Project short title: Global Comparison of Volcanic-Hosted Massive Sulphide (VMS) Districts

Duration: 2004-2009

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Project Secretary: Rodney Allen (see above)

Date of submission of report: 21 December 2009
1. **Website address(es) related to the project**

IGCP-502 uses Lulea University of Technology (LTU), Sweden, as host institution. Access is via the home pages of the Institution of Applied Chemistry and Earth Sciences, and the Division of Ore Geology and Applied Geophysics <http://www.ltu.se/tkg/>. The first page of the IGCP-502 site is at: <http://www.ltu.se/tkg/avd/Geovetenskap/d23216/IGCP>

This website is linked to the International Geoscience Programmes home page (via Geoscience, Earth Resources).

2. **Summary of major past achievements of the project**

- The project has built up an active scientific network that includes the majority of the world’s leading scientists in the field of volcanic-associated massive sulphide (VMS) ore deposits, plus 41 scientists from 21 developing countries and many postgraduate students. This network now comprises 215 scientists from 43 countries.
- Increased level of cooperation amongst several government institutions, universities and private mineral resource companies in Turkey, Russia, Namibia, Mexico, Morocco, Canada, Sweden, Spain, Australia, Saudi Arabia and Peru. This increased cooperation has been of tangible benefit to all involved, and especially to scientists in the developing countries. This effort has also resulted in several tens of joint papers concerning VMS mining districts all around the world.
- Discovery of fossil hydrothermal chimneys in a VMS deposit of Cretaceous age in Turkey during an IGCP-502 field workshop in 2004. This is the first discovery of hydrothermal chimneys in Turkey and one of few such discoveries in ancient rocks in the world. Further similar discoveries have been made by the Russian team in the Palaeozoic VMS deposits of Nikolayevskoe, Artemyevskoe, Zarechnoe and Molodezhnoe.
- Joint field meeting with IGCP-450 in Namibia and South Africa in 2005 concluded that classification schemes for VMS deposits don’t allow for transitional deposit types between the end-members VMS, SEDEX, BIF, epithermal and skarn deposits. This has a negative effect on exploration strategies worldwide. Accordingly, our project is studying transitions between VMS and SEDEX deposits in the Rosh Pinah area, Namibia, and between VMS, BIF and skarn magnetite deposits in Bergslagen, Sweden, and seeks to revise the classification and genetic models of VMS deposits.
- Increased awareness of the effects of metamorphism, deformation and weathering on massive sulphide deposits, and how these processes affect the economics of mining.
- Short courses in Turkey and Peru on submarine volcanism and VMS mineralization.

3. **Achievements of the project this year only**

3.1. **List of countries involved in the project (*countries active this year)**

IGCP-502 has 215 participants (see list at section 8) from the following 43 countries:

- Argentina*
- Australia*
- Brazil*
- Bulgaria
- Canada*
- China*
- Cuba
- Czech Republic*
- Great Britain*
- Greenland
- Hungary
- India*
- Iran*
- Ireland
- Japan*
- Kosovo
- Norway
- Oman
- Papua New Guinea
- Peru
- Portugal
- Russia*
- Saudi Arabia*
- South Africa
3.2. General scientific achievements and social benefits

- The IGCP-502 group produced a number of high quality publications during 2009 (see list attached in section 8). Several of these have resulted from scientific exchange and “networking” at IGCP-502 meetings and field workshops.
- The IGCP-502 Special Volume of Mineralium Deposita Journal entitled: "Key Issues And Controversies In The Geological Setting And Genesis Of Volcanic-Hosted Massive Sulphide (VMS) Deposits" continued to progress during 2009 and will be sent to the editor for publication in 2010 (see sections 4 and 8.3). Of the 18 manuscripts, 15 have been received and reviewed or are currently being reviewed, and 3 manuscripts remain to be reviewed.
- Realization of a Japanese-Russian expedition to the massive sulphide deposits of the Urals Mountains and of a Russian-Turkey expedition to massive sulphide deposits in Turkey.

3.3. List of meetings with approximate attendance and number of countries

IGCP-502 ran three meetings this year. The first meeting was held in Morocco and was organized by IGCP-502 members at Cadi Ayyad University, Marrakech. The meeting commenced with a one day symposium on VMS ore deposits of the Marrakech region (see meeting report below) that was attended by 30 participants from 10 countries. This symposium was followed by a five day field workshop to various ore deposits of the Marrakech region and the High Atlas Mountains.

The second meeting was during the large SGA 2009 (Society for Geology Applied to Ore Deposits) congress in Townsville, Australia, 17-20 August. IGCP-502 sponsored session B2: “Sedimentary and volcanic-hosted Cu, Cu-Zn and Pb-Zn deposits” chaired by Jan Peter, Stuart Bull and Rodney Allen (http://sga2009.jcu.edu.au/program/working-themes-for-the-sga-sessions). This session was the largest, best attended, and most successful of the whole SGA meeting with 39 contributions presented by authors from 17 countries (see meeting report below).

The third meeting sponsored by IGCP-502 was the scientific session “Mineral Deposits and Metallogeny of the Black Sea region” at the “Geology of the Black Sea Region” Symposium held in Ankara, Turkey during October. Nine participants from IGCP-502 attended the meeting.

3.4. Educational, training or capacity building activities

3.4.1. Field workshops
IGCP-502 ran a field workshop in Morocco this year following the IGCP-502 symposium in Marrakech (see section 3.3 above). This workshop had 20 participants from 10 countries, including 5 scientists from developing countries and 7 PhD students. The IGCP-502 field workshops are very popular and have proved to be an excellent way of disseminating experience and skills between scientists from the developed and less developed countries.

3.4.2. Post-graduate students
Fourteen PhD and MSc students have been sponsored by, or involved with, IGCP-502 activities during 2009: Mohamed El Mimouni (Morocco), Fardin Mousivand and Alireza Monazami (Iran), Kemal Revan (Turkey), Hannah Grant, William Gray and Amanuel Bein (Canada), Jorge Carriedo, Carmen Conde and Nieves G. Miguelez (Spain), Peter Dahlin, Tobias Bauer and Nils Jansson (Sweden), Johannes Mederer (Switzerland).

In the framework of the project, during 2009 there have been several graduate theses completed: one M.Sc. thesis (Hannah Grant, Canada), two Ph.D. theses (Erin Powe and Angela Page, Canada) and one Licentiate thesis (Nils Jansson, Sweden).

3.5. Collaboration, capacity building activities, and in particular participation of scientists from developing countries, including young and women scientists

IGCP-502 continues to involve, engage, and assist scientists from Iran, Namibia, Peru, Russia, Turkey and Morocco (see sections above and previous reports). The project’s 215 members include 41 scientists from 21 developing countries: Morocco, Namibia, Mexico, Bulgaria, Georgia, Cuba, China, Equador, Ghana, Myanmar, Papua New Guinea, Hungary, Iran, India, Kosovo, Russia, Turkey, Argentina, Peru, Venezuela and South Africa (see list of members in section 8). Furthermore, this number is not a true picture of the participation from developing countries, because in many cases the project has just one or two email contacts with chosen IGCP-502 co-ordinators in these countries. These co-ordinators disseminate information from our project to other scientists in their country. About half of the participants from developing countries are young scientists and 6 are women. It is difficult to reach women scientists in many developing countries, because these countries generally nominate men as their representatives, but we are trying to overcome these obstacles. Scientists from Morocco, Turkey, Russia, Iran, India, Argentina and Mexico have been particularly active in the project this year. The project supervises several PhD and MSc students from developing countries (see section 3.4.2).

3.6. List of most important publications in 2009 (including maps; no abstracts)

The projects incorporated within IGCP-502 produced 35 major peer-review papers, and 3 books and other peer-review publications during 2009 (see list in section 8.2).

3.7. Activities involving other IGCP projects, UNESCO, IUGS or others

No specific collaborative projects involving other IGCP projects were carried out this year. However, collaborations continue that were stimulated by previous joint workshops such as the joint field workshop held by IGCP-450 and IGCP-502 in Namibia and South Africa in 2005 and the joint work between the Finnish team and IGCP-486 on Bi-Pb-Te sulphide minerals.

4. Activities planned

The project completes one year of OET (On Extended Term) at the end of 2009 and we have not planned to extend the OET basis. However, the legacy of IGCP-502 will continue with two main activities during 2010. The first activity is to complete the IGCP-502 Special Volume of Mineralium Deposita Journal (see sections 3.2 and 8.3). The second activity is that the International Association on the Genesis of Ore Deposits (IAGOD) has invited the IGCP-502 leadership to run a scientific session on “Volcanic-hosted massive sulphide deposits” at the 13th Quadrennial IAGOD Symposium in Adelaide, Australia, 6-9 April 2010 (see website: http://www.allocasionsgroup.com/IAGOD2010 then click on downloadable program). The aim of IAGOD and the IGCP-502 leadership is that this symposium will highlight some of the achievements of IGCP-502.
Although IGCP-502 must inevitably end, the project members will continue their joint work and activities as a working group under the auspices of the Society of Applied Geology (SGA, www.e-sga.org) (see also below).

5. **Project funding requested**

No funding is requested from IGCP/IUGS. However, several projects set up during IGCP-502 will continue to be funded by other organisations.

6. **Request for extension, on-extended-term-status, or intention to propose successor project**

The leadership of IGCP-502 has proposed a successor project under the auspices of the Society of Applied Geology SGA, www.e-sga.org). We consider this the best way to preserve the scientific network of 215 scientists and the related projects set up during IGCP-502.

7. **Financial statement ($ USD only)**

The project was on extended term during 2009 and received no funds from IGCP. US$ 2,535,603 was obtained from other sources in 2009. A summary of this funding is attached in section 8.5.
8. ADDITIONAL INFORMATION NOT INCLUDED IN THE FIVE MAIN TEXT PAGES OF THIS REPORT

8.1. List of participants in IGCP-502 and their email addresses (215 members)

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8.2. List of publications in 2009 (including maps; no abstracts).

8.2.1. Most important peer review literature (those dated 2008 were actually published in 2009)


8.2.2. Books, Special Volumes and other peer reviewed publications


8.3. Update of the contents of the IGCP-502 Special Issue of Mineralium Deposita

Title: "Key issues and Controversies in the Geological Setting and Genesis of Volcanic-hosted Massive Sulphide (VMS) deposits"
Publication: Special volume of Mineralium Deposita Journal
Editors: Allen, Peter, Tornos

Contents
1) Introduction to the Special Volume and synthesis of results. Rodney Allen, Jan Peter, Fernando Tornos
2) Tectonic Settings of VMS Deposits. Richard Herrington + co-authors
3) The timing and location of VMS deposits in the evolution of the NE Honshu volcanic arc, Japan. Or: The roles of felsic and mafic arc magmatism in the formation of VMS deposits: evidence from the NE Honshu Arc, Japan. Ryoichi Yamada, Takeyoshi Yoshida
4) Volcanic facies and eruption styles related to kuroko-type massive sulphide deposits: a re-assessment based on the Hokuroku district, NE Japan. Rodney Allen, Takeshi Ohguchi
5) The relevance of recent studies of the modern ocean floor to understanding the tectonic and volcanic setting of ancient VMS deposits. Cornel de Ronde + co-authors

7) The Roles of Felsic and Mafic Magmatism in the Formation of VMS Deposits. Steve Piercey + co-authors

8) The Role of Magmatic Fluids and Volatiles in the Formation of VMS Deposits. David Huston + co-authors

9) Basinal fluids and the origin of massive sulfides: A numerical fluid flow study from the Iberian Pyrite Belt. Carmen Conde, Matthai, Fernando Tornos


11) A Critical Appraisal of the Role of Oceanic Anoxia in the formation of VMS Deposits. Wayne Goodfellow, Jan Peter, Steve Piercey

12) Black shales and massive sulphides: causal or casual relationships. Sáez, R., Moreno, C., Almodóvar, G.R. and González, F.

13) Hydrothermal sedimentary rocks associated with VMS deposits. Jan Peter and co-authors

14) The formation of gold-rich VMS deposits. Patrick Mercier-Langevin and co-authors

15) Textural and Chemical Evolution of Clastic Sulphide Textures in VMS deposits. Maslennikov and co-author(s) Bruce Gemmell, Ron Berry

16) Post-depositional tectonic modification of VMS deposits and its economic significance. Ricardo Castroviejo and Cecilio Quesada

17) Applicability of Heat and Fluid Flow Modelling in the Study of VMS Deposit Formation. Larry Cathles

18) Supergene alteration of VMS deposits. Paco Velasco + co-authors

8.4. Meeting reports:

8.4.1. IGCP-502 Symposium and workshop, Marrakech, Morocco

Title: The Hercynian Volcanic-Hosted Massive Sulphide Deposits of Morocco
Date: 22-28 March 2009
Place: Cadi Ayyad University, Marrakech, Morocco
Itinerary: Symposium on 22 March, followed by field workshop 23-28 March

Program for symposium, 22 March 2009
9:15 - 9:20 Opening remarks (R. Allen)
9:20 - 9:30 Welcome and instructions to foreign participants (A. Essaifi, A. Belkabir)
9:30 - 9:55 S. Brunet. The VMS deposits of the Marrakech region
Coffee Break
10:30-10:55 Moreno C. Biostratigraphical and paleoenvironmental features of the Draa Sfar massive sulphide deposit.
10:55 – 11:20 Belkabir A. Mineralogy and Hydrothermal Alteration of the Draa Sfar VMS Deposit.
11:20-11:55 Lotfi F. Geology, mineralogy and isotopic signatures of the Koudiat Aïcha polymetallic (Zn, Pb, Cu) massive sulphide deposit.
Lunch Break
Scope of Meeting
The meeting commenced with a one day symposium on VMS ore deposits of the Marrakech region (see above) that was attended by 30 participants from 10 countries. This symposium was followed by a five day field workshop to various ore deposits of the Marrakech region and the High Atlas Mountains. The field workshop was attended by 20 scientists from 10 countries, including Morocco, India, Turkey, Russia, Argentina and Saudi. Four women scientists and 7 PhD students attended the meeting and workshop.

Achievements of Meeting
• The Moroccan members of IGCP-502 organised and ran an excellent symposium and field workshop.
• The meeting was attended by a good mix of international experts, local Moroccan scientists, Mining industry geologists, scientists from developing countries and PhD students, with the result that there was excellent scientific exchange and multi-disciplinary debate.
• The formal presentations at the meeting were of high quality.
• The field workshop was supported by the Moroccan mining industry and especially the ONHYM-Managem group.

Outcome of Meeting
• Participants gained an appreciation of the geology and ore deposits of the Palaeozoic massifs of the Hercynian fold belt of Morocco.
• The Hercynian age massive sulphide deposits in Morocco are unusual compared to VMS deposits world-wide. They commonly occur in successions dominated by argillitic sedimentary rocks, and volcanic rocks are only locally abundant.
• The group concluded that there is considerable potential for new mineral discoveries of massive sulphide deposits in the Hercynian fold belt, and there is also great potential for future research of the known deposits.

8.4.2. Society for Geology Applied to Ore Deposits (SGA) Biennial Meeting
Title: Sediment- and volcanic-hosted copper-zinc-lead deposits
Date: 16-20 August 2009
Place: Society for Geology Applied to Ore Deposits (SGA) Biennial Meeting, Townsville, Australia

Program for symposium
Monday 17th August: Main Auditorium
Session B2: Sedimentary and volcanic-hosted Cu, Cu-Zn and Pb-Zn deposits
Chairs: Stuart Bull and Jan Peter

1.30-2.00 pm Keynote: Recent Advances in Understanding Mineralizing Processes in the Iberian Pyrite Belt, Jorge Relvas, University of Lisbon
2.00-2.15 pm  Mantle(?) volatiles in the Lombador orebody, Neves Corvo, Portugal, John Walshe, CSIRO

2.15-2.30 pm  Indium in the Lagoa Salgada orebody, Iberian Pyrite Belt, Portugal, Daniel de Oliveira, Nacional de Energia e Geologia

2.30-2.45 pm  Whole-rock oxygen isotope composition of the world-class Archean LaRonde Penna gold-rich VMS deposit, Georges Beaudoin, University Laval

3.30-5.30 pm  Poster Sessions 1: Student Posters

Wednesday 19th August: Main Auditorium
Session B2 (cont)
Sedimentary and volcanic-hosted Cu, Cu-Zn and Pb-Zn deposits
Chairs: Stuart Bull and Jan Peter

8.30-8.45 am  Genetic implications of a pervasive K-alteration zone at the Rosh Pinah VHMS-SHMS deposit, Namibia, Gregor Borg, Halle University

8.45-9.00 am  3D-modelling of the Central Skellefte District, Sweden, Tobias Bauer, University of Technology Sweden

9.00-9.15 am  High to intermediate sulfidation, shallow marine, sulfide mineralisation in the south-eastern Tyrrenian Sea, Italy, Bruce Gemmell, CODES University of Tasmania

9.15-9.30 am  Gold-rich shallow submarine hydrothermal systems along the Tonga Island Arc, Ulrich Schwarz-Schampera, Federal Institute Geosciences Natural Resources

9.30-9.45 am  The importance of seals (in the formation of stratiform sediment-hosted base metal deposits), Stuart Bull, CODES University of Tasmania

9.45-10.00 am  Sources of sulphur in the Katanga Copperbelt, Democratic Republic of Congo, Hamdy El Desouky, Katholieke University Leuven

10.00-10.30 am  Break

10.30-10.45 am  The stratiform Cu-Co ore deposits at Nkana-Mindola (Zambia): The influence of tectonism in their occurrence, Philippe Muchez, K.U. Leuven

10.45-11.00 am  Basin scale alteration features and their implications of ore formation in the Paleoproterozoic Peräpohja Schist Belt, northwestern Finland, Markus Kyläkoski, Geological Survey of Finland

11.00-11.30 am  "Keynote: A magmatic – hydrothermal origin for the giant Broken Hill Pb-Zn deposit, Anthony Crawford, CODES University of Tasmania

11.30-11.45 am  The Aggeneys-Gamsberg Zn-Pb Ore District, South Africa and Cannington Ag-Pb-Zn deposit Queensland Australia: Broken Hill-type birds of a feather?, Abraham Rozendaal, University Stellenbosch
1.00-1.15 pm The Bluebush prospect, NW Queensland: diverse base metal enrichments in a giant sedimentary pyrite deposit, Peter McGoldrick, CODES, University of Tasmania


1.30-1.45 pm A regional mineralizing event in the Mackenzie Mountains, Northwest Territories, Canada, Sarah Gleeson, University of Alberta

1.45-2.00 pm Regional and localized fluid flow in the Southern Irish Midlands: A hybrid fluid-flow model for the Rathdowney Trend, Aaron Johnson, Northwest Missouri State University

2.00-2.15 pm Supermountains and the genesis of (super)giant sediment-hosted stratiform Cu deposits, Rick Squire, Monash University

2.15-2.30 pm Ore textures and isotope signatures of the peridiapiric carbonate-hosted Pb-Zn deposit of Bougrine, Tunisia, Salah Bouhlel, University of Tunis el manar

3.30-3.45 pm A former oil-gas reservoir in the giant Jinding Zn-Pb deposit, SW-China: Implications for ore accumulation, David L Leach, U.S. Geological Survey /SGA

3.45-4.00 pm Geology and geochemistry of the lead-zinc carbonate-hosted MVT mineralization in the North Semnan, Central Alborz, Iran, Mohammad Ali Nekouvaght Tak, GeosMining Minerals Consultants

4.00-4.15 pm The German Kupferschiefer deposits – what about the precious metals? Sabine Walther, Martin Luther University

4.15-5.00 pm Poster Sessions 3

Scope of Meeting
IGCP-502 organised and convened session B2, a 2-day thematic session entitled “Sediment- and volcanic-hosted copper-zinc-lead deposits”. (http://sga2009.jcu.edu.au/program/working-themes-for-the-sga-sessions). Rodney Allen, Jan Peter, and Stuart Bull were the organizers and Peter and Bull were convenors. The session comprised 39 contributions presented by authors from 17 countries. Each accepted oral and poster abstract was published as a 4-page extended abstract in a Conference Proceedings volume, co-edited by Allen, Peter, and Bull.

Achievements of Meeting
• The IGCP-502 session was the largest, best attended, and most successful of the whole SGA meeting.
• The presentations and abstracts were of very high quality.

Outcome of Meeting
• Many excellent new interpretations were presented for the origin of sediment- and volcanic-hosted copper-lead-zinc deposits, ranging from Broken Hill in Australia to Jinding in China.
The IGCP-502 session highlighted the similarities and differences between the sediment-hosted and volcanic-hosted ore deposit types; and especially that there are both strong similarities and differences.

The group concluded that it will be of considerable benefit for future research to compare and contrast the sediment- and volcanic-hosted ore deposit types.

8.5. Additional funding obtained by project members from other sources (only funding for 2009 is shown)

Vinnova-Industry 4D modelling of the Skellefte VMS district, Sweden: 650,000 USD
Swedish Geological Survey-Mining industry: VMS research, Bergslagen 150,000 USD
Boliden Mineral and Lulea University, Sweden, for IGCP-502 coordination 20,000 USD
CAMIRO (Canada): Geochemistry of shales/exhalatives in vectoring to ore 65,000 USD
Canadian Foundation for Innovation and Ontario Research Fund: Effects of geosphere-biosphere interface on element migration in the near surface. 831,703 USD
Strategic Investment in Northern Economic Development (SINED) Canada:
Hyperspectral data in the detection of hydrothermal alteration 495,000 USD
MTA Turkey: VMS type massive sulphide deposits in the Pontides 104,000 USD
MTA Turkey: International collaboration with IGCP-502: 30,000 USD
MTA Turkey: Cyprus type VMS deposits of Eastern Anatolian Region 95,400 USD
NBDNR-Minerals (Canada) funding for MSc and PhD projects 88,500 USD
Japan Mining Industry Association: Joint Japan-Russia workshop on VMS 6,000 USD

Total additional funding 2,535,603 USD

Rodney Allen, Fernando Tornos, Jan Peter
21 December 2009