MAIN TOPICS

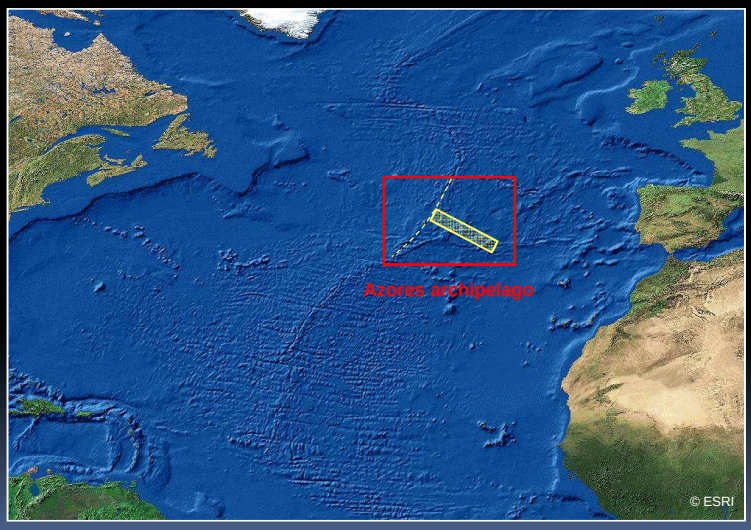
* Characterization of the study sites - Geological setting

* Secondary manifestations of volcanism
  - Azores archipelago volcanic gas emissions (from subaerial to submarine environment)

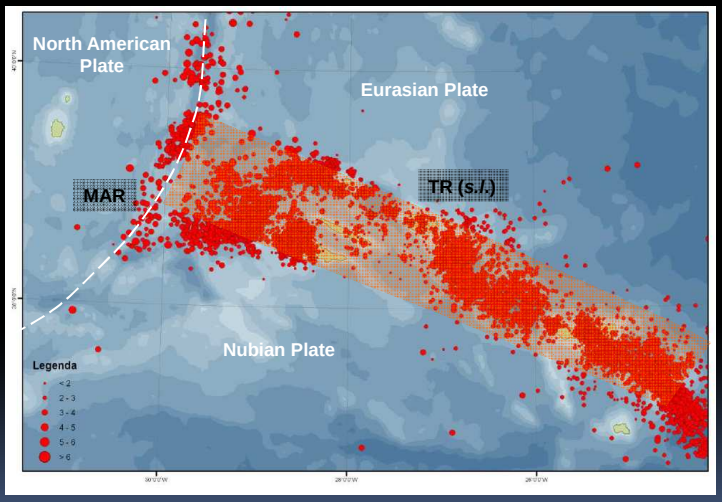
* Submarine gas emissions
  - Gas sampling
  - Analytical procedures
  - Results
  - Discussion (importance of these studies)

* Conclusions, applications and challenges

AZORES ARCHIPELAGO LOCATION – GEOLOGICAL SETTING

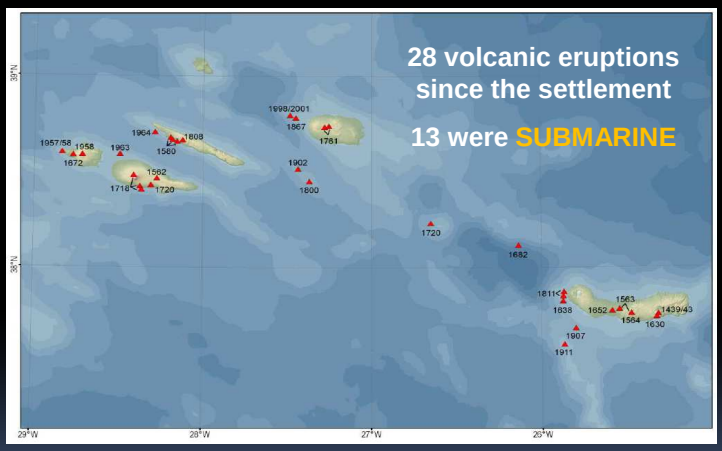


AZORES ARCHIPELAGO – SEISMICITY



Epicentral location of earthquakes in the Azores region for the period 1997 to 2009 (CIVISA)

AZORES ARCHIPELAGO – HISTORICAL VOLCANISM



Location of the historical eruptions in the Azores archipelago since the settlement (15th Century – CIVISA)

NOWADAYS – SECONDARY MANIFESTATIONS OF VOLCANISM

SUBAERIAL

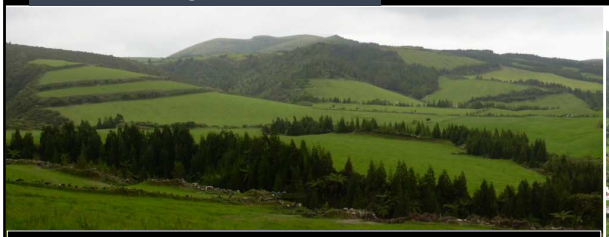
Visible gas emissions

Hydrothermal fumaroles

Thermal springs

Cold CO_2-rich springs

Not visible gas emissions



Diffuse degassing areas – CO_2, ^{222}Rn

NOWADAYS – SECONDARY MANIFESTATIONS OF VOLCANISM

Hydrothermal fumaroles

Maximum outlet temperature ~ 100ºC

-São Miguel Island (*Furnas and Fogo volcanoes*)

-Terceira Island (*Pico Alto Volcano*)

-Graciosa Island (*Caldeira Volcano*)

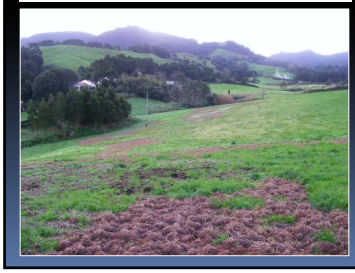
-Pico Island (*Pico Volcano*)

-Faial Island (*Capelinhos Volcano*)

H_2O, CO_2, H_2S, H_2, CH_4, O_2, He, N_2, Ar, CO, ^{222}Rn

Diffuse degassing areas

Gas released at the surface through faults/fractures



CO_2 diffuse degassing areas are present in almost all the islands

CO_2, ^{222}Rn

NOWADAYS – SECONDARY MANIFESTATIONS OF VOLCANISM

SUBMARINE

http://www.horta.uac.pt/intradop/noticias7/20060706/P7030931_610.jpg

Submarine gas emissions recognized in the vicinities of several islands:

-São Miguel Island (*Mosteiros, Porto Formoso and Ribeira Quente*)

-Graciosa (*Ponta Barca and Ilhéu de Baixo*)

-S. Jorge (*Queimada*)

-Faial (*Espalamaca*)

-*Banco D. João de Castro* (between São Miguel and Terceira islands)

Under water, even the diffuse degassing areas are visible!

SUBMARINE GAS SAMPLING

Physical (e.g. temperature, fluxes) and chemical (gas composition) information are important to characterize these emissions

Collection of gases using the Giggenbach methodology (bottles filled with NaOH 4N and under vacuum)

- Acid gases (CO_2, H_2S) dissolve in the basic solution;

- The non condensable gases (H_2, He, CH_4, O_2, N_2, Ar, CO) remain in the headspace of the bottle

Time of sampling is important!

ANALYTICAL PROCEDURES

Samples analyzed in the CVARG Laboratories (University of the Azores)

►Gas chromatography (Chromatograph *Perkin Elmer, model AutoSystem XL or Chromatograph Perkin Elmer Clarus 580*)

Detectors: Thermal Conductivity

Columns: MS packed column and MS 5A plot column

Carrier gas: He and/or Ar

He, H_2, O_2, Ar, N_2 and CH_4

►Potentiometric titration (Automatic titrator from *Radiometer Copenhagen, model* VIT90 Video Titrator

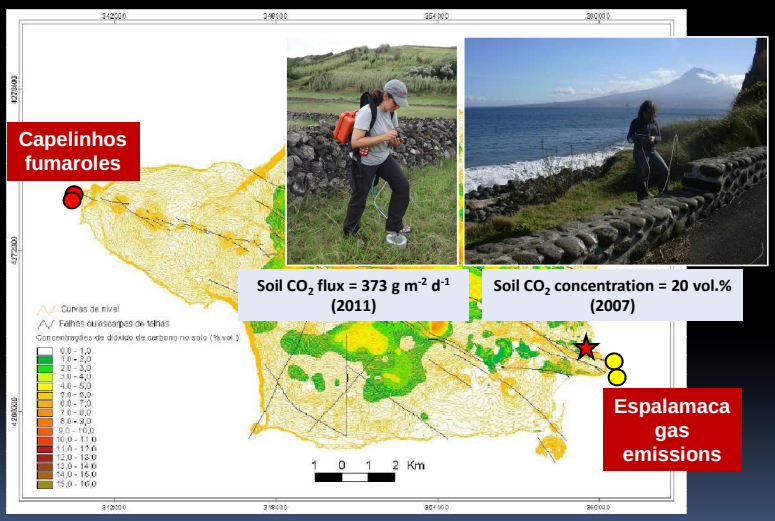
CO_2

► Colorimetric titration (titration with mercury acetate using dithizone for end point detection)

For more details see: Moreno et al., 2016 – poster session

H_2S

FAIAL ISLAND – DEGASSING AREAS



Soil CO_2 degassing map of Marcos (2006) integrating work from Faria (2002)

RESULTS – ESPALAMACA SUBMARINE EMISSIONS

Chemical components (molar%)	Faial Island Espalamaca 22-05-2015
CO_2	98.17
H_2S	0.000
CH_4	b.d.l.
H_2	b.d.l.
He	0.0200
N_2	1.49
O_2 + Ar	0.057
O_2	0.290
Ar	0.031

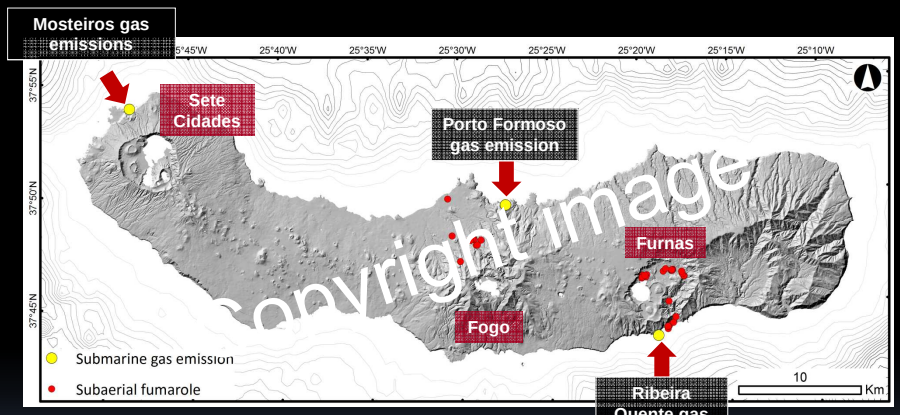
Capelinhos fumaroles – gas analyses (Ferreira, 1994)

Chemical components (molar%)	Faial Island Capelinhos 09-03-1993	Faial Island Capelinhos 13-03-1993
CO_2	0.013	0.029
H_2S	n.d.	n.d.
CH_4	n.d.	n.d.
H_2	n.d.	n.d.
He	-	-
N_2	90.88	90.81
O_2 + Ar	9.110	9.170
Temperature (°C)	91.0	88.8

►CO_2 is the most abundant dry gas in the submarine degassing vents of Espalamaca (> 98 vol.%).

►Minor concentrations of N_2, O_2, Ar and He are also measured. CH_4 and H_2 were not detected.

SÃO MIGUEL ISLAND – DEGASSING AREAS



(Legend: 100 m depth contour lines based on GEBCO_08 data)

RESULTS – SUBMARINE EMISSIONS

Chemical components (molar%)	Faial Island	São Miguel Island		
	Espalamaca	Mosteiros	Porto Formoso	Ribeira Quente
	22-05-2015	21-04-2015	08-07-2013	06-07-2014
CO_2	98.17	99.75	99.97	99.59
H_2S	0.000	0.000	0.000	0.095
CH_4	b.d.l.	0.001	3.87×10^{-5}	0.014
H_2	b.d.l.	b.d.l.	b.d.l.	0.039
He	0.0200	0.0008	n.d.	0.0011
N_2	1.49	0.19	0.02	0.21
O_2 + Ar	0.057	0.053	0.004	0.048
O_2	0.290	0.055	(a)	(a)
Ar	0.031	0.005	(a)	(a)

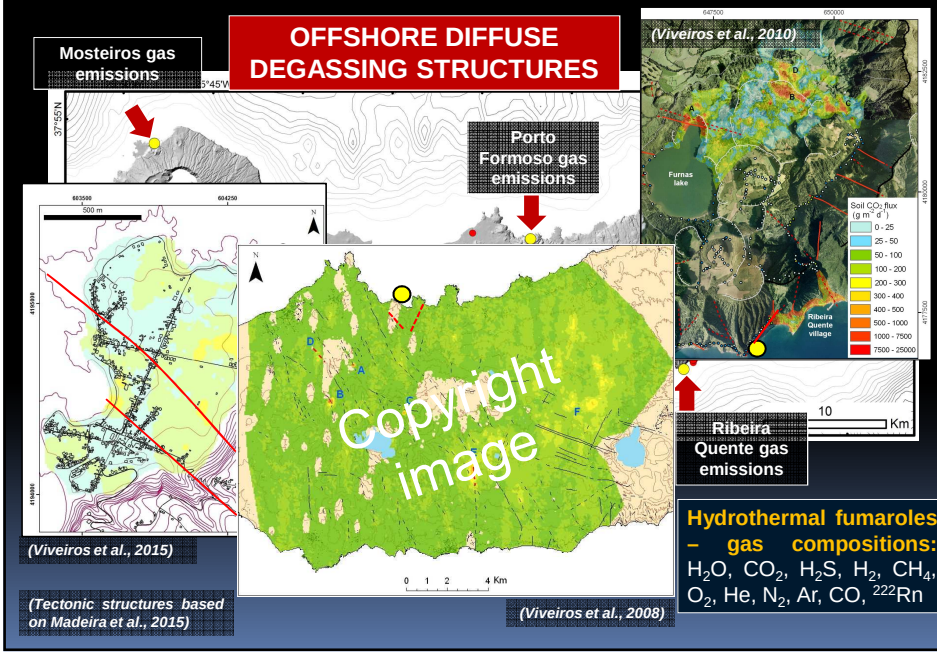
► CO_2 is the most abundant dry gas in the degassing vents located offshore São Miguel Island (> 99 vol.%).

► Minor concentrations of N_2, O_2, Ar and CH_4 were detected in all samples.

► H_2S and H_2 were detected ONLY in Ribeira Quente submarine gas emissions.

Ribeira Quente fumaroles – typical hydrothermal composition

SÃO MIGUEL ISLAND – DEGASSING AREAS



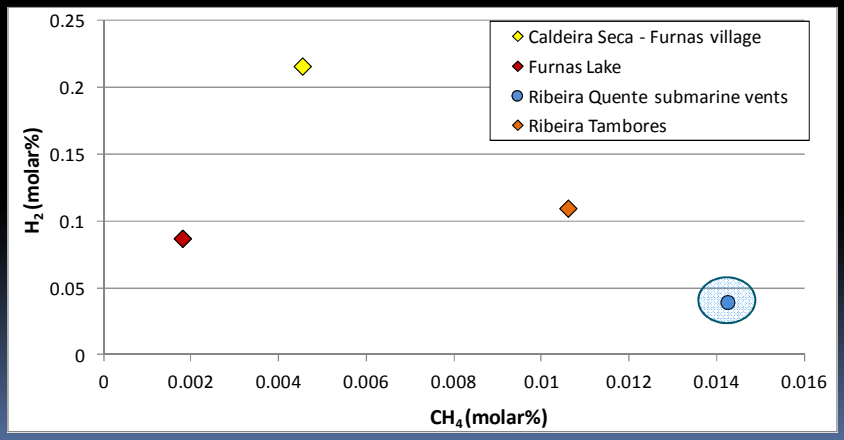
Hydrothermal fumaroles – gas compositions: H_2O, CO_2, H_2S, H_2, CH_4, O_2, He, N_2, Ar, CO, ^{222}Rn

RESULTS – FURNAS VOLCANO GAS EMISSIONS

Submarine emissions located in the high flux areas show typical gas composition of hydrothermal systems (CO_2 dominated, presence of H_2S, H_2 and CH_4)

Gas ratios are important to define the thermodynamic conditions of the feeding reservoirs → Seismo-volcanic monitoring

(Furnas Volcano suaberial data: Caliro et al., 2015)



CONCLUSIONS, APPLICATIONS AND CHALLENGES

► Submarine emissions located offshore of Faial and São Miguel islands show gas compositions that can be compared with the inland degassing sites.

► Gases released by Ribeira Quente submarine fumaroles, located in the south flank of the Furnas Volcano, have similar hydrothermal composition as the subaerial fumaroles found out at Furnas caldera.

► Gas emissions observed at Espalamaca, Mosteiros and Porto Formoso are CO_2 dominated and similar to the diffuse degassing structures identified inland (strong tectonic control).

Research projects:

MOFETA Project (FCT Exploratory Project)