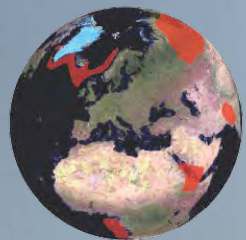


VMAPP: Product Overview



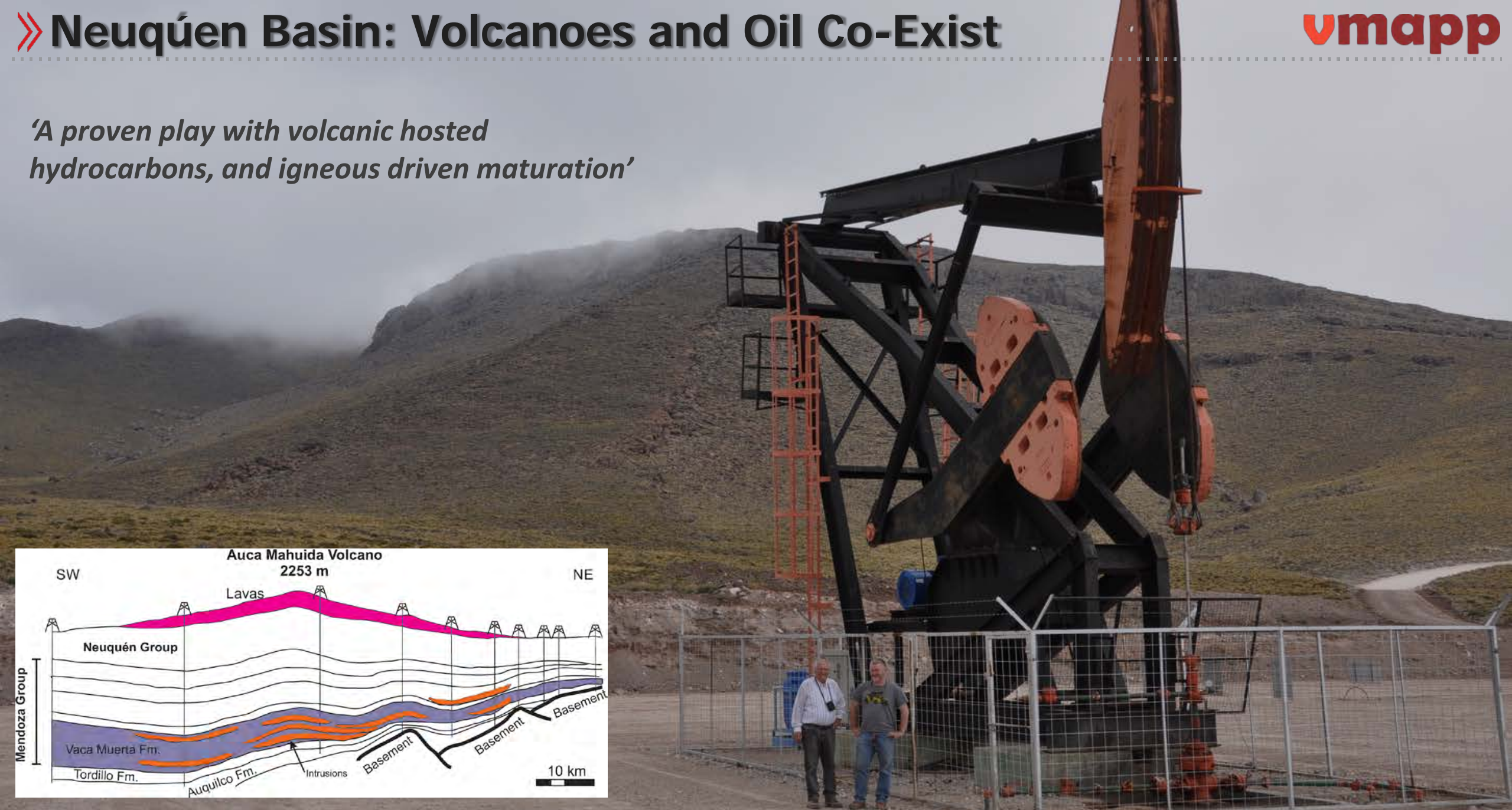
vmapp
Volcanic Margin
Petroleum Prospectivity



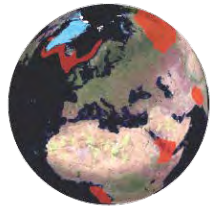
Confidential Document
Version 3
07/04/2017
www.vbpr.no

>> Neuquén Basin: Volcanoes and Oil Co-Exist

'A proven play with volcanic hosted hydrocarbons, and igneous driven maturation'



>> Production well near summit of Auca Mahuida volcano (sketch from Rossello et al., 2002)



vmapp

**Volcanic Margin
Petroleum Prospectivity**

Aim: *New understanding and training on volcanic margin deposits and processes for higher exploration success*

Audience: *Petroleum companies exploring rifted margins and volcanic basins - targeted information for explorers, seismic processors, petrophysicists, basin modelers and drilling engineers*

Core Modules

Manuals and training material

Research Modules

Main petroleum prospectivity issues in volcanic basins

Consultancy

Optional in-house consultancy on proprietary data

Field Workshops

The team have long experience in running field workshops worldwide



Project group

Three companies (VBPR, DougalEARTH and TGS) with long and complimentary experience in petroleum exploration of volcanic margins and volcanic basins world-wide

Duration: 2013-2016

Full multi-client project
Available from Jan 2017

Reports

CM1 | Volcanic systems and deposits

- Volcanology
- Volcanic classification systems
- Geodynamics and plumbing systems
- Sills, dikes and vent complexes
- Extrusive volcanics

CM2 | Petrophysical properties and drilling

- Volcanic borehole geology
- Wireline, cuttings and core analysis
- Drilling through volcanics
- Integrated borehole best practices

CM3 | Sub- and intra-basalt seismic imaging

- Best practices for seismic imaging
- Wave propagation in igneous rocks
- Geophysical models of volcanic sequences
- Case histories

CM4 | Seismic interpretation of igneous units

- Data screening and QC
- Interpretational methods
- Best practices for seismic interpretation
- Case histories and pitfalls

CM5 | Volcanic basin petroleum systems

- The total petroleum system and volcanics
- Advantages and disadvantages
- Play models and worldwide examples

Key contributors

CM1 coordinator: Dougal Jerram

- John Millett (VBPR)
- Olivier Galland (Univ. of Oslo)
- Richard Walker (Univ. of Leicester)
- Nick Schofield (Univ. of Aberdeen)

CM2 coordinator: John Millett

- Dougal Jerram (DougalEarth)
- Anne Wilkins (Univ. Aberdeen)
- Sverre Planke (VBPR)

CM3 coordinator: Sverre Planke

- Stephen Bannister (GNS, New Zealand)
- Dwarika Maharjan (VBPR)

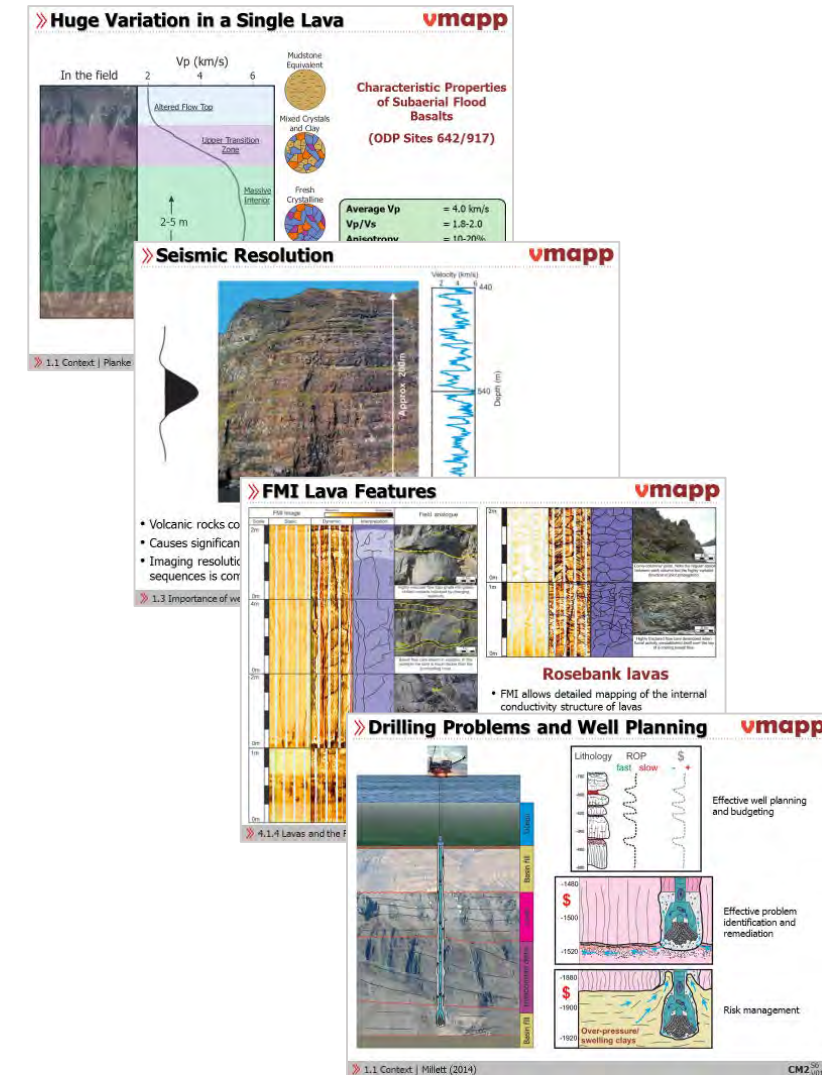
CM4 coordinator: Dougal Jerram

- Nick Schofield (Univ. of Aberdeen)
- Sverre Planke, John Millett (VBPR)
- Ben Manton, Dwarika Maharjan (VBPR)

CM5 coordinator: John Millett

- Karthik Iyer (Geomodelling Solutions)
- Olivier Galland, Henrik Svensen (Univ. of Oslo)
- Nick Schofield (Univ. Aberdeen)
- Dougal Jerram (DougalEarth)
- Sverre Planke (VBPR)

Strong project group with diverse backgrounds in volcanic margin and basin research





Box Set of Manuals

Five printed bound modules in box set with digital files including:

- Manuals
- Modules as PDFs
- Accompanying PowerPoints of each Core Module



Reports

RM1 | The basalt - sediment transition

- Improved confidence on base basalt interpretation
- Intra- and sub-basalt reservoir potential
- Sub-basalt imaging
- Field analogues and cases (e.g. Greenland, Africa)

RM2 | Volcanic petrophysics

- Volcanic reservoir properties
- Developments in volcanic borehole analysis
- Petrophysical database
- Field/borehole cases (Iceland, Hawaii, Skye)

RM3 | Maturation and migration

- Intrusion induced maturation
- Fluid expulsion around sills
- Hydrothermal vent complexes
- Petroleum system modeling

RM4 | Rift to drift transition

- Breakup volcanism
- Nature of continent-ocean transition
- Thermal evolution of rifted margins
- NE Greenland sills and vent complexes
- Case histories

RM5 | Evaporites, carbonates and volcanics

- Salt-magma interaction and gas generation
- Carbonate-volcanic sequences
- Influence on fluid migration and trapping
- Basin modeling
- Field analogues and cases (e.g. Siberia)

Key researchers

RM1 coordinator: Sverre Planke

- Dwarika Maharjan, Amer Hafeez, John Millett (VBPR)
- Dougal Jerram (DougalEarth)
- Processing by TGS, PSS-GEO, DECO

RM2 coordinator: John Millett

- Dave Healy, Natalie Farrell (Univ. of Aberdeen)
- Sverre Planke (VBPR)
- Dougal Jerram (DougalEarth)
- IMAGE - Iceland VSP (EU Project)
- Univ. of Hawaii / ICDP
- OSG of ICDP, GFZ Potsdam

RM3 coordinator: Sverre Planke

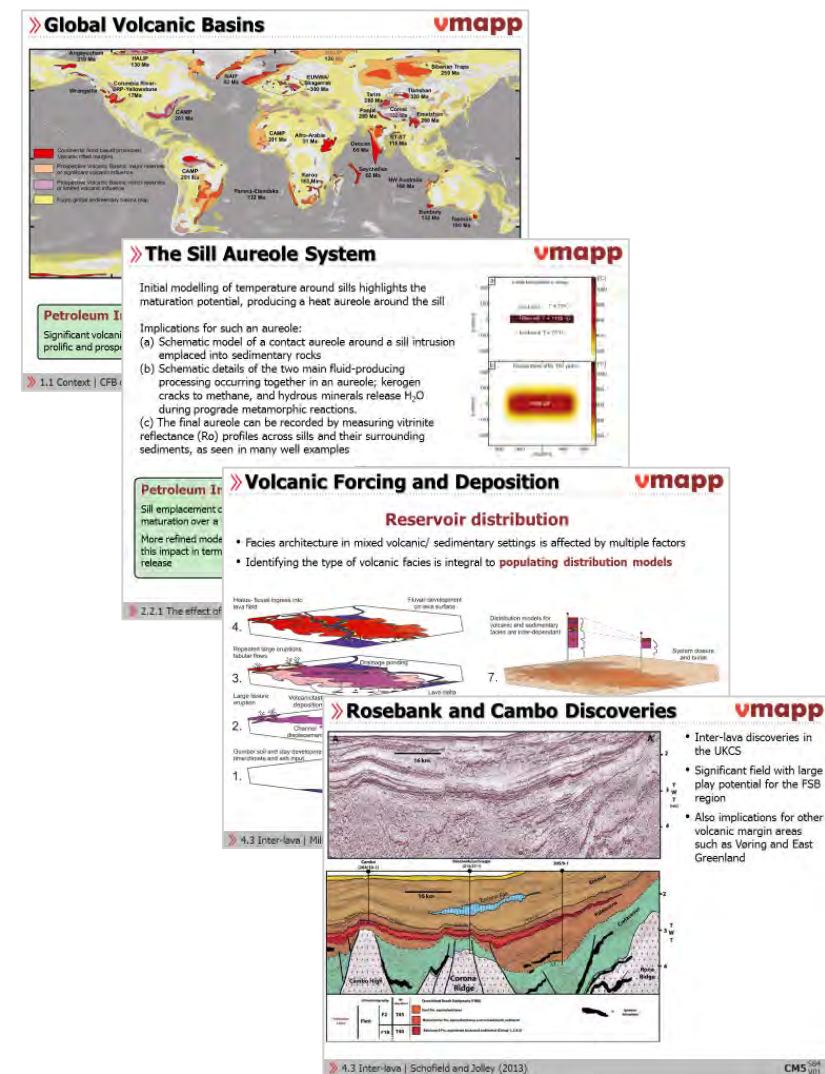
- Karthik Iyer, Dani Schmid (Geomodeling Solutions)
- John Millett (VBPR)
- Dougal Jerram (DougalEarth)
- Henrik Svensen (Univ. of Oslo)

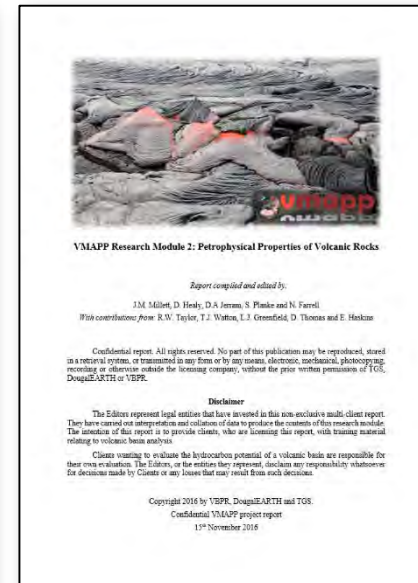
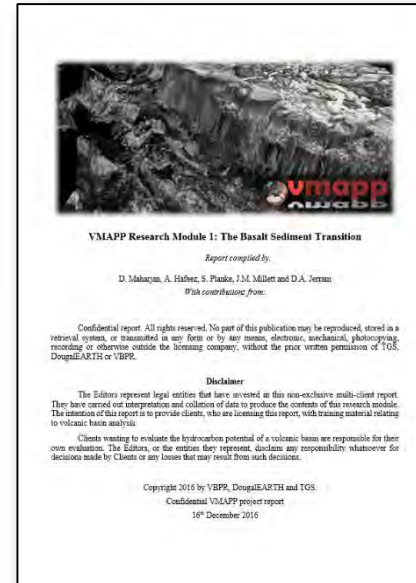
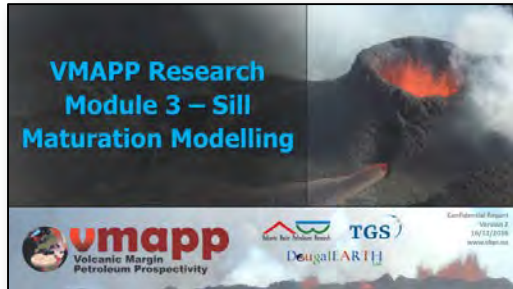
RM4 coordinator: Sverre Planke

- Peter Reynolds, John Millett, Mikal Trulsvik (VBPR)
- Dimitri Zastrozhnov, Dwarika Maharjan (VBPR)
- Dougal Jerram (DougalEARTH)
- Dani Schmid, Karthik Iyer (Geomodeling Solutions)

RM5 coordinator: Dougal Jerram

- Henrik Svensen (Univ. of Oslo)
- Sverre Planke, John Millett (VBPR)

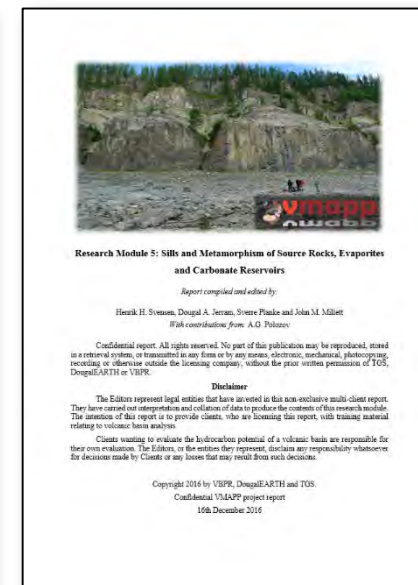
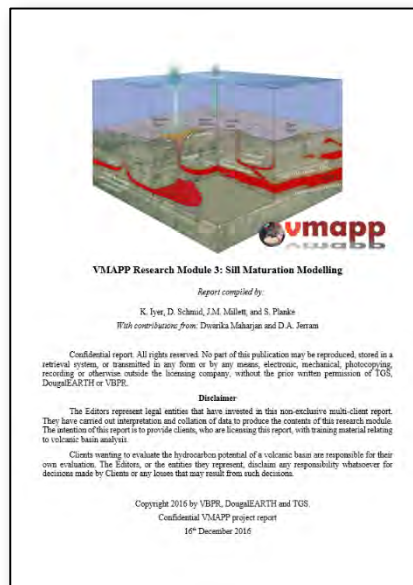




Digital Reports and Data

VMAPP is built on research excellence. New data and results are presented within five Research Module themes. In order to remain at the cutting edge of research, the project coordinators are involved in a wide range of collaborative scientific work which has fed into the Research Modules.

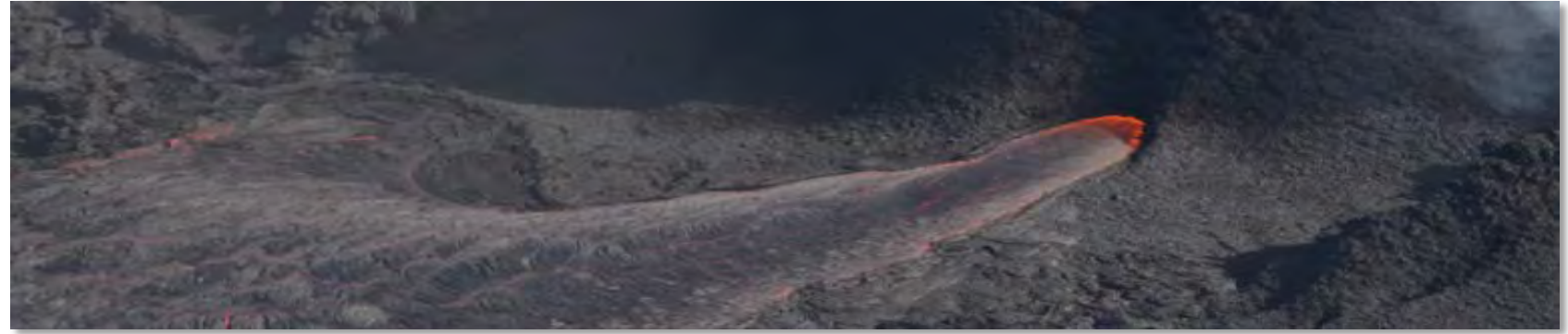
- Research Module data, reports and Power Point files included as a digital archive
- Associated scientific papers (50 PDF files) and meeting abstracts (50 references)



Highlights

Project results presented in

- Five *Core Modules* (CM) reports and associated ppt's
- Five *Research Modules* (RM), pdf reports (9), ppt's (3), and petrophysical data
- In-house **workshop** presenting project results
- Optional in-house **consulting** and/or **field trips** in volcanic basins world-wide (e.g. Karoo, Argentina, Iceland, UK)



Volcanology

CM1

RM2 (Hawaii
Televiewer facies)

Seismic Imaging

CM3

RM2 (Iceland VSP)

Petroleum Systems

CM5

RM3 (maturation)
CM2 (drilling)
RM5 (evaporates)

Petrophysics

CM2

RM2 (basalt lab data,
Hawaii well logs)

Seismic Interpretation

CM4

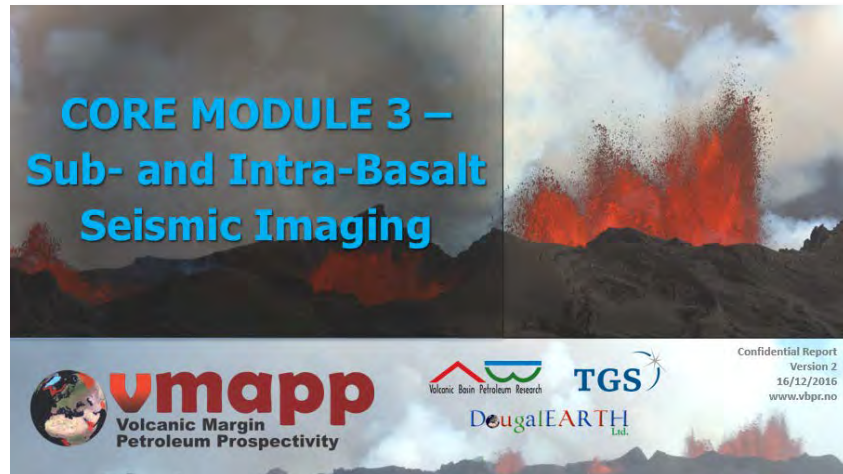
RM1 (base basalt)

Case Histories

RM4 (NE Atlantic)
CM5 (Neuquén,
W Shetland, Vøring)

CORE MODULES (5 modules as pdf reports and ppt's)

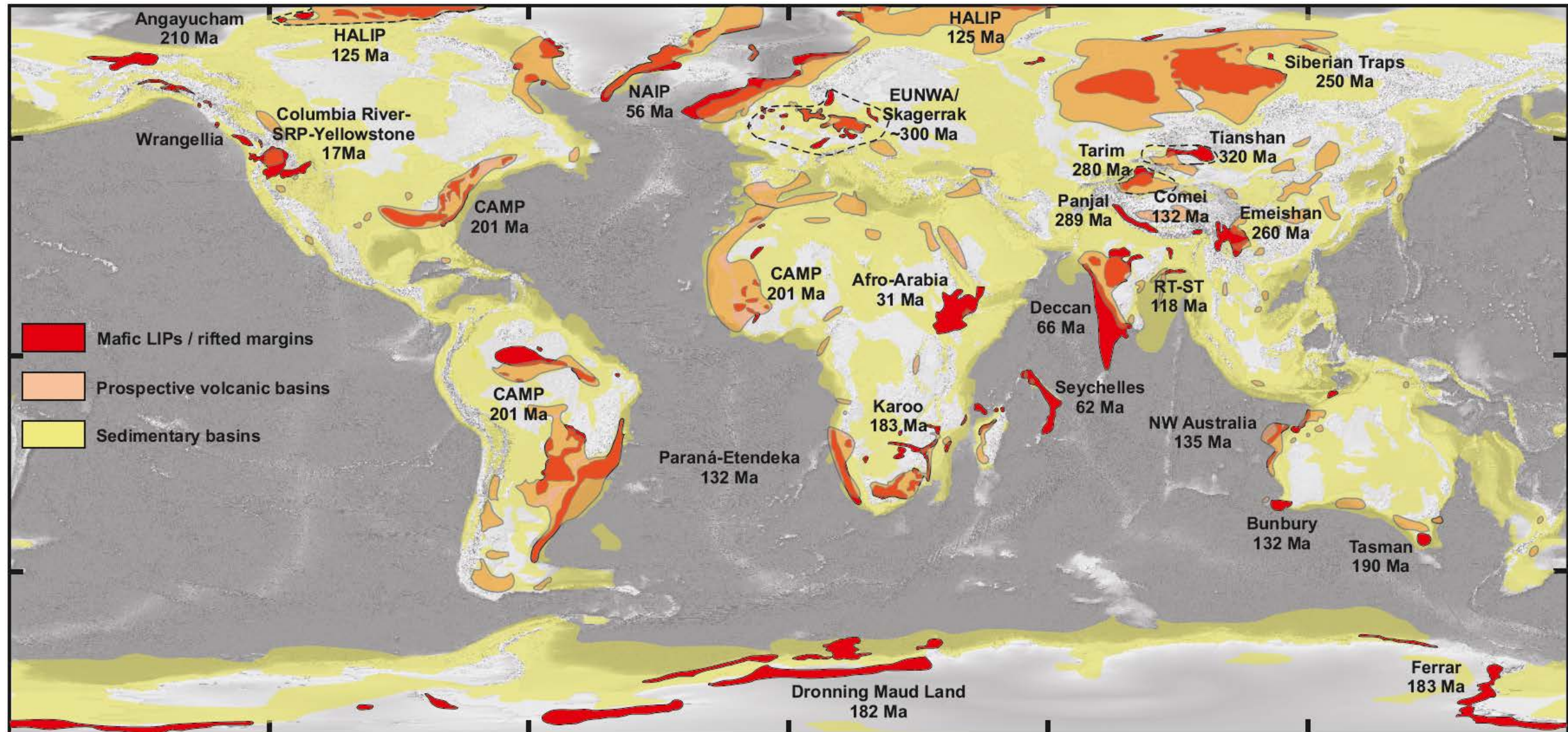
- Jerram, D.A., Millett, J.M., and Planke, S. (eds.), 2016. VMAPP CM1 – Volcanic Systems and Deposits. VMAPP project report and PowerPoint file, VBPR/DougalEARTH/TGS, Oslo, 194 pp. and 240 slides.
- Millett, J.M., Jerram, D.A., and Planke, S. (eds.), 2016. VMAPP CM2 – Petrophysical Properties and Drilling. VMAPP project report and PowerPoint file, VBPR/DougalEARTH/TGS, Oslo, 124 pp. and 147 slides.
- Planke, S., Millett, J.M., and Jerram, D.A. (eds.), 2016. VMAPP CM3 – Sub- and Intra-Basalt Seismic Imaging. VMAPP project report and PowerPoint file, VBPR/DougalEARTH/TGS, Oslo, 110 slides.
- Jerram, D.A., Millett, J.M., Schofield, N., and Planke, S. (eds.), 2016. VMAPP CM4 – Seismic Interpretation of Igneous Units. VMAPP project report and PowerPoint file, VBPR/DougalEARTH/TGS, Oslo, 130 pp. and 169 slides.
- Millett, J.M., Jerram, D.A., and Planke, S. (eds.), 2016. VMAPP CM5 – Volcanic Basin Petroleum Systems. VMAPP project report and PowerPoint file, VBPR/ DougalEARTH/TGS, Oslo, 228 pp. and 149 slides.



RESEARCH MODULES (9 pdf reports and 3 ppt's)

- Maharjan, D., Hafeez, A., Planke, S., Millett, J.M., and Jerram, D.A. (eds.), 2016. VMAPP RM1 – The Basalt-Sediment Transition. VMAPP project report and PowerPoint file, VBPR/DougalEARTH/TGS, Oslo, 75 pp. and 182 slides.
- Millett, J.M., Healy, D., Jerram, D.A., Planke, S., and Farrell, N. (eds.), 2016. VMAPP RM2 – Petrophysical Properties of Volcanic Rocks. VMAPP project report, VBPR/DougalEARTH/TGS, Oslo, 122 pp.
- Millett, J.M., Planke, S., and Jerram, D.A. (eds.), 2016. VMAPP RM2 – Geophysical Logging and Petrophysics of PTA2 and KMA1 Boreholes, Saddle Region, Big Island, Hawai'i. VMAPP project report, VBPR/DougalEARTH/TGS, Oslo, 56 pp.
- Millett, J.M., Paris, J.C., Helgadottir, H.M., Planke, S., Blischke, A., and Jerram, D.A. (eds.), 2016. VMAPP RM2 – Wireline Logging and Cutting Analysis in Well K-18, Krafla High-Temperature Area, NE-Iceland. VMAPP project report, VBPR/DougalEARTH/TGS, Oslo, 84 pp.
- Planke, S. (ed.), 2016. IMAGE-D4.2: Summary Report of WP 4.2: Active Seismic with VSP. IMAGE project report with RM2 support, VBPR/DougalEARTH/TGS, Oslo, 70 pp.
- Iyer, K., Schmid, D., Millett, J.M., and Planke, S., and Jerram, D.A. (eds.), 2016. VMAPP RM3 – Sill Maturation Modelling. VMAPP project report and PowerPoint file, VBPR/DougalEARTH/TGS, Oslo, 55 pp. and 100 slides.
- Zastrozhnov, D., Iyer, K., Schmid, D., Planke, S., Millett, J.M., Trulsvik, M., and Jerram, D.A. (eds.), 2016. VMAPP RM4 – Norwegian Margin Crustal Transect Thermal Modelling. VMAPP project report, VBPR/DougalEARTH/TGS, Oslo, 46 pp.
- Reynolds, P., Planke, S., Millett, J.M., Jerram, D.A., and Trulsvik, M. (eds.), 2016. VMAPP RM4 – Intrusions and Hydrothermal Vent Complexes Offshore NE Greenland. VMAPP project report, VBPR/DougalEARTH/TGS, Oslo, 37 pp.
- Svensen, H.H., Jerram, D.A., Millett, J.M., and Planke, S. (eds.), 2016. VMAPP RM5 – Sills and Metamorphism of Source Rocks, Evaporites and Carbonate Reservoirs. VMAPP project report, VBPR/DougalEARTH/TGS, Oslo, 60 pp.

» Prospective Volcanic Basins found World-Wide



A volcanic basin can be defined as a sedimentary basin with a significant amount of **primary deposited volcanic rocks**

Examples include:

North Atlantic (Norway, Greenland etc.) South Atlantic (Namibia, Angola, Brazil), Australia Margins, SE Asia, India and many others.....

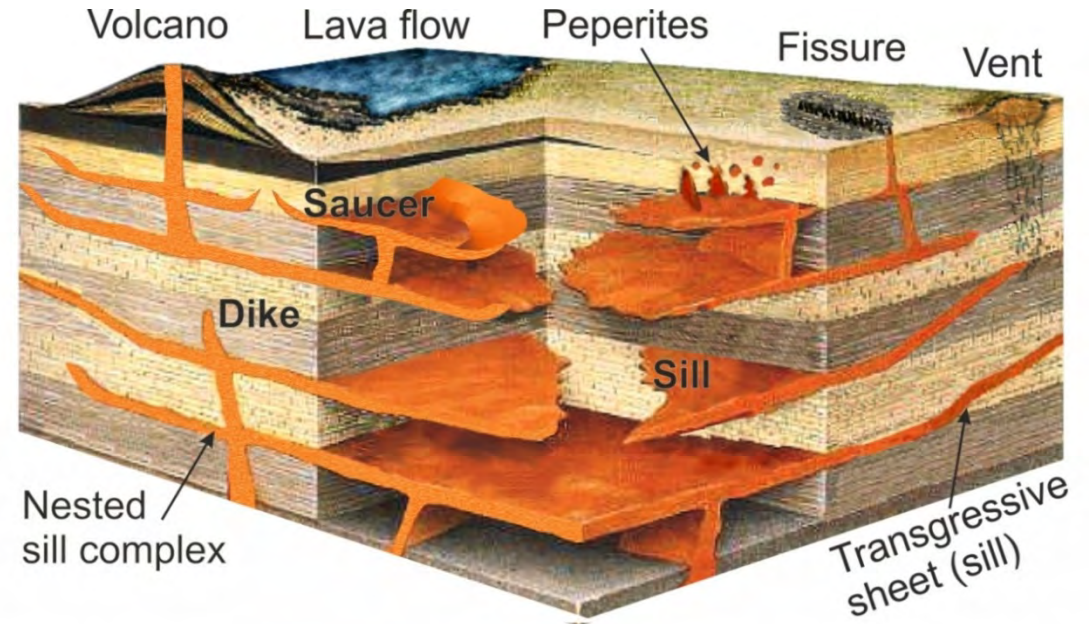
Petroleum Implications

Emplacement

Maturation: Increased hydrocarbon maturation in maturation aureole

Migration: Enhanced hydrothermal circulation and generation of migration pathways

Traps: Lifting and deformation of the overburden possibly forming traps



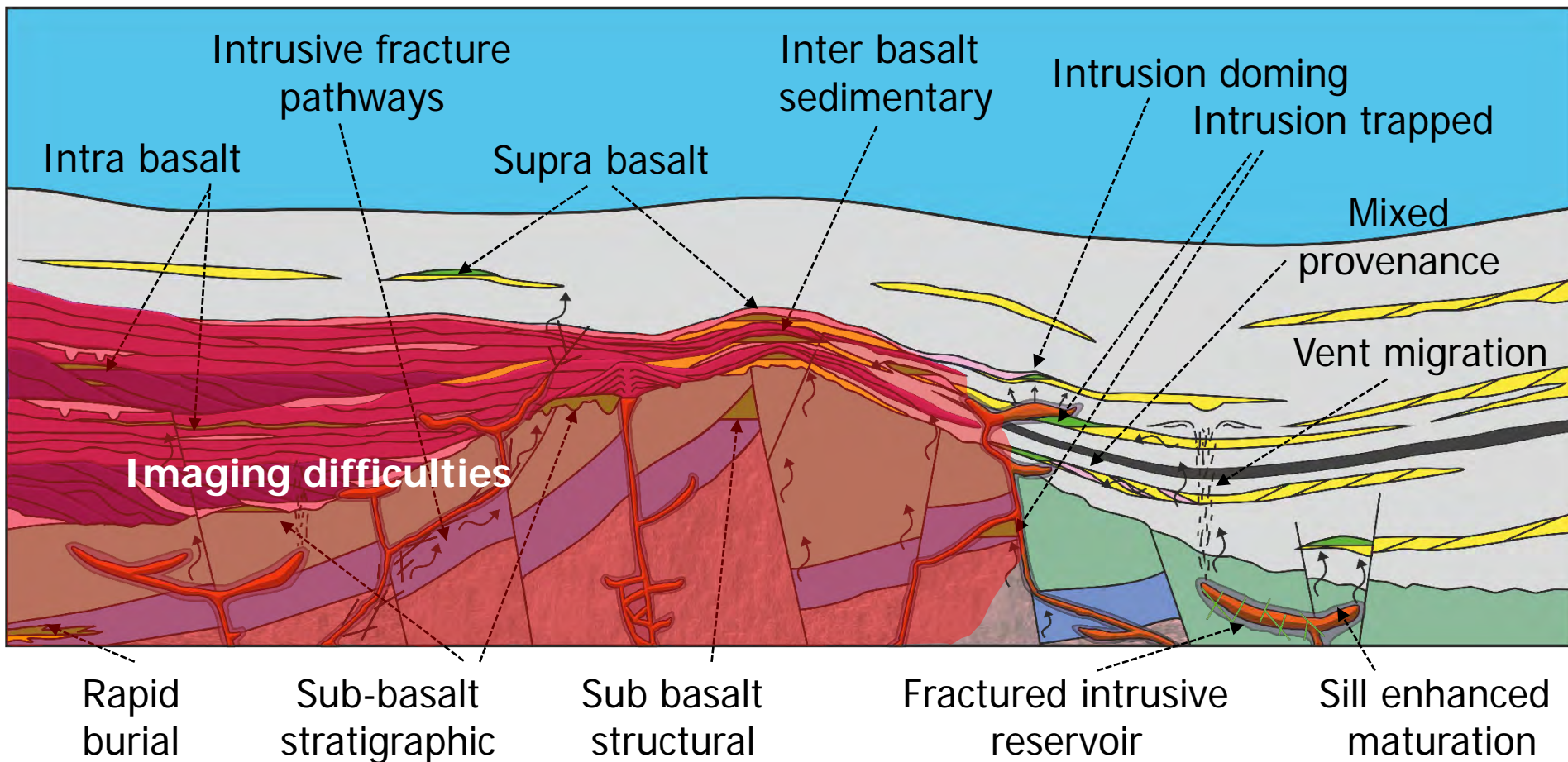
Post-Emplacement

Migration: Re-use of fracture systems. Barriers and compartmentalization (sills, dikes, hydrothermal vent complexes and aureoles)

Traps: Differential compaction

Seals: Tuff






Maturation Migration Traps







Volcanic rocks

	Subaerial lavas		Intrusive
	Hydroclastic		Volcani-clastic/genic

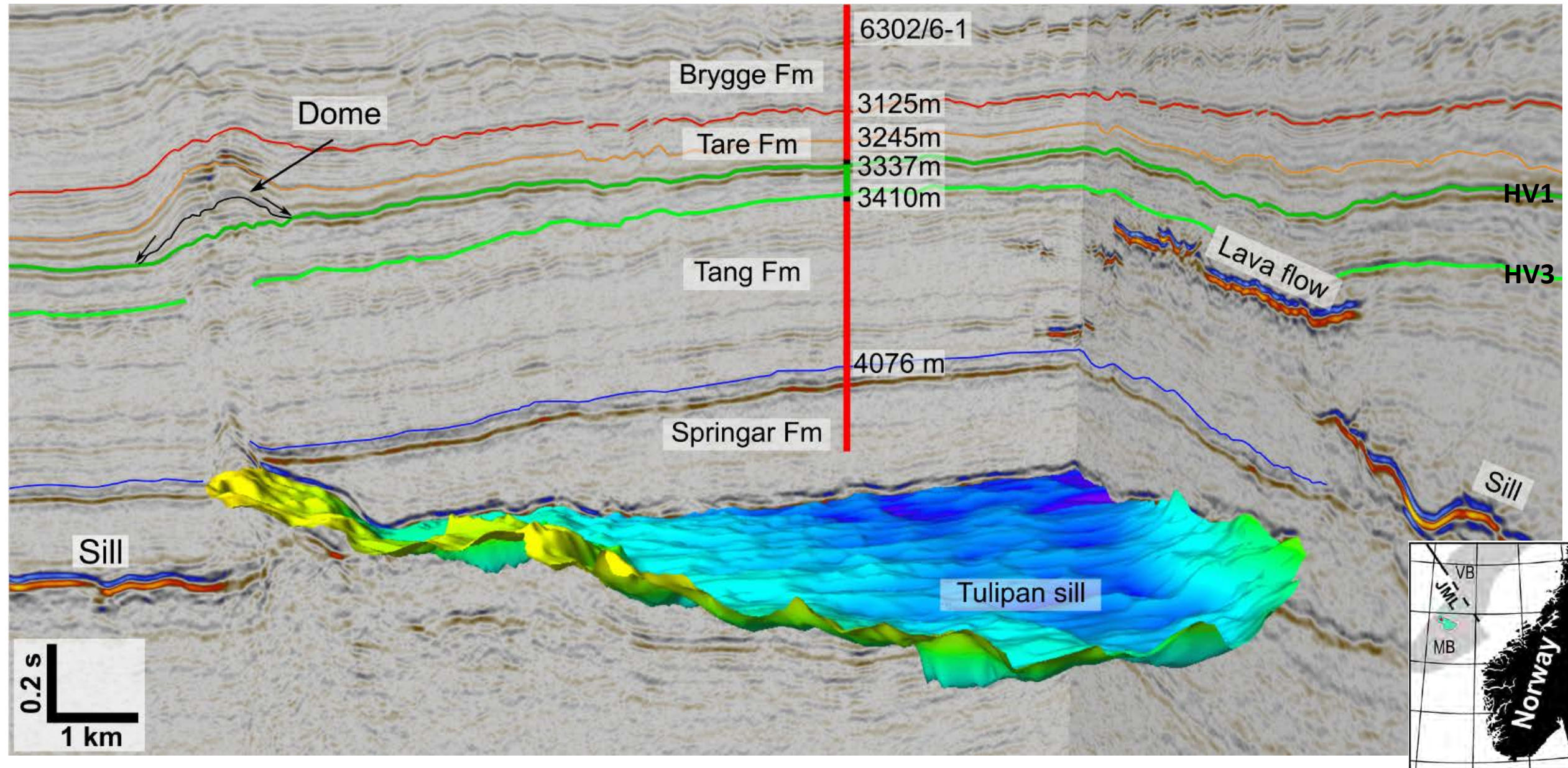
Non volcanic rocks

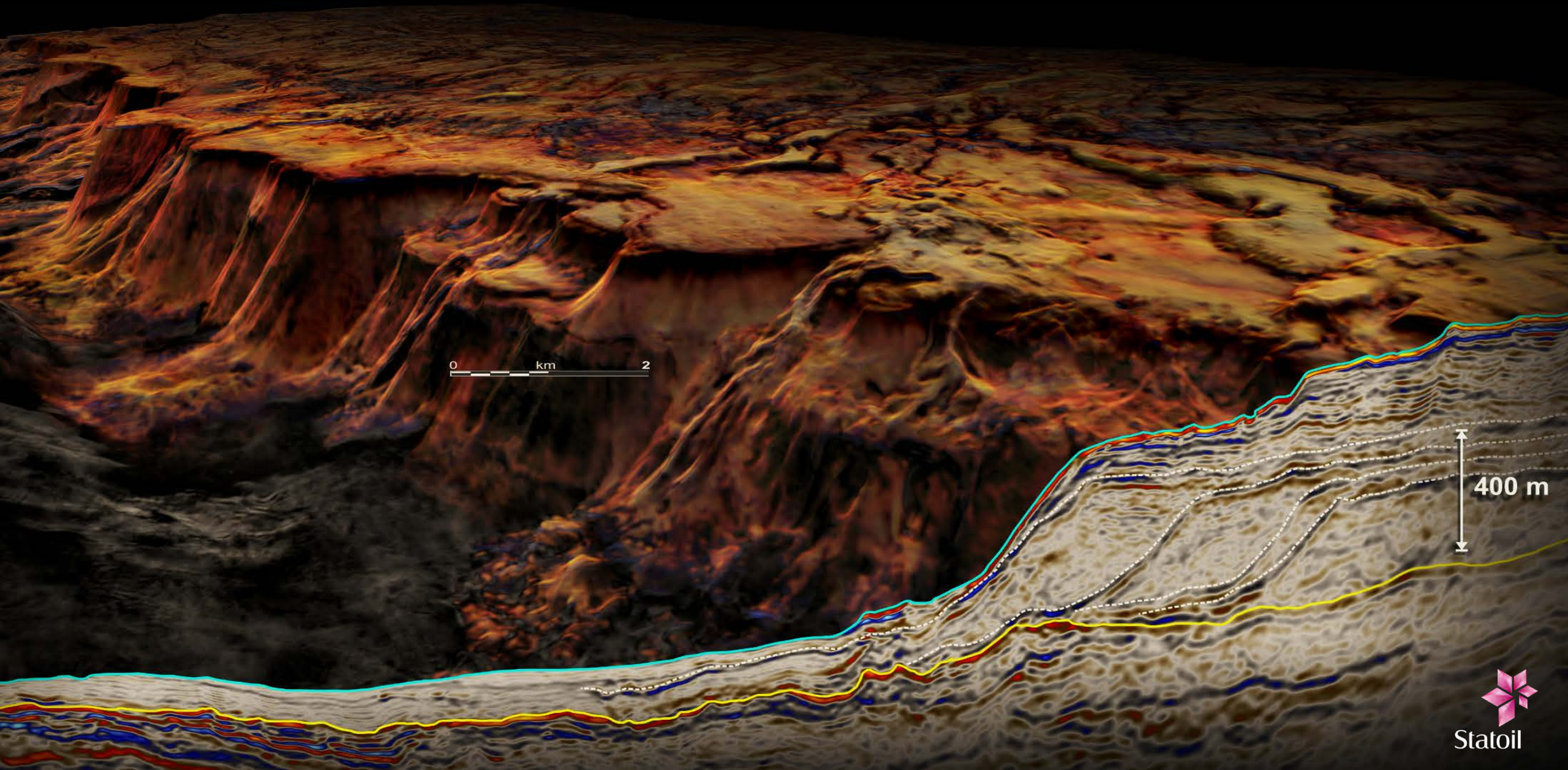
	Palaeozoic and basement		Syn-volcanic source rock
	Mesozoic basin fill		Sand rich layers
	Cenozoic mud rich		

Symbols

	Hydrocarbon migration		Local uplift
	Hydrocarbons		Hydrothermal venting

» Deep Saucer-Shaped Sills and Vent Complexes





Statoil

>> Sub-basalt Sediments on W Greenland

vmapp

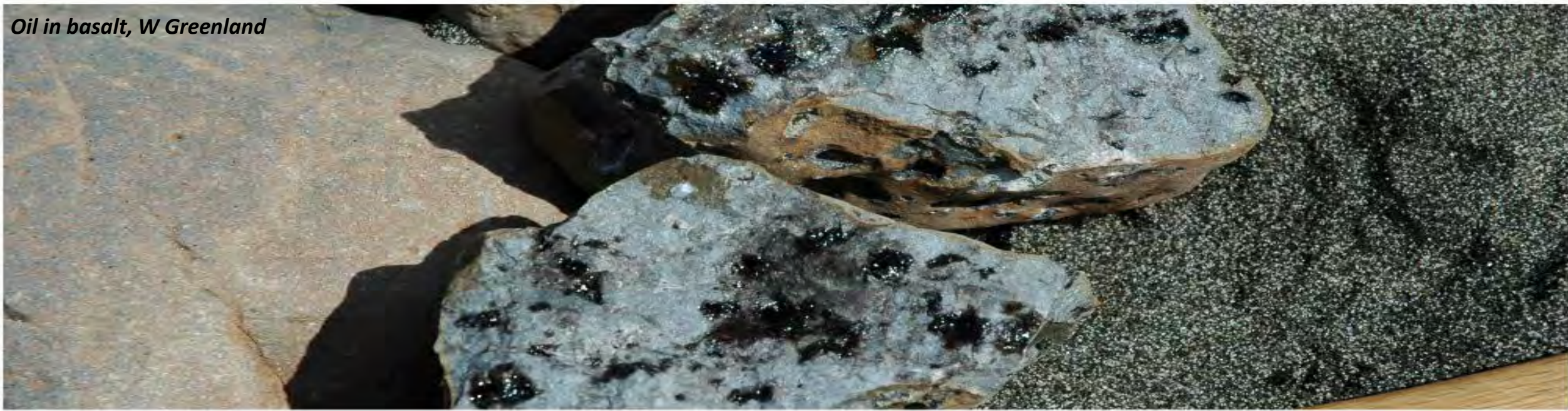
Lava flows

Lava delta

Sub-basalt sediments



Oil in basalt, W Greenland



VBPR AS

Oslo Science Park
Gaustadalléen 21
N-0349 Oslo, Norway
Ph: (+47) 21 08 07 50
Email: vbpr@vbpr.no
Web: www.vbpr.no

DougalEARTH Ltd.

31 Whitefields Crescent
Solihull B91 3NU, UK
Ph: (+44) 779 617 6501
Email: dougal@dougalearth.com
Web: www.dougalearth.com

TGS

Lensmannslia 4
N-1386 Asker, Norway
Ph: (+47) 66 76 99 00
Email: EURsales@tgs.com
Web: www.tgs.com

