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METALLOGENIC MAPS: USES AND SHORTCOMINGS IN MINERAL EXPLORATION

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A B S T R A C T

Traditional metallogenic maps are published in a variety of styles with little international standardisation. Their purpose is usually to encourage and assist mineral exploration. In that they have serious shortcomings, but they are useful in giving first impressions of geological prospectivity for conventionally classified mineral deposits and some guidance on exploration techniques. Digital information systems with vast and exciting capabilities will eventually make them superfluous.

INTRODUCTION

When the organisers of this meeting invited me to speak about metallogenic maps I did not realise immediately how difficult that was going to be. From the start there was the difficulty that I have never been quite sure what "metallogenesis" actually means, or which branches of geoscience contribute most to an understanding of metal concentrations and their expression as mineral deposits.

Then when I set about reviewing a selection of metallogenic maps from around the world I found that they differed greatly in the types of information on offer, how detailed it was and how it was delivered. With paper maps there is a wide spectrum from elaborate, interpretative maps that go into considerable detail about mineral deposits and their geological setting and are often backed up by information-packed memoirs, to plots of selected mineral deposits on a simple base and with only rudimentary classification.

Information delivery took me into the most difficult area of all - what to say about digital metallogenic maps. This is an immensely complicated subject, full of jargon and gibberish, promise and pitfalls. Here we are not really talking about maps but about multi-themed packages of digital data that can be used to produce maps but can also be used in various other ways.

I hope you will forgive me for having to generalise a great deal, and sometimes for not giving credit where it is due. In preparing this paper I consulted numerous maps within the spectrum I mentioned, but they may not have included the very best in their class or the most recent editions. I shall be referring mainly to paper maps at scales of 1:200,000 and smaller, which raise many of the same issues as their digital equivalents.

The purpose of metallogenic maps

Metallogenic maps are a specialised product and expensive to compile. Sales often do not cover production costs, so why are they made ? For each map that question needs a clear and logical answer.

One reason is national prestige. Metallogenic maps, in the broad sense that covers mineral deposit maps, can be used to announce a nation's mineral endowment. That can be a matter of interest and pride even if mining is no longer encouraged. The recently published metallogenic map of the British Isles probably belongs in that category, at least where the United Kingdom is concerned.

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Another, commoner reason is to promote mineral exploration, by illustrating past discoveries and indicating areas with superior mineral endowment. That seems a perfectly sound motive. Countries that want to promote mineral exploration face intense competition for funds, both because the total world-wide spend on mineral exploration is strictly limited and has lately gone into sharp decline (Table 1), and because contenders for a share of that total are becoming more numerous and more sophisticated. For countries like Spain it is fortunate that many of them undo the good of their promotional efforts by making things very difficult for explorers who take the bait.

Other utilitarian reasons are sometimes given for compiling metallogenic maps. One is to give planners and regulators an idea where exploration is likely to be concentrated in the future and new discoveries could put pressure on existing infrastructure. I am dubious about their value for these purposes as they typically do not distinguish between mineral fields with genuine ore potential and those that made the grade under different economic conditions, and important new discoveries are quite often made in unexpected places (see later). As for environmental reasons, in my view entirely different sorts of maps are needed to indicate risks and hazards that relate directly to metallogenic inheritance, e.g. maps of old mining workings and of toxic element concentrations in overburden and groundwater.

The main scientific reason for this type of map-making is to summarise graphically what is known about metal concentrations in the form of mineral deposits and how they relate to their geological setting. The underlying belief is that mineral deposits mark key events and processes in crustal evolution, and also help to throw light on aspects of geology that cannot be observed directly.

How should metallogenic maps be judged? Different types of geoscientists would answer differently. Mineral explorers are entitled to an opinion since unless their work is based on good, up-to-date geoscience it is little more than a lottery. To introduce my own views on the style of map that serves my profession best I will reflect briefly on the bewildering variety of approach that one finds in paper maps.

Styles of metallogenic map

Paper maps have the following main elements: Linework, symbols and decoration, colour scheme, legend and marginalia. Commonly they are accompanied by a memoir or explanatory booklet containing a bibliography.

On most of these points there is a wide range of practice. Some maps use numerous symbols and try to convey a lot of information that way; others use far fewer and rely on colour or text to top up information provided by symbols. Colour schemes may be simple or elaborate, clear or confusing, eye-pleasing or startling. As Table 2 indicates, there are few standards in the use of colour.

Table 1 : Global exploration spend

Year	1994	1995	1996	1997	1998
US$ Millions	**2,130**	**2,690**	**3,620**	**4,034**	**2,830**
Year-on-year	(+12%)	(+26%)	(+31%)	(+15%)	(-30%)

Note:
Provisional figures show a further decline of 23% in 1999
World economic growth over the period was 1.7-3.3%p.a.

Source: The Mining Journal, 22 October 1999

Table 2: Colour coding of elements

Map:	Europe	Arab World	Spain
	1:2.5M	1:5M	1:1M
COPPER	Light green	Red	Mid green
NICKEL	Purple	Green	Green/lilac
ANTIMONY	Deep pink	Pink	Deep red
TIN	Red	Brown	Purple

Some maps pack a lot of information into sub-maps and other marginalia, or into memoirs that may themselves contain numerous maps and tables. Others have their say in the main map and largely leave it at that. I could give examples on all these points but I think they would only be of interest to specialist map-makers.

The divide between different styles of map-making is most clearly seen in different styles of legend. Map-making to display mineral endowment in its geological context goes back a long way, but the maps we use today and those that set the fashions they follow are essentially products of geological thinking in the second half of the 20th century.

Three formalised models for the legends of metallogenic maps can be distinguished - the Russian, European and North American models. The Russian model was originally developed for the 16-sheet metallogenic map of the USSR at a scale of 1:2.5 million that was completed in 1971. In that and its progeny the design was strongly influenced by the Bilibin school of metallogeny, which put special emphasis on relations between endogenous mineralisation and magmatism accompanying various stages of what used to be known as geosynclinal cycles. Plate tectonic and lineament concepts were accommodated later, resulting in maps that embody a wealth of information but are difficult to read and require constant reference back to the legend.

The European model, devised mainly by the BRGM during the 1960s and 1970s, is conceptually similar in emphasising the relationship of mineralisation to tectonic stages. However, the symbology is simpler and more meaningful, deposits and districts are located more precisely on the map and cross-referenced by number to listed information, and altogether the result tends to be much more user-friendly.

The North American model, developed by the USGS in the 1970s, tries not to align itself with any particular school of metallogeny. Neutrality and objectivity are its hallmarks, and some people think that the results are elaborate mineral deposit maps rather that full-blooded metallogenic maps. The symbols for mineral deposits are more complicated than in the European model and closer to those in the Russian model, making the maps rather difficult to use. The symbology was probably designed with computerisation in mind, though as far as I know it is not yet possible to generate symbols directly from databases.

Philosophically, my preference is for the North American model. I am agnostic about metallogeny, and judge what other people think by its ability to deliver bigger and better mineral discoveries. In those terms, I see no reason to prefer, say, Russian or French styles of thought over those that produced the North American model.

As geoscientists, I believe we are still very much in the dark about why large orebodies of some of the most important types are clustered in particular geological regions (metallogenic provinces) and appear to shun others where the geology is very similar; also why some types of orebody seem to have only one or two really large representatives, in geological settings that are replicated in kind all over the world. Whether we are talking about orebodies in clusters or orebodies as geological singularities it is often far from clear why they are located precisely where they are.

Porphyry copper and copper-gold deposits are a good example of the danger of being too selective in compiling information for metallogenic maps. Always one has to be careful not to be misled by geographic unevenness in the quantity and quality of past exploration, which in turn reflects the uneven spread of economic rewards for mining, but in this case the true world-wide distribution of deposits is quite well known, their tendency to cluster is well established, and their common association with convergent plate margins is clear.

Numerous models have been put forward to account for the characteristics of porphyry copper systems. Collectively they attach special metallogenic significance to a wide range of geological phenomena, some mappable but others essentially matters of scientific deduction and outside the scope of conventional metallogenic maps. In reality, the prospectivity of a region for well-mineralised porphyry systems may depend most fundamentally on such things as the geometry, rate of descent and sediment load of a subducted slab of oceanic crust, and it is rare for a metallogenic map to display things like that. The same is true for other major influences on the ore potential of porphyry-type mineralisation, like emplacement level and erosion history.

Uses and limitations in mineral exploration

What do mineral explorers want from metallogenic maps is part of a bigger question: what do they want to know about about an area - whether a country, a district or something smaller - before they commit to exploring it? “Commit” is the right word as it may take years to make a discovery. It is likely to be an expensive commitment - establishing a presence in a new area may well cost over $100,000 and serious exploration programmes typically cost over a million dollars a year.

In a nutshell explorers want to know:

- the area’s geological prospectivity for what they want to find
- its explorability in a practical sense - is getting around difficult or easy, is it safe or dangerous, and are discoveries feasible with available techniques?
- the availability of mineral rights - exploration rights to start with - and the terms and conditions for holding them
- any serious barriers to capitalising on a discovery - infrastructual, environmental, social, legal, political or whatever.

I should add that I am referring to explorers, whether big companies or juniors, who really do want to discover and mine orebodies, not the sort who mainly want to make themselves rich by playing the market in shares or prospects. That sort has a role in the great business of securing metals and mineral supplies for the future, though some of them are rogues and scallywags. Conventional metallogenic maps address the first point about geological prospectivity, and provide some information about what I called explorability. They are typically silent about mineral rights and about environmental and human barriers to mine-making. Digital systems, on the other hand, can stack layers of information about those and many other subjects.

At the most basic level, conventional maps help explorers by drawing attention to areas where there are precedents for the sort of discovery they want to make, and by providing information about known mineralisation that may be crucial to designing an effective exploration programme. To put it another way, they highlight good hunting territory, indicate what types and sizes of prey may be there, and suggest how hunters should equip themselves.

To move to a higher level of use one has to rely on interpretations and conjectures. Metallogenic maps tend to have a lot of interpretation built into them, particularly in respect of:

- the genetic affinities of known mineralisation
- identification of metallotects (metal-rich geological units and packages)
- the outlines of metallogenic provinces

Because of the limitations of scale, paper maps usually cannot explain themselves properly on these points and need to be backed by a memoir or something of that sort. The information they provide may be perfectly respectable, but it is no more than a snapshot of what the map compilers and their sources thought at a particular time. Perhaps they were wrong, and perhaps the correct interpretation has yet to be made.

From the standpoint of my profession, conventional metallogenic maps have other important shortcomings:

1. They are selective about the mineral deposits they show

This is unavoidable with small-scale maps and often true also of relatively large-scale maps. It is important because geological prospectivity is not restricted to areas teeming with known mineralisation. Sometimes a scattering of minor occurrences can signal important but neglected exploration potential. They can easily be left out of the reckoning if, say, the map compilers screen out occurrences with little or no historic production.

2. They give little impression of three-dimensional prospectivity

Metallogenic maps are essentially two-dimensional - they show outcrop geology and usually do not give enough information to model subsurface geology. For mineral explorers, on the other hand, the main hunting ground is in that third dimension, which is why they rely so much on geophysics and drilling. Some types of target, high-grade gold mineralisation for instance, can be attractive at depths of hundreds and even thousands of meters. A lot of opportunities can open up and close off in the unmapped space between outcrop and the depth at which exploration becomes economically pointless.

3. They are conservative in outlining metallogenic provinces

Partly that is an extension of the last point. More generally I mean that they tend to rely on mainstream opinion in showing the outlines of metallogenic provinces, and to be cautious about extrapolating them. That draws attention to a key difference between mineral explorers and the geoscience institutions that normally publish metallogenic maps. Success in mineral exploration very often depends on thinking unconventionally, beyond the limits of established truth and sometimes at a tangent to it. Rio Tinto's recent discovery of a high-grade copper orebody near Seville, outside the conventional limits of the metallogenic provice to which it belongs, is a good example.

4. They tend to be constrained by artificial boundaries

Mineral explorers like to see the whole picture, the whole of the Ossa-Morena Zone for instance. Sometimes they learn more by seeing it as it was over some period in the geological past, in its relationshipship to geological units that may since have been scattered by plate tectonics. None of this is made easy by maps that stop at political boundaries and neglect to deal with geology in the fourth dimension - time. The general lack of internationally-respected conventions for the design of metallogenic maps adds to the problem.

A fundamental shortcoming is the discrepancy between how metallogenesis is defined and how it is represented in metallogenic maps. The definition in the latest edition of the Oxford Dictionary of Earth Sciences is: "study of the origin of <u>ore</u> deposits and the interdependence in space and time between this <u>process</u> and other geological processes".

"Ore", strictly speaking, is mineralisation with intrinsic profit potential. It is not within the aims or the ability of metallogenic maps to distinguish between that class of mineralisation and other sorts. The best they can do is to show which deposits have been or are productive and at what scale, perhaps giving some details in a memoir or database but never, in my experience, mentioning profitability.

As for processes, they usually make no attempt to answer some of the biggest questions about mineralisation - where its constituents came from, what pathways they followed, and what controlled their eventual deposition. Instead they use relationships between mineralisation and its geological setting to invoke genetic models from a fairly standard menu, leaving it to others to check their deductions and work out processes and controls at the appropriate scale.

Yet despite their limitations metallogenic maps are a useful starting point for the work of mineral explorers - one of a number of information sources explorers use in deciding where funds and all the effort and expertise that exploration calls for should be invested. They can be very influential in giving a general impression of geological prospectivity, and some idea of practical explorability, and are sometimes decisive in attracting exploration to particular areas. By presenting the right types of information to creative minds they can even draw attention to specific exploration targets. That is rare, and always it is up to explorers to check what they say in the field and then, build it into a successful exploration programme.

Characteristics of a useful metallogenic map

The usefulness of a metallogenic map depends basically on: (a) the quantity and quality of information available to its compilers, and (b) their skill in selecting, summarising and displaying the information. It depends also on such things as the effectiveness of the responsible agency in making the map known and accessible to potential users, but I must leave issues of that sort aside.

Scale is a key factor as it largely decides how much information can be presented graphically and how easy it is to read. Also it decides the size of the map or of component map sheets. Map-reading should not be a wrestling match with paper, not should it torture the eye-sight of people with normal vision. It is one of the advantages of digital maps, that their scale can be varied to suit the user, though normally they have been designed for display at a particular scale, with inflexibilities that cannot reduced by changing scale.

In my experience, maps at a scale larger than 1: 1 million rarely find a good compromise between legibility and informativeness. In well mineralised areas they tend to be overcrowded, and too diagrammatic in outlining metallogenic features. Accordingly they tend to stay in map cabinets, or to end up as wall hangings that are rarely referred to except for arm-waving. Their main value is quite often in the literature that goes with them, used semi-independently of the map itself. On the trade-off between scale and informativeness, I think ITGE has found a good compromise by issuing both an overview map at a scale of 1:1 million, showing selected mineral deposits on a simple geological base, and reasonably detailed metallogenic maps for the whole country at a scale of 1:200,000. The former does not pretend to be a metallogenic map, but read together with the accompanying memoir gives a good first impression of the mineral endowment of Spain as it was known in the mid-1980s.

Here we are touching on another criterion of usefulness - that maps and accompanying information should be up to date or at least easily updateable. Pressure on resources makes it impossible for organisations like ITGE to publish updated maps more than once in a long while, and in the meantime much can change in the knowledge and understanding of an area's geology and mineral resources.

Sharing new knowledge with the user community is part of the brief of Geological Surveys (and something I know ITGE does in many ways). But it can raise problems for them because of the rules they work under - about impartiality and quality assurance, for instance - and always there is the question of how information should best be managed and transferred. Digital systems can have big advantages in this connection.

A third criterion is that maps should be unbiased. Several types of bias can be distinguished, some deliberate and others not. One example of deliberate bias is classifying mineral deposits in line with pre-conceived ideas about their relationship to, say, particular magmatic or orogenic events. I am making no accusations about this, but we all know that geologists sometimes take liberties with science in trying to get their own views across.

Another example is providing one type of information rather than another because it is felt to be more relevant to the purpose of the map. Showing isotopic ages of mineralisation rather than magnetic anomalies could be an illustration of that. Not showing magnetic anomalies, on the other hand, is just as likely to be an example of non-deliberate bias, imposed by non-availability of regional information and ultimately by the constraints of scale.

In reality, metallogenic map-makers have a near-impossible task in trying to make the same product appeal equally to mineral explorers, academics and other user groups. Perhaps in that they are following outdated traditions.

Has metallogenic map-making fallen behind the times ?

Time and science have added enormously to our knowledge of mineralisation and mineral deposits since today's map-making traditions were pioneered. Mineral exploration has moved on too, finding large new areas of interest and concern. Starting with those that are used to put mineral deposits in context, I will now comment on the usefulness to explorers of various classes of information that usually appear, or usually do not appear, on paper maps.

Geography and infrastructure

Metallogenic maps generally show cities, large towns and the main road and rail routes. That is helpful, and may give a first impression of whether some metallogenic feature is disadvantaged by being remote from arterial transport or, perhaps, by being close to a built up area.

Topographic information is usually skimpy, which is only to be expected but can give false impressions of explorability. It does help to know from the start that that interesting cluster of (say) gold occurrences in Tertiary volcanics is 5,000 meters high and only approachable by mountaineers.

A type of information that is rarely given is the whereabouts national parks, nature reserves and suchlike. Again, one would not expect it to be, and for accuracy and detail all these types of information are most appropriately brought in from other sources. I should, however, make the point that some of them may be more critical to ground selection than many types of geoscientific information.

Geology (stratigraphy, lithology, petrology)

The main choice here is between broadness and narrowness in subdividing and classifying. It is a tussle between what are known in English as "lumpers" and "splitters". Between simplifiers and complicaters some would say, but that is not really fair. For an area as geologically diverse as Europe it is not suprising that the legend of the 1:2.5 million metallogenic map recognises ten classes each of sedimentary, plutonic and volcanic rock, and five classes of metamorphic rock. For comparison, the legend of the 1:200,000 Ponferrada sheet mentions 14 rock types in all, and the map gives only a general idea of the distribution of some of them.

I need hardly say that rock types and ages are of great interest to mineral explorers. Many exploration programmes revolve around targeting particular stratigraphic intervals and rock associations because, locally or regionally, empirically or theoretically, they offer much greater chances of discovery than others. So much so obvious, but what does it say about metallogenic maps?

I think it says that paper maps should be as accurate as possible on these parameters, as detailed as their scale will allow, and used mainly to gain general impressions. Other types of source material are generally needed to refine those impressions and turn them to practical use. There is a strong case for compiling information under this heading in digital format so that it can be integrated in a Geographic Information System (GIS).

Geotectonics and structure

Geotectonics - my shorthand for crustal evolution in its plate tectonic context - is at the heart of metallogeny. Full-blooded metallogenic maps usually make a feature of distinguishing between different geotectonic terranes and trying to explain their development and relationships. I will not attempt to summarise how they do that, through an unregulated mix of symbols, decorations, colour schemes and text, on the map and in its legend, in marginalia and in memoirs.

This type of information certainly has the ability to bring out crucial relationships between mineral deposits and their geological setting, for instance a relationship between porphyry copper deposits and particular stages of magmatism in particular terranes. However, there is a tendency to make maps confusing by laying it on too thick. I distrust the idea that the greater the detail the more the likelihood of finding useful relationships. The truth is that relating mineralisation firmly to specific geotectonic features is still very difficult in some of today's most active exploration territories, for instance the goldfields of central Nevada.

Metallogenic maps usually show major faults, sometimes with information about their attitude and sense of movement. Commonly they show fold axes and indicate the geometry of folds. Geolineaments - "unusual alignments" in the words of the European 1:2.5 million map - are quite commonly shown too. All can provide valuable information to mineral explorers, sometimes to the extent of drawing attention to specific targets.

Geochemistry and geophysics

Metallogenic maps are interpretive by nature so they typically do not show much raw information in these categories. On the geochemical side they generally restrict themselves to information about specific mineral occurrences - elements they concentrate and their rough proportions is usually as far as that goes - and to indicating enrichment features that I refer to below as metallotects and metallogenic provinces. With geophysics some maps show major gravity and magnetic anomalies and a few show seismic epicentres and their approximate depths.

Their reticence is understandable given the density of other types of information, and in practice mineral explorers look elsewhere for geochemical and geophysical information, which nowadays they prefer to get digitally rather than on paper. Nevertheless, I should say that these types of information may well say much more about prospectivity than some types that are standard on conventional metallogenic maps.

Metallotects and metallogenic provinces/districts

Metallogenic maps usually try to sum up deduced relationships between mineralisation and its geological setting by drawing attention to situations and areas with a superior mineral inheritance. By situations I mean geological packages and assemblages known as metallotects. By areas I mean anything from a 1,000km long province to 50km long district or zone.

To repeat an earlier point, the big question is whether the resulting maps really help explorers, by alerting them to ore potential that is not apparent from, say, non-interpretive plots of mineral deposits on a simple geological base. One aspect of that is whether they go beyond the obvious, by showing the true natural limits of metallogenic districts and provinces rather than limits set by convention and exploration experience.

There is no general answer to the question and I will not labour it.

Mineral deposit attributes

Here is a list of most of the attributes I found in a world-wide sample of metallogenic maps:

- Name/number Commodity/commodity group or association
- Metal proportions
- Chemical class (sulphide, oxide,etc.)
- Ore mineralogy
- Gangue mineralogy
- Morphology
- Orientation
- Deposit size/scale of production
- Genetic type/style of mineralisation
- Isotopic age of mineralisation
- Nature of hostrocks
- Age of hostrocks
- Style of alteration

Providing information under even half of those headings symbolically is obviously difficult. Maps that rely on symbols and colour schemes to do so tend to be hard to decypher and to blur important distinctions. The first item on the list is not so much an attribute as a reminder that numbering systems make it easier to provide a lot of supplementary information in memoirs and marginalia.

Mineral explorers should be receptive to any and all information about known mineralisation in areas that interest them, so there is nothing on the list that I would describe as superfluous. The problem is that under some of the headings the information is likely to be subjective and may be outright misleading.

A relatively innocuous example is deposit size, which conventionally means the sum of past production and remaining reserves and resources where known. Of course there are better ways of finding out about deposit size than consulting metallogenic maps, but at least one would expect the maps to be objective and clear on this point. In fact there is quite a wide range of practice in using words like "small", "medium" and "large" (Table 3). Sometimes one has to read the small print carefully to work out how size thresholds have been set. Few maps explicitly take a world view in setting them, with the result that "large" may simply mean "large by the standards of the map area". Occasionally objectivity seems to have been sacrificed to a determination to show that the area concerned does contain large deposits of some attractive metal like gold.

More likely to mislead is subjectivity in classifying deposits by shape, style and genetic affinity. On these attributes the best prescription is to see for yourself and keep an open mind, unless thorough exploration and good science have provided clear-cut information.

Map compilers generally do not have the luxury of seeing everything for themselves and keeping open minds, so they may unwittingly pass on information that has been distorted by history or prejudice. Old information can be very misleading about shapes and styles, and who knows how many unvisited or "disappeared" deposits have been misclassified for that reason. Recent information can be suspect too, when it comes from the type of observer who unfailingly describes massive sulphide deposits as stratiform and syngenetic, jumps to similar conclusions about foliation-parallel lodes in metamorphic rocks, and makes indiscriminate use of words like "porphyry".

Digital metallogenic maps

This is an immensely complicated subject and I am no expert. On those grounds and because few metallogenic maps have yet been released in dig-

Table 3: Size thresholds for large gold deposits in various maps

South and East Asia	500 tonnes
France	200 tonnes
Spain	100 tonnes
Western Australia	50 tonnes
Other measures:	
Tasmania	Contained value more than A$ 1 billion in 1988 terms
Europe	More than about 2 million ounces (62 tonnes)
Britain	Total resource more than 10% of world production in 1992 i.e. more than about 225 tonnes

ital format I was tempted to avoid it. But the future is digital, and I should like to finish by looking in that direction.

The Red Guard of the Information Revolution would have you believe that digital systems are already superior in every way - infinitely more powerful and flexible than traditional systems, more cost-effective, easy to master and maintain, and a whole lot else. I share their vision, but not their willingness to gloss over the limitations, demands and cost of existing digital systems. In reality, going entirely digital at present is as likely to cause headaches and budget overruns as it is to deliver better, more useful products.

In the digital future that is bearing down on all of us, a metallogenic map will be the creation of whoever wants to use it or sell it. Numerous versions may be iterated on screen before one is printed on paper. It will be one type of output from a large selection of constantly updated relational databases that provide layers of uniformly georeferenced data for integration in a 3D digital model that may extend deeper than the lithosphere.

Forward-looking companies and geoscience institutions have been working along these lines for years. Geological Surveys are making more and more of their information available in digital format. Some are pinning their future on digital products - not conventional maps and memoirs but "customised" electronic assemblages of whatever data and derivatives can be sold at a profit. The internet already is swarming with lead-ins to geoscience information including metallogenic maps. Table 4 shows the results of a recent Web search.

Visiting a small sample of the Web sites showed a high proportion that simply contained listings of paper maps available for sale or reference. Entries flagged as having a Spanish connection often had little or nothing to do with Spain as far as I could see.

To get the flavour of digital products in the field of metallogenic mapping I refer you to two that have recently come onto the market. One, available in a Spanish version, calls itself a Geological Information System for the Andes and was developed by the BRGM (Table 5). It is being marketed by the Mining Journal, London. The other, from the Council for Geoscience in Pretoria, is a digital metallogenic map of subequatorial Africa at a scale of 1:5 million. They both come on CD-ROMS costing about $1,500, run on PCs with normal specifications, and embody industry-standard data handling software.

The only way to get a proper appreciation of products like these - their weaknesses as well as their strengths - it to have a hands-on demonstration. Describing them in words is difficult and misses the point: they are intensely visual and (unlike paper maps) capable of displaying a great variety of images and information.

Digital information systems have vast and exciting capabilities. They can store and organise enormous amounts of information and are intrin-

Table 4 : Geoscience map entries reported by www.google.com

	WWW entries	"Relevant to Spain"
Geophysical maps	11,246	851
Geochemical maps	3,346	234
Mineral deposit maps	2,138	133
Metallogenic maps	283	26

Table 5: Data layers for Andes GIS

Raster (images)
Topographic relief and discontinuities
Gravimetry (Bouguer and residual anomalies and gradients)
Gravimetric-structural pattern
Gravity model of the Nazca plate
SPOT 4 vegetation
Vector (shapes)
Geography and infrastructure (powerlines, railways,etc.)
Geological maps at scales from 1:50,000 to 1:1 million
Holocene volcanism
Faults
Rock geochemistry
Heat flow
Seismicity
Mineral deposit maps (backed by extensive databases)
Coal mines and coalfields

sically capable of modelling exploration potential in four dimensions. Eventually they will make conventional metallogenic maps superfluous, though I think that time is still some way off. Going all-digital is expensive and difficult, especially for geological surveys with large holdings of data from before the computer age.

ITGE and its counterparts have an important decision to make - whether to set the pace as a service to the user community (which may be hard to define and not entirely supportive) or leave the running to commercially and academically inspired special interest groups.

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