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The Interactive Raw Material Information System ("IRIS") of Austria - the computer based Metallogenetic Map of Austria

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Abstract. During the past decades intensive programs were carried out to document the mineral occurrences and deposits, and the geochemical and geophysical distributions in Austria. These data were the base for the "Metallogenetic Map of Austria", which was designed and coordinated by L. WEBER. The map was drawn digitally and printed along with a voluminous explanation text book by the Austrian Geological Survey. As a further step an Interactive Raw material Information System (IRIS) was established.

Key words: Eastern Alps, Bohemian Massif, mineral deposits, metallogenetics, geochemistry, aeromagnetics

From the "Metallogenetic Map of Austria" to "IRIS"

Various geochemical and geophysical investigations have been initiated by the Austrian Ministry for Economy and the Ministry for Science during the past decades covering the areas of most of the Austrian states. More than 30000 stream sediment samples and more than 6000 heavy mineral samples from the Bohemian Massif and the crystalline complexes of the Eastern Alps were collected, analyzed, and published in the "Geochemical Atlas of the Republic of Austria 1:1 M" (Thalmann et al., 1989).

An aeromagnetic survey program was carried out in 1977 to 1982. Different flight levels were used because of the rugged topography. The results were published in several scientific publications (see Blaumoser, 1992).

Since 1978 most of the Austrian mineral occurrences have been investigated and documented in detail. A brief overview is given by Haditsch (1979).

Weber, acting as chairman of the "Mineral Deposits Branch" of the Austrian Mining Association, suggested hamonizing the various data from modern geology, tectonics and mineralization into the "Metallogenetic Map of Austria." A project team with more than 40 representatives of science and industry was formed in 1991. The project was financed by the Austrian Academy of Science, the Geological Survey, the Austrian Science Foundation, the Technical Museum and the Austrian Mining Association. Support of software and hardware infrastructure was provided by the Joanneum Research Forschungsgesellschaft m.b.H. and the Kansas Geological Survey.

As a first step a data base containing information on more than 3000 mineral occurrences (mineral content, location, geological framework, tectonic unit, host rock, age of host rock, shape and size of mineralization, orientation, literature and more) was established. This very important basis for the following steps of the project took several years to complete.

The next step was a first attempt to summarize mineral occurrences by their similarities such as host rocks, shape, and tectonic framework, in order to define specific metallogenetic districts. More than 150 districts were differentiated and discussed in detail which required several more workshops to conclude.

To distinguish between different mineralizations (stratiform-lenticular; veins-lodes; disseminated-stockwork; irregular shaped; or mineralizations in drill holes only) and mineral groups (Iron and steel alloying metals, base metals, special metals, precious metals, industrial minerals and mineral fuels) special shaped colored symbols were designed for the map. Each symbol reflects the location of the mineralization, its shape, mineral content, size and orientation.

As the existing geological map of Austria, published in 1935 (Vetters 1933) was no longer a suitable geological base, a new geological map of Austria had to be compiled by F. Ebner at a scale of 1:500.000. The digital map was created by using GIS software ARC-INFO by the Austrian Geological Survey.

After 6 years of intensive research work, the Metallogenetic map of Austria along with a very detailed "Handbook of Mineral Occurrences of Ores, Industrial Minerals and Mineral Fuels of Austria" (Weber, ed., 1997) was presented to the public at the International Symposium "Energievorräte und mineralische Rohstoffe: Wie lange noch?" (Weber, 1997). This was the first map of its kind in Austria. The legend of the Metallogenetic Map is in German and English. The textbook and the computer based system is in German only.

To avoid an "information overload" the visualization of features on the map had to be restricted (e.g., the num-

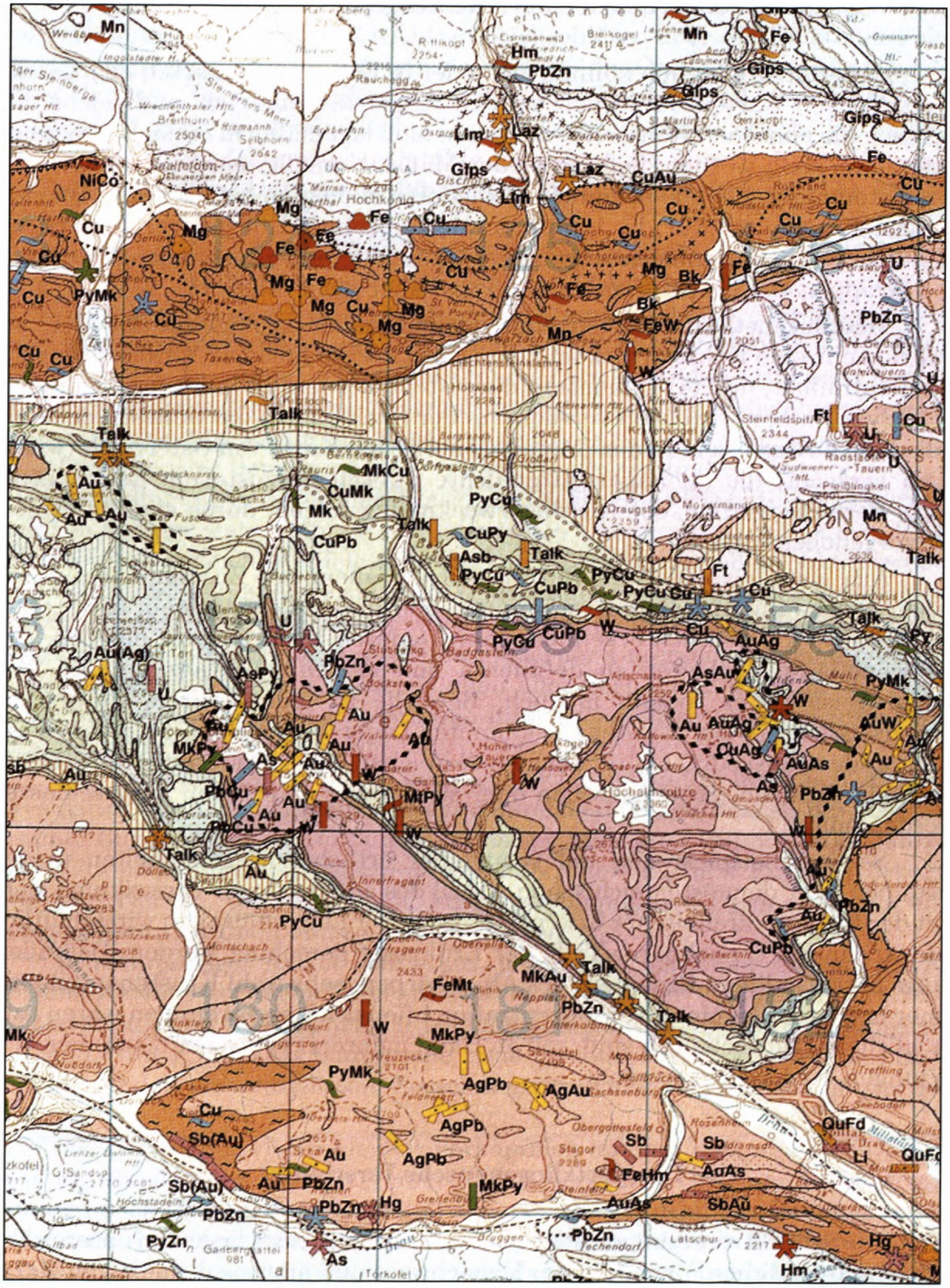

Fig. 1: Metallogenetic Map, detail (Central Alps, different gold districts).

ber of mineralization symbols displayed is related to the scale of the map). Therefore only the most important mineral occurrences had to be taken into consideration. On the other hand, it was impossible to visualize the results of the stream sediment geochemistry simultaneously. Each analyzed element (out of 35 elements) required a separate map.

Once a map is printed, corrections or changes are no longer possible. That, plus the fact that much information from geochemistry and geophysics could not be included

on the printed map, are reasons why the CD-ROM project has been launched. The aim of this project was to visualize geology, tectonics, geochemistry, airborne and terrestrial geophysics, and mineral occurrences simultaneously. The fact that all the data (geology, tectonics, mineralizations, geochemistry, and geophysics) had been stored digitally, made the project easier.

The first CD-ROM version of the "Metallogenetic Map of Austria" was presented mid 2000 to the public as "IRIS". IRIS is the abbreviation of Interactive Raw Materials Information System. The hardware requirement is described in detail below.

IRIS allows to visualize geology, tectonics, tectonics below surface, topography, drainage-system, analytical results of 35 elements of the geochemical survey, aeromagnetic survey, mineralization simultaneously, separate or in combinations. A zoom function allows the user to magnify areas of interest.

The IRIS data base provides the possibility of dynamically completing or correcting data as a main advantage of a computer based information system. It is in strict contrast to a printed map which exists only in a static and unchangeable form.

Basic data and scientific content of IRIS

IRIS is a simultaneous approach based on 5 layers containing the following maps:

- Geological map
- Metallogenetic map
- Geochemical map
- Aeromagnetic map
- Topography (situation), drainage system

Comprehensive information such as location of metallic raw materials, industrial minerals and mineral fuels in Austria can be generated by visualizing data for more than 3000 mineralizations (occurrences and deposits) in an interactive way.

Geology, tectonics

Austria comprises parts of the Variscan Bohemian massif, the Eastern and Southern Alps, Tertiary basins and Quaternary deposits. Magmatic intrusive bodies are situated at the Periadriatic lineament zone at the border of Eastern and Southern Alps. The geological base map shows the regional geological systems subdivided into two categories: major geological units and subunits. They also may be differentiated by lithology (Tab. 1).

The purpose for differentiation of subunits into lithologies is:

- to differentiate carbonate from siliciclastic rock
- to indicate basic (basaltic), acidic volcanic rock and ultrabasic rock
- to show the metamorphic facies.

Geological information is available through the layer "Geologie" and may be combined with the tectonic layer (activation of the menu field "Tektonik"). The layer offers an option to locate undifferentiated or differentiated tectonic lines. By activating the dynamic legend (left part of screen) tectonic units are determined as faults or 1st and 2nd order thrust faults (both categories proved and assumed). The layer "Tektonik Basement" is related to the pattern of faults and thrust planes in the pre-Tertiary basement of the Molasse zone and other Neogene basins, based on oil and gas exploration work.

Topography (Situation), drainage system

By using the button "Situation" the topography will be displayed. This option available with larger magnification only, as in the general overview it is impossible to read the content. The same is with the drainage system ("Gewässernetz").

Geochemistry

The IRIS-System also contains geochemical background information of the Bohemian massif and the internal zones of the Eastern Alps (Austroalpine crystalline and Paleozoic zones), derived from stream sediment sampling and analyzing of 35 elements (published in the Geochemical Atlas of Austria (Thalmann, et al., 1989).

Analyzed elements: Ag, Al, As, Ba, Be, Ca, Ce, Cr, Co, Cu, Fe, Ga, K, La, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, Sb, Sc, Sn, Sr, Th, Ti, U, V, W, Y, Zn, Zr.

The mapping of geochemical data is one of the main advantages of this computer based information system and enables a practicable way to visualize the results of geochemistry, geology and mineralizations information simultaneously.

The concentration of each element (represented by categories in ppm or %) is visualized by colored dots. More detailed information is shown by activating the legend and clicking the sample location in the map.

Aeromagnetic

Aeromagnetic data is based on aeromagnetic survey work in 1977 - 1982 (Blaumoser, 1992). In a larger scale (general overview) positive anomalies of the total magnetic intensity are shown in areas as red shadings (light to dark according to percentage of intensity), negative anomalies as green shadings. In smaller scales (larger magnification) the total magnetic intensity is expressed by red and blue isolines, respectively indicating positive or negative anomalous magnetic domains. In both situations the active dynamic legend indicates the amount of the anomalies in nT and altitude of the flight levels in meters.

Mineralizations and metallogenetic districts

IRIS provides an extensive data base of 3029 Austrian mineral occurrences / deposits. Information on mineralization is given by choosing a particular deposit (mouse click in the map) of one of the metallogenetic layers described below, when the "i"-button is active. Detailed information is available by activating the list "all occurrences/deposits", shown in separate windows of the activated layer described below. The data base includes (e.g. Fig. 6):

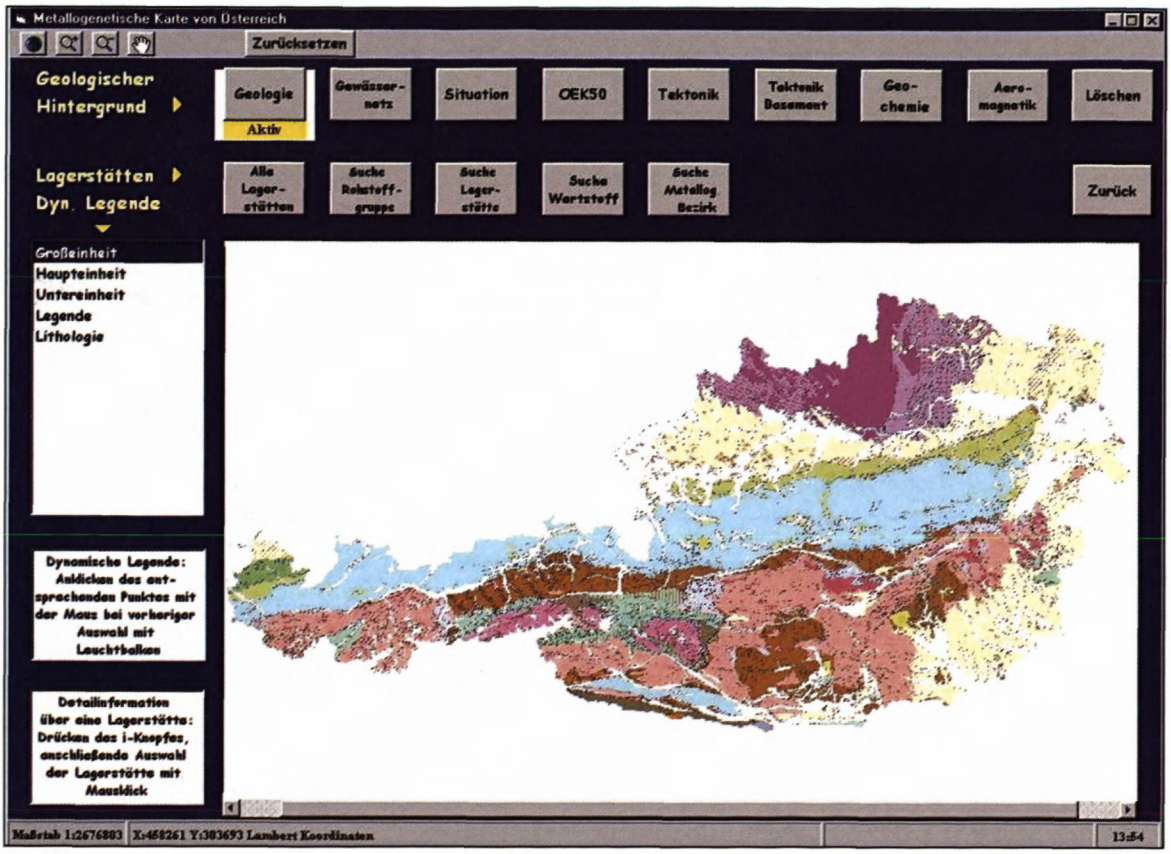

Fig. 2: Main menu of IRIS, general overview with layer „Geologie".

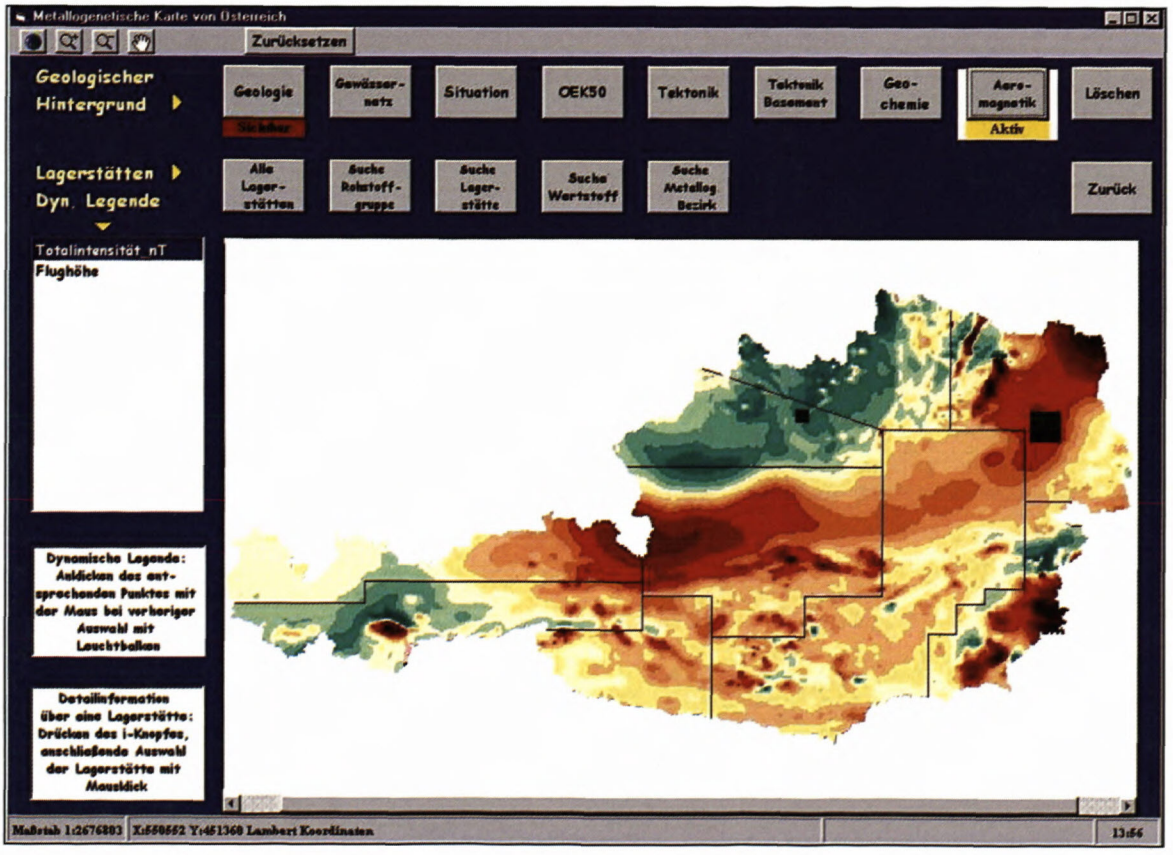

Fig. 3: Main menu of IRIS, general overview with layer „Aeromagnetik": total magnetic intensity: red shadings: 20 - 375 nT; yellow shadings: 0 - 20 nT, green shadings: 0 -50nT.

Tab. 1: Geological units of Austria. Boldfaced letters represent great regional geological systems. Differentiation into major units, subunits and lithologies. n.d. = no differentiation.

Major units	Subunits	Lithologies
	Quaternary	
n. d.	n.d.	n.d.
	Tertiary Basins	
n.d.	-Molasse zone, intramontane basins	Tertiary sediments n.d., volcanic rocks
	-Allochthonous molasse	n.d.
	-Ernstbrunn "Klippen"	n.d.
	Bohemian Massif	
n.d.	-Permocarboniferous of Zöbing	n.d.
	-Metamorphic of the Moldanubian and Moravian Complex	differentiated
	-South Bohemian Pluton	n.d.
	Eastern Alps	
Helvetic Zone	-Helvetic Zone	n.d.
	-Liebenstein, Feuerstätter nappe	n.d.
Rhenodanubian Flysch Zone	-Flysch units	n.d.
	-Ybbsitz-Zone	n.d.
Penninic Windows (Engadin, Hohe Tauern, Rechnitz)	-Permomesozoic units	differentiated
	-Zentralgneiss unit	n.d.
and Arosa-Zone)	-pre-granitoid formations	n.d.
	-"Altkristallin"-Fm.	differentiated
Austroalpine Units	-Permomesozoic units of Calc- areous Alps and Drau Range	differentiated
	-Gosau-Group	n.d.
	-Central Alpine Permomesozoic	differentiated
	-Marine Carboniferous units	n.d.
	-Silbersberg nappe (Greywacke zone)	n.d.
	-Continental Carboniferous molasse	n.d.
	-Early Paleozoic units	differentiated
	-Permocarboniferous granitoids	n.d.
	-Austroalpine metamorpic units	differentiated
	Periadriatic intrusive Rocks	
Periadriatic Intrusive Rocks	n.d.	differentiated
	Southern Alps	
n.d.	-Triassic	n.d.
	-Upper Carboniferous - Permian	n.d.
	-Early Paleozoic - Lower Carboniferous	differentiated

- name of the occurrence/deposit
- mineral content
- geographic position and coordinates
- geological data (geological unit, metallogenetic district, lithology and age of host rock, orientation of deposit, shape of deposit)
- isotopic data (Pb, S, U if known)
- vitrinite reflectance of coals
- remarks
- references

Further information is given by figures (pictures of surface and underground outcrops, geological maps and cross-sections).

Metallogenetic information can be retrieved from the IRIS application by activating the legend, the "i"-button and the menu fields:

- "Alle Lagerstätten" (all deposits)
- "Suche Rohstoffe" (search for raw material groups)

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- "Suche Lagerstätte" (search for occurrence/deposit)
- "Suche Wertstoff" (search for particular mineral commodity)
- "Suche Metallogenetischer Bezirk" (search for particular metallogenetic district).

All deposits/occurrences

In a larger scale (general overview) 3029 sites of occurrences/deposits are visualized by colored circles. The circles/symbols indicate individual groups of raw materials (specification of the groups see below):

- red: iron and ferro-alloy metals
- green: sulfides in general
- blue: non ferrous metals
- yellow: precious metals
- orange industrial minerals
- purple: special metals
- black: hard coal
- gray: graphite
- brown: lignites
- red/green: oil and gas.

In the general overview individual symbols characterize the shape of a deposit:

- stratiform, lenticular
- veins, lodes
- disseminated, stockwork
- irregular
- explored in drillholes.

Symbols are orientated (in relation to strike direction), wherever orientation of stratiform/lenticular and vein deposits are proved. Additional information is available by activating the dynamic legend:

- name of the occurrence/deposit
- state of the deposit (in operation or not)
- group of raw materials (see below)
- mineral commodity (see below)
- orientation (if known) of stratiform/lenticular and vein occurrences/deposits (see above)
- shape of the deposit (see above)
- importance of the deposit (minor and major importance).

Deposits of "major importance" are marked by larger symbols which indicate the specific groups of raw materials (general overview only). The category "major importance" includes all deposits still in operation or being exploited in the past decades. Deposits of economic importance in the future are also shown in large symbols. Other deposits were classified as deposits of "minor importance".

search for a group of raw material:

All mineral occurrences/deposits are arranged in specific groups (in brackets the number of occurrences/deposits):

- iron and steel alloying metals (463)
- base metals (468)
- non ferrous metals (167)
- precious metals (90)
- special metals (169)
- industrial minerals (1135)
- mineral fuels (537).

Deposits of each group can be visualized according to their position in the layer "search of mineral group". In a separate window all occurrences/deposits of the selected group is listed, including the major mineral paragenesis of the occurrences/deposits and position in the respected province of Austria.

search for mineral occurrence/deposit:

This layer includes a list of all occurrences/deposits within Austria (alphabetically) nominating the mineral commodities and geographical position (provinces).

By selecting one occurrence/deposit in the list the location is shown by a blinking dot (map "all occurrences/ deposits") to select and zoom a more detailed area more easily. More information to the selected occurrence/ deposit is displayed in a separate window immediately.

search for a mineral commodity:

All mineral commodities and the number of all known occurrences/deposits are listed alphabetically. A certain commodity may be selected from this list and all sites of the respected mineral commodity will be displayed on the screen. A list with all occurrences/deposits of this commodity appears in a separate window as well.

search for metallogenetic district:

Most of the mineral occurrences/deposits are grouped to districts. By knowing the sensitive problem in defining minerogenetic/metallogenetic units the term "metallogenetic district" is used for mineralizations with similar paragenesis, host rock lithology, shape and tectonic framework. mineralizations of a particular metallogenetic district are assumed to be of the same origin and age.

All districts are listed in alphabetical order. The district to be displayed can be selected by moving the light bar. After activating the enter-key only sites of this particular district will be shown on the screen. A detailed list with all occurrences/deposits within the district will occur in a separate window.

According to their similarities in paragenesis, host rocks, shape, and so forth, the following districts and their number in the major geological systems of Austria are processed.

Selected applications

1. Bohemian massif: Graphite district Variegated Series

The Austrian part of the Bohemian massif is part of the Middle European Variscan belt. The tectonic units are set up of medium to high grade metamorphic rock intruded by a huge mass of Variscan (Carboniferous) granitoids. Significantly there is an inverse metamorphic pattern with the highest (granulitic) metamorphic facies

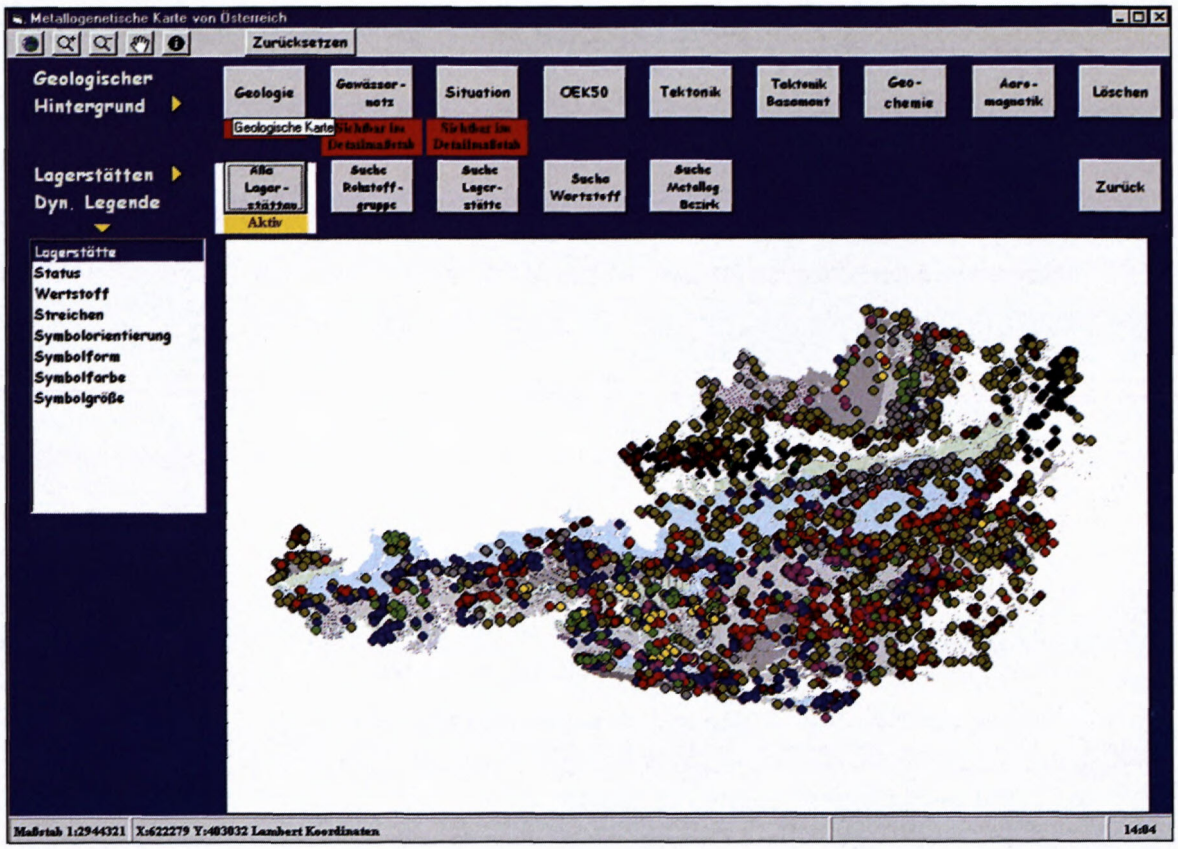

Fig. 4: Main menu of IRIS, general overview with layer „Alle Lagerstätten" (all deposits/occcurrences).

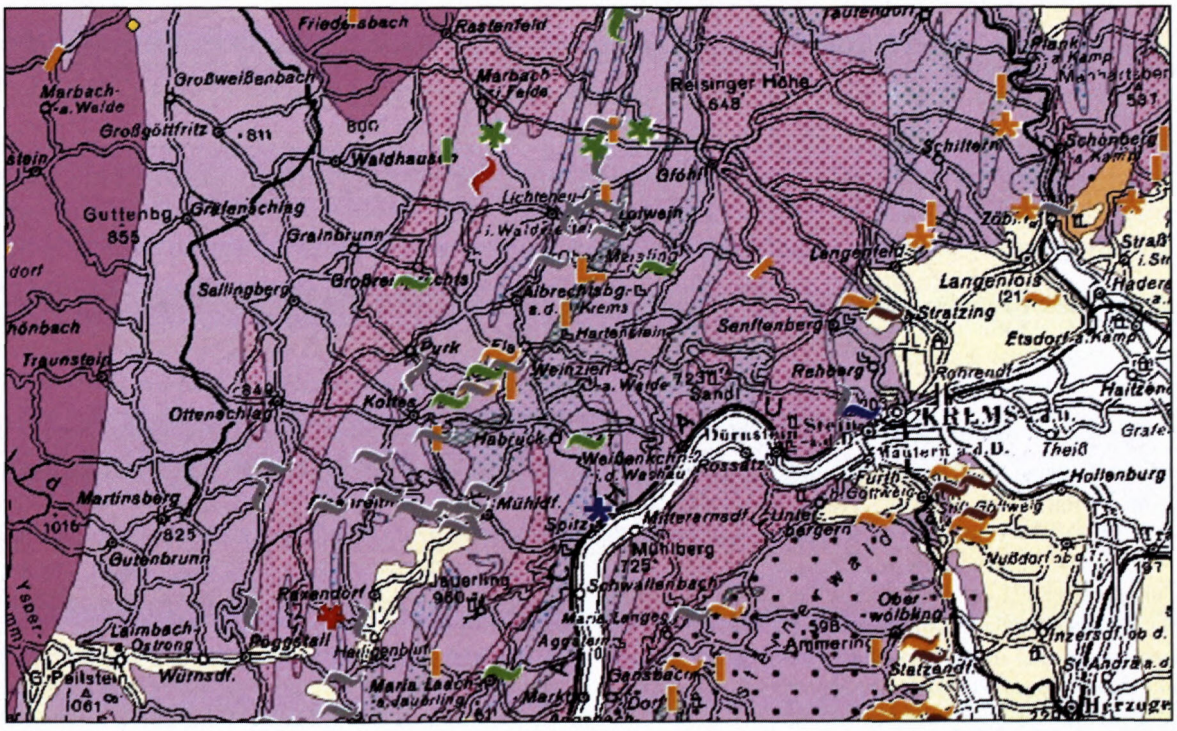

Fig. 5: Detail from the Bohemian Massif with graphite occurrences (grey symbols) of the „Graphite district Variegated Series".

Detailinformation der Lagerstätte

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Lagerstätte:              Trandorf (Weinberg)
Bundesland:               NOe

Wertstoff:                Gra
Nebenprodukt:

Lage:  zwischen Amstall und Elsenreith

ÖK50-Blatt:               36
Meridian:                 34
BMN-Koord. Rechtswert:     67400
BMN-Koord. Hochwert:      360200
Gauß-Krüger-Koord.  y=    -76000
Gauß-Krüger-Koord.  x=   5360200

Lagegenauigkeit:          sichere Ortsangabe

G e o l o g i s c h e r   R a h m e n

Großeinheit:      Böhmische Masse
Haupteinheit:     Moldanubikum
Untereinheit:     Moldanubisches Metamorphikum
Bezirk:           Grafitbezirk Bunte Serie
Lithofazies:            Saure Metasedimente
                        123
Nebengestein:           Kalkmarmore, Paragneise, Amphibolite
Schichtbezeichnung:     Bunte Serie
Alter des Nebengest.    EC?
Form der Lagerstätte:   lagenförmig (Orientierung bekannt)

Isotopenwerte Nebengestein
  Blei:
  Schwefel:
  Uran:

Isotopenwerte Mineralisation:
Bemerkung:
mehrere Grafitlinsen, tektonisch steilgestellt; ehem. Grubenfelder
Weinberg und Weinbergwald-Neu; Förderung 364931 t Rohgraphit. Rest-
vermögen bis zu 25000 t Graphit bei Tieferlegung der Abbausohle.

Literatur:

WEBER, L. (1987 b):
Die geologischen Grundlagen des Grafitbergbaues in
Niederösterreich.- In: Bergbau in Niederösterreich,
Studien und Forschungen aus dem Niederösterr. Inst. f.
Landeskunde, 10, 369-387, Wien.
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Fig. 6: Detail information of the Trandorf graphite deposit (example).

overprint within the uppermost tectonic units. The Bohemian massif is eroded to deep crustal levels and therefore is devoid of any important ore mineralization.

A characteristic Late Proterozoic sequence of amphibolite, schists, gneisses and marbles (Bunte Serie; "variegated series") hosts numerous occurrences/deposits of flaky graphite deriving from sapropelitic protoliths, metamorphosed during Variscan orogeny.

In IRIS some 78 occurrences/deposits of graphite are archived, summarized within the "Graphitbezirk Bunte Serie" ("Graphite district Variegated Series"). In a map of small magnification this district can be well defined by the swarm of the respective symbols (Fig. 5). In a small scale (great magnification) the symbols indicate the stratiform - lenticular character of the deposits and, if the orientation is known always a striking direction according to the general N-S strike of the "Bunte Serie" which is situated within the Moldanubian nappe complex east of the Gföhl gneiss and west of the Moravian nappe complex.

Today only the Weinberg deposit is in operation. This deposit is marked (in Fig. 5) by a larger symbol. Data of all deposits are archived in IRIS; Fig. 6 displays the base data for the Trandorf deposit (geographic position, geological situation, mineral commodity, byproducts, remarks and some references). There are available three figures as well (landscape with characteristic black col-

Tab. 2: Specification and number of metallogenetic districts in the great regional geologic system of Austria.

Districts related to mineral commodities	Bohemian Massif	Eastern Alps	Tertiary basins	Southera Alps
Iron and steel alloying metals				
iron ore i.g.		8		
iron/copper ore		1		
siderite		3		
hematite		3		
molybdenum	1			
manganese		2		
tungsten		2		
Non ferrous metals				
antimony		1		
lead/zinc		9		
lead/zinc (fahlore)		1		
lead/zinc baryte		1		
lead/zinc/iron		1		
copper		3		
polymetallic ores		19		
pyrrhotin/pyrite ("Kieserz")		7		
fahlore		3		
copper/iron ore		1		
copper (magnesite)		1		
copper/uranium ore		1		
polymetallic baryte-fluorite				1
Special metals				
bauxite		1		
Sb(As, Cu, Pb, Cu); Au, As-ore		1		
spodumene pegmatites		2		
uranium/fluor	1			
uranium ore		4		
Precious metals				
precious metal ore i.g.		2		
gold		7		
gold-tungsten		1		
silver		1		
Industrial minerals				
chromite-asbestos (magnesite)		1		
asbestos		1		
oil shale		2		
baryite		2		
bentonite		1		
bitumenous marls		1		
specularite		1		
evaporite		8		
graphite	1	1		
kaolin	1			
magnesite		2		
magnesite (siderite)		1		
magnesite (talc)		1		
magnesite (vermiculite)	1			
magnesite-scheelite		1		
phosphate-evaporite		1		
phosphate		1		
quartz-feldspar-pegmatite		2		
quartz sand - clay				1
talc-leucophyllite		2		
vermiculite	1			
Energy fuels				
anthrazite		1		
hard coal		4		
lignite/hard brown coal		2	22	
oil/gas			2	

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ored soils covering the deposit; the open pit showing the generally heavily metamorphosed character of the deposits; graphitic gneisses with layered pyrite mineralization). In the stream sediment geochemistry, slightly enhanced V content indicates the sapropelite protolith character.

2. Schlaining antimony (stibnite) ore district

The Schlaining antimony (stibnite)-ore district (Cerny, et al. 1997) is situated in the Penninic Rechnitz Window in the southeastern margin of the Eastern Alps, close to Austrian/Hungarian border. The low grade volcanosedimentary metamorphic host rock (Cretaceous Rechnitz Group) is of oceanic origin (South Penninic ocean) and includes tectonic relicts of ophiolite complexes (Koller & Höck, 1992). During the Late Paleogene the Penninic oceanic units were overridden by the Lower Austroapline Crystalline complex.

The oceanic and ophiolitic Penninic unit is bearing some small scale stratiform sulfide Fe/Cu-mineralizations and the vein type stibnite mineralizations of the Schlaining antimony district. The Schlaining mine was in operation until 1990. Some of these deposits contain remarkable Hg-minera-lization. In some locations talc and asbestos were formed by hydrothermal alteration of the ultrabasic rocks.

Chromite mineralizations are not known in the Rechnitz window although the geochemical stream sediment information indicates some Cr anomalies. The geochemical anomaly fits perfect with an areomagnetic anomaly. However, no chromite mineralizations are to be expected: The lack of chromium mineralization may be explained by the fact, that chromite mineralization occurs during the cooling of ultramafic melts. However chromium is likely a constituent of minerals like hornblendes, pyroxenites and so on. As a matter of fact, a careful interpretation of geology, geochemistry and geophysics is extremely necessary to distinguish between prospective areas and areas of minor interest.

Further Ni content of stream sediments partly reflects ultrabasic areas and their surroundings. Nevertheless such examples demonstrate how to use IRIS as a strategic instrument in the conception of mineral exploration projects. In the aeromagnetic information the pronounced magnetic anomaly is also related to the Penninic unit.

Outlook

The positive experience with IRIS is a big challenge to improve the data base and the interactive handling. The present release of IRIS allows to visualize only one element at once. In a next step the information supplied by the geochemical data base will be extended using multivariate geostatistical methods. By means of a Principal Component analysis areas of higher mineral potential may easily be separated from areas of minor interest. Geochemical anomalies in a favorable geologic framework, which fits with geophysical anomalies as well may indicate prospective zones. On the other side a careful interpretation of the data allow to distinguish between zones of potential mineralizations from zones of industrial pollution.

Other future steps will be the implementation of further geophysical data (gravity) and additional geochemistry (provinces of Niederösterreich and Oberösterreich) as well as a new layer displaying the metamorphic overprints of the Variscan and Alpine orogenic cycles.

GIS-Software and applied functions

IRIS was developed in Visual Basic 6.0 from Microsoft and MapObjects 2.0 from ESRI. MapObject is an ActiveX control (OCX) with more than 45 programmable ActiveX Automation objects that can be plugged in to many standard Windows development environments such as Visual Basic. The required GIS-functionality is supplied by MapObjects. The development was done under Windows NT 4.0.

The following functions have been used out of Map Objects integrated by Visual Basic:

- display, zooming, panning
- activate or erase maps by mouse click out of a given menu and overlay them using the transparency feature. The priority for the visibility of the maps is fixed.
- data support for ESRI shapefiles, TIFF- and JPEG Files
- 'map tip'-function to identify the detailed legend by clicking on a location.
- 'hot link'-function to show the mineral data base content including photo documents for a selected location
- display queried mineral deposit locations by using the 'blinking feature'
- maps using standard and specifically designed mineral location symbols in True Type Format.
- automatic change to the appropriate map display depending on the scale - e.g. change of symbols, change of visibility of geographic background map (topography, drainage system), change from raster to isolines for the aeromagnetic map.

Data supplier and used data formats

- Geological data base - digital version supplied by the Geologische Bundesanstalt (GBA), Vienna.
  Formats: TIFF-file for the patterns, shapefiles for the polygon information - like geological units, line shapefile for the tectonic lines.
- Metallogenetic data base - supplied by L. Weber
  Formats: point shapefile for the alphanumeric data and JPEG-Files for the photo documents.
- Geochemical data base - digital version supplied by G. Hausberger, copyright by GBA.
  Format: point shapefile
- Aeromagnetic data base: digital version supplied by G. Hausberger, copyright by GBA.
  Formats: Polygon shapefile for the overview map, line shapefile for the isolines,polygon shapefile for the flight levels.
- Topography (situation), drainage system - supplied by the Bundanstalt für Eich- und Vermessungswesen, Vienna.
  Format: TIFF-Files.

Technical requirements to run IRIS

Operating System: Windows 95, 98 or NT (version 4.0 and SP3 or higher),
Hardware: 64MB RAM, a minimum of 250MB free disk space. Pentium with 166 MHz or higher.

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