Annual Report* of IGCP Project No. 502

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

Duration: 2004 - 2008

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Project Secretary: Rodney Allen (see address above)

Date of submission of report: December 19, 2008

Signature of project leader(s):
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 39 scientists from 21 developing countries and postgraduate students. This network now comprises 207 scientists from 43 countries.
- Increased level of cooperation amongst several government institutions and private mineral resource companies in Turkey, Russia, Namibia, Mexico, Morocco, Canada, Sweden, Spain, Australia and Saudi Arabia. This increased cooperation has been of tangible benefit to all involved, and especially to scientists in the developing countries.
- 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.
- 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. Papers on these topics are included in the IGCP-502 special volume (see below).

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

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

IGCP-502 has 207 participants (see list at section 8) from the following 43 countries. During 2008 we attracted 14 new members and increased our coverage to 2 new countries.

| Argentina* | Great Britain* | Norway* |
| Brazil* | Greenland | Oman |
| Bulgaria | India* | Peru |
| Canada* | Iran* | Portugal |
| China* | Ireland | Russia* |
| Cuba | Japan* | Saudi Arabia |
| Czech Republic* | Kosovo | South Africa* |
| Denmark* | Malaysia | Spain* |
| Equador | Mexico | Sweden* |
| Finland* | Morocco* | Switzerland* |
| France | Myanmar | Turkey* |
| Ghana | Namibia | USA* |
| Georgia | New Zealand* | Venezuela |
| Germany* | | |
3.2. General scientific achievements and social benefits (Meetings listed under heading 3.3.)

- The IGCP-502 group produced a large number of high quality publications during 2008 (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 2008 (see sections 4.1, 8.3).
- The Turkish team has been very engaged in IGCP-502. During 2008, they carried out applied research in the Giresun, Trabzon and Eastern Anatolian regions. An exciting result is the discovery of a copper-rich massive sulphide horizon along the Eastern Anatolian Thrust Zone. Preliminary results suggest that this new mineralization is a Cyprus-type massive sulphide. Drilling and further studies are underway to determine whether the new discovery can lead to a mining operation.
- The Russian team discovered hydrothermal vent chimneys for the first time in the Palaeozoic VMS deposits of Nikolayevskoe, Artemyevskoe, Zarechnoe and Molodezhnoe.

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

3.3.1 33rd International Geological Congress, Oslo, Norway, 6-14 August 2008
IGCP-502 organised the scientific session MRD-08 entitled: “Volcanic-hosted massive sulphide deposits - Controls on distribution and timing”. 28 excellent papers were presented by authors from 17 countries, including the developing countries India, Yemen, China, Russia, Iran, Mexico and Argentina (see meeting report below).

3.4. Educational, training or capacity building activities

3.4.1. Field workshops
IGCP-502 ran two field workshops this year. The first workshop was run in the Bergslagen mining district in Sweden in cooperation with the 33rd IGC (Excursion 12, see meeting report below). This workshop had 30 participants from 14 countries. The second field workshop was run in Kasakhstan and Russia with focus on the Rudny Altay VMS deposits. This workshop was attended by 8 scientists from Kasakhstan, Russia and England. 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. This year the field workshops provided an opportunity for 17 scientists from developing countries and 3 PhD students to interact with VMS specialists in the IGCP-502 group.

3.4.2. Post-graduate students
Ten PhD and MSc students have been sponsored by, or involved with, IGCP-502 activities during 2008: Fardin Mousivand (Iran), Alireza Monazami (Iran), Marcello Imana (Peru), Carmen Conde (Spain), Joseph Zulu (Africa), Hannah Grant, William Gray and Amanuel Bein (Canada), Peter Dahlin and Nils Jansson (Sweden).

3.4.3. Collaboration and capacity building activities
IGCP-502 continues to assist scientists in Iran, Namibia, Peru, Russia, Turkey and Morocco (see previous reports). These projects are aimed at introducing new technology, methods and experience to the local organizations. This year, collaboration between the Spanish, Canadian, French and Moroccan teams resulted in 10 major publications on VMS deposits in Morocco (e.g. Belkabir et al., 2008; Marcoux et al., 2008; Moreno et al., 2008; see full list in section 8.2). In Turkey the Mineral Research and Exploration Authority (MTA) has 3 projects in collaboration with IGCP-502 for which MTA provided 547,000 USD. The Czech team continued collaboration with the Spanish team on the distribution of PGE in VMS deposits of
the Iberian Pyrite Belt (Pasava et al. 2007), and with IFM-GEOMAR (Germany) on the study of PGE fractionation in seafloor hydrothermal systems (Pasava et al. 2007).

3.4.4. Short courses
IGCP-502 members ran 5 short courses during 2008. J. Peter presented “Hydrothermal sediments” and “Target Vectoring for Massive Sulfide Deposits” in Sudbury Canada; S. Piercey and J. Peter presented a course on VMS deposits to the Newfoundland and Labrador Chamber of Mineral Resources; F. Tornos presented "Sulfuros masivos y su encuadre geológico" at the XIII Congreso Latinoamericano de Metalogenia in Lima Peru; M. Hannington presented a course on VMS deposits in Turku Finland; and P. Golani held a short course on ore deposit modeling and mineral exploration at Zawa Mines, Udaipur, India.

3.5. Participation of scientists from developing countries, and in particular young and women scientists
The project’s 207 members include 39 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, Venuzuela 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 5 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.

Scientists from Morocco, Turkey, Russia, Iran, India, Argentina, Mexico, China and South Africa 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. Publications in 2008 (including maps; no abstracts).
The projects incorporated within IGCP-502 produced 56 major peer-review papers, and 8 books and other peer-review publications during 2008 (see list in section 8.2).

3.7. Activities involving other IGCP projects, UNESCO, IUGS or others
Collaboration and capacity building activities continue in Namibia and stem from the joint field workshop held by IGCP-450 and IGCP-502 in Namibia and South Africa in 2005.

The Finnish team has collaborated with IGCP- 486 in joint research on Bi-Pb-Te sulphide minerals.

4. Activities planned
4.1. General goals
The general goal of IGCP-502 is to make a major step forward in the understanding of where, when and how VMS deposits form during the evolution of extensional plate margin terranes. We believe that in order to make this step forward it is essential to compare and contrast the geology of the world’s major VMS mineral belts so that the critical common features can be distinguished from the myriad of other less important features. The IGCP-502 field workshops are an important step toward realizing this goal. To date IGCP-502 has run field workshops in 10 VMS belts in 12 different countries.

A major specific goal is the IGCP-502 Special Issue of Mineralium Deposita Journal. An update on the contents of this volume is provided in section 8.3 below. The volume is
scheduled to contain 18 papers; about half of the manuscripts have been received by the editors. The other half should be submitted during the first half of 2009. Due to delays by authors, our estimate for the publication date has been shifted to late 2009.

4.2. Tentative list of specific meetings and field trips (please list the participating countries)

4.2.1. IGCP-502 Field workshop, Morocco, March 22-28, 2009
A 7-day field workshop to discuss the geology and genesis of VMS deposits of the Marrakech region has been organised by the Moroccan team of IGCP-502. To date we have received registrations from Morocco, Argentina, Turkey, Sweden, Spain, Canada and New Zealand.

4.2.2. Society for Geology Applied to Ore Deposits (SGA), Townsville, Australia, 2009
SGA is one of the largest scientific organisations in the world concerning earth science applied to ore deposits. IGCP-502 has been invited by SGA to run the major scientific session on “Base metal ore deposits” at the bi-annual congress in 2009. We have accepted this offer.

4.2.3. Geology of the Black Sea Region, Ankara, Turkey, October 2009
IGCP-502 is invited to run the session on “Mineral Deposits and Metallogeny of the Black Sea region” at the International Symposium on the Black Sea Region in Ankara.

4.3. Publication in Episodes Journal
IGCP-502 plans to write an article for Episodes Journal during 2009 on the goals and accomplishments of the project and future work needed.

5. Project funding requested

IGCP-502 requests full funding from IGCP/IUGS. Section 7.2 and 8.7 provide details of funding that was granted to IGCP-502 from other sources for 2008. A similar amount of funding has been requested from these organisations for 2009.

6. Request for extension

IGCP-502 "Global VMS Project" is now in the fifth year. We would like to extend the project for one more year. Reasons for an extension are:
1. We are in the middle of writing and editing a special IGCP-502 volume on VMS deposits for Mineralium Deposita. We see now that this volume will take at least until the second half of 2009 to complete (see more details in sections 4.1 and 8.3).
2. The Moroccan team, who have been active in the IGCP-502 project, have organised an IGCP-502 meeting for March 2009. This is an important opportunity for Moroccan earth scientists to work together and organise an IGCP meeting.
3. IGCP-502 has been invited to organise scientific sessions at international conferences in Australia and Turkey in 2009 (see details above).

7. Financial statement ($ USD only)

7.1. Use of IGCP funds

IGCP-502 was allocated US$ 8,000 for 2008 by the IGCP committee. This funding was used completely to support project members, especially those from developing nations, to attend project meetings. The financial statement is attached below in section 8.

7.2. Additional funding obtained from other sources (funding for 2008 only is shown)

US$ 2,569,000 was obtained from other sources in 2008. Details are attached in section 8.7.
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 (207 members)

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8.2. List of publications in 2008 (including maps; no abstracts).

8.2.1. Most important peer review literature (those dated 2007 were actually published in 2008)


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) What are the large-scale volcanic-tectonic structures that host clusters of VMS deposits: rift basins, calderas, cauldrons? Harold Gibson, Rodney Allen
6) 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
8) The Roles of Felsic and Mafic Magmatism in the Formation of VMS Deposits. Steve Piercey + co-authors
9) The Role of Magmatic Fluids and Volatiles in the Formation of VMS Deposits. David Huston + co-authors
10) Basinal fluids and the origin of massive sulfides: A numerical fluid flow study from the Iberian Pyrite Belt. Carmen Conde, Matthai, Fernando Tornos
12) A Critical Appraisal of the Role of Oceanic Anoxia in the formation of VMS Deposits. Wayne Goodfellow, Jan Peter, Steve Piercey
13) Black shales and massive sulphides: causal or casual relationships. Moreno, C., Sáez, R., Almodóvar, G.R. and González, F.
14) Hydrothermal sedimentary rocks associated with VMS deposits. Jan Peter 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
Applicability of Heat and Fluid Flow Modelling in the Study of VMS Deposit Formation. Larry Cathles

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


Title: Volcanic-hosted massive sulphide deposits - Controls on distribution and timing
Date: 11 and 14-20 August 2008
Place: 33rd IGC Oslo Norway
Itinerary: Symposium MRD-08 at 33rd IGC on 11 August, followed by field workshop in Sweden 14-20 August

Scope of Meeting
This meeting comprised a 1-day symposium in Oslo followed by a 6 day field excursion in the Bergslagen mining district, Sweden. The symposium included 28 presentations with authors from 17 countries. The symposium opened with a group of presentations on the regional tectonic, volcanic and structural settings of VMS deposits world-wide and in Iran, India, Spain and Finland. This was followed by a group of presentations on specific VMS deposits and exploration strategies in the Bergslagen and Skellefte mining districts in Sweden, and Bathurst, Canada. The symposium then focused on specific features of modern and ancient VMS hydrothermal systems, and finally on the application of new concepts and analytical techniques. Each section started with a longer introductory presentation, which was followed by shorter specific studies. Valery Maslennikov (Russia) delivered the keynote paper: Trace elements in ancient and modern “black smokers”. The poster session comprised a diverse and interesting range of studies on VMS deposits and mining districts in Yemen, Iran, China, Mexico, Sweden, Canada, Argentina (Deception Island) and Japan. The symposium was attended by about 200 scientists and generated lively discussion. The field workshop was attended by 30 scientists from 14 countries, including the developing countries listed above. Six women scientists attended the meeting.

Achievements of Meeting
• The meeting was attended by field geologists, modern seafloor specialists, igneous petrologists, ore deposit geologists and geochemists, with the result that there was excellent scientific exchange and multi-disciplinary debate.
• The 28 formal presentations at the meeting were of very high quality.
• The meeting was attended by a good number of scientists from developing countries (see above) and PhD students.
• The field workshop was well supported by the Swedish mining companies: Boliden Mineral, Zinkgruvan Mining and Dannemora Mineral.

Outcome of Meeting
• Participants gained an appreciation of the geology and ore deposits of the Bergslagen mining district, which is one of the most unusual and scientifically exciting metal mining provinces in the world.
• Discussions during the field workshop led to the conclusion that the unusual polymetallic ore deposits in the Bergslagen Province include features typical of VMS, SEDEX, intrusion-related skarn and Broken Hill-type deposits. The Bergslagen ore deposits are difficult to classify as just one of these ore deposit types.
• A group of scientists made a plan to propose an international multi-disciplinary project to study the similarities and differences between the Bergslagen polymetallic ore deposits and two other regions where similar geology and ore deposits are thought to occur: Broken Hill, Australia, and Gamsberg, South Africa. This proposal will be submitted to
funding organisations and mining companies in Sweden, South Africa and Australia during 2009.

8.5. Financial statement for 2008

IUGS funds forwarded by IUGS treasurer USD 8000

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8.7. Additional funding obtained from other sources (only funding for 2008 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
Spanish Ministry of Education and Science, for IGCP-502 coordination 8,000 USD
MTA Turkey, applied VMS research associated with IGCP-502: 547,000 USD
Iranian Grant to M. Ziaii: for study of VMS deposits in Iran 50,000 USD
GNS Science New Zealand for research of VMS deposits and the sea floor: 700,000 USD
CNRS (Canada) grant to Nick Arndt for study of Kidd Creek ore deposit 3,750 USD
Geological Survey of Canada TGI-3: Study of LaRond-Bousquet area 50,000 USD
CAMIRO (Canada) “Hydrothermal event recognition” 130,000 USD
DIVEX Canada: “Mineralogy applied to mineral exploration” 130,000 USD
NSERC Discovery Grant Canada to S. Piercey 18,000 USD
Aur Resources/Teck-Cominco: Study of Duck Pond VMS deposit, Canada 25,000 USD
Sabina Silver Corporation, Canada: Silver in Hackett River VMS, Nunavut 12,000 USD
Russian Academy of Science: “Global comparison of ore facies of VMS” 10,000 USD
Czech Geological Survey: Grant to J. Pašava. 2,250 USD
Australian Research Council grant to study the tectonics of VMS deposits 10,000 USD

Total additional funding 2,569,000 USD

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