GLOGOS, A New Global Onshore Gas-Oil Seeps Dataset*

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Abstract

Petroleum seeps have historically been important drivers of global petroleum exploration. Still today they can serve as direct indicators of gas and/or oil subsurface accumulations. In particular the assessment of the origin of seeping gas is a key task for understanding, without drilling, the subsurface hydrocarbon potential, genesis and quality; e.g., the presence of shallow microbial gas, deeper thermogenic accumulations, the presence of oil and non-hydrocarbon undesirable gases (CO_2, N_2, H_2S). Seeps are then indicators of tectonic discontinuities (faults) and fractured rocks; they can also represent geo-hazards and sources of greenhouse gas (methane) and photochemical pollutants (ethane and propane).

A new global dataset of onshore gas and oil seeps (GLOGOS) is here presented. GLOGOS includes more than 1150 seeps from 84 countries (version August 2009), and it is continuously updated and expanded. The dataset includes geographical and gas-geochemical data (molecular and isotopic composition of the main gases). Many seeps are recently discovered or never reported in other databases. Seeps are catalogued by country and classified in three types: gas seeps, oil seeps and mud volcanoes. All seeps have a bibliographic or www reference. GLOGOS is a unique tool for hydrocarbon exploration, assessment of Total Petroleum Systems and geo- structural studies.

Introduction

Natural hydrocarbon seepage has for many years served petroleum exploration as a direct indicator of gas and/or oil subsurface accumulations (Link, 1952; Jones and Drozd, 1983; Rhakmanov, 1987). Surface macro-seeps (visible gas vents or oil leaks from the soil or rock outcrops) are generally an indication of a fault in an active Petroleum Seepage System (Abrams, 1995) belonging to a Total Petroleum System (Magoon and Schmoker, 2000; Etiope et al., 2009a). The assessment of the origin and flux of the seeping gas is therefore a key task for understanding, without drilling, the subsurface hydrocarbon potential, genesis and quality; e.g., the presence of shallow microbial gas, deeper thermogenic accumulations, oil and nonhydrocarbon undesirable gases (CO_2, N_2, H_2S). The global number of terrestrial seeps seem to exceeds 10,000 (Clarke and Cleverly, 1991), but only a small number has been directly investigated. A global analysis of more than 200 onshore seeps worldwide (including 143 mud volcanoes) revealed that methane is thermogenic in about 80% of the cases, microbial gas is in only 4% of seeps, mixed gas in the remaining cases (Etiope et al, 2009a). Other studies have demonstrated how gas seeps can indicate subsurface petroleum biodegradation (Etiope et al, 2009b), which has an important impact on hydrocarbon quality, and it may influence exploration and production strategies.

More generally, gas and oil seeps are important for four main reasons:
1. Seeps can be indicators of petroleum or natural gas reservoirs.
2. Seeps indicate the occurrence of a fault.
3. Seeps can represent a geo-hazard for societal community and industry.
4. Seeps are natural sources of greenhouse gas.

Indicators of Petroleum or Natural Gas Reservoirs

1. Seeps have driven petroleum exploration in many countries. They can assist hydrocarbon exploitation in the assessment of geochemical and pressure variations during fluid extraction, and they are fundamental for the definition of the Petroleum Seepage System (Abrams, 2005). The geochemical analysis of seeping gas, in particular, can be effective to understand the potential and nature of subsurface accumulations.

Occurrence of a Fault

2. Seeps are effective indicators of tectonic discontinuities and rock formations with enhanced secondary permeability, providing information on the location and depth of gas-bearing faults. Mud volcanism, in particular, has been extensively studied for its sensitivity to seismic activity (Mellors et al., 2007).

Geo-Hazard for Societal Community and Industry

3. Seeps may represent hazards for humans and buildings. Explosions and sudden flames may occur in gas-rich environments (boreholes, soil), if methane concentrations reach explosive levels of 5-10% in the presence of air. When methane is accompanied by hydrogen sulfide (e.g., in salt diapirism zones), seeps can be toxic or even lethal under some circumstances (Etiope et al., 2006). Hazardous conditions can be also induced by variable density mud, especially in the mud volcanoes, which can lead to formation of "quicksand", with risks for people and animals. Seeps and mud volcano plumbing can damage building and infrastructures by gas-pressure build-up in the subsoil or by general degradation of geotechnical properties of soil foundations.

Natural Sources of Greenhouse Gas

4. Offshore and onshore seepage, including microseepage, is an important source of greenhouse gas (methane; Etiope et al, 2008) and photochemical pollutants (ethane and propane; Etiope and Ciccioli, 2009). Onshore and offshore seeps (together with diffuse microseepage) are estimated to be the second most important natural source of atmospheric methane, after wetlands, both on global scale and European scale (Etiope, 2009 [and references therein]). The evaluation of the gas flux is, then, an important task for understanding the potential of underground gas accumulations, the possible hazard, and the impact into the atmosphere. In this respect, the gas flux from a given category of source (in this case "natural gas seep") is a fundamental parameter for the definition of the "emission factor", which is the basic element for upscaling procedures and greenhouse gas emission estimates on large scales (Etiope et al, 2007a).

Seep Databases

Although petroleum seeps are very important for both scientific and energy exploration purposes, presently only a few and limited global onshore seep databases are available which report complete geographic and geochemical data, with special reference to gas seeps. Available seep databases are commercial products for oil industry (e.g., GIRTM by Fugro Robertson Ltd) and are derived mainly from older datasets (Link, 1952; BP SEEPS in Clarke and Cleverly, 1991; Simon Petroleum Technology, 1992). These databases, however, have incomplete or ambiguous descriptions of seeps, with repetitions and inactive impregnations being included. Most seeps refer to oil seeps and impregnations, and very few gas seeps are reported, rarely including gas geochemical (compositional and isotopic) data. A number of gas seeps studied and described in recent literature are not included.

Following a long research on gas seepage, a new global dataset of onshore gas and oil seep has been recently developed. It includes gas seeps or mud volcanoes previously unreported, and many gas geochemical data which are fundamental for the evaluation of subsurface accumulation linked to the seeps. The dataset, named GLOGOS (Global Onshore Gas-Oil Seep), is described in the present note.

Description of the Dataset

GLOGOS dataset is the result of ten years of studies and investigations on natural hydrocarbon seepage phenomena. It is a list of more than 1150 terrestrial (onshore) seeps from 84 countries (version August 2009), including a series of geographical and geochemical data, based on original research and extensive literature and internet web surveys. Seeps are classified in mud volcanoes, gas seeps, and oil seeps.

Mud volcanoes release a three-phase (gas, water and sediment) mixture. Gas is typically released from gryphons, craters or bubbling pools (salses). There is a wide literature on genesis, typology, distribution and significance of mud volcanoes (e.g., Kopf, 2002; Milkov, 2005; Etiope et al., 2007b).

Gas seeps refer to gas manifestations which are independent of mud volcanism. They may include:

- Water-seeps, which release an abundant gaseous phase accompanied by water discharge (bubbling springs, groundwater or hydrocarbon wells); water may have a deep origin and may have interacted with gas during its ascent to the surface.
- Dry-seeps, which release only a gaseous phase, such as gas vents from outcropping rocks or through the soil horizon or through river/lake beds. Gas bubbling from groundwater-filled wells, or other shallow-water bodies, should be considered dry-seeps, since surface water is only being crossed by the gas flow. Dry gas flow through rock and dry soil can produce flames by self-ignition (fire seeps or everlasting fires); more generally, however, many vents can be easily ignited artificially.

GLOGOS also reports some non-natural seeps;, i.e., anthropogenically induced seeps such as those produced by coal mining.

GLOGOS Structure

The dataset is integrated in a single Excel file and subdivided into 6 continental regions:
EUROPE (including Azerbaijan and Russia), ASIA, AFRICA, NORTH-AMERICA, CENTRAL-SOUTH- AMERICA, OCEANIA.

The following types of information are reported:
1. Country
2. Estimated total number of seeps occurring in the country (according to published literature, web resources).
3. Longitude/Latitude geographic coordinates (variable format).
4. Name of the petroliferous basin or geographic area or region.
5. Type of seep: Gas, Oil, MV (mud volcano). For MV, the name can refer to a group or cluster of seeps. They are reported in different colours: Black: Gas seeps, Blue: Mud volcanoes, Green: Oil seeps, Brown: non-natural seeps (likely generated by anthropogenic activity).
6. Seep name or sample name.
7. Reference: bibliographic or web source (the complete reference list is in the last page of the Excel file).

The following data are also provided for gas seeps and mud volcanoes:

- $\delta^{13}C_1$: isotopic ratio of carbon of CH_4 (‰, PDB) 4
- δD_1: isotopic ratio of hydrogen of CH_4 (‰, SMOW)
- CH_4: methane concentration (%)
- C2: ethane concentration (%)
- C3: propane concentration (%)
- C1/(C2+C3): "Bernard" ratio

Other gases (such as CO_2, N_2, Ar, He, H_2S, C4+ alkanes) and isotopic ratios ($\delta^{13}CO_2$, $^3He/^4He$, $\delta^{15}N$) can be available for some seeps and included upon request. For a few seeps also gas flux data (flux from the ground to the atmosphere) can be available.

An example of a data table extracted from GLOGOS is shown in Figure 1.

The GLOGOS data are checked and selected in order to avoid seep repetitions (other databases may report duplicate or more data for the same seep, leading to a "false" -overestimated- total number of seeps), to distinguish non-natural seeps, and omit gas manifestations clearly related to geothermal processes (e.g., CO_2- rich gas unrelated to petroleum occurrences).

Table 1 summarizes the number of seeps for each continent and typology for the version GLOGOS-AUG09. The percentage of attributes in version GLOGOS-AUG09 is shown in Table 2.

Bibliography and Auxiliary Material

All seeps are referenced, by published scientific articles, reports or by www sources. The bibliographic material is available as electronic files. A Google-Earth kmz file for the visualization of many seeps (especially mud volcanoes, e.g., Figure 2), a series of photo (such as those in Figure 3), and specific maps are also available.

COUNTRY	Estim.N. seeps	LON	LAT	Basin/Region	Type	Name or Sample ident.	ANALYS	REFERENCE	deltaC1	deltaD	CH4	C2	C3	C1/C2+C3	M.FLUX
Georgia	15	45° 50'	41° 45'	Yori river	MV	Akhtala (1)	C, I	Valyaev et al (1985)	-43		89.9	0.15		599	
Georgia		45° 50'	41° 45'	Yori river	MV	Akhtala (3)	C, I	Valyaev et al (1985)	-46		90.82	0.44		206	
Georgia		45° 50'	41° 45'	Yori river	MV	Akhtala (4)	C, I	Valyaev et al (1985)	-46.4		85.34	0.01		8534	
Georgia				Yori river	MV	Pkhoveli	C, I	Valyaev et al (1985)	-56.7		81.37	0.02		4069	
Georgia				Yori river	MV	Lakbeli	C, I	Valyaev et al (1985)	-44.4		72.58	2.76		26	
Georgia		45°45'58"	41°20'36"	Yori river	MV	Baida	C, I	Valyaev et al (1985)	-42.3		91.65	0.07		1309	
Georgia				Yori river	MV	Aladzhigi	C, I	Valyaev et al (1985)	-46.1		78.25	0.16		489	
Georgia		45°50'39"	41°14'40"	Yori river	MV	Tyulkitapa	C, I	Valyaev et al (1985)	-53.1	-196	89.03	1.15		77	
Georgia		45°55'	41°26'	Yori river	MV	Kila Kupra	C, I	Valyaev et al (1985)	-48.9		97.81	0.39		251	
Georgia		45°46'	41°19'48"	Yori river	MV	Polpoi-Tebi		Lavrushin et al (1996)							
Greece	10	21°18'49.28"	37°38'34.32	W. Peloponnese	Gas	Katakolo Faros	C	Etiope et al (2006)							10
Greece		21°19'6.50"	37°38'39.18"	W. Peloponnese	Gas	Katakolo Harbour	C, I	Etiope et al (2006)	-31.2	-136	9.3	0.135	0.006	66	>50
Greece		21° 7'1.22"	37°51'30.00"	W. Peloponnese	Gas	Killini	C, I	Etiope et al (2006)	-49	-174	17.2	0.093	0.0001	185	1.4
Greece		21°41'37.54"	38°11'39.09"	N. Peloponnese	Gas	Patras Coast	C, I	Etiope (private)	-73.93	-210.9	81.91	0.0052		15752	1.2
Greece		21°35'53.42"	37°30'50.00"	W. Peloponnese	Gas	Kaiafas	C, I	Etiope et al (2006)	-47.5	-166.5	8.5				
Greece		21°17'2.43"	38° 0'21.60"	W. Peloponnese	Gas	Kotychi	C, I	Etiope (private)	-69.74	-202.3	92.52				
Greece		21° 4'18	38°49'44	Epirous	Gas/Oil	Trifos	C, I	Etiope (private)	-66.7	-175					
Greece		25	35.3	Med	Gas	Crete seep		Oil Tracer (2007)							
Greece		21.112	37.89	Ionian	Oil	Keri lake Zakynthos	C, I	Etiope (unpublished)							
Ireland		-6.2833	53.0666		Oil	seep		Oil Tracer (2007)							
Italy	30	37°26'	13°24'	SICILY	Gas	Occhio Abisso C.Eraclea	C	Etiope et al (2004)			96.2				2.7
Italy		37° 37'	13° 26'	SICILY	Gas	Censo fire	C, I	Etiope et al (2007)	-35.1	-146	76.4	0.591	0.083	113	6.2
Italy		9°41'37.44"	44°47'54.63"	PO BASIN	Gas	Montechino	C, I	Etiope et al (2007)	-33.98	-132.6	95.3	2.460	1.020	0	100
Italy		10° 5'43.00"	44°29'20.00"	PO BASIN	Gas	Miano	C, I	Etiope et al (2007)	-39.38	-168.4	98.44	0.153	0.001	639	200
Italy		11°46'25"	44°02'47"	PO BASIN	Gas	M.Busca fire	C, I	Etiope et al (2007)	-35.81	-160.9	58.44	1.55	0.504	28	9.2
Italy		12° 1'54.24"	44°40'43.02"	PO BASIN	Gas	Comacchio	C, I	Etiope, unpublished	-76.14	-223	66.81				
Italy		15°47'	40°19'	S.Apennine	Gas	Tramutola	C, I	Etiope et al (2007)	-42.12	-193.8	82.61	0.267	0.001	308	2400
Italy		11°18'8.10"	44°45'22.39"	PO BASIN	Gas	Corporeno	C, I	Etiope et al (2007)	-65.98	-174.1	66.52	0.038	0.001	1706	
Italy		10° 20' 19"	44° 37' 13"	N.Apennine	MV	Torre	C, I	Etiope et al (2007)	-39.1		96.79	0.037	0.0004	2588	
Italy		10°19'39.76"	44°37'49.12"	N.Apennine	MV	Rivalta	C, I	Etiope et al (2007)	-41.38	-180.6	98.32	0.018	0.001	5175	12
Italy		10°34'33.91"	44°33'28.01"	N.Apennine	MV	Regnano	C, I	Etiope et al (2007)	-45.72	-152.6	96.78	0.15	0.004	628	34
Italy		10°49'24.70"	44°30'50.93"	N.Apennine	MV	Nirano	C, I	Etiope et al (2007)	-45.65	-185.5	98.26	0.051	0.005	1755	32.4
Italy		10°53'2.46"	44°26'23.05"	N.Apennine	MV	Ospitaletto	C, I	Etiope et al (2007)	-45.6	-183.3	96.62	0.044	0.001	2147	1.4
Italy		11°27'20.74"	44°20'9.39"	N.Apennine	MV	Dragone	C, I	Etiope et al (2007)	-58.4	-219	88.85	3.007	1.001	0	0.3
Italy		11°44'9.89"	44°18'31.85"	N.Apennine	MV	Bergullo	C, I	Etiope et al (2007)	-69.43	-180.2	98.61	0.046	0.001	2098	1
Italy		14° 2'57.24"	42°36'36.56"	Adriatic Abruzzo	MV	Pineto	C, I	Etiope et al (2007)	-73.11	-188.2	94.13	0.036	0.001	2544	2.7
Italy		13°35'58.38"	37°22'33.27"	Sicily	MV	Maccalube1	C, I	Etiope et al (2007)							394

Figure 1. Example of data structure of GLOGOS.

Figure 2. Example of seep visualization by Google-Earth (Maccalube mud volcano in Italy).

Figure 3. Photos of gas seeps (natural fires).

COUNTRY	Estim.N. seeps	LON	LAT	Basin/Region	Type	Name or Sample ident.	ANALYS	REFERENCE	deltaC1	deltaD	CH4	C2	C3	C1/C2+C3	M. FLUX
Georgia	**15**	45° 50'	41° 45'	Yori river	MV	Akhtala (1)	C, I	Valyaev et al (1985)	-43		89.9	0.15		599	
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Italy		13°35'58.38"	37°22'33.27"	Sicily	MV	Maccalube1	C, I	Etiope et al (2007)							394

Table 1. Number of seeps for each continent in version GLOGOS-AU09.

	Countries	Oil seeps	Gas seeps	Mud Volcanoes	Total seeps	Gas seeps or MV with analysis
EUROPE	16	39	40	211	290	180
ASIA	29	85	48	54	187	53
AFRICA	14	35	5	0	40	2
N.AMERICA	2	114	323	0	437	307
C.S.AMERICA	19	82	6	30	118	16
OCEANIA	4	45	15	28	88	38
TOTAL	*84*	*400*	*437*	*323*	*1160*	*596*
			GAS MANIFESTATIONS (gas seeps +MV)			
			760			

	% of total seep	% of gas + MV seeps
Total gas + MV seeps	66	
coordinates	75	
type	100	
name	97	
references	100	
CH_4 isotopes		71
C_1-C_3 composition		79
Measured flux		6

Table 2. Attributes in version GLOGOS-AU09.

Conclusion

GLOGOS is a new global dataset of onshore gas and oil seeps which includes more than 1150 seeps from 84 countries (version August 2009). The dataset includes geographical and gas-geochemical data (molecular and isotopic composition of the main gases). Thanks to specific studies, GLOGOS includes many exclusive seeps, recently discovered or never reported in other databases. Seeps are catalogued by country and classified in three types: gas seeps, oil seeps and mud volcanoes. All seeps have a bibliographic or www reference.

Seeps are valuable indicators of underground hydrocarbon resources; in this respect, GLOGOS is a cost-effective tool for a re-evaluation of petroleum potential studies in already explored basins and/or for an assessment of new prospects in frontier and unexplored areas. GLOGOS and related information can be requested by contacting the author of this paper.

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