ESF Magellan Conference: Large Igneous Provinces and Mass Extinctions

Vienna, Austria, 7-10 May

Theme and aims of the workshop

At both margins of the northern Atlantic, sedimentary rocks are overlain by flood basalts and are invaded by basaltic intrusions. The magmatic rocks are parts of the North Atlantic Volcanic Province, which initially erupted onto the continents in Greenland and Ireland and subsequently into the sedimentary basin that developed as rifting proceeded some 55 million years ago. Sequences of submarine eruptions, observed as seaward-dipping reflectors in seismic profiles, occur in the north, central and southern Atlantic and parts of the Indian Ocean margin. Older examples of large igneous provinces are preserved on the continents, as, for example, in the East Siberian sedimentary basin and the Siberian flood basalt province.

Volcanic basins are of major interest to academic and industry geologists for several reasons:

- The origin of large igneous provinces is subject of intense debate amongst petrologists, geochemists and geodynamicists; one school believes that the provinces formed through melting in large mantle plumes and are thus a manifestation of an unusual style of mantle dynamics; the other school relates them to normal plate tectonic processes. Resolution of the issue has major implications for magma-forming processes and large-scale mantle geodynamics.
- The large petroleum reservoirs occur off the coasts of Norway, Brazil, Angola, NW Australia in basins invaded by basaltic intrusions. The intrusions complicate interpretation of seismic profiles and constitute a special type of petroleum trap. Intrusion of basaltic magma influenced the development and maturation of the petroleum deposits.
- The world's richest Ni-Cu-platinum-element deposit, at Noril'sk-Talnakh in Russia, is hosted by basaltic intrusions in the Siberian sedimentary basin and other similar deposits are a target of major mineral exploration companies in other regions.
- Eruption of flood basalts and the intrusion of magma into sedimentary basins impacted global climate. The emplacement of the North Atlantic Volcanic Province coincides with the Paleocene-Eocene thermal maximum; the emplacement of basaltic magmas in Siberia probably caused the end-Permian mass extinction, the largest biological crisis in the evolution of life on Earth. The linkage between magma-sediment interaction and thermogenic gas emissions has important implications for long-term climate evolution, including that of the present day.

Volcanic-sedimentary sequences at continent margins have been targeted by numerous expeditions of the ocean-drilling program (e.g. Legs 104, 120, 152, 163, 183) as well as by dredging and geophysical studies of national oceanographic programs. Both on-shore and off-shore segments of large igneous provinces have been explored by drilling.

The specific goal of our meeting was to bring together scientists from numerous disciplines and of diverse backgrounds in order to discuss how combined oceanic and continental drilling could address the scientific issues outlined above and provide guidelines and information for exploration companies in their search for petroleum and mineral deposits. To investigate the scientific issues required the input of field and structural geologists, volcanologists, petrologists, sedimentologists, geochemists, geophysicists, petroleum and mineral-deposits geologists, paleontologists, atmospheric chemists, and climate modelers. Interaction was encouraged between scientists of all these disciplines, as well as between academic and industry scientists and members of the ocean- and continental drilling programs.

Organization and Realization of the Workshop

The Workshop was made up of three separate but related activities: a half-day session at EGU, a one-day workshop on the Siberian traps, and a two-day workshop on volcanic basins. An NSF grant funded the Siberia session and the ESF funds were used for the two-day Magellan workshop. Most participants attended all three days. By combining the three activities we were able to attract a large group of high-level, multinational scientists to Vienna and to contribute to a very successful session at EGU.

(1) A session at the Annual Meeting of the European Geosciences Union (EGU). This session on Friday 7th May 2010, called "Large Igneous Provinces and Mass Extinctions" was convened by Henrik Svensen and Lindy Elkins-Tanton. We held it specifically on Friday afternoon so as to combine with the workshop sessions on the weekend and despite this unfavourable time slot, the room was continually full with about 130 participants.

Program

Mark Richards and Victoria Ridley Deep Crustal Structure beneath Large Igneous Provinces and the Petrologic Evolution of Flood Basalts

Anatoly Nikishin, Konstantin Sobornov, and Natalia Pravikova Lithospheric inhomogeneity - the main factor controlling the Permo/Triassic Siberian plume location

Seth D. Burgess and Samuel A. Bowring Evaluating a link between eruption of the Siberian Traps and the End-Permian Mass Extinction with high-precision geochronology

Vladimir Pavlov, Frederic Fluteau, Roman Veselovsky, and Anna Fetisova Geomagnetic secular variations and volcanic pulses in the Siberian traps

Benjamin A. Black, Linda T. Elkins-Tanton, Michael C. Rowe, and Ingrid Ukstins Peate Volatile Release From The Siberian Traps Inferred From Melt Inclusions

Ingrid Aarnes, Henrik Svensen, Stephane Polteau, James A. D. Connolly, Yuri Y. Podladchikov, and Sverre Planke Large scale sediment degassing during contact metamorphism of shales in volcanic

Henk Visscher, Henrik Svensen, Cindy Looy, Kirsten Fristad, Alexander Polozov, and Sverre Planke Palynological constraints on timing and duration of Siberian Traps volcanic events

Jonathan Payne, Mindi Summers, Brianna Rego, Demir Altiner, Youyi Yu, Jiayong Wei, and Daniel Lehrman Recovery of foraminifers from end-Permian mass extinction: A case study from a carbonate platform in southern China

Giada Iacono-Marziano, Virginie Marecal, Michel Pirre, Nicolas Arndt, Clément Ganino, and Fabrice Gaillard The Fate and Environmental Consequences of Reduced gas Mixtures Resulting from Magmatic Intrusion into Carbonaceous Rocks

Marco Roscher, Henrik Svensen, and Frode Stordal Climate models of the end-Permian - challenges and perspectives

Roland Mundil, Steve Denyszyn, Bin He, Ian Metcalfe, and Xu Yigang Emeishan volcanism and the end-Guadalupian extinction: New U-Pb TIMS ages

Fred Jourdan and Lena Evins The Kalkarindji Large Igneous Province and the Early-Middle Cambrian Extinction.

(2) Saturday May 8, 2010: Siberia workshop

Program

Geochronologic constraints

8:45 Andy Saunders

9:00 Seth Burgess

Petrologic investigations

9:15 Ben Black: Lava, tuff, and intrusive melt inclusions and volatile release

9:30 Alexander Polozov: Melt inclusions from the Nepa pipe

9:45 Ingrid Aarnes: Modelling of aureoles and experimental results

10:00 Kwan-Nang Pang : Geochemistry of Noril'sk aureoles

Tectonic and geophysical investigations

10:30 Volodia Pavlov and Roma Veselovskiy

10:45 Anatoly Nikishin

11:00 Lev Vinnik

Paleontology

11:15 Jon Payne

11:30 Katya Meyer

12:00 PM LUNCH

Climate

1:00 Marco Roscher: Siberian Traps and paleoclimate modeling

Summary and outlook for field work and sampling

1:15 Lindy Elkins-Tanton: Existing sample collection and 2010 field plans

1:30 Sverre Planke: Project background and new Siberia fieldwork plans

2:30 PM CLOSED SESSION for PROJECT MEMBERS

(3) Sunday May 9: Magellan conference; "Volcanic basins: scientific, economic and environmental aspects"

Program

9:00-9:40 "Barren' and "fertile" LIPs – Steve Barnes

Background information and description of selected provinces

9:40 Mantle plumes and flood volcanism – A. Saunders (Univ Leicester)

10:20

Coffee 11:00

11:10 Off-shore Norway – S. Planke (Univ Oslo)

11:40 Antrim volcanics – M. Cooper (BGS, Belfast)

Lunch 12:30

13:30 Karoo – S. Polteau (Univ Oslo)

Important processes

14:10 Tectonic framework – T. Torsvik (Univ Oslo)

14:50 Contact metamorphism and venting – H. Svensen

Coffee – 15:30

16:00 Degassing during magma-carbonate interaction – G. Iacono-Marziano, F. Gaillard

16:40 Discussion

Monday May 10: Magellan conference

Applied aspects

9.00 Magmatic ore deposits – N. Arndt,

9.40 Ore deposits in the Siberian province - A. Polosov

10:20 Petroleum in volcanic basins – S. Planke (Univ Oslo)

Coffee 11.00

11:30 Durham Volcanic Margin Consortium: An academic industry partnership for research and training – D. Jerram (Durham)

Lunch

13.30 Discussion and conclusions

Outcomes of the Workshop

(1) Science

The main scientific product of the workshop was the exchange of new information and interpretation presented by speakers during the four days of seminars and talks, followed by active discussion of various controversial issues. These covered the complete range of discipline presented by the participants, from field and structural geology, volcanology, igneous and metamorphic petrology, paleontology, geochemistry and geophysics, petroleum and mineral deposits studies and atmosphere and climate modelling. Notable examples of fruitful interchanges are:

- Interaction between petrologists, geochemists, paleotologists and climate modelers to quantify the amount and types of thermogenic gases released from aureoles around intrusions, to model their dispersion through the atmosphere and to predict their impact on the biosphere. The contrasting effects of the expulsion of CO_2 and other greenhouse gases which cause rapid but progressive heating that indirectly impacts the biosphere, was contrasted with the release of toxic gases like SO_2, CO and the halocarbons whose impact is more immediate. The long-term effects as the biosphere recovered were also discussed.
- The mechanism of emplacement of intrusions beneath flood volcanic provinces received the attention of field geologists, petrologists, geochemists, structural geologists and physical modellers. Attention was focused on the dimensions, mineralogy and geochemistry of contact metamorphic aureoles because this

information was key to modelling the extent of gas release. It was shown that the width of aureoles varies greatly, a variation that was attributed in part to the dynamics of magma flow through the intrusion and in part to the characteristics, particularly the fluid content, of the wall rocks.

- Interaction between petrologists, geochemists, geodynamicists and geophysicists who discussed the causes of flood volcanism and more generally the nature of the mantle source and how it interacted with the oceanic or continental lithosphere. The question of whether that source was a plume was considered (most participants thought so), and models describing the detailed effects of a large plume on the continental lithosphere were presented and evaluated.
- The question of the timing of flood volcanism and mass extinctions was addressed using new extremely high quality data form the laboratories of several participants. Direct comparison was made between the ages of igneous intrusions and tuffs from type stratigraphic sections. It was shown that at the level of quality of most laboratories, the match between Siberian flood volcanism and the Permian-Triassic boundary was excellent, but some cutting-edge data from MIT reveals some discrepancies.

(2) Practical outcomes

Another level of interaction involved discussions between scientists universities and governmental organizations about how to develop the applied aspects of the program. Unfortunately no representatives for the organizing committees of the international oceanic and continental drilling programs (IODP, ICDP, ECORD) were able to attend the workshop. On the other hand we had scientists from the Geological Survey of Northern Ireland, the Australian CSIRO, and the Volcanic Basin Petroleum Research of Norway. Notable talks were:

- Mark Cooper from the Northern Ireland Geological Survey gave an overview of the geophysical and geochemical data obtained during the Tellus program and described how these data could be used to improve our knowledge of the magmatic and tectonic history of the Antrim basalts, part of the North Atlantic Magmatic Province. He also described activities of mineral exploration companies in the region, and on the basis of this, a cooperative research program was set up between the Universities of Grenoble, Glasgow and Oslo, the Northern Ireland Geological Survey and Lonmin, a mineral exploration company. Two Masters level students will spend their summer breaks working in Northern Ireland and Scotland on this project.
- Alexander Polosov of the Institute of Geology of Ore Deposits in Moscow described iron deposits in magnetite pipes around the fringes on the Siberian flood volcanic province. He related textures and structures in these pipes to escape vents of thermogenic gases released from contact aureoles surrounding sills of the magmatic provinces and described how they could be modelled using the approaches developed by geologists and physicists of the University of Oslo.
- Steve Barnes of the CSIRO described the work that his group have made in the development of tools that can be used for the exploration for magmatic Ni-Cu sulfide deposits and discussed how these tools might be applied to the North Atlantic Magmatic Province.

- Sverre Planke of the Volcanic Basin Petroleum Research organisation described his work on the petroleum fields off the coast of Norway and the influence that magmatic intrusions have on the formation of, and exploration for, these deposits.
- Dougal Jerram gave an overview of the Academia-Industry partnerships that are being developed at Durham University and discussed how participants of the workshop might become involved.

Participants : Breakdown by country

Australia	1
Austria	1
China	1
France	4
Germany	1
Ireland	1
Netherlands	3
Norway	7
Philippines	1
Russia	7
Switzerland	1
UK	4

Participant List - Magellan Conference

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Budget

	Euros
Administration fee for Floralis (6%)	720
Room rental	3099,42
Projector rental	524,99
Catering - lunch and coffee breaks	2981,84
Conference dinner	1527,6

Reimbursements to participants

Arndt Nick	520
Bryan Scott	600
Fernandes, Karina	298
Gaillard, Fabrice	520
Iacono-Marziano, Giada	214
Jerram Dougal	480
Pang Kwan-nang	1191
Planke Sverre	520
Polteau, Stephane	520
Roscher, Marco	520
Saunders, Andy	269
Tejeda Maria	191
Visscher, Henk	600
	6443

Total cost	15 296,85
Funds from ESF	15 000
Deficit (paid by N. Arndt)	296,85