Turun yliopiston Geologian laitoksen 50-vuotisjuhlaseminaari, 15–16 lokakuuta 2008

- 50th Anniversary of the Department of Geology at the University of Turku, October 15–16, 2008

Turun yliopiston geologian laitos juhlii 50-vuotista taivaltaan

Timo Saarinen, Turun yliopiston geologian laitoksen johtaja

Geologian opetus aloitettiin Turun yliopistossa syksyllä 1958. Nyt on aika juhlistaa 50-vuotista taivalta. Viiden vuosikymmenen aikana geologia Suomessa on nähnyt kukoistuksen ja laman hetkiä, mutta nyt geologia on taas osoittanut merkityksensä. Räjähdysmäisesti kohonnut kallio- ja maaperän raaka-aineiden kysyntä, nopeasti muuttuva ympäristö ja ilmastonmuutos ovat nostaneet geologisen tutkimuksen ja opetuksen merkitystä yhteiskunnassamme. Geologialla on valoisa tulevaisuus ja me Turun yliopiston geologian laitoksella haluamme kutsua teidät kaikki juhlistamaan tätä kansamme.

The Department of Geology at the University of Turku Celebrates its 50th Anniversary

Timo Saarinen, Head of the Department of Geology at the University of Turku

Geology teaching started at the University of Turku in the autumn of 1958 and it is now time to celebrate the first 50 years. During the last decade, geology in Finland has experienced good and bad times but geology has now again shown its importance. There is an exploding expansion in the need for rock and soil raw materials in our rapidly changing society. At the same time, the change of the global climate has added a new aspect for the society to understand the meaning of geological research and teaching. It is within the frames of this bright future that we want to welcome you all to celebrate this anniversary with us at the Department of Geology at the University of Turku.

Presentations by Professor Emeritus and Former Students

Heikki Papunen, Professor Emeritus: Hístory of the Department of Geology in Turku (see page 138 in this issue)

Origin of Outokumpu type boulders

L.J. Pekkarinen, Outokumpu

In February 2008 it was a hundred years since a copper ore boulder was discovered at Kivisalmi in Karelia, eastern Finland, which led to the discovery of the Outokumpu ore in 1910. After the discovery of the Kivisalmi boulder, similar ore boulders have been found elsewhere in Karelia but their provenance is still under debate. The results of the GEOMEX project inspired to a new investigation of the Outokumpu type boulders, which included thin section and research report material of the twenty best known ore boulders, compiled from the archives of Outokumpu Mining Oy and the Geological Survey of Finland. For comparison, outcrop material from the Outokumpu, Luikonlahti, Riihilahti, Miihkali, Kylylahti and Hietajärvi ores was studied. The following source areas can be suggested based on geochemical and mineralogical compositions, fluid inclusions and metamorphic grades of the boulders and the directions of glacial transportation.

Eastern sector

The Vaivio, Selkie I – II, Röksä and Karvonen boulders have metamorphic grades which equal metamorphic zone B and may have an origin from Outokumpu or similar ore outcrops. The Vanaja (Sarvinki) boulder is different and can have originated from the Luikonlahti area. The Kylylahti ore outcrop is in metamorphic zone A, but there are no matching boulders to that.

The South-East sector

The Kettulankatu, Kivisalmi, Enanniemi, Taskila, Ikolansaari, Muljula, Nivunki, Rokkala and Potoskavaara boulders have chemical features and metamorphic grades matching zone B, so Outokumpu is a possible source area also for them. The Retula, Ryttylä, Sotasaari I – II and Hylekaarre (Heinonniemi) boulders represent a narrow fan at Savonranta and differ from other boulders geochemically and mineralogically, e.g. with pyrrhotite dominating instead of pyrite and with a metamorphic grade matching zone C. The glacial transportation direction is mainly to the east, which excludes the Hietajärvi mineralization as a realistic source, and the real origin of this fan is still not known. The dominating sulphide in the far-transported Sortavala boulder is pyrrhotite, but limited investigation material prevents further comparisons.

To conclude, each Outokumpu type ore boulder indicates a certain ore type, which, together with the glacial transportation direction, gives an idea of the provenance. The ore outcrop itself must, however, be pinpointed by other exploration methods. In this moment there are preparations under way for the opening of a new mine in Kylylahti, which proves that there is still a potential for Outokumpu type of ore in North Karelia.

Pyhäsalmen kaivos – kaivosgeologiaa 50 vuotta

Timo Mäki, INMET, Pyhäsalmi Mine Oy

Pyhäsalmen malmi löytyi 22.8.1958, kun Erkki Ruotanen oli kaivamassa lapiolla uutta kaivoa kotitalonsa pihalla. Erkki oli käynyt aiemmin samana vuonna malminetsintäkurssin ja hän toimitti kaivon pohjalta räjäyttämänsä mielenkiintoisina pitämänsä kivet kilpailuun. Tulokset julkaistiin nopeasti lehdissä ja löytö tuli myös Outokumpu Oy:n tietoon. Geologi Olavi Helovuori vieraili paikalla 29.8. ja lähti välittömästi tekemään valtausvarausta nimismiehen toimistoon. Mutta löytäjän eno, Evert Ruotoistenmäki, oli ehtinyt edelle ja tehnyt alueelle varauksen. Outokumpu teki nopeasti sopimuksen Evert Ruotoistenmäen kanssa ja geofysiikan mittaukset sekä kairaus saatiin heti käyntiin. Jo kuukauden kuluttua tehtiin kairalävistys; 38,5m kiisumalmia sisältäen 0,87% Cu, 5,71% Zn ja 47,9% S. Ensimmäinen malmiarvio valmistui helmikuun lopussa 1959 ja se sisälsi 17Mt malmia pitoisuudella 0,85% Cu, 2,8% Zn ja 37% S.

Kaivoksen rakentaminen alkoi vuoden päästä löydöstä elokuussa 1959 ja tuotanto alkoi vain kolme ja puoli vuotta myöhemmin, 1.3.1962.

Geologisten tutkimusten pääpaino tuotannon alkaessa oli malmin mineralogisissa tutkimuksissa. Malmin pohjoispää oli voimakkaasti hapettunut ja se aiheutti ongelmia rikastamolla. Kaivoksen omassa hielaboratoriossa tehtiin tuhansia preparaatteja hapettumisasteen selvittämiseksi.

Vesiongelmat olivat myös alussa kiusana ja vesivuotojen selvittely työllisti geologista ryhmää ensimmäisten vuosien aikana. Kalliomekaaniset ongelmat lisääntyivät tuotannon siirtyessä maan alle. Pitoisuudet putosivat ja raakkulaimennus kasvoi.

Raakkulaimennus saatiin kuriin 1980-luvun puolivälissä pienentämällä louhoskokoa, tehostamalla lujitusta ja tihentämällä näytteenottoa. Koulutuksella oli myös vaikuttava merkitys. Kaikki oppivat ymmärtämään raakkulaimennuksen taloudellisen merkityksen.

Tietokoneet tulivat geologisen työn avuksi 1980- luvun puolivälissä. Malmia ryhdyttiin luokittelemaan ei niinkään pitoisuuksien avulla vaan ns. nettoarvon avulla. Talon sisällä kehitetty ohjelmisto nimeltä ”Tussu” oli ensimmäinen geologisen tiedon ja tuotannon suunnitteluun tarkoitettu ohjelmisto. Outokummun oma kaivossuunnitteluohjelmisto ”Minenet” otettiin käyttöön vuonna1990 ja vuonna 1998 siirryttiin käyttämään Surpac -ohjelmistoa.

Pyhäsalmen kaivosta on syvennetty useaan otteeseen ja samalla syvyysjatkeiden tutkimukset ovat edenneet syvemmälle. Vuonna 1995 tehdyssä tuotantosuunnitelmassa malmia oli jäljellä vain vuoden 2000 elokuuhun. Tällöin päätettiin aloittaa uusi etsintävaihe ja sen tuloksena löytyi 19.12.1996 Pyhäsalmen syvämalmi. Tämä löytö toi lisää malmia varantoihin niin, että nykyiset malmivarat riittävät vuoteen 2017. Malminetsinnän lisäksi rikastamon syötteen optimointiin liittyvät työt olivat tärkeässä asemassa 1990-luvulla

Uuden syvämalmin löytymisen jälkeen geologiset työt keskittyivät ”perusgeologiaan”, eli malmin rajan ja sen pitoisuuksien määrittämiseen. Lisäksi panostus kalliomekaanisiin tutkimuksiin on kasvanut. Syvemmälle mentäessä malminetsintä kaivoksen alueella on jatkunut ja uusia etsintämenetelmiä on otettu käyttöön, mm. seismiikka ja reikätomografia. Normaalit etsintäreiätkin ovat jo yli 1000m pitkiä.

Pyhäsalmen malmia on louhittu 22.8.2008 mennessä yhteensä 43,7 Mt. ja jäljellä on vielä n. 13,5Mt. malmia. Oman malmin lisäksi kaivoksen rikastamolla on käsitelty yhteensä 1,5 Mt. satelliittikaivosten malmia. Näiden kaivosten geologiset tutkimukset on tehty Pyhäsalmen geologien toimesta.

Olli Helovuori vastasi geologisesta ryhmästä vuoteen 1982 asti. Ollin jälkeen 1980- luvulla kaivosgeologin tehtäviä hoitivat; Jouni Reino, Vesa-Jussi Penttilä, Markus Ekberg ja Tauno Huhtala. Kaivosgeologiset työt siirtyivät Timo Mäen vastuulle v. 1991. Merkittävän työsaran Pyhäsalmen geologisissa töissä ovat tehneet myös Eero Rauhamäki, Harri Rosenquist, Risto Juhava, Reijo Uusitalo, Jukka Pitkäjärvi, Jyrki Korteniemi, Marko Matinlassi, Markku Lappalainen ja Petri Saarela. Tällä hetkellä kaivoksen geologiseen osastoon kuuluvat tuotannosta vastaavat geologit Katja Sahala ja Mikko Numminen sekä malminetsinnässä geologit Marko Holma, Irmeli Huovinen ja Kjell Kurten. Tapio Virtanen on vastannut lähes koko tuotannon ajan, yli 45 vuotta, kaivoksen geologien näytteistä ja kairasydänten käsittelystä.

Pyhäsalmen malmin löytyminen sattui samalle vuodelle kuin Turun yliopiston geologian laitoksen perustaminen. Kaivoksen ja geologian laitoksen yhteistyö on sujunut erinomaisesti ja esimerkillisesti, mistä osoituksena lukuisat kaivoskurssit ja malmigeologiset tutkielmat.

Geochemical methods applied to mining impact studies

Marja Liisa Räisänen, Geological Survey of Finland, Kuopio

Geochemistry plays an important role in solving environmental impacts and assessing risks of extracted industry on soils, surface waters and groundwater, and subsurface water. The presentation will show the applications of multielement analysis, element speciation and geochemical fractionation with which contamination source or impact mechanisms can be recognised. Multielement analysis is based on element determination with ICP-AES (or ICP-OES) and MS-ICP techniques. The identification of key elements or indicator elements of effluents or contaminative reactions enables to identify the polluter (source) and to determine deteriorating mechanisms (example on water media). Element speciation is a tool for identify oxidation forms of elements. For instance the toxicity of chromium depends on its chemical form; chromium III is essential nutrient and non-toxic whereas compounds of chromium VI are carcinogenic. The example represented concerns the distribution of chromium VI and III in surface water samples collected from two mine sites and surrounding area of the stainless steel work. Geochemical fractionation methods (batch of selective extractions or sequential extraction scheme) are used for elucidating the form in which the pollutant is held. The key issue is commonly to distinguish the content of mobile and immobile fractions and factors controlling the fraction stability. The fractionation is also a helpful tool for estimating the weathering rate of tailings and waste rocks and in situ precipitation. This knowledge is needful when selecting closure and after-care method of waste facilities.

Current activities, presented by the Professors at the Department of Geology at the University of Turku

Bedrock Geology and Mineralogy

Olav Eklund

Education in bedrock geology and mineralogy at the Department of Geology is continuously evaluated with regards to how courses support one another. We are seeking the correct balance of the amount of information that should be given and in what order depending on the experience level of the students. We (Krister Sundblad, Timo Kilpeläinen and myself) are trying to develop a curriculum in which the students realise that igneous petrology, structural geology, metamorphic petrology, sedimentology and economic geology are all integrated aspects of bedrock geology. In addition to theoretical instruction, our curriculum includes a significant amount of time for practical exercises in petrography (both macro and microscale) at all experience levels. A particular strength of the department is that all our theoretical courses are connected to field courses in the archipelago of SW Finland. At the Master's level, students are expected to work more independently, supplementing their theoretical classes with individual studies in the laboratory and with the computer.

More recent cooperation established with our neighbours at the Laboratory of Material Science provides us with access to electron microscope, ESCA-analyses and atomic force microscopy. This enhances our capabilities for mineralogical education and research. Another exciting development is our recent partnership, along with the Department of Geology at Åbo Akademi University, with the company Topanalytica for the acquisition of an electron microprobe.

The research in bedrock geology is financed principally by the Academy of Finland (AF), The Finnish Graduate School in Geology (FGSG), TEKES and K.H. Renlund Foundation (Renlund). The main ongoing bedrock research projects in bedrock geology are:

The earliest magmatism in the accretionary arc complex of southern Finland. Docent Markku Väisänen is a fulltime senior researcher in this AF project.

Petrology of 1.8 Ga lamprophyres, carbonatites and granites in the Fennoscandian shield. This project includes active collaboration with the Clausthal University of Technology (Germany), Texas Tech University (USA), The University of Massachusetts, Amherst (USA) and St.Petersburg State University. This research is financed by FGSG and Renlund.

The 1.87 Ga extension in the central parts of the Fennoscandian shield. A project where the FIRE-lines are interpreted with field observations and analogue modelling in laboratory scale. Partners in this project are the Department of Seismology at Helsinki University, Geological Survey of Finland and the Tectonic Laboratory at University of Frankfurt (Germany). The project is principally financed by Renlund.

Correlation between surface geology and geophysics in rapakivi batoliths. This project is closely integrated with economic geology and financed by Renlund.

The research in mineralogy is divided into basic research and applied environmental mineralogy. At the moment, the basic research is principally focused on fluorapatites and tri-octahedral micas in alkaline rocks. This research is financed by FGSG, Renlund and the Outokumpu Foundation.

The environmental mineralogy has three main objects:

Micas as ammonium adsorbators and their reuse as soil-improvers. (TEKES and Renlund). Researchers at Swedish Polytechnic in Vaasa are conducting the large-scale experiments of this project.

Testing different carbonates for gypsum precipitation in coal power plants.

Testing minerals and rocks for CO_2 sequestration.

The two last mentioned projects are included in the research consortium Carbonates in Energy Technology "Caretech", financed by AF. Partners in Caretech are the Laboratory of Heat Engineering at Åbo Akademi University, the Department of Energy Technology at Helsinki University of Technology, the Laboratory of Material Science at University of Turku and the Department of Geology, University of Turku.

Ore Geology

Krister Sundblad

In 50 years, the University of Turku has been a center for teaching and research in Ore Geology in Finland, for a long time in close cooperation with Outokumpu OY. During the last decade, the conditions for Ore Geology in Turku (and Finland) has, however, experienced a number of changes:

1) Outokumpu OY left the exploration market and was replaced by a number of private companies.

2) The mining industry enjoys better economic conditions than ever.

3) Ore Geology teaching at University of Turku (Turun Yliopisto) and Åbo Akademi has merged into one teaching programme.

4) Ore Geology teaching in Turku is now in English.

This new situation has made cooperation with industry partners more complex in spite of the increased need for our students. At the same time, through the English teaching programme we have an increased ability to attract students from foreign countries. A synergy effect of this is that all students now become bi-lingual (many even tri-lingual), which is essential for the new, globally-flavoured job market in Finland.

The ambitions for Turku is to provide a spectrum of courses in all fields of *Economic Geology*; particularly *Ore Geology*, create an understanding of the geologic *and* economic frame works for the concept of ores by providing numerous theoretical and practical courses. These provide knowledge, understanding and answers on: What is Ore and how do Ores form? What economic and political processes control feasibility for various ore types? How can new mineral resources be found and quantified? The courses are suitable to those who see a future in Exploration and Mining as well as to those who aim for an academic career.

Although most of the teaching and research programmes in economic geology in Turku is done by myself, several top class (some of them world class) teachers provide additional high level education: Nigel Cook (University of Oslo; Ore Petrology), Jeffrey Hedenquist (University of Ottawa; Epithermal ores and Porphyry systems), Tapio Halkoaho (GTK, Kuopio; Orthomagmatic ores), Pasi Eilu (GTK, Espoo; Metallogeny of Gold) and Timo Mäki (Pyhäsalmi Mines; the National Course in Mine Geology).

The Autumn Short Courses in Ore geology aim to attract top scientists to Finland and to tie industry geologists closer to science and students. The first courses were held by J.W. Hedenquist (2007): Exploration for epithermal deposits, and transitions to the porphyry environment) and M. Hannington (2008): Submarine Hydrothermal Systems and Ancient VMS Deposits. These courses have been attended by an international audience, both with respect to students and professionals.

A spicy aspect on our courses in exploration methods is that they are arranged under such realistic conditions that they have been efficient enough to identify new mineral deposits at several sites. The first case was the discovery of a new complex sulphide system in southern Sweden (Sundblad et al., 2006). It was followed by the rediscovery of the ancient silver ores in Forsby (Koskenkylä) in southern Finland in 2005. The activities during the last two years have revealed an unexpected ore potential in the anorogenic granites in the Svecofennian parts of Sweden, Finland and Russia (Sundblad & Ahl, 2008). The concrete results of the exploration course are so valuable that a commercial branch has been estabished (Wildeman OY), in order take care of the legal and economic aspects of the new mineral discoveries. This company has recently made the first claim applications in southeastern Finland.

Current research programmes include three main topics: 1) Polymetallic ores in anorogenic granitic environments, 2) VMS types in Caledonian and Kalevian turbidites 3) Devonian orogenic Pb-Zn mineralization.

References

Sundblad, K., Björklund, A., Dumell, A. & Lehtilä, T., 2006. Evidence for volcanic-hosted Ag-Pb-Zn-Cd-As-Bi-bearing hydrothermal mineralization in southern Sweden. 27th Nordic Geological Winter Meeting, Oulu, p. 157.

Sundblad, K. & Ahl, M., 2008. Metallogeny of Indium in the Svecofennian Domain. Key note lecture at International Geological Congres no 33 in Oslo.

Quaternary glacial sequence stratigraphy

Matti Räsänen

Most of the geologists who got their education in the 1960s and 1970s in the newly founded Department of Geology at the University of Turku or some other Finnish university had to read the world widely used textbook of Richard Foster Flint: *Glacial and Pleistocene Geology,* published in 1957. Here this experienced North-American geologist already stated that glacial strata are composed of *glacial sequences*, which are composed of a till bed with overlying sorted sediments.

Since then the concept of *sequence* and especially the method of *sequence stratigraphy* has gained increasingly importance as an interpretative tool to solve practical geological problems especially within petroleum geology in marginal marine basins. This started in the 1960s by Laurence L. Sloss who defined a *sequence* as an unconformity bounded genetic package of geological strata. In the end of 1970s Peter R. Vail at Exxon started to use the unconformity bounded sequences to correlate sea level word widely. In this phase *sequence stratigraphy* as a tool revolutionised much of stratigraphical research. The somewhat static (and for some of you boring) stratigraphical and paleontological scheme e.g. presented in the much in Skandinavia used textbook in historical geology of *Leif Størmer: Jordens och livets historia*, changed into a dynamic three to four dimensional theatre, where world and local ocean levels were dynamically changed through tectonical and eustatical changes, causing rapid lateral shifts in the focus of deposition at basin margins.

After this first bloom of *sequence stratigraphy* within the research of marginal marine basins, it is now increasingly applied also into other type of depositional systems. *Glacial sequence stratigraphy* now defines the *glacial sequences* of Flint as the basic genetic packages of strata, which are bounded by unconformities. The controls in glacial depositional and erosional systems are naturally different than in marine sequence stratigraphy but the interpretive framework works much in the same way. It is in this context the traditional Quaternary and glacial geology with its different subfields of sedimentology, micropaleontology, shallow geophysics etc. is nowadays studied and taught at the University of Turku. By applying *glacial sequence stratigraphy* the society is provided with more accurate information on the past behaviour of the Quaternary ice sheets and the structure and nature of the resulting glacial deposits. The correlation of the spatial stratigraphical information with the unusually good decadal and even annual high-resolution chronologies that are available from Quaternary marine, lake and glacial ice records is a central challenge for the research. In this way it is possible to construct local high-resolution chronostratigraphic and diachronic time stratigraphies. A well-constructed time stratigraphic framework will enhance the numerous applied uses of Quaternary geological data.

Annually Laminated Lake Sediments

Timo Saarinen

There are 187,888 lakes (defined as a body of standing water larger than 500 m^2) in Finland. Lakes and their catchments respond biologically, physically and chemically to climate and environmental changes and these responses are recorded in the lake sediments. In some particular cases these changes can be dated in annual or even seasonal resolution. Consequently, it is not a surprise that lake sediment research is a rapidly increasing field in Finnish Quaternary science. Annually laminated lake sediments or varved sediments are one of the most valuable of terrestrial palaeoclimate records, which may reach back in time in continuous sequences for tens of thousands of years. A varve can be defined as a set of laminae deposited during one year. Because of their precise chronological control and even seasonally discernible laminae, varves provide excellent study material for high-resolution paleoenviroment and palaeoclimate reconstructions. Annually laminated lake sediments found in Central and Eastern Finland have been studied effectively over ten years at the Department of Geology.

Recent research topics of annually laminated lake sediments include e.g. investigation of varve dated paleosecular variation of the Earth's magnetic field, including relative paleointensity, solar forcing on the lake sedimentation, X-ray density studies of Lake Megata sediments (Japan) and micro-XRF and SR-XRF high resolution geochemical investigations of epoxy impregnated sediments.

Geology teaching in lacustrine and marine sediments is connected to research. New advanced level courses include e.g.: Physical and chemical methods of lacustrine and marine sediments, Sub-Arctic lake sediment coring field course in Kevo field station and Practical image analysis in Quaternary geology.

Presentations by Associated Teachers; Honoury Doctor and Docents

Porphyry to epithermal transition: Lithocaps and high-sulfidation deposits form on the shoulders of porphyry systems

Jeffrey W. Hedenquist, University of Ottawa, Canada, as well as Honoury Doctor of the University of Turku, Finland and Honorary Lecturer of the Society of Geologists

Porphyry copper-gold deposits are intrusion-centered, and commonly are largely hosted by early and syn-mineralization intrusions that are conduits for the magmatic fluids that form alteration and mineralization. Early high-temperature potassic alteration is related to hypersaline liquid, which forms when a low-salinity magmatic fluid intersects its solvus and a large amount of vapor separates and ascends, leaving the liquid at depth. The vapor contains acidic volatiles, including SO_2 and HCl, and condensation of this vapor creates a shallow zone of hypogene advanced argillic alteration at epithermal levels in the system, formed at the same time as the deep potassic alteration. The potassic alteration is typically overprinted by later and lower temperature phyllic alteration, characterized by chlorite and muscovite; this is formed by a lower salinity fluid than that which creates the potassic alteration, although both have a magmatic origin. During ascent and cooling, the muscovite-stable fluid reaches pyrophyllite stability above the porphyry deposit; consumption of silica from the rock to produce pyrophyllite (±diaspore, dickite, alunite) from muscovite commonly creates a patchy texture in the rock. This reaction zone marks the transition from the porphyry to epithermal environment.

Condensation of the early magmatic vapor, where it does not discharge as volcanic fumaroles, creates a reactive fluid containing acidic species such as H_2SO_4 and HCl. These acidic species cause the extreme hydrolytic leaching that forms residual silicic and advanced argillic zones at relatively shallow levels. The conduits of vapor condensate ascent are structurally controlled, and if a geologic horizon is present, the condensate may flow laterally due to hydraulic gradients created by topographic relief, forming a large silicic and advanced argillic lithocap. This residual quartz is the principle host to subsequent high-sulfidation mineralization, if formed by later ascent of a mineralizing fluid (e.g., possibly related to the muscovite-stable fluid that overprints the deep potassic alteration). Whether or not mineralized, the silicic lithocap typically forms on the shoulder of the causative intrusion, rather that directly over the intrusion and possible porphyry deposit. The reason for this is the extreme hydrolytic leaching that only occurs upon dissociation of the acid species below 250 to 300 ºC, and hence away from the hot plume that forms directly over the intrusive source.

Exploration of lithocap-hosted high-sulfidation (enargite-gold) deposits, as well as assessment of the intrusions that underlie all lithocaps, and which potentially are associated with porphyry copper-gold deposits, can be greatly assisted by assessment of the characteristic alteration mineralogy and zonation that defines the position – lateral, vertical, and temporal – exposed within the overall magmatic-hydrothermal system. Evidence for porphyry deposits in areas of minimal erosion occurs as fragments brought to the surface in diatremes.

Trace element geochemistry of sphalerite: insights from LA-ICP-MS analysis

Nigel John Cook[1], Cristiana L. Ciobanu[2], Masaaki Shimizu[3], Leonid Danushevskiy[4], Mira Valkama[5] and Krister Leon Sundblad[5]

1. Natural History Museum, University of Oslo, Boks 1172 Blindern, N-0318 Oslo, Norway
2. South Australian Museum, Adelaide, S.A., Australia
3. Department of Geology, University of Toyama, Japan
4. CODES, University of Tasmania, Hobart, Tasmania, Australia
5. Department of Geology, University of Turku, Turku, Finland

Sphalerite is an important host mineral for a range of minor and trace elements. Levels of trace elements in sphalerite have implications for economic exploitation and processing of Zn-ores, as well as in environmental remediation. In situ LA-ICP-MS analysis has been applied to understand the distribution of Ag, As, Bi, Cd, Co, Cu, Fe, Ga, Ge, In, Mn, Mo, Ni, Pb, Sb, Se, Sn and Tl in sphalerite from >30 deposits, including specimens with wt.% levels of Mn, Cd and In. The aim was to constrain ranges of solid solution in natural samples, compare the data with published phase equilibria, distinguish between solid solution and micro-scale inclusions, and to identify potential geological or genetic controls on sphalerite geochemistry.

Indium concentrations are of particular interest. Like Cd, Co, Ga, Ge, Hg, In, Fe, Mn and Se, indium enters sphalerite in solid solution. Sphalerite from Toyoha, Japan, contains complex zoning. In-bearing sphalerite (up to 6.7 wt.% In) coexists with Sn-rich sphalerite (up to 2.3 wt.%). Indium concentrations correlate with Cu, corroborating coupled $(Cu^{+}In^{+++}) \leftrightarrow 2Zn^{++}$ substitution. Tin, however, correlates with Ag, suggesting a second coupled substitution involving Ag and Sn.

Sphalerites from several indium occurrences within the Wiborg batholith, Finland, and from the polymetallic skarn ores at Pitkäranta, Russian Karelia, are included in the study. Mean In concentrations in sphalerite from Jungfrubergen and Getmossmalmen (both within the Wiborg batholith) are 1471±51 ppm and 216±22 ppm, respectively. Sphalerite from vein occurrences at Korsvik (Wiborg batholith), in which roquesite ($CuInS^2$) is exsolved, contain 5,480 and 6,340 ppm. Sphalerite without exsolved roquesite from the same locality contains as much as 3–4 wt.% In. Zoned sphalerite from polymetallic skarn ores at Pitkäranta, associated with the Salmi batholith, has shown levels of 326±147 ppm. In samples without discrete indium minerals such as roquesite, the concentration of In within sphalerite and the modal abundance of sphalerite in the ore correlate well with bulk In contents, indicating that sphalerite is the primary host for the element.

Concentrations and fractionation of In and other elements into sphalerite are influenced by type of deposit, crystallization temperature, metal source, cooling history and proportion of sphalerite in the ore. Local metal source, crystallization temperature and cooling history may contribute to the partitioning of trace elements (In, Ga, Ge etc.) between sphalerite and discrete minerals of these elements.

Estimating undiscovered mineral resources in Finland

Pasi Eilu, Kalevi Rasilainen, Geological Survey of Finland, PO Box 96, 02151 Espoo, Finland

The Geological Survey of Finland has started a four-year project "National resources of useful minerals" to estimate the amounts of useful mineral resources of Finland within one kilometre depth in the crust. The known and possible, as yes undiscovered, resources of the following metals will be assessed: Au, Cu, Ni, PGE and Zn. Along this work, also a partial assessment of undiscovered resources of Ag, Cr, Fe, Pb, Ti and V will be achieved. The purpose is to produce high-quality information for national and regional planning for land use and natural resources management as well as for environmental planning. The work will enable accounting of metallic natural resources according to the principles of sustainable development. It will also produce new information for metallogenic and lithological research and for national level planning of minerals exploration. The procedure selected for the work is based on the three-part quantitative assessment method developed in and used by the U.S. Geological Survey since 1975. Statistical methods of data analysis and integration that treat and express uncertainty are applied. The procedure is flexible to use varying amounts of objective geological data and subjective expert knowledge and it generates reproducible assessment results. The final products of the project include 1) a database with the background information used for the national resource assessments, 2) national and areal mineral resource estimates, 3) a final report containing a summary on the results, a description of the methods and international reference materials used and an assessment of the quality of the results. ♦

MERKKIPÄIVIÄ

23.11.	**Jorma Kalliokoski**	**85 v.**
9.11.	**Pasi Eilu**	**50 v.**
27.11.	**Jukka-Pekka Palmu**	**50 v.**