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THE APPLICATION OF PUBLIC GEOLOGICAL DATA IN DESCRIPTION OF RAW MATERIALS FOR HYDROMETALLURGICAL PROCESSES

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This paper describes a method for getting the geological, mineralogical and geochemical information from an ore deposit or prospect area and its ore body. The information is needed to select a suitable hydrometallurgical processing method. Usually the first step is to go through expensive and time-consuming field explorations and a number of rock sample analyzing processes. By using existing public deposit information for that purpose, it could be possible to save time and money. A literature study was done about possible sources of public geological information related to world's ore mineral deposits. The study included also a couple of experimental cases where the information-searching procedure was tested in practice. The test minerals were gold and lateritic nickel. The results of the tests show that there are different kinds of mineral deposit databases and that in most cases it is possible to find the needed information. It was found that there are benefits in this type of information gathering system, but there are also some downsides such as the reliability of information.

keywords: mineral, ore deposit, database, hydrometallurgy

1. INTRODUCTION

When choosing a suitable hydrometallurgical processing method for an ore body, certain important geological features should be known first. These include deposits geology and ore body mineralogy and geochemistry. The methods for getting all the geological information needed are field and laboratory explorations, which are usually expensive and time consuming. Field tests include geological surveying, geophysical

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explorations, drill core sampling and the core sample analysing with different methods (Papunen et al., 1986). The drill core sampling is the most expensive exploration method, but it is also the most important method (Grönholm et al., 2006). The chemical analysis together with the mineral composition analysis is the most important information when choosing the hydrometallurgical processing method. Both of these analyses are performed from the core samples. Some of the core sample material is pulverised for the chemical analysis and some of the core sample is made into thin sections for mineralogical analysis and polished sections for resources approximation (Papunen et al., 1986). All these studies have to be done before there is any confirmation of the processing ability of the ore body in question.

The above-mentioned situation usually creates problems in mining companies' point of view, because they have to invest on research that does not necessarily result in financial benefit. There is always a possibility that the ore mineral or the valuable metal in the deposit is locked with the host rock in the way that is impossible to liberate it economically with the methods available. However, in some cases there could be another way to get the geological information needed to make decisions for processing methods. The more accurate and more expensive geological explorations and surveys could then be done after suitable hydrometallurgical process alternatives have been selected based on geological information.

This article describes a data-mining study related to geological information. The main idea of the research was to find out public information sources, such as deposit or mineral databases, where to look for the geological information needed. Another aim was to explore the promising information sources and evaluate their usability as help in choosing a hydrometallurgical process. This part is focussed on geological information using the existing documentation in the databases. The research included also experimental cases where the information-searching procedure was tested in practice. Possible problems that occurred during the testing and the reliability and the quality factors that should be considered when using the information found were discussed.

There are different kinds of mineral and deposit databases made about old ore deposits and prospects. It became clear that in most cases it is possible to get the information needed, not necessarily in directly from the databases, but through them by using the database as search portal. There main benefit is economical, as the information gathered through the databases does not require new fieldwork. There are few risks such as the age and reliability of the information, but the risks can be properly taken into account.

2. PUBLIC SOURCES FOR GEOLOGICAL INFORMATION

There are different types of possible sources of deposit or prospect information such as scientific articles written about deposit areas, official exploration and survey reports and deposit or mineral databases. The last one contains usually all kinds of references to the other two information types in its reference list. This makes the databases very good starting places for searching the information, as they are more like search engines.

Deposit or mineral databases are usually public and freely accessible in the internet, containing variable amount geological, geographical and other general information about the deposits and prospects that are in the database. Almost every country, continent or groups of countries have their own databases, which are usually created and administrated by geological surveys or similar organizations. In some cases, mining companies are also connected to the maintenance of the databases. The main goal of the databases is to make geological information public and easier to find for everybody. Table 1 contains the most usable freely accessible databases discussed in this work and a short description of the type of the database. The internet addresses of the databases are listed in the reference list of this article.

There were also databases worth mentioning that are not listed in Table 1, because they were either liable to charge or created with language other than English. They are South African Mineral Deposits Database (Samindaba), African-European Georesources Observation System (AEGOS), which will be completed in 2011 and Info Terre made by BRGM, which is France's leading public institution involved in the Earth Science field for the sustainable management of natural resources, surface and subsurface risks (BRGM 2008). It is also very positive that the databases are continuously improved and new databases will probably be created.

3. GENERAL USABILITY OF DATABASES

Almost all of the databases have many other functions than just being a search engine for deposit information. However, in this case that was the main interest, so it was convenient to make the evaluations based on how suitable and easy to use they are when searching the original exploration reports written from the deposits. This means, how easy it was to find the reference lists from the deposits and to locate the listed material in readable form. Table 2 shows the results of the evaluation. As the results indicate, most of the databases are very suitable for this kind of information retrieval.

The optimal database for the information retrieval described in this paper fulfils following characteristics: The database must give out sufficient amount general information about a deposit such as commodities, host rocks, deposit type, reserves, resources, geographical coordinates etc. Most important, the reference list should be presented so that it is easy to find and comprehend, because that is the source material to get the information needed.

Table 1. Databases found in the original research

Database	Description
FODD - Fennoscandian ore database	Database found from the web site of the Geological survey of Finland (GTK). It contains all the deposits in the Fennoscandian area. It has been created together with the Geological Surveys of Finland, Sweden, Norway and Russia.
MRDS - Mineral Resources On-Line Spatial Data	Database created and administrated by The United States Geological Survey (USGS). It contains deposit information all around the world, also industrial mineral deposits.
ACP – African, Caribbean and Pacific group of states mining data bank	Database contains information about all deposits from African, Caribbean and Pacific states.
GECO - Geology for an ECOnomic sustainable development of Congo	A small mineral database that is limited to the copper – cobalt and uranium minerals from the Katanga copper belt and extended by some other species that can be of special importance for identifying specific stratigraphical or structural entities.
GEMS- Geographic Exploration and Mining Services	Database created and administrated by the Geological Survey of Ireland. It contains all the possible information available in public about deposits in Ireland.
BGS - British Geological Survey	From the web site of the British Geological Survey can be found number of different databases (GeoIndex). They cover all of the geology of the British Islands.
TIS -Titles Information System	Database made by The Northern Territory Geological Survey of Australia (NTGS). It is created for public reporting of The Northern Territory's ore deposits. There is also list of other databases in the web site.
DODEX – Geoscience Greenland	Database of the deposits in Greenland. The database is only a search engine for the exploration rapports.
Geology of India - Map Service	A database made by Geological Survey of India. It contains information about ore deposits of India and other geological information.
GERM - The Geological Resource Map of New Zealand	A mineral database made by GNS science, a New Zealand government research organization. The database contains all the ore deposits in New Zealand.
(GeoVIEW.WA) Interactive Geological Map Australia	A database made by the Geological Survey of Western Australia (GSWA) that contains all of the deposits in Western territory of Australia.
SARIG - South Australian Resources Information Geoserver	A mineral database made by PIRSA (Primary Industries and Resources SA), which is The Minerals and Energy Division in South Australian government.

Table 2. Databases evaluation for suitability for information retrieval.
Scale I = very poor, II = poor, III = moderate, IV = good, V = very good

Database	User interface	Suitability for the information retrieval
FODD - Fennoscandian Ore Database	Map	V
MRDS - Mineral Resources On-Line Spatial Data	Map	IV
ACP - Mining data bank	Map	III
GECO - Geology for an ECOnomic sustainable development of Congo	Map and Text editor	II
GEMS- Geographic Exploration and Mining Services	Map	IV
British Geological Survey	Map	II
Tis -Titles Information System	Map	Needs a registration in order to function properly
DODEX - Geoscience Greenland	Text editor for retrieval of reports	V
Geology of India - Map Service	Map	IV
Interactive Geological Map (GeoVIEW.WA) Australia	Map	IV
SARIG – South Australian Resources Information Geoserver	Text editor	V
GERM - The Geological Resource Map of New Zealand	Map	II

4. GEOLOGICAL INFORMATION AND SEARCHING PROCEDURE

4.1. GEOLOGICAL INFORMATION AND ITS USE

The information that hydrometallurgist needs when making decision about processing regards geology, mineralogy and geochemistry of the deposit. In this case, geology means the information about the host rocks, main metals, deposit structure, shape etc. Geological properties have a big impact on the whole mining project, because the chosen excavation method is usually based on them (Papunen et al., 1986), but those methods are not considered in this article. From mineralogy, it is important to know at least what kind of minerals the host rock consists of and how the valuable metals are combined with the host rock. For example, are they in small or large disseminations within the host rock or as an element in the composition of the minerals in the host rock? The purpose of the geochemical analysis is to specify the elemental composition of the minerals in the host rock. This is probably the most informative data for a hydrometallurgist. However, knowing only the elemental compositions of the minerals is not enough, because there are plenty of minerals that have the same elemental composition, but the elements are combined together with different chemical bonds and the minerals have different structures. Hydrometallurgist needs specifically the information how the elements are bonded and this is obtainable by connecting the geochemical data with the mineralogy.

During the evaluation of an ore body, the three main datasets include size, chemical analysis and mineralogy of the ore body. The size and chemical analysis of the ore body will determine what kind of leaching techniques can be used. Large ore bodies with low-grade ores are best leached with dump, heap or vat leaching. Rich ore bodies that can be concentrated are best treated with reactor leaching. In some cases, it is not economical to mine and transport the ore then in-situ leaching can be considered. The selection of the leaching technique depends on the metal content and particle size of the ore body, with or without pre-treatment steps (Fig. 1).

The intergrowth of minerals will affect the selection of leaching technique (Fig. 2). In cases where the minerals are easily separated by mechanical methods, the selection of leaching technique and leaching chemistry has more freedom. In cases where mechanical separation of minerals is difficult the leaching must be based on dissolving all minerals in order to get the valuable metals in solution.

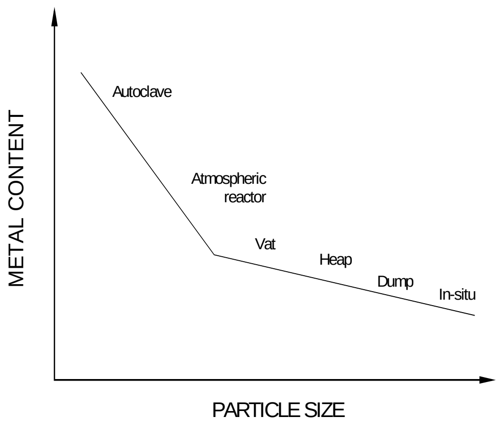

Fig. 1. Alternative leaching techniques depending on particle size and metal content of the raw material

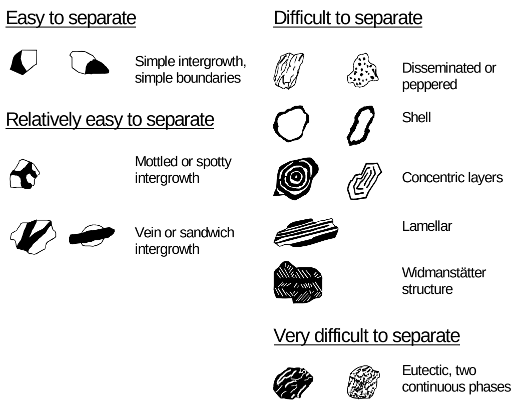

Fig. 2. Basic intergrowth patterns of minerals, after (Hayes, 1985)

The chemical and mineralogical analysis of the ore body will determine the leaching chemistry to be used. The task of the leaching step is to liberate wanted metals from the minerals and, as far as possible, keep the unwanted metals in their compounds. Depending on the compounds in the ore body (*i.e.* minerals), oxidizing or reducing and acid or alkaline chemistry can be used. The aims for selection of the leaching chemistry are to maximize mineral dissolution rate and to ensure that the dissolved metal remains as cation or complex for the subsequent purification steps. The electron configuration of the mineral allows some preliminary alternatives for selection of leaching chemistry (Hayes, 1985):

– minerals of the s-block, i.e. chlorides, carbonates or sulfates of alkaline or earth alkaline metals are usually easily dissolved in water
– minerals of the 3d-block are oxides or sulfides of Fe, Co, Ni, Cu, Zn, Cr, Mn and Ti. Oxides are dissolved in acids and sulfides with acid oxidative leaching
– minerals of the 4d- and 5d-block include for example Zr, Nb, Ta, Mo and noble metals. The oxides of the block are leached with strong acids or alkalis. Noble metals are leached with oxidative leaching and complexing agent. Sulfides are leached with oxidative leaching and sometimes an autoclave is needed
– minerals of the 4f-block include for example rare earth metals. They are often leached from phosphates or carbonates. The 5f-block minerals are radioactive and for example, uranium is leached from oxide with acid
– the p-block includes minerals of Al, Sn and Pb. The oxides of Al are leached with alkali. The sulfides are processed with zinc sulfides or Cu-Ni-Fe-sulfides.

4.2. SEARCHING PROCEDURE

It might be convenient to start the information search from the databases, but as it turned out in the progress of the research, they are mostly just search engines for the details. It also became clear that the geochemical analyses were in every case unavailable directly from the database. In order to get the analyses it was necessary to go through the reference material listed in the database.

Although the references are not necessarily accessible through the database or in Internet, there still are usually mentioned journals which contain the articles or places where to look for the exploration reports.

Figure 3 shows a flow chart of the procedure used in the information retrieval. The procedure is as follows:

– search the wanted deposit or prospect from the database, view the information given there, and gather all the usable data such as the reference list
– try to find the references in readable form and again gather all usable data. If all the needed information has been found, the mission is completed
– if the references did not answer all questions, try to find the secondary

references, which are the references of the reference articles found through the database.

The information retrieval procedure was found to be effective. A very good strategy for finding the reference material is to use for example Google Scholar search engine. Another strategy for reference material is to use library services, but in that case, it should be a library specialized in the field. The information retrieval procedure does not always give the desired results as it turned out in one of the research's experimental cases. In the next chapters three of the experimental cases are presented; one in which all the information needed was found very easily and one where it was not found at all. In the third one the information was eventually found, but it was not easy.

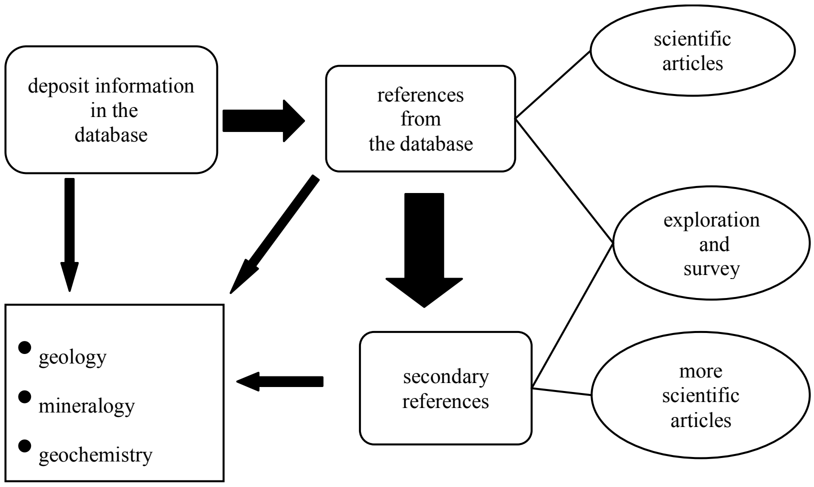

Fig. 3. Flow chart for the retrieval of geological information

4.3. FIRST CASE: MOUNT DAVIES NICKEL PROSPECTS 1-3

The first case is lateritic nickel, for which information was found quite easily. There were three Mount Davies Nickel prospects found through SARIG-database (Sarig 1, 2009) in the same area of South Australia (Fig. 4). They were named as prospect 1, 2 and 3. Although the information given by the database was rather limited, it actually described how the nickel was bonded with the other basic elements of the host rock. Other good feature in this database was that the exploration reports and the articles written about the prospects were directly accessible through a web link found under the general information of the database.

For the Mount Davies Nickel prospects 1-3 almost all the needed information was found very quickly and without any difficulties. Only the chemical analyses in the exploration reports, as they turned out to be, were partial, but probably informative enough.

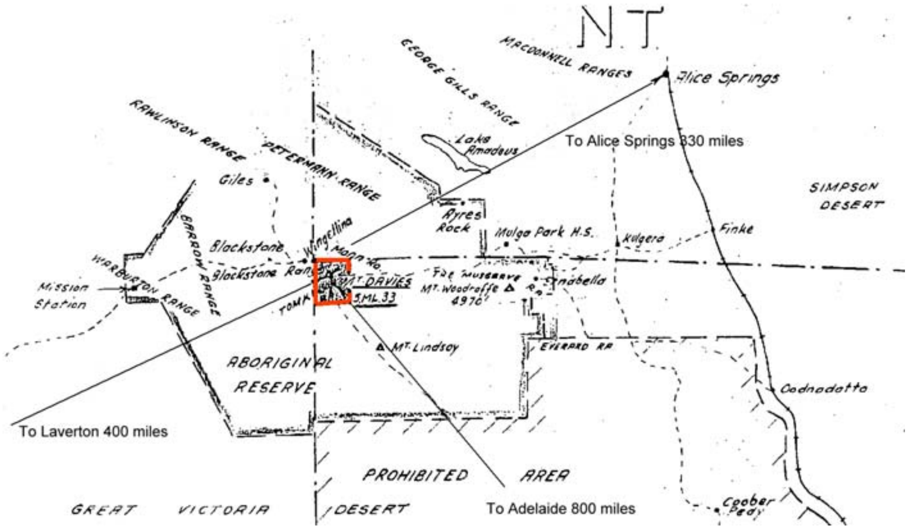

Fig. 4. The location of the Mount Davies Nickel prospects. The prospects 1-3 are located in the red square (Thompson et al., 1960)

4.4. SECOND CASE: RED MOUNTAIN LATERITE

The second case is also about lateritic nickel, but in this case search results were quite poor. Red Mountain Laterite is a lateritic nickel deposit (Ridenour, 2009) in California, USA, (Fig. 5). The MRDS database, from where it was found, offered some basic information such as geographical location, size of the deposit, list of the rock types, commodities and references.

The retrieval of the more detailed information was left to be found in the reference material. However, in this case those references were nowhere to be found in readable form. There were indications that the articles and exploration reports do exist, as links were found through Google Scholar, but the publications were not found in downloadable form. Other search channels came also out empty. They would probably have been available in the archives of the offices that had made the explorations and surveys, but to get them from there was not possible in this work.

4.5. THIRD CASE: NEAR ROUND HILL

The third case is a gold deposit, where at first no information was found in the database. Near Round Hill is a gold deposit in the shear zone of the Round Hill in

New Zealand (de Ronde et al., 2000). The GERM-database through which the near Round Hill-deposit was found did not give any other information about the deposit than is shown in Table 3. No reference material was mentioned and there was no other search portal on the web sites of the Geological Survey of New Zealand.

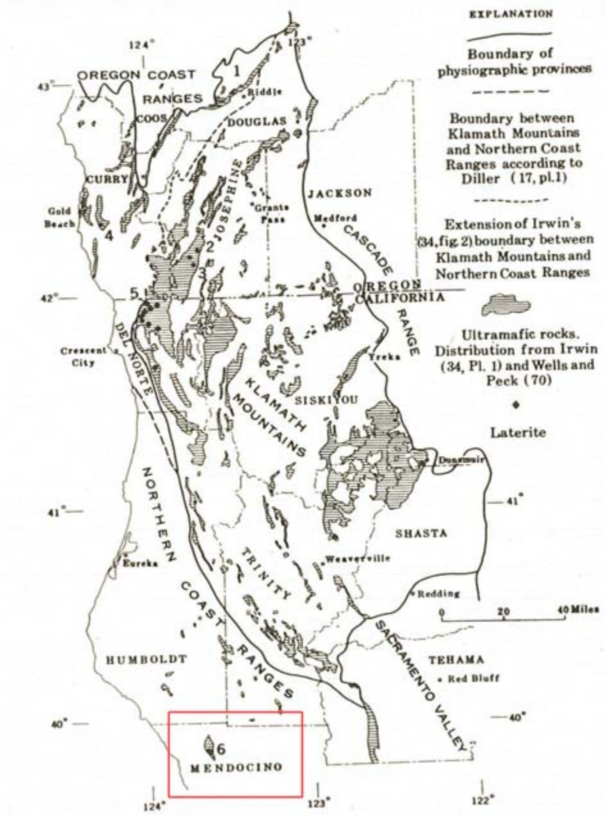

Fig. 5. Map of N.W. California and S.W. Oregon showing physiographic provinces, distribution of ultramafic rocks and locations of lateritic deposits. Rounded with red rectangle is the location of the Red Mountain Laterite (No. 6) (Hotz, 1964)

This kind of situation was actually quite promising for further research, because in this case only other channels and search engines were left in order to find more information. First search engine that was used was Google Scholar and it found a reference of an article that was originally published in the Economic Geology journal (de Ronde et al., 2000). It was a research about finding evidences about magmatic ore fluids. The article itself was found with no difficulties through library services. Although the article was not primarily about the deposit exploration in the sense of finding gold and referring the progression of the exploration, it still gave usable geological and mineralogical information. However, the chemical analyses results shown were evidences about gases and fluids that might have been in the ore before crystallizing and their composition, as it was the articles main theme. On the other hand, the information about the fluids might also be quite interesting from hydrometallurgy point of view.

Table 3. The information sheet from GERM-database about near Round Hill gold deposit (Germ 1, 2010)

Summary Details for D46/e26	
Lat/Long	46°21'10.6''S 167°49'53.9''E
NZMG Coordinate	(D46) 2112200 5415999 (New Zealand Map Grid)
Site Name	near Round Hill
Compiled Date	20-Jul-1987
Site Type	outcrop (LI)
NZGS File Number	263
Commodities	Metals (ME): Aluminium, Antimony, Chromium, Cobalt, Copper, Gold, Iron, Lead, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Platinum, Silver, Titanium, Tungsten, Uranium, Vanadium, Zinc
Feature Commodities	Gold, Platinum

5. DISCUSSION

The procedure of retrieval of geological information and using the information found has advantages but there are also disadvantages and risks. The advantages of this method are savings in time and money in the stage where alternative processing methods are evaluated. However, the savings in time and overall costs depend on the quality of the information found and how the information can reduce necessary explorations. The real benefit in using public information is that the new explorations are done only after processing alternatives are narrowed. The explorations are targeted to verify the geological data needed for the process alternatives.

There are important factors that should be taken into account when using the public information and results. These factors include the credibility and reliability of the database, its articles and exploration reports, and the age of the exploration and surveys made. The database can be trusted when the creator and administrator is known. As known authorities usually administer the public databases, credibility is seldom a risk. The articles are scientifically valid when they have been published in some of the known scientific journals. Reports can usually be trusted when known authorities or companies have done them. The age of the articles and reports can affect the quality of the information. Older publications have often less accurate information than the newer ones, simply because today more research methods are available and their accuracy is better.

One criterion for a reliable report is that the report has been made using some known reporting standard, such as JORC-code or NI-34 101. JORC-code is an ore deposit reporting standard created by The Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy (JORC-code, 2004). NI-43 101 is a reporting standard or rule created by Canadian Securities Administrators (CSA) (FORTUNA, 2010; CSA, 2005). In addition, Committee for Mineral Reserves International Reporting Standards (CRIRSCO, 2006) has recently taken an interest in the reliability of exploration reports and have a vision for creating a single, worldwide standard for public reporting of ore deposits and prospect (CRIRSCO, 2006). However, it is always crucial to understand the subject of the article or the purpose of the explorations, because that might have an impact on the real usability of the information. For example, a survey made to estimate a deposit for a certain metal can lack information about other valuable metals that have come to interest tens of years after the survey has been done.

Overall, it is easy, time saving and economical to have the preliminary research done by searching public sources using the method described here, as it needs only one person to do the work. The disadvantage in this method is that it is not guaranteed that enough information will be found. Some fieldwork has to be done in every case.

6. CONCLUSION

The findings of this work show that the many different kinds of public information is available about ore deposit. They also indicated strongly that some of those public information sources could be used as preliminary information sources. It also became clear that the internet based ore and mineral databases are in most of the cases used just as search engines for the specific information needed, such as the geology, mineralogy and geochemistry of a deposit. It turned out that in many cases the valuable information that can be get from the database is the list of the references, where the deposit information is taken from.

However, the most important thing to remember is to never trust blindly the information found in the internet. The results of explorations, which have been done by some unknown party for a different purpose than the information is now needed, are seldom useful. In those cases, the information is only usable as preliminary and no important decisions shall be made based on them.

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DEPOSIT DATABASES INTERNET ADDRESSES

FODD: http://geomaps2.gtk.fi/website/fodd/viewer.htm
MRDS: http://mrdata.usgs.gov/mineral-resources/mrds-us.html
ACP: http://mines.acp.int/html/accueil_en.html
GECO: http://www.gecoproject.org/?page=minerals&
GEMS: http://www.mineralsireland.ie/Available+Exploration+Data/Exploration +report+search.htm
BGS: http://www.bgs.ac.uk/GeoIndex/index.htm
TIS: http://dmetis.nt.gov.au/tis/OLQ.ASP?WCI=Main&WCE=getPageSize&WCU=
DODEX: http://jupiter.geus.dk/Dodex/pages/search.jsf.
Geology of India - Map Service: http://www.portal.gsi.gov.in/public_html/gis/ Guest/viewer.htm.
GERM: http://data.gns.cri.nz/minerals/germ/buildframe.jsp.
GeoVIEW.WA: http://www.dmp.wa.gov.au/7113.aspx#7116.
SARIG: http://www.minerals.pir.sa.gov.au/sarig

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Artykuł opisuje metodę pozyskiwania danych geologicznych, geochemicznych i mineralogicznych dla złóż rud i obszarów poszukiwania złóż. Informacje te są potrzebne w celu ustalenia optymalnych metod przeróbki hydrometalurgicznej. Pierwszym etapem w takim przypadku są zwykle kosztowne i długotrwałe badania geologiczne połączone z licznymi analizami próbek skał. Można zaoszczędzić dużo czasu i pieniędzy posługując się w tym celu ogólnie dostępnymi informacjami na temat złóż. Przeprowadzono literaturowe poszukiwania ogólnodostępnych danych geologicznych na temat światowych złóż minerałów. W pracy opisano również kilka przykładów praktycznego zastosowania opisanych procedur poszukiwania informacji. Przykłady te dotyczyły minerałów laterytowych niklu oraz złota. Rozważane przykłady pokazały, że istnieje wiele różnych baz danych o złożach minerałów i w większości przypadków można znaleźć niezbędne dane. Stwierdzono, że korzystanie z tego typu metod może przynieść korzyści, trzeba się jednak liczyć z ograniczona wiarygodnością tak pozyskanych informacji.

słowa kluczowe: minerał, złoża, ruda, hydrometalurgia, bazy danych