas, but geological characteristics of orebodies and their rock associations have still to be visualized. The time-tested exploration search for (near)-analogs of important model deposits is still the basic approach and it will be around for a long time, even as the future ores will be found under increasingly thick cover. The skills of visual recognition of geological features indicative of ore presence can best be gained in the field, but the second best experience comes from examination and study of the real geological materials assembled in systematically organized geological sample sets. The Lithotheque knowledge system of recording and interpreting mineral deposits is based on sets of miniaturized rock/ore samples permanently attached to rigid plates and stored like books for instant access. It has been designed to bridge the gap between written text or a lecture and a field visit with minimum demand on space and servicing. The sample images and supplementary materials are transmitted via internet. The existing Data Metallogenica and Lithotheque systems, now based in Australia, could be adopted internationally and established in a number of regional centers contributing local knowledge to global metallogeny and exchanging material. This would enhance the practical component of mineral resources education and ore finding.

Keywords: *LITHOTHEQUE, Data Metallogenica (Original), future mineral resources, mineral deposit expert system, global mineral database; miniaturization of geological sample sets; mineral exploration; international geo-information exchange; electronic images of mineral deposit sample suites.*

Introduction: Civilization based on metals

Mining, primitive smelting and utilization of metals have about 9000 years long history. With roots mainly in the Middle East (Iran is considered a cradle of copper mining and smelting) metals supplies grew very slowly throughout the human history accelerating during the Industrial Revolution when most of the 92 naturally occurring elements had been discovered and utilized shortly afterwards. In the past 50 years demand for metals has increased almost exponentially, in parallel with population explosion. Minerals industry, from primitive diggings and backyard smelting of yesteryear to the present vertically integrated resource corporations, has so far been able to supply the global metal demand although shortages occasionally developed. With the present yearly world consumption of 15 million tons of copper it will be necessary to find a copper deposit equivalent in size to one and half Sarchesmeh's every year.

Most of the global metal supply come from "world class" (Singer 1995) or "giant" (Laznicka, 2006, 2010) deposits and very few have been discovered in the 1990s when the price of metals was very low.

The world was running out of metal resources then and situation has improved only when metal price increased after 2003. The newly discovered resources announced in 2008-2009 added about 8.5 years of supply to the world's copper inventory (less for other metals). Traditional mineral occurrences at surface have been significantly depleted and the future ore discoveries will increasingly be made under progressively deeper cover. The cost of discovery and with it the price of metals will increase. Mineral exploration will require ever more sophisticated methodology and high quality exploration professionals.

Mineral exploration

The first generation of ore deposits was found by accident, in most cases by lay persons. The discovery established a precedent employed as a standard in the search for additional deposits of similar appearance and setting: initially in the same area, later outside it, now globally. The earliest miners-prospectors in ancient Sumeria (now parts of Iran and Iraq), ancient Egypt

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and adjacent lands, in Andalusia, China, pre-colonial Mexico, Peru and parts of Africa, clearly used this technique as is indicated by the style and pattern of hundreds of ancient workings scattered in the area and perhaps best displayed in Saudi Arabia (Fig. 1). The old miners were illiterate and left no written record. Visual exploration flourished in the Middle Ages, gradually recorded in the literature that culminated in the 1556 book *De Re Metallica* by Georgius Agricola, but still without the benefit of specialized education, literature, research and state geological surveys. This locally persisted until the early 1900s; in South Australia alone 1200 mineral occurrences have been found by visual prospecting between 1840 and 1890, tested by excavations and shallow mining, and recorded by Brown (1908). Less than 1% of these occurrences became producing mines (mostly of copper) and they are repeatedly re-visited and re-examined by modern exploration companies as they might provide clues for economic deposits to be developed. Scientific and technological advances in exploration only appeared some 100 years ago and gradually intensified to evolve into the present mammoth research, education, information and technology establishment that assist the ore finders of today. Despite the advanced state of knowledge, many world-class ore finds have been made by the 19th and early 20th centuries prospectors who knew little about geosciences yet discovered the Witwatersrand, Timmins, Broken Hill, Kalgoorlie, California and Victoria goldfields just by traversing and field observation, sometimes with panning for heavy minerals (mostly gold).

This continued through the 1930s and 1960s with discovery of the "black mountain with streaks of copper" by Jacques Dozy in 1936 (now the site of the great Ertsberg-Grasberg camp in Papua); recognition of the Carlin and adjacent "trends" in Nevada; and rise of the Yilgarn Craton Ni province in Australia from zero to 5 Mt of contained nickel thanks to re-examination of old gossans known to the 1800s gold diggers, using inspiration and visual images imported from Canada. Visual ore discoveries are still being made despite the dominance of high technology and research: Voisey's Bay, the largest Canadian nickel find in decades, has been made in 1994 by two prospectors who landed their helicopter on a gossan they spotted from the air. The huge Red Dog zinc-lead deposit in Alaska was first reported by a bush pilot. And even the academic researchers sometimes prove their theories and models by going into the field to find what they predicted; the discovery of the Felbertal scheelite deposit in Austria in the 1970s, now the largest European tungsten deposit by professors from the Munich University, is a glaring example.

By present day, virtually every place in the world has been seen and visited by geologists, and inventory of visually conspicuous orebodies at the surface that

remain to be discovered has been seriously depleted. Yet thousands of mostly regional junior mining companies hold a great number of mineral showings, prospects and old mining sites some of which are eventually going to make it into producing mines. It is estimated that up to 80% of newly developed mines are based on discoveries "in headframe shade" (that is, in established mining regions) of which a significant percentage are old mines or diggings. They disappear fast due to reclamation and land development and the valuable geological record they provided is lost. Although future mineral exploration will increasingly rely on discoveries of deposits under cover indicated by indirect technology (geophysics, geochemistry, drilling), no deposit is proven until the orebody is actually intersected and the ore first visually, then technologically, identified and evaluated. Visual experience is essential for evaluation of early drilling results so that the next drill hole is to be positioned at the most prospective site. So visual skills retain, and actually increase, in importance and books could be written about cases when potential orebodies have been missed by geologists who failed to creatively and skillfully "read the rocks" in outcrop or drill core. Predominantly visual geological experience combined with standard exploration tools like geological mapping, sampling and shallow drilling has resulted in discovery of major deposits at a fraction of cost paid by major corporations (Lowell, 2001). "Reading the rocks" is thus THE essential component of exploration methodology and will remain so regardless of technological and scientific progress. Yet this discipline is being increasingly downgraded by educators where students are at best rushed through museums of selected perfect mineral specimens, and by the overwhelming dominance of paper and electronic information disseminated from comfortable city offices. Where and how can explorers develop the all important familiarity with geological materials to guide them to the orebody?

Open displays of geological collections in public museum focus on the exceptional that enlighten the general visitors (especially school tours) on one hand, and specialist mineralogists, paleontologists and other geoscientists on the other. The more typical museum material to inspire explorationists, if any, is locked in depositories but its existence is rarely realized and access is difficult to gain. Local company museums at various mines as at the Broken Hill Zinc Corporation, Sullivan Mine in Canada and at many Soviet and Chinese mines were open to company staff and professional visitors. They used to provide excellent tangible knowledge but when the mine closed (or money ran out) the museum disappeared, its collections scattered. This leaves the government drill core libraries as the most encouraging practical development of the 1960s and beyond. Establishment of the South Australian core library in Glenside in 1978

and comparable libraries elsewhere in Australia, Canada, United States has been a remarkable foresight of governments and an investment that benefits the present, and will benefit the future, mine finders. Despite the recent progress of bringing visual images of drill core, with some physical properties, to the global public via internet (e.g. the HyLogger scans; Keeling et al., 2004), the amount of drill core held is overwhelming, repetitive and very local. It is not suitable for comparisons of numerous deposits and mineralized systems, especially those that involve materials from important world deposits used as standard to search for similar deposits elsewhere. The exploration industry as well as the mineral research establishment would benefit from a uniformly organized database of world's mineral deposits and their environments supported by real geological materials that could be objectively examined, unencumbered by conceptual models of the day that keep changing. The geological sample sets on display should be of limited complexity in order not to overwhelm, yet carefully selected to present an objective "story" of a deposit. They should be the equivalent of abstracts to longer paper reports, and be available for physical inspection and on-line (electronic images) browsing. Such system is already here and it is called Lithotheque and Data Metallogenica.

Lithotheque, A Rock Library

Lithotheque (from Greek) means "rock library". We gave this name to a style of arrangement of sets of miniaturized rock and ore samples that are, in systematic fashion, permanently attached (cemented) to

rigid (originally cardboard, now aluminum) page-size plates that could be held, like books, in library-like stacks suitable for open browsing. The present Lithotheque originated in the field in Queensland, Australia in 1970 as a means of keeping systematic visual record of localities visited and examined during field reconnaissance of the "Tasman Geosyncline" by Peter and Sarka Laznicka, working for Australian Selection (Pty) Ltd.

The collection of some 70 cardboard lithotheque plates with up to 20 samples each was assembled on the go and it provided an excellent factual basis for report compilation. It delighted the management as a credible base for specialist follow-up. I have produced similar lithotheque field collections as a component of reports submitted to governments and mining companies (Figure 2) and kept my own collection growing, improving, and supporting professional education while with the University of Manitoba in Canada and afterwards.

A typical "rock library" consist of a number of plates with miniaturized samples ("rock books"), also called lithotheques (abbreviated LT; Fig. 3). A standard lithotheque plate measures 7x11 inches (=17.8x28 cm) and fits into a custom made 12x12x12 in. (=30.5 cm) slotted wooden cube. The cubes, taking 20 plates each in either vertical or horizontal position, can be manipulated separately or assembled into a 1.8m high storage wall (Fig. 4). 3 linear meters of such a wall accommodate 1200 plates, that is up to 24,000 miniaturized samples. The space economy, cleanliness and instant accessibility are excellent and suitable for office or boardroom placement.



Fig. 1a. Millenia old diggings near Hamdah, Arabian Shield, indicate the presence of an unusual listvenite-style gold mineralization. 1b. Century-old Cu-Au gougings in albitites, Waukaloo, South Australia inspired explorers to drill around and discover the 70 Mt @ 0.47% Cu, 0.46 g/t Au buried Kalkaroo deposit.



Fig. 4. Lithotheque “library” when at the University of Manitoba. The great space economy and ease of access are apparent.

The sample layout on each plate follows the typical progression: oxidized ores/rocks -->ore varieties-->alterations-->host rocks-->associated rocks. Localities (deposits) are represented by one or more plates with up to 20 mini-samples each. Each miniature sample (approximately 5 x 4 cm in size) is permanently attached (cemented) to its aluminum "mother board". This prevents loss, misplacement and damage to samples and it preserves the position of each sample in the uniform arrangement scheme. This is ideal for record keeping (for example, samples that have been physically tested for spectra (PIMA), magnetic susceptibility, electrical properties, etc. that can be re-tested at any time), and for permanent record of lithology of deposits now closed and reclaimed. Such record remains preserved indefinitely and can be made accessible to the public. Lithotheque collection could be used for visual and property comparisons, as terminology and description standards, as materials for self-study. Alternative lithotheque sample arrangements may include drill core slabs, oversize samples, unconsolidated materials (Fig. 5). Friable or powder-like samples are kept in transparent plastic "jewel boxes" cemented to the plate like the solid materials. Each lithotheque sample plate is accompanied by explanation sheet ("legend"). The

presently used standardized sheet (Fig. 6) comprises a graph (usually a generalized cross-section of a deposit, orebody, outcrop) of geological (rock) units and lettered ore types, alterations and structural features. The rock units are numbered from the youngest to the oldest. The ore plots, labeled M (=mineralization), could be simple or complex. Coexisting ore varieties like replacements, disseminations and veins are numbered M1, M2, M3, respectively. Ores modified by weathering (e.g. gossans, oxidation zones) are shown as MW (e.g. MW1, MW2). Redeposited (resedimented) ores are MS. "A" stands for hydrothermal alterations (e.g. A1, A2) and when the ore component cannot be visually separated from its altered host the object is labeled MA (MA1, MA2). Bx stands for breccias, F for fault rocks, FA for hydrothermally altered fault rocks. Units shown in the graph are chronologically explained in the upper table in the explanation sheet (Fig. 6), whereas the lower table describes individual samples assembled in the corresponding lithotheque. The actual samples are numbered on grid, or sequentially. Whereas samples incorporate the "permanent truth", the legends require update every few years as terminology an interpretations change.

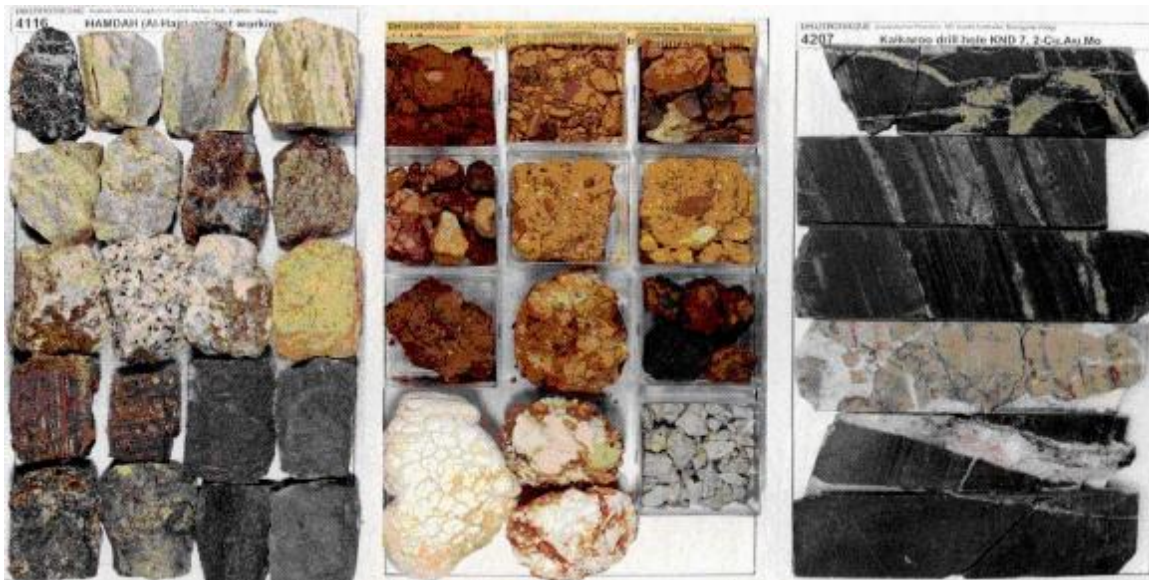

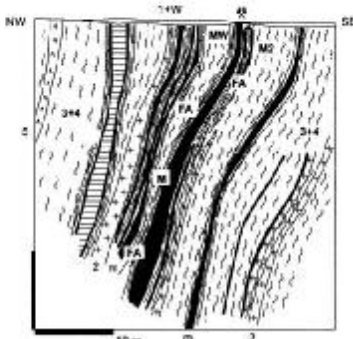


Fig. 5. Alternative forms of samples attached to Lithotheque. Left: standard 20 sample set (Hamdah-Au, KSA); Center: Friable samples kept in transparent plastic boxes, attached to plate. This set has to be kept in horizontal position (Goulds Dam-U, South Australia); Right: Slabs cut from drill core (Kalkaroo Cu, Au, South Australia).

	DMO- LITHOTHEQUE	Geotectonic Province/System, Country, Geological subdivisions
0000	number	Locality (and subdivisions)-commodities

Generalized (simplified) cross-section (or map, stratigraphic column) of Locality, usually modified published graphic. Mineralization (M) is shown in solid black, or as outline. Geological units are numbered (usually from youngest to oldest) and explained below.



Locality 0000, diagrammatic cross-section based on (reference)

LTO 0000 LEGEND 4-2008 (date of last revision)

Unit No	Unit Description
1	Geological age (letter code [read below] or absolute age in Ma/Ga), Unit name and description
2,3,etc.	

LTO 0000 SAMPLE DESCRIPTION (collected and assembled by....., year). **SAMPLE NUMBERING (GRID)** numbering where each cell on sample plate has a number, even if empty. Five rows of four columns: 1,2,3,4; 5,6,7,8; 9,10,11,12; 13,14,15,16; 17,18,19,20). **SEQUENTIAL** numbering where each sample has its number, regardless of position; this is used mostly with oversize samples).

Unit No	Sample Description	Sample No
1 (unit)	Brief description of the Lithotheque sample, numbered in right column	e.g. 1, 2
2,3,etc.		

TYPES OF UNITS

1, 2, 3,....	geological (stratigraphic, lithologic) units hosting mineralization, and locally associated mineralizations (e.g. metallic ores) in general and usually "primary", if more than one, use M1, M2, M3..
M	mineralization (e.g. metallic ores) in general and usually "primary", if more than one, use M1, M2, M3..
MW	weathering-modified ("secondary") ores in oxidation & secondary sulfide zones, gossans, etc.
MS	resedimented ores (in relation to the "primary" M's)
MX	anthropogenic metal-bearing objects, e.p. tailings, dumps
MA	mineralization and (usually hydrothermal) alteration treated jointly
F	"fault rocks" filling deformation structures (faults, shears), e.g. mylonite, phyllonite, fault breccia, gouge
FA	altered (usually hydrothermally) fault rocks
FM	mineralized fault rocks
Bx	breccias (all genetic varieties)
A	(wall rock and regional) alterations (usually hydrothermal); if more than one, A1, A2, A3....
1A, 2A, etc.	altered geological units
W	weathering (supergene modification) of units; e.g. 1W, 2W, 3W . Weathering varieties: W1, W2, W3...
mt	thermal (contact) metamorphism superimposed on units

CODES OF GEOLOGICAL TIME ABBREVIATION

Stratigraphic division	Age Ma (from)	Abbreviation
Phanerozoic	570 (540)	PnZ
Cenozoic	65 (64.4)	CZ
Quaternary	1.6	Q
Tertiary	65 (64.4)	T
Pliocene	5.3 (4.8)	Pl
Miocene	23 (23.7)	Mi
Oligocene	36.5	Oi
Eocene	53 (57.8)	Eo
Paleocene	65 (64.4)	Pe
Mesozoic	250	MZ
Cretaceous	135 (140)	Cr
Jurassic	205	J
Triassic	250	Tr

Stratigraphic division	Age Ma (from)	Abbreviation
Paleozoic	570 (540)	PZ
Permian	290	Pe
Carboniferous	355	Co
Devonian	410	D
Silurian	438	S
Ordovician	510	Or
Cambrian	570 (540)	Cm
Precambrian	-4200	PCm
Proterozoic	2500	Pt
Neoproterozoic	1000	Np
Mesoproterozoic	180	Mp
Paleoproterozoic	2500	Pp
Archean	-4200	Ar

3 (e.g. Pe3) upper (late) (e.g. Upper Permian)
 2 (e.g. Pe2) middle (e.g. Middle Permian)
 1 (e.g. Pe1) lower (early) (e.g. Lower Permian)

Fig. 6. Template for a standard Lithotheque explanation sheet ("legend") with explanations of codes and abbreviations.

Data Metallogenica (Original) DM(O)

Data Metallogenica (DM) is the name of a knowledge (expert) system on mineral deposits of the world the backbone of which is the collection of lithotheque (LT) plates. There are additional components:

- Archive of folders where each LT plate is accompanied by field photos, slides (diapositives) and videos if available, notes, maps and literature reprints;
- Macrotheque, a collection of hand specimens, many with thin and polished sections, organized by lithotectonic associations as in the Total Metallogeny-Geosites compilation of 241 rock forming environments and lithologic associations of the world that show and describe sites of mineral deposits (Laznicka, 2001, 2004; Fig. 7);
- Collection of thin- and polished sections;
- Catalogues, search files, inventory databases in MS-Access and Excel. With this are integrated external databases like GIANTDEP, a database of the world's giant metallic deposits (a simplified GIANTDEP database is a part of the book "Giant Metallic Deposits..."; Laznicka 2006, 2010);
- Archive of results of non-destructive (physical) tests performed on DM materials like PIMA spectra (5000 plus determinations made);

- Depository of duplicate samples and offcuts available for wet (destructive) analysis and for exchange.

DM was held and gradually developed at the University of Manitoba in Canada between 1972 and 1999 as a private family venture and it provided factual basis for the Empirical Metallogeny book series (Laznicka 1985, 1993). Readers were welcome to come over, examine the material and ask questions. In mid-1999 DM relocated to Australia and was installed at the Australian Mineral Foundation (AMF) complex in Glenside, an Adelaide inner suburb, as a part of industry and some governments-sponsored project managed by Amira International. Unfortunately, AMF went out of business at the end of 2001, after 28 years of distinguished service and Amira became the sole DM owner and manager. Upon termination of lease by new landlord in 2005 DM lost its home and the physical collection has been put into storage where it awaits reinstallation into substitute premises, hence it is not accessible at present.

The collection of images of DM materials, especially the high-resolution photographs of all 3500 plates with their explanation sheets, is now transmitted via the active website www.Datametallogenica.com owned by Amira International in Melbourne.

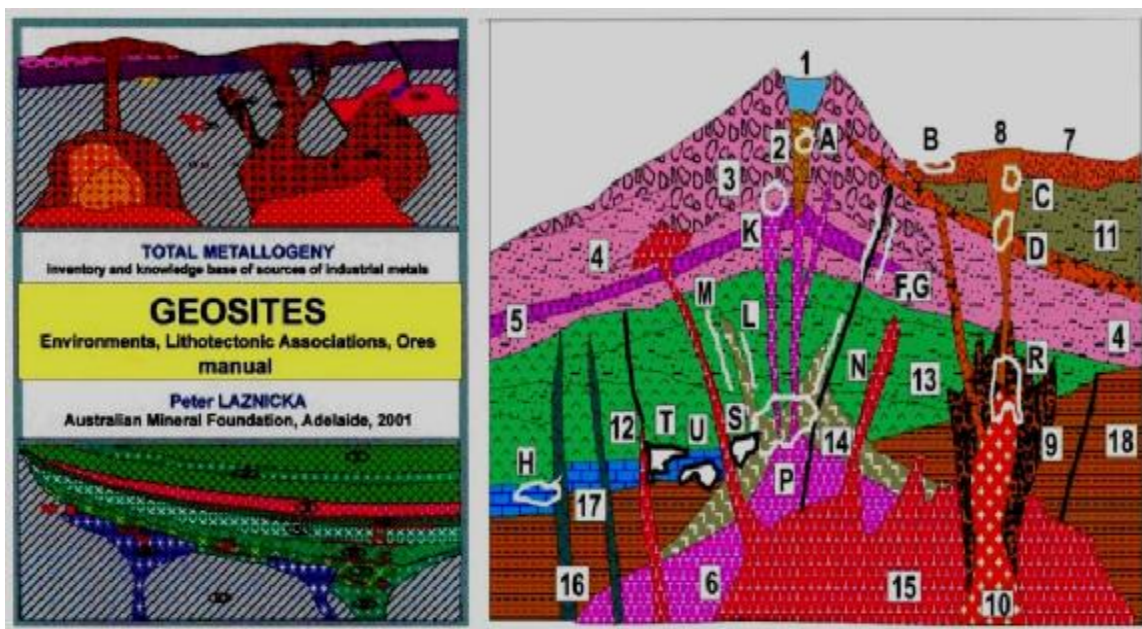


Fig. 7. Total Metallogeny-Geosites book cover (Laznicka 2001 & 2004) and a typical rocks/ores "inventory diagram" (empirical model) of a shallow Andean volcano-plutonic system in a stratovolcano.

During the brief 6 years of Data Metallogenica active existence in Adelaide the physical collection grew to some 3500 lithotheque (LT) plates representing deposits in 75 countries (presently there are some 4000 LT's from ~80 countries) so it covers the world's practical metallogeny in a greater detail than any other product in existence. The DM website has been on line since 2002 and is internationally accessible on subscription. When in Glenside DM supplied practical education and advice to project sponsors and after termination of the founding projects to any interested visitor. "Hands-on" workshops were organized and non-destructive testing of samples was encouraged. Several thousand samples have been subjected to PIMA spectra analysis and some of the results appear in the DM website. The Glenside DM centre was a one-stop place where industry and government professionals could, in a short time, peruse and compare an enormous amount of practical information in the form of geological materials, literature reprints, original field notes and photos, to gain inspiration and formulate new ideas directly applicable to mineral exploration. Of the ~4000 worldwide Lithotheque

plates in Data Metallogenica and its extension DM Original, South Australia has the strongest representation (~210 plates or some 5% of the entire collection) that is due to DM location in Adelaide, the State capital, and support by the State Geological Survey (PIRSA). Two geological province of highest interest to explorers and international investors, the Gawler Craton (home of the Olympic Dam super-giant deposit of Cu, U, Au; Fig. 8) and Curnamona Craton (home of Broken Hill, still the world's largest Pb-Zn-Ag deposit) have most detailed coverage and most of the historic mineral occurrences and mines can be found there. The images (lithotheque plate photos, explanation sheets, field photos, descriptions) can be accessed, without charge, at the South Australian Government SARIG website (www.sarig.pir.sa.gov.au). They are an important component of information package about mineral prospectivity of the State suitable for browsing by local and international explorers and investors. Comparisons can be made between materials from major international deposits and local undeveloped prospects to search for similar features.



Fig. 8. Portion of Lithotheque assembly representing mineral occurrences in the Gawler Craton of South Australia (home of the huge Olympic Dam Cu-U-Au deposit). These images and descriptions can be accessed, for free, at www.sarig.pir.sa.gov.au.

Integration of factual information about global ore distribution

We are now blessed with about 4 million accumulated literature references, of which some 25% have some relevance to ore prediction and future discovery. Not only is it physically impossible to read even a fraction of this deluge, but most of publications are words and data difficult to visualize by geologists who work in the field. If "picture is worth thousand words", than a set of geological samples should be worth a hundred thousand, and the actual field visit a million. Data Metallogenica can provide the geologist with a set of images from the various types of (especially significant) world's mineral deposits that can be identified in the field or drill core and interpreted by analogy. The magic and, for some, mysterious IOCG "family" of deposits (Hitzman et al., 1992) inspired by the 1975 discovery of the Olympic Dam deposit worth more than \$ 600 billion, would become more "real" if a selection of its members could be seen and compared in the form of sample sets (Fig. 9). This could help to eliminate targets assigned to this group of deposits on the basis of reading alone followed by imagination and it could reduce costly drilling of low-prospectivity targets. Even more interesting for explorationists than looking for repetition of a known ore type would be an "educated speculation" about the possible IOCG mutations, variations, relationships with different types of mineral deposits for which the recognized IOCG existence provides some leads and inspiration. When DM was fully deployed and staffed in Glenside, we provided assistance along these lines and there were a number of inspired customers; hands-on workshops were organized to increase explorationists' familiarity with this important type of orebodies also present in Iran (e.g. in the Bafq area) and possibly elsewhere. The Lithotheque/Data Metallogenica (DM/LT) technique of objective, primary data recording and presentation offers, in the age of computers and electronic global networks, a means of instant extension and integration of the printed knowledge offered by journals and books into the realm of actual geological materials (Fig. 10). Most graphics in my recent book "Giant metallic Deposits..." (Laznicka 2006, 2010) correlate with graphic information duplicated in Data Metallogenica in which some 60-70% of the world's "ore giants" are represented. The graphics contain references to the DM sets so a reader who is a DM subscriber can instantly access, browse, peruse, save or print the images available there. Having made a selection of deposits most relevant for a given purpose the reader can eventually visit on foot (after re-installation) the DM physical collection presently in Adelaide, Australia for hands-on comparison and nondestructive testing. Alternatively, a selection of deposits of interest can be confronted with descriptions and graphs of geological settings ("geosites", "plays") in which the selected deposits usually reside, and learn

about the most probable sites of ore occurrence there and their characteristics. The book, database and poster "Total Metallogeny-Geosites" (Laznicka 2001, 2004) comprise 241 "geosites", believed to be a complete empirical representation of the world's rock/ore forming environments and lithologic associations (even those so far lacking major deposits). From there it is a short distance to the realm of conceptual models of ore deposits that have an extensive literature and are popular with explorationists (e.g. Kirkham et al., 1993; Economic Geology 100th Anniversary Volume, 2005; U.S. Geological Survey mineral deposit models by Cox and Singer, eds., 1986). Government websites, increasingly providing free information about their mineral potential in order to attract exploration and investment, would greatly increase their appeal if, in addition to written word and sometimes field photographs, included images of sets of representative geological materials. For this purpose Lithotheque would be an ideal medium, given its uniform format of compact information. Field information recorded and rendered in Lithotheque format has direct application in prospectivity assessments of territories, under way in several jurisdictions and in exploration target generation.

Global Lithotheque/Data Metallogenica network that every country or region could join

Lithotheque/Data Metallogenica format of gathering, storing and disseminating realistic geological knowledge has a forty years history of experimentation and constant improvement. It is a mature, operating system. The Amira's DM and my own DMO together include close to 4000 Lithotheque sets from some 3,500 localities (mostly metallic deposits) in 85 countries and are still growing. Although this coverage is substantially greater than what is offered by any other organized visual knowledge system, it is still very incomplete and the coverage is globally uneven. Whereas Canada, United States, Australia and several European countries have a relatively dense Lithotheque coverage, the coverage of other important mineralized countries and regions is spotty (e.g. Russia, China) or nonexistent (Fig. 11). The latter include such geologically important countries like Iran, a cradle of copper mining and processing. The reason for this local under-representation is limited funding (90% of the LT sets have been collected on location by a single person lacking regular institutional funding) and, even more, by political and logistic problems that restrict access to, and samples export from, some countries. Although the existing DM described here, now based in Australia, is likely to continuously grow and improve as has been the case for the past 40 years, it is unlikely that it will ever approach the magic number of 100,000 world's deposits in need of visual characterization.



Fig. 9. Set of Lithotheque plates used to compare selected deposits in the IOCG class with the Olympic Dam ore giant. The plates are (from left to right, then down): 1. Olympic Dam; 2. Prominent Hill; 3. Manxman; 4. Mount Painter, all in South Australia; 5. Pea Ridge, Missouri; Dolores Creek, Yukon.

MINERAL DEPOSITS & METALLOGENY: KNOWLEDGE INTEGRATION

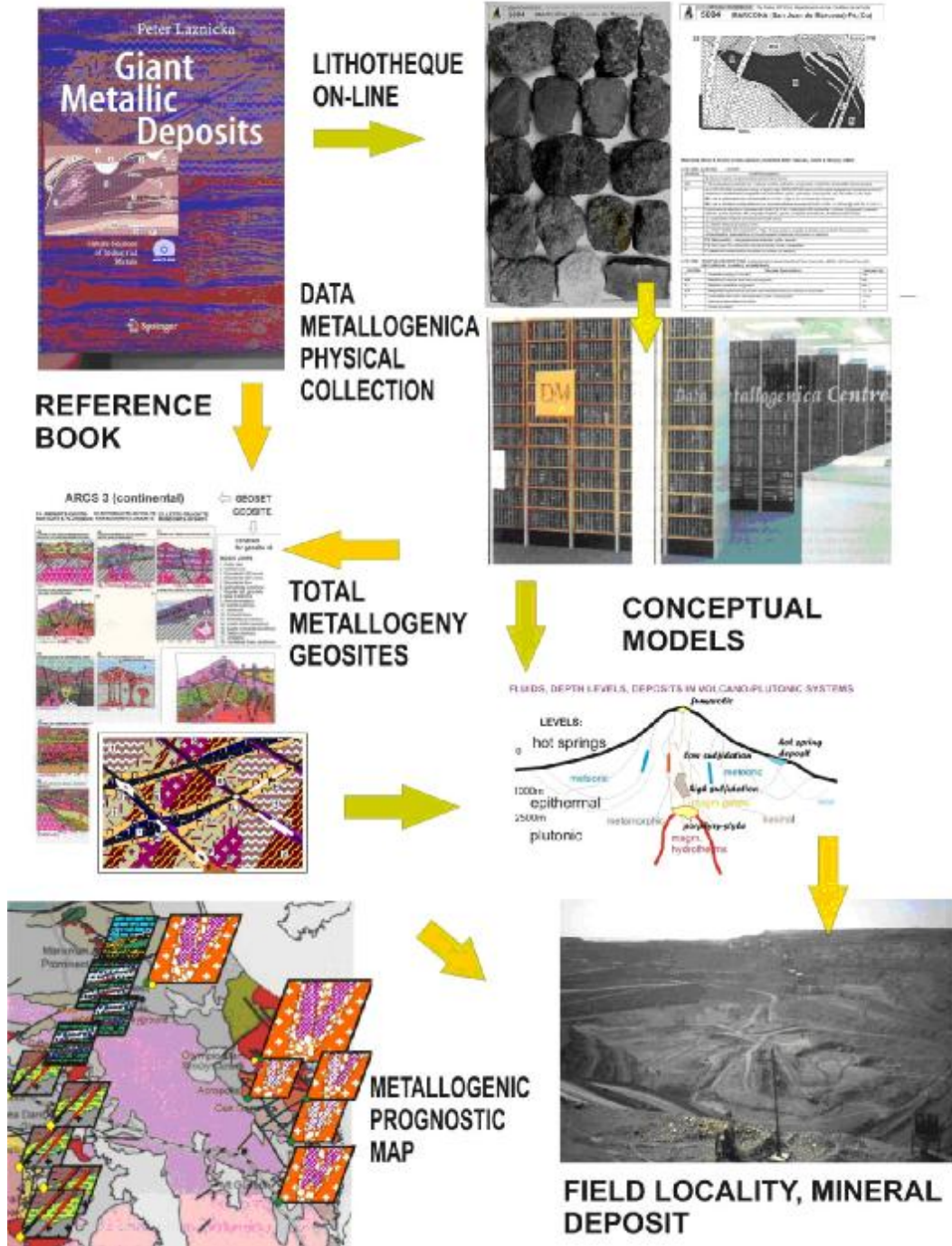


Figure 10. Integration and extension of knowledge about metallogeny and world's metallic deposits that starts with a reference book. The supplementary materials that greatly extend the knowledge gained are partly available on-line (through internet) but eventually would require international travel to Data Metallogenica showroom in Adelaide, Australia (after it reopens) and to various deposits somewhere in the world.

DM is now held by a private organization “on behalf of the world’s industry” that does not have public financial support, hence it has to charge subscription fee to pay for its existence. The fee, although modest for individuals, denies access to colleagues from the less affluent countries (even unsupported individuals from the rich countries), who would most benefit from the knowledge available. The answer is a global network of LT/DM centers locally created, managed and owned, willing to adopt the LT/DM methodology (for free!) in order to maintain uniformity, compatibility and a potential for exchange. Lithotheque is a “poor person’s” means of collecting and keeping geological materials that requires no costly equipment to produce, needs a minimum of space, has a low cost of transportation so it is affordable to organizations, even individuals, with very limited means. Yet it is a great global equalizer. One can often hear lament from colleagues in the less affluent countries that they cannot compete with the more fortunate researchers in affluent economies who enjoy access to the most up to date research equipment and high research funding. This creates differences on the basis of wealth which is beyond our means to change. But every country or territory in the world “has geology” (most with mineral deposits too; Fig. 12) and understanding of this geology is a part of the global picture. Regardless of relative wealth, every territory on Earth contributes to the overall geological knowledge that we all share. Lithotheque and Data Metallogenica are one of the means of making this knowledge more realistic and to use it in support of mineral exploration. What I propose

below is a way of how to disseminate this knowledge more equitably so that anyone with a computer and internet access could share it.

My vision is of a global network of DM/LT centers locally owned and operated by national organizations or individuals. These could be located in country capitals or other locations, based at state geological surveys, universities, professional societies. Each centre would maintain a DM/LT style collection of geological materials focused on their jurisdiction (e.g. Iran, Kerman Province) or sometimes a specialized collection (e.g. of porphyry copper deposits). The collection, if possible staffed by person(s) who combine geological experience, curatorial ability and presentation skills, would ideally be open to local and foreign visitors for study. Local ownership would enhance the information credibility (not “second hand” knowledge) and it would eliminate external interference. Gradually, the local collection would grow into international one by additions of Lithotheque sets from foreign deposits obtained by staff collecting and exchange. This would make visual comparisons based on major world’s mineral deposits as standards possible and the material would also contribute to education of students as well as practicing professionals. Each centre would maintain its website of DM-style images and knowledge, accessible by worldwide audiences. This would enhance the prestige of the centers and their countries and contribute to understanding of ore deposits essential for future mineral discoveries on which depends the economic future of humanity.

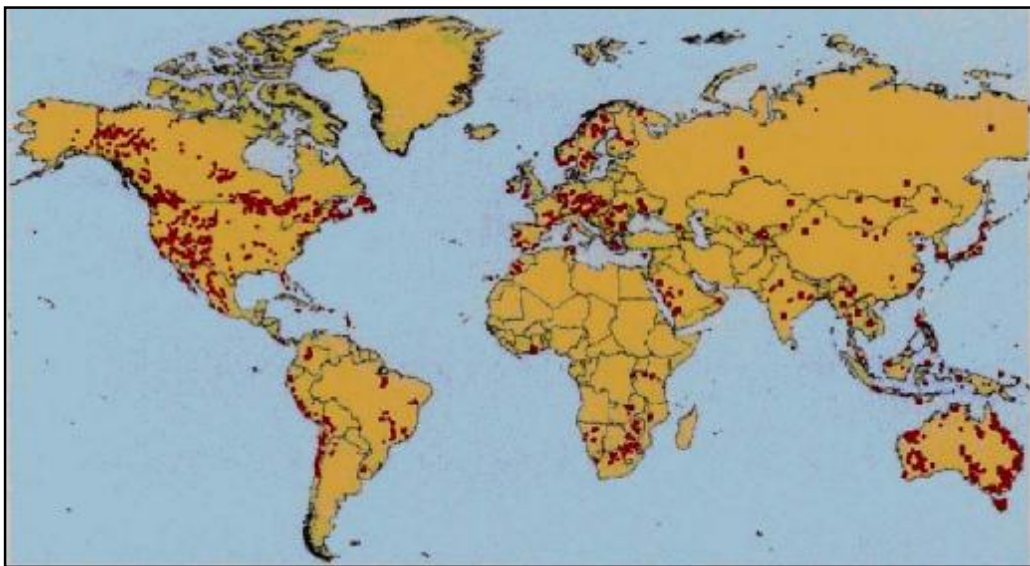


Fig. 11. Locations of Lithotheque sets that are presently included in Data Metallogenica and Data Metallogenica Original (about 4000 entries in ~85 countries). The uneven coverage caused by limited funding and logistico-political obstacles are apparent. If the Lithotheque system were adopted by a number of countries sharing information, many gaps would quickly disappear.



Figure 12. Lithotheque representation of deposits and lithology in the important Alligator Rivers uranium province in northern Australia.

Conclusions

There is an increasing global demand for commodities that include metals while the existing ore deposits rapidly deplete. New discoveries, especially of the giant deposits, are essential for economic progress, but they are increasingly more difficult and costly to find. Ore search, increasingly of buried deposits, is assisted by advanced technology yet the ability of explorers to visually recognize ores and geological indicators of ore presence, for example in drill core, remains essential and indispensable. This requires a means of technical, especially post-university, education of explorationists in the art of visual recognition and evaluation of geological materials ("reading the rocks"). The best expertise is gained by long practical field work and international visits, but this has been available to a small number of specialists only. It is beyond the means of the majority of geological practitioners, especially the junior ones.

The second best means of gaining visual experience is by examination and study of geological materials. Museum and teaching collections are rarely representative of the types of modern ores sought and they, as well as drill core libraries, are mostly local and

lack examples of important global example deposits. They require large space and staffs, difficult under financial constraints. Here, material miniaturization and "computer-age" organization can help and the LITHOTHEQUE-Data Metallogena (Original) (LT-DMO) system, proven and in existence for over 40 years, can help. A proposal is made to geological and mineral (mining) organizations in countries and territories of the world to adopt the LT-DMO format (for free!) and establish national/regional collections of miniaturized geological sample sets, then place the images on their websites. Such websites and collections would become components of a global network where, for example, Iranian geologists would be able to access and compare images from deposits in Canada, Australia, Russia and other countries (if these countries decide to participate), and offer the same in return. This way every country, regardless of her affluence and access to research equipment, could contribute her share of factual geological knowledge to the rest of the world (for minimal cost), and retain control over the information contributed. I would be happy to provide information and advice about the proposed system and offer training.

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