Investigation of self-sustaining combustion of a coal waste heap in Scotland.

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Presentation outline

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- Site description
- Physical changes
- Gas analysis
- Evidence for smoldering
- Implications for self-sustained smoldering remediation
- Summary

What is a ‘bing’?

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Bing; a colliery waste heap; gob pile (US), coal spoil pile, refuse bank, culm pile, slag heap.

- primarily residue from coal cleaning and washing operations, with a high residual carbon content.

Bogside bing, N.Lanarkshire

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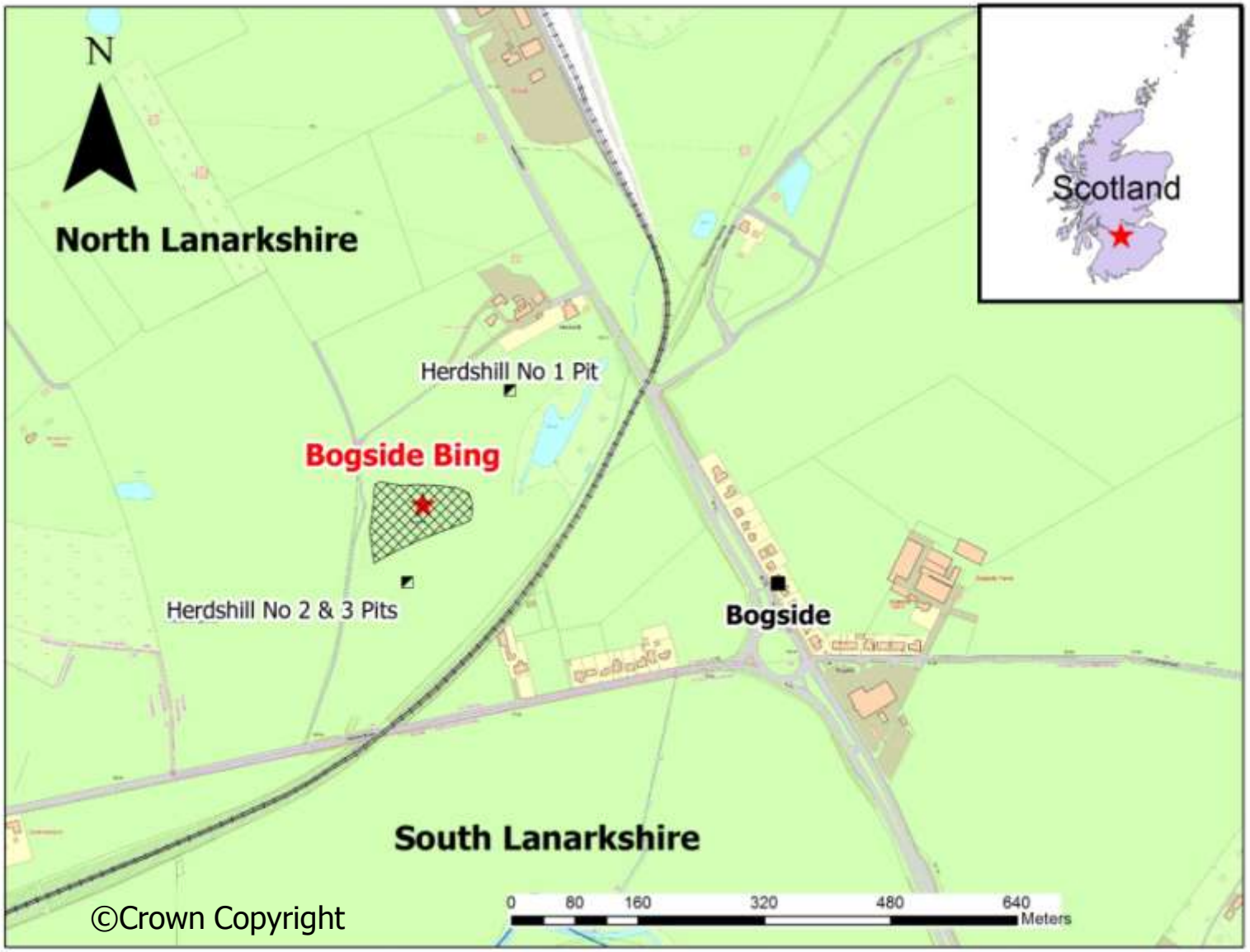
- Bogside bing is one of 560+ bings in Scotland.
- Composed of waste from the Herdshill #2 & #3 pits, operated by Coltness Iron Works.
- In production from ~1860 until 1931, so bing is approximately 80 years old.
- Mined seams in Carboniferous Lower Coal Measures
- First visible signs of combustion in 2008.
- Roughly the combustion front has spread across 45% of the bing.

Site map


N
North Lanarkshire
Scotland
Herdshill No 1 Pit
Bogside Bing
Herdshill No 2 & 3 Pits
Bogside
South Lanarkshire
©Crown Copyright
0 80 160 320 480 640
Meters

Aerial view


Map
Traffic
No sign of combustion but material recently removed from west end of bing.
Image date 1 Jan 1999 (source: Google Earth)
200 ft
50 m
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View from SE

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View from SE

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Pre-combustion–black shales

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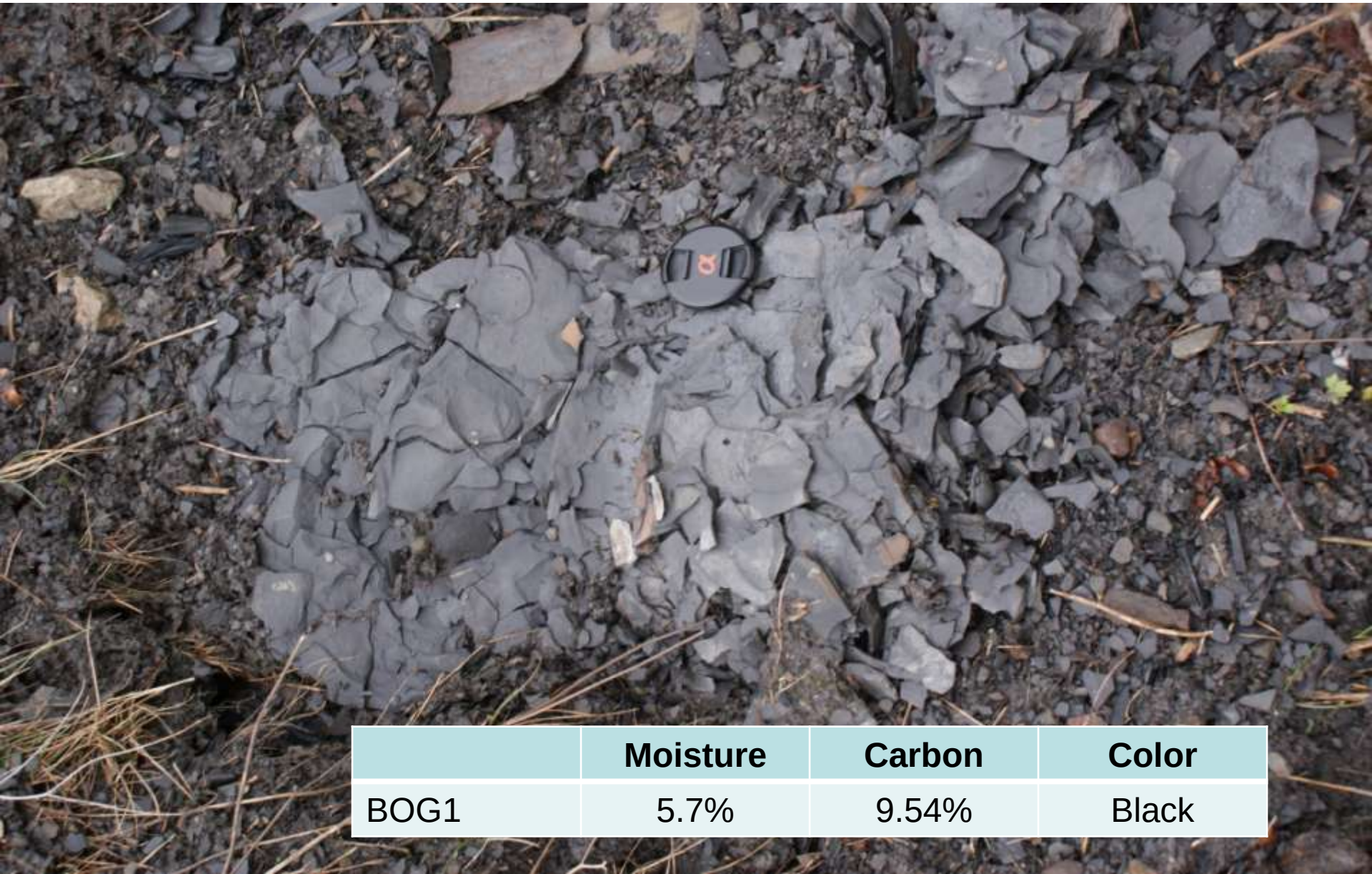

	Moisture	Carbon	Color
BOG1	5.7%	9.54%	Black

View from SE

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Post-combustion –'red blaes'

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Post-combustion –'red blaes'

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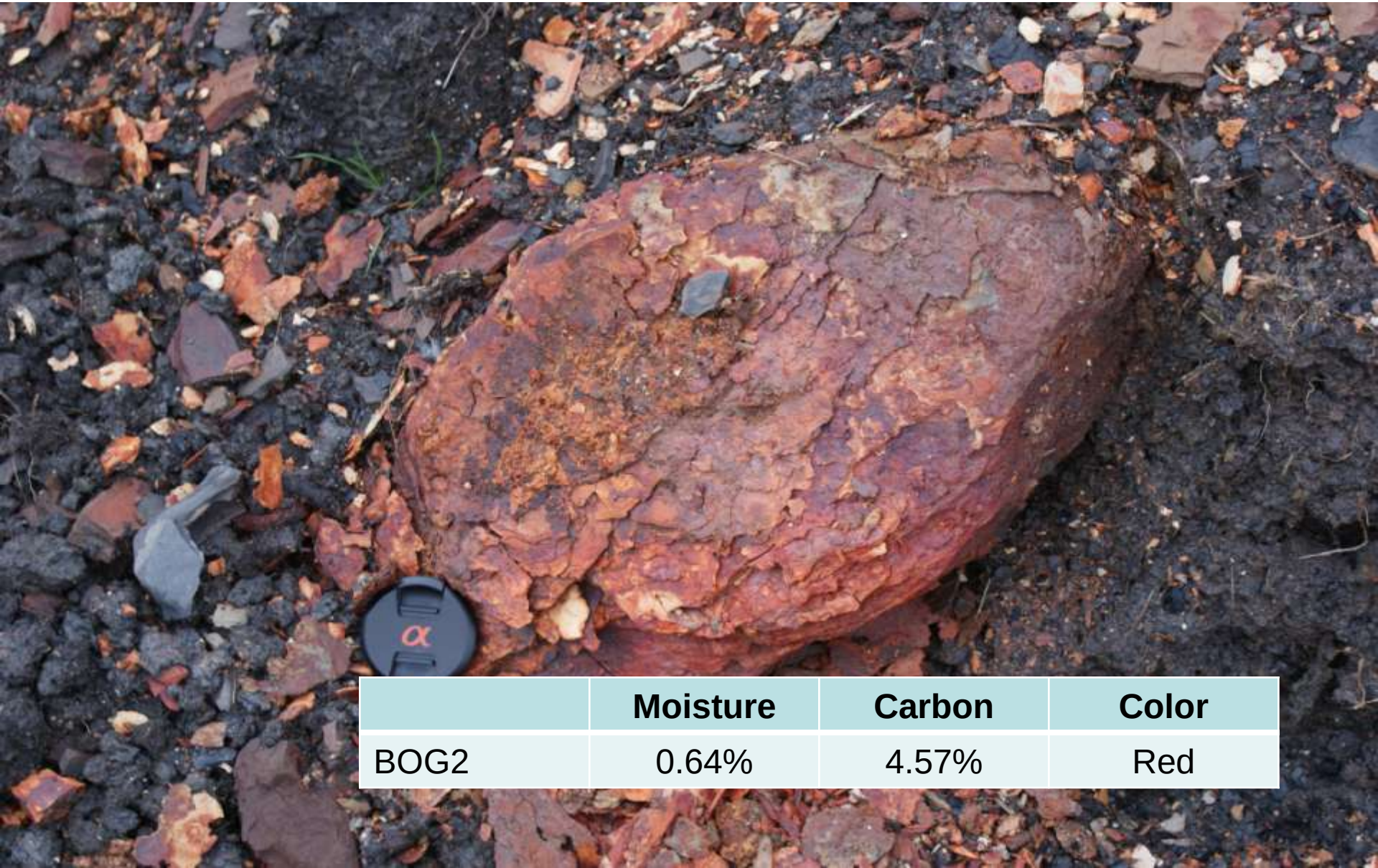

	Moisture	Carbon	Color
BOG2	0.64%	4.57%	Red

Sample locations

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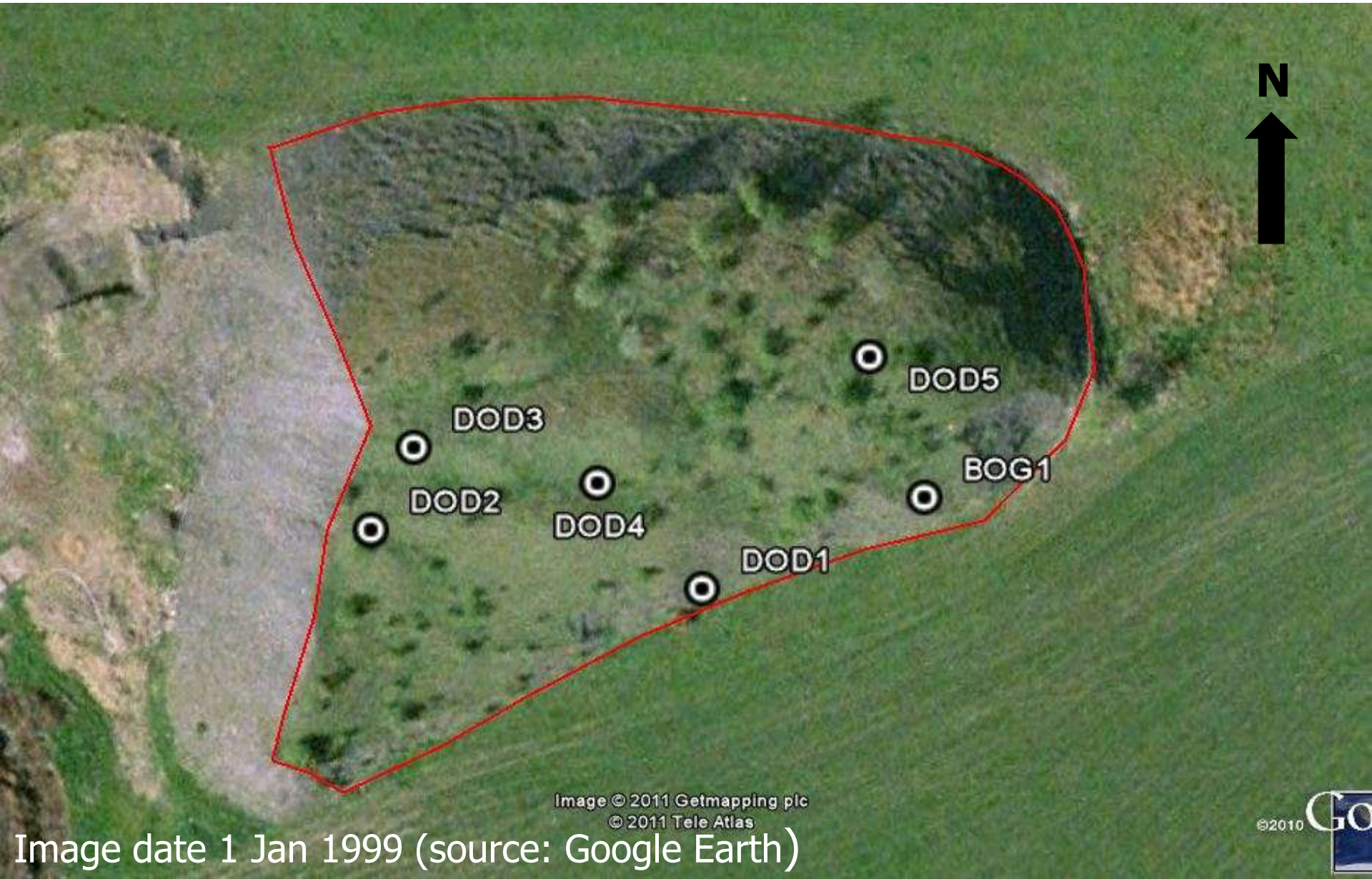

Image date 1 Jan 1999 (source: Google Earth)

Elemental analysis

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	As ppm	Cd ppm	Cr ppm	Cu ppm	Fe ppm	Hg ppm	Mn ppm	Ni ppm	Pb ppm	Se ppm	Zn ppm
BOG1	<3	<5	**113**	49	35,000	bdl	184	37	20	bdl	93
DOD1	**63.4**	**6.3**	81.7	**71.1**	**56,632**	bdl	**205**	**37.2**	**328**	4.7	58
DOD2	2.3	3.9	77.6	39.0	28,303	**60.6**	171	26	55	29	100
DOD3	8.1	2.2	52	45	20,049	2.2	72.2	20.9	116	**224**	89
DOD4	1.8	2.9	50.9	21.7	25,774	0.6	191	22.1	26.2	3.4	**122**
DOD5	1.9	1.7	36	30.8	15,502	bdl	179	25.4	74.5	bdl	122

- Minor enrichment of some potentially toxic metals

Vents

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Fissures

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Fissures

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Infra-red imaging of vent

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Infra-red imaging of vent

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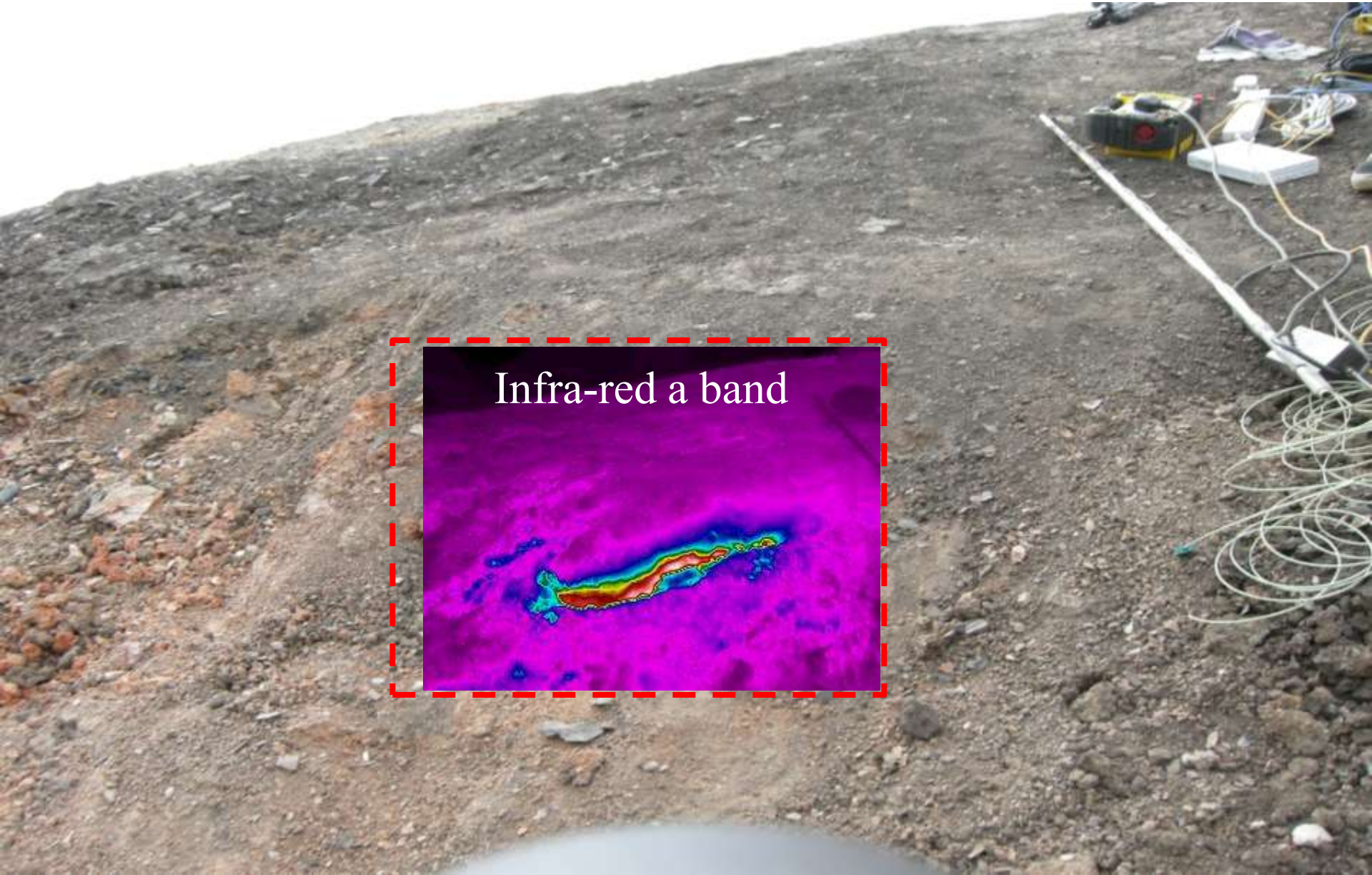

Vent gas analysis

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Sample locations

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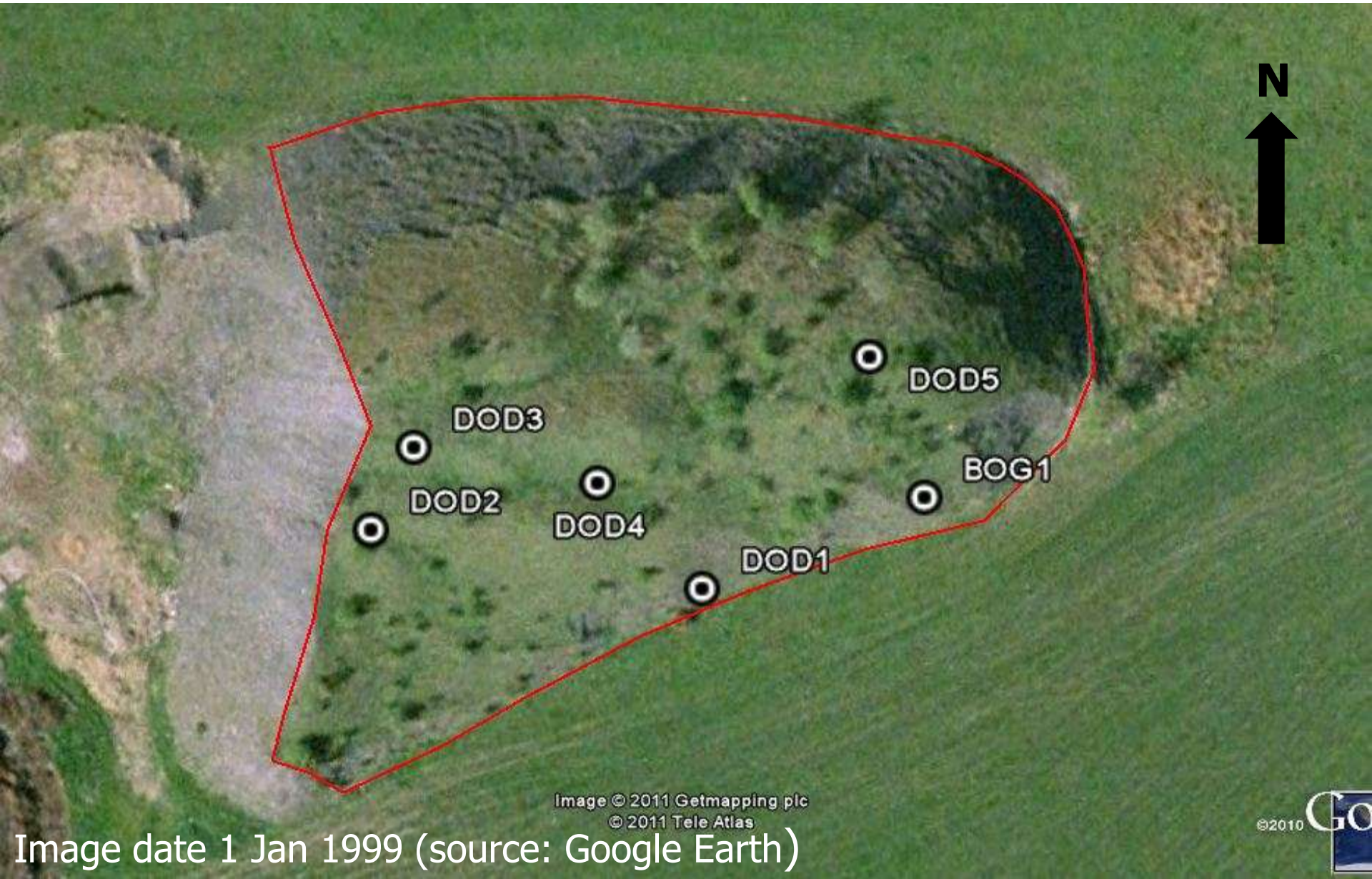

Image date 1 Jan 1999 (source: Google Earth)

Gas analysis

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	Blank	DOD4(1)	DOD4(2)	DOD3 (1)	DOD3 (2)
H_2O (vol%)	0.99	1	0.94	0.95	0.98
CO_2 (vol%)	0.09	0.81	1.91	0.6	0.51
CO (ppm)		13	33	14	10
SO_2 (ppm)			trace	trace	
CH_4 (ppm)		116	274		
C_2H_6+ (ppm)		10	27	trace	trace
O_2 (vol%	21.41	20.41	19.06	21.03	21.04

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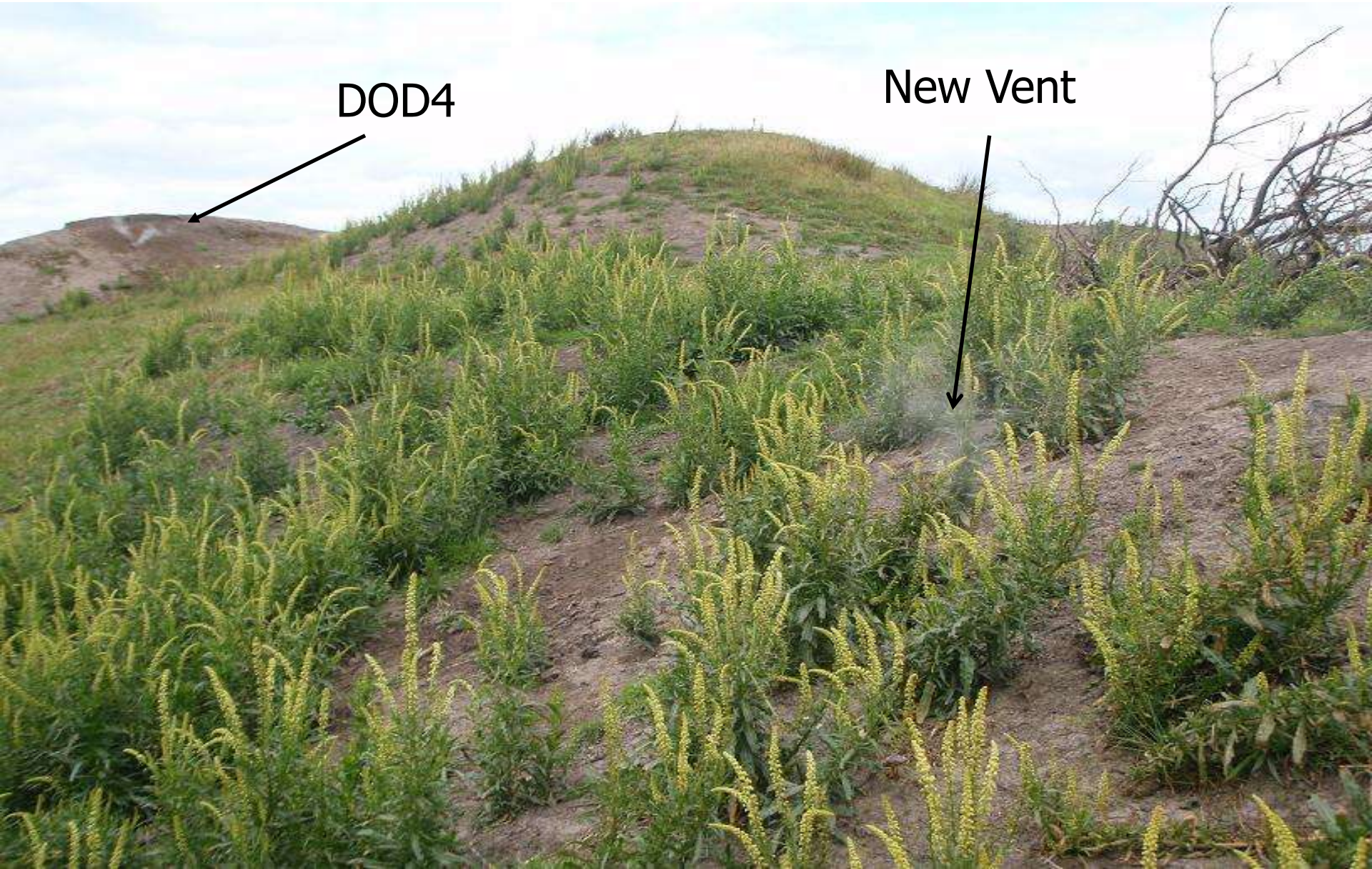
DOD4 19 May 2011

Sample point DOD4 is initially in the drying zone, but within a month temperature has increased and the moss surrounding the vent has died.

DOD4 10 June 2011

New vents



Smoldering

Photo ©Anupma Prakash

Smoldering

- Flameless combustion.
- Low peak temperature (~600°C)
- Low heat of combustion (~5 kJ/g)
- Creeping propagation (~0.1 mm/s)
- Heterogeneous reactions at surface of condensed-phase fuel.
- Endothermic pyrolysis & exothermic oxidations.
- In-depth burning in porous media.
- Combustion reaction is typically incomplete.

Photo ©Anupma Prakash

Rein, *Intern. Review Chemical Engineering* 2009

Centralia, PA

- In 1962 a fire reached entry to an abandoned mine… and still burns today.
- Centralia was evacuated by order of the US government.
- There is fuel for over 200 years

Evidence for smoldering

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- No visible evidence of flame.
- Self sustaining; analogous to charcoal grill.
- Heap temperatures within smoldering range.
- Presence of CH_4 and H_2O in gas vent measurements.
- Pore sizes create oxygen-limited combustion environment.
- Red 'blaes' collapse after combustion further limits transition to flame.

Progression of combustion front

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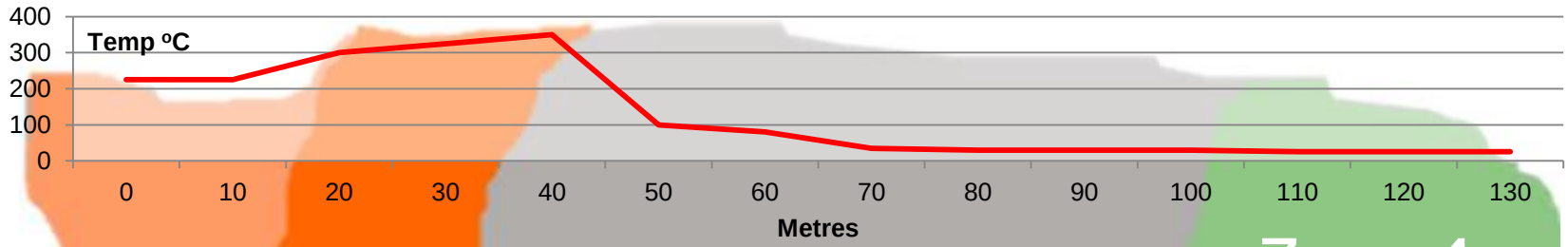


Zone 4 black Shale

Zone 3 out-gassing zone

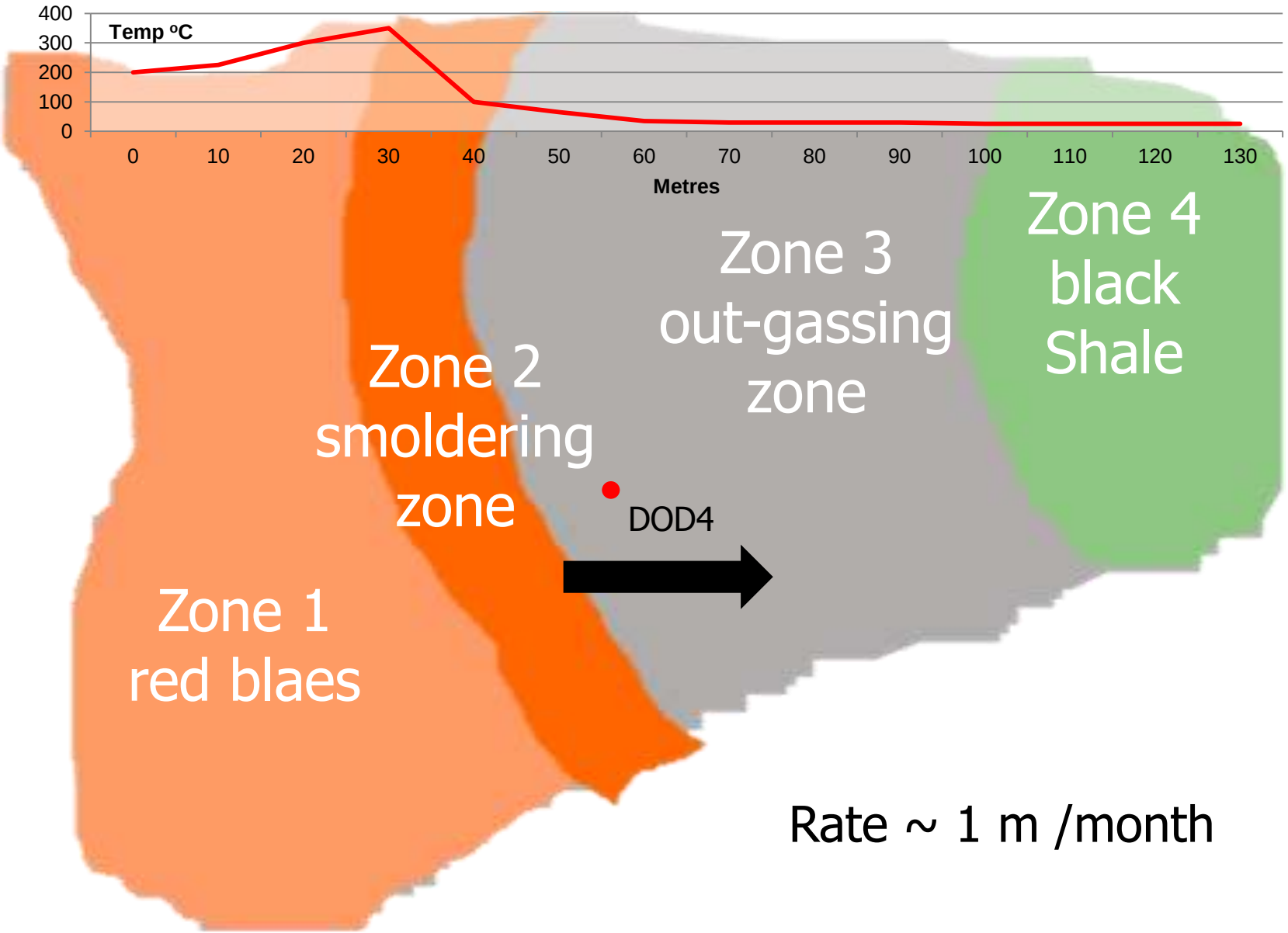
Zone 2 smoldering zone

DOD4

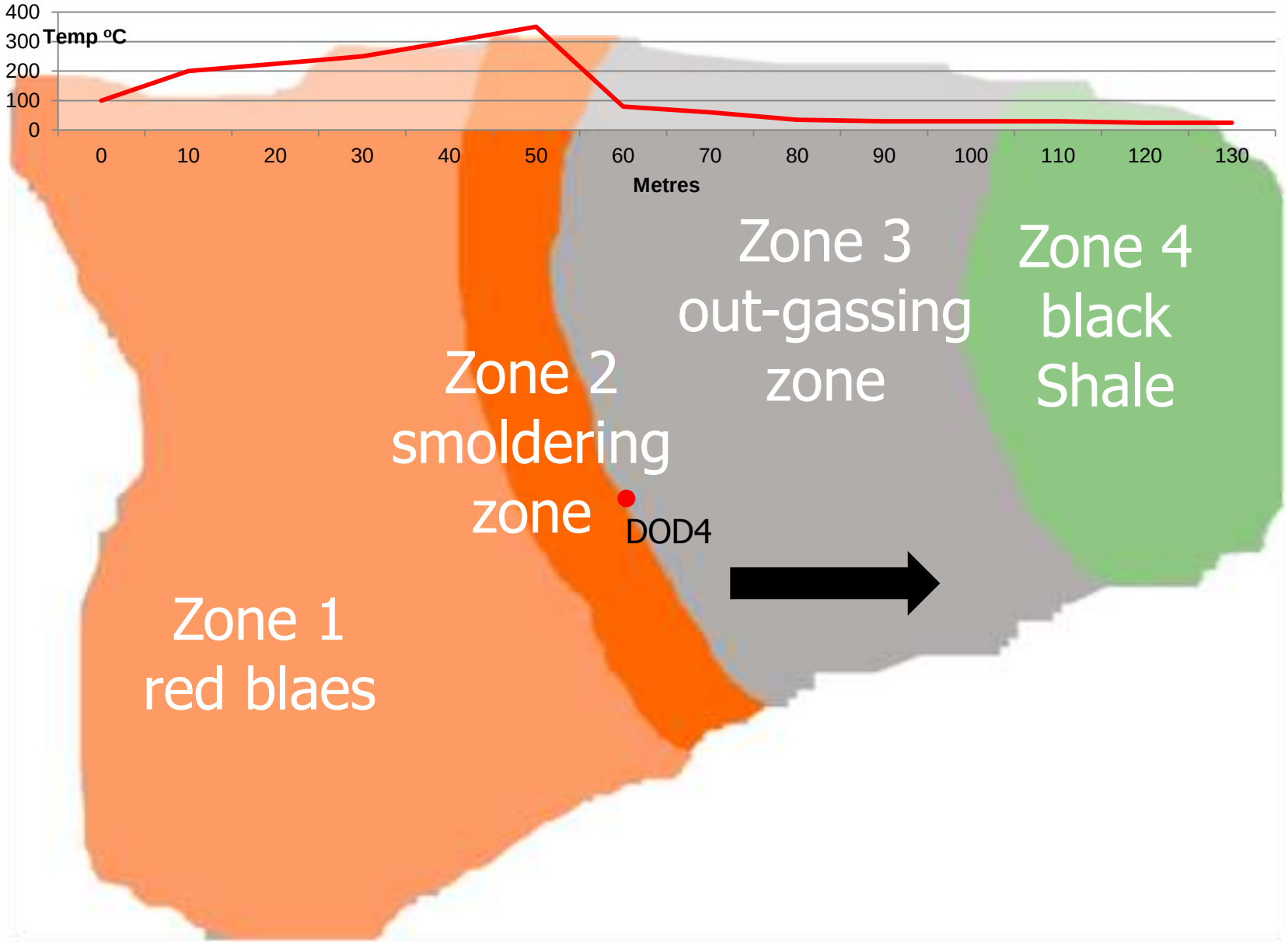
Zone 1 red blaes

Rate ~ 1 m /month

Progression of combustion front



Progression of combustion front



Self-sustaining treatment

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http://star.siremlab.com/

star
Self-sustaining Treatment for Active Remediation

Summary

- Slow oxidation of carbonaceous material in the heap causes internal temperature to rise.
- Combustion probably initiated by removal of material from west side of heap increasing air flow.
- Smoldering combustion initiated, progresses as a front through the heap.
- Structural changes in heap promote fracturing, further increasing air flow; chimney effects.
- Stability of slopes compromised by loss of vegetation and fractures.
- Zone of out-gassing and drying ahead of main combustion – marked by vents and moisture release.

Questions?

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