Utilization of coal wastes in municipal waste landfill reclamation – a Katowice-Wełnowiec case study, Poland

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Katowice Siemianowice Śląskie

POLAND

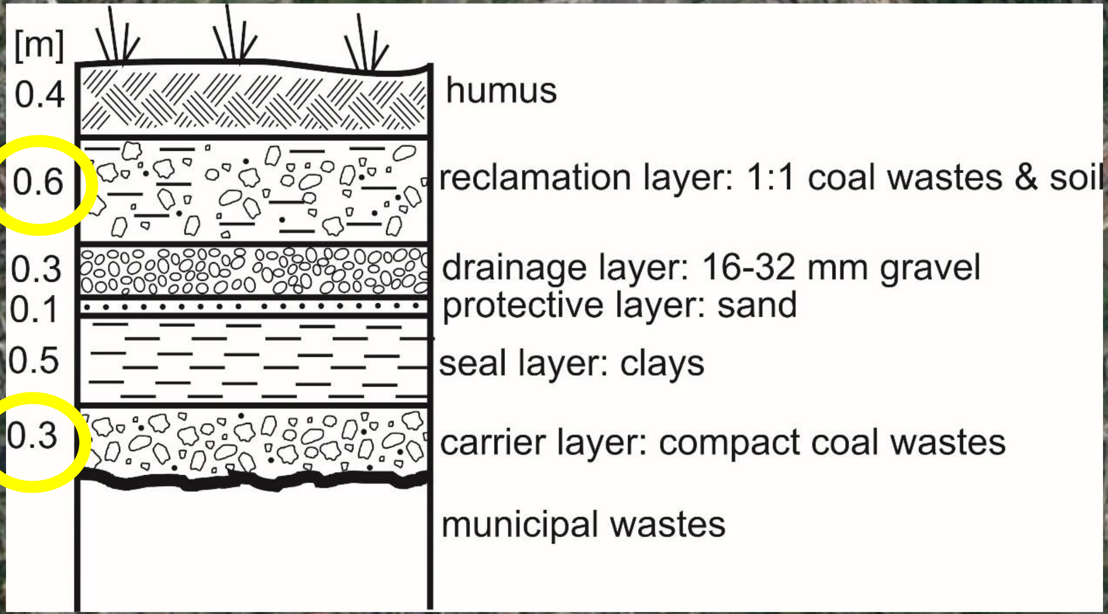
Silesian Voivodeship

KATOWICE-WEŁNOWIEC DUMP

~2.5 km

1991-1996:
rubbish dump
area ca 1.6 ha
1.6 mln tonnes of **wastes:**
22.6% of **coal wastes**
21.5% of **municipal wastes**
40% of **building wastes**
40% of **composting plant wastes**

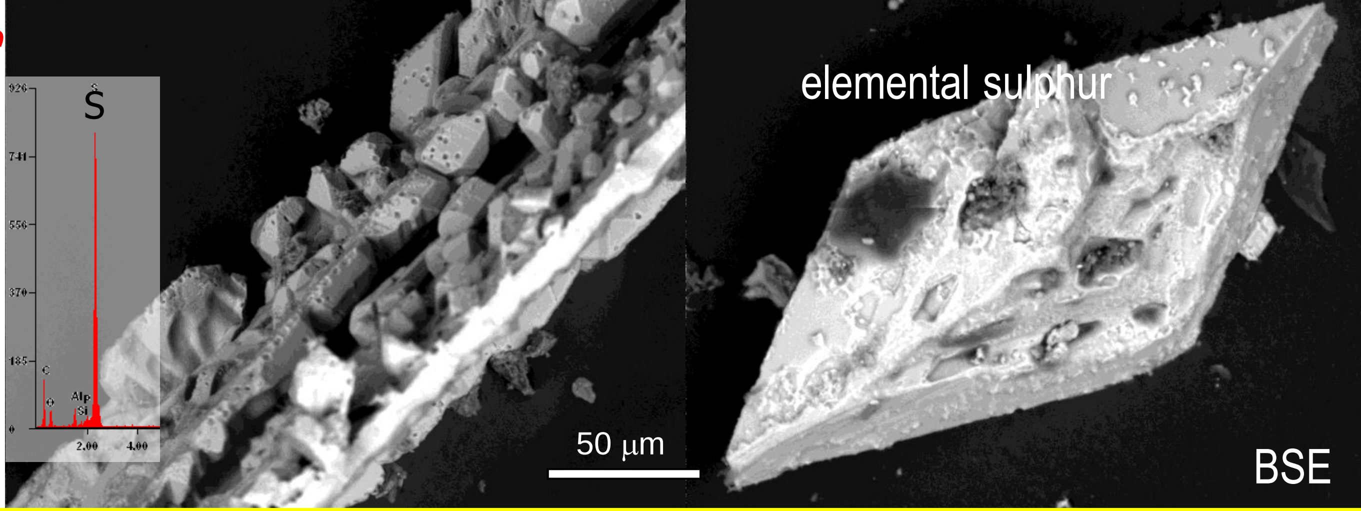
1998:
municipal waste landfill reclamation with multi-barrier system:



2001:
methan exploitation:
gas collecting installation with 39 boreholes

northern slope, eastern part


south-eastern slope


S
50 µm
elemental sulphur
BSE


Katowice-Wełnowiec dump
December 5, 2008
Google Earth
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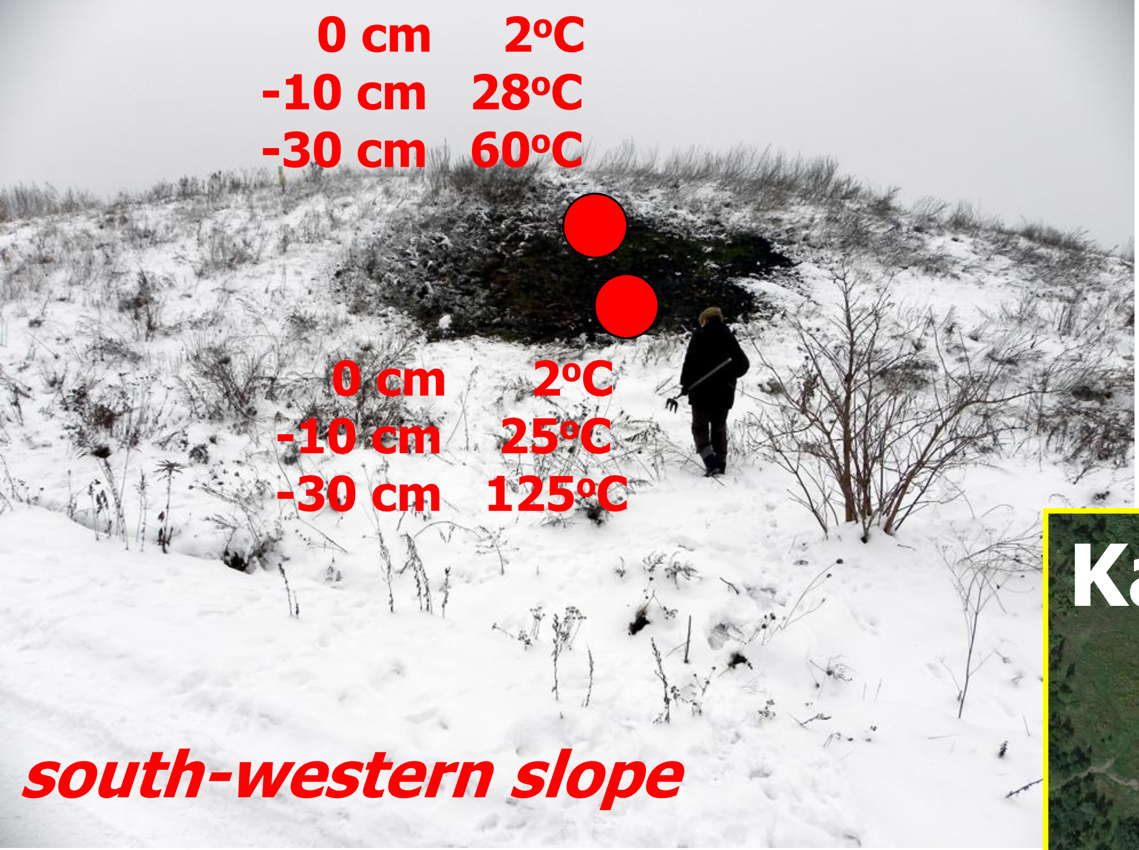
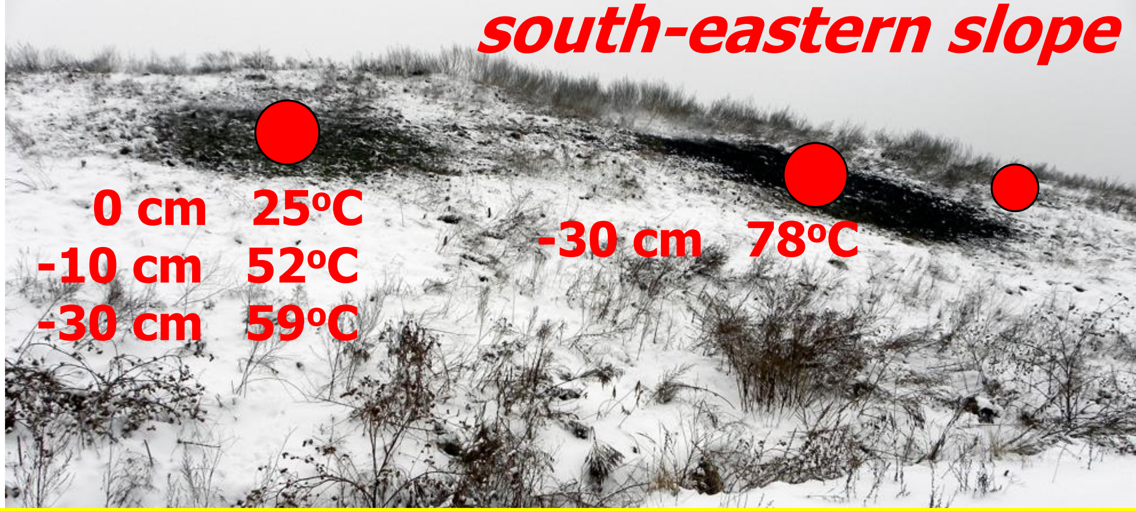
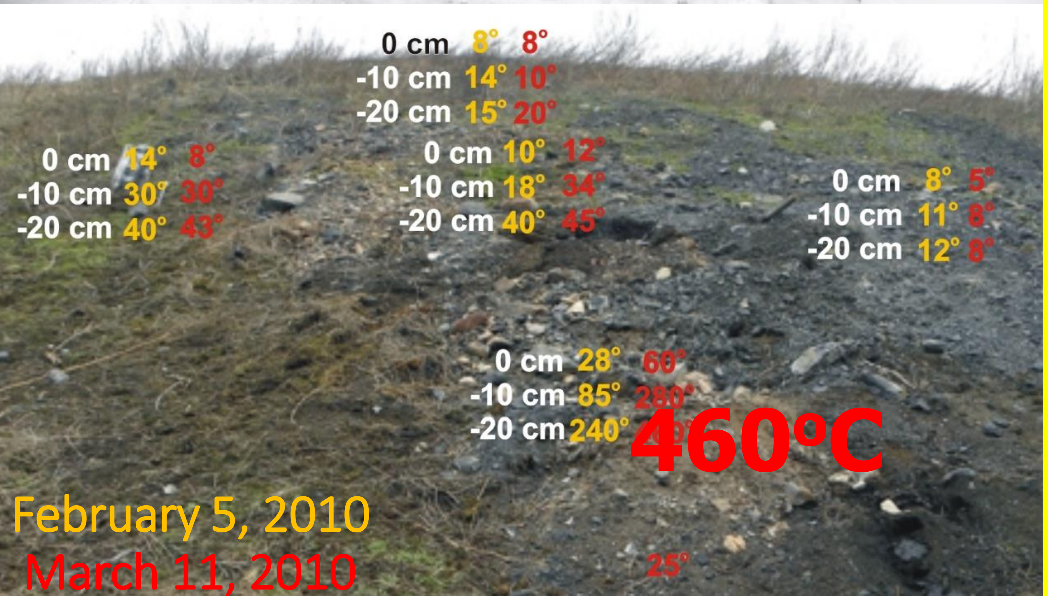
100 m
N



0 cm 2°C
-10 cm 28°C
-30 cm 60°C
0 cm 2°C
-10 cm 25°C
-30 cm 125°C
south-western slope



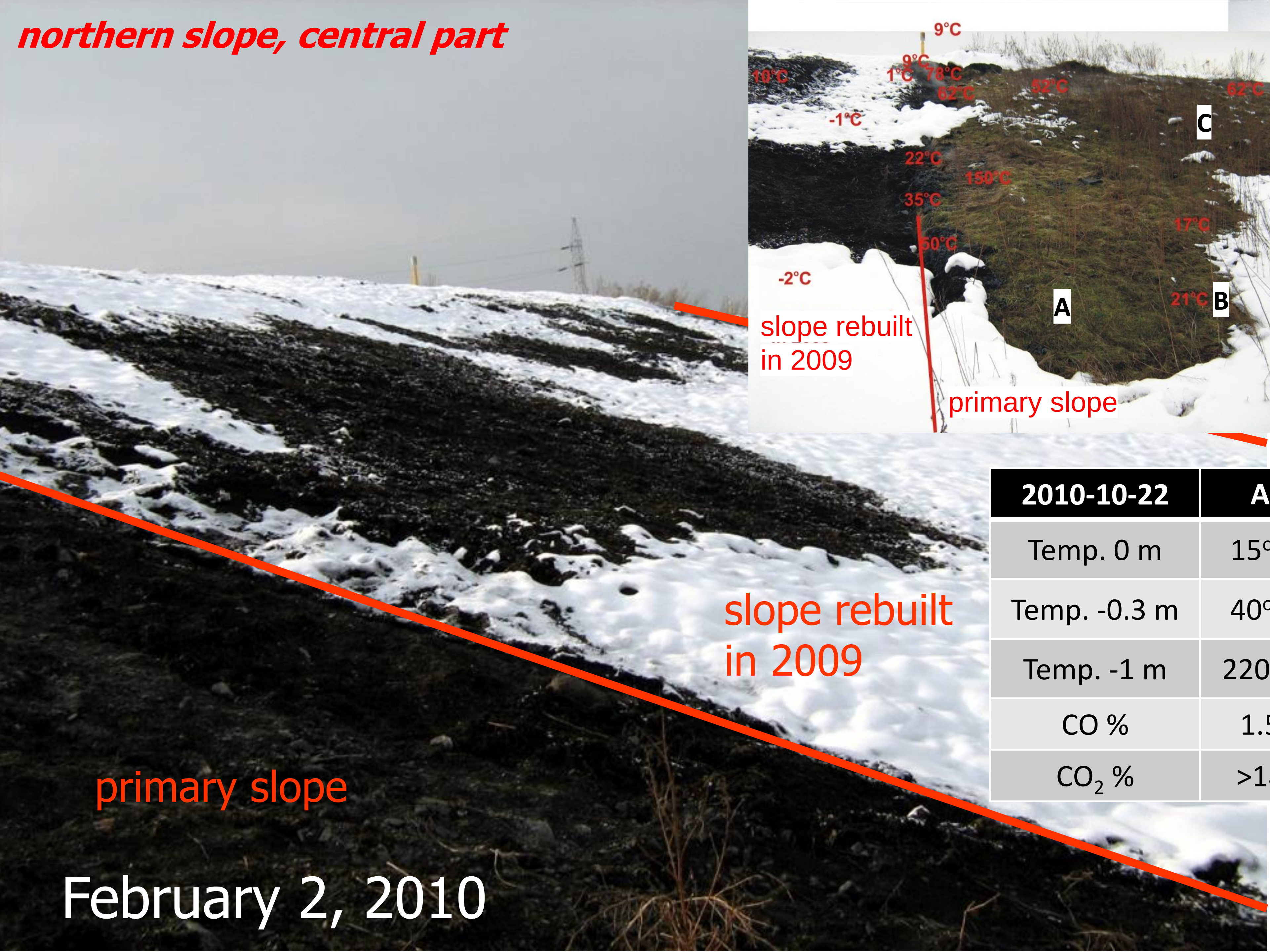
south-eastern slope
0 cm 25°C
-10 cm 52°C
-30 cm 59°C
-30 cm 78°C



0 cm 8° 8°
-10 cm 14° 10°
-20 cm 15° 20°
0 cm 14° 8°
-10 cm 30° 30°
-20 cm 40° 43°
0 cm 10° 12°
-10 cm 18° 34°
-20 cm 40° 45°
0 cm 8° 5°
-10 cm 11° 8°
-20 cm 12° 8°
0 cm 28° 60°
-10 cm 85° 280°
-20 cm 240°
460°C
25°
February 5, 2010
March 11, 2010

Katowice-Wełnowiec dump
January 16, 2010
Google Earth
©2017 Google
100 m
N


-3 m 40ºC
-1 m 70ºC
-1 m 350ºC
northern slope, central part
Katowice-Wełnowiec dump
Google Earth
©2017 Google
December 1, 2009
100 m
N



2011-03-29

2010-10-22	A	B	C	D
Temp. 0 m	15ºC	55ºC	20ºC	85ºC
Temp. -0.3 m	40ºC	90ºC	48ºC	670ºC
Temp. -1 m	220ºC	220ºC	110ºC	n.d.
CO %	1.5	>3	2.5	n.d.
CO_2 %	>18	>18	>18	n.d.

Aims:

- to discover the fire's origin,
- to determine thermal activity influence on organic and inorganic geochemistry, petrography, and mineralogy of the wastes and leachates,
- to apply geophysics to distinguish:
  - municipal and coal wastes
  - burnt and unburned coal wastes,
- to determine a real thickness of coal wastes used for reclamation,
- to prove if the planned multi-barrier system of municipal waste landfill reclamation was applied at any part of the Wełnowiec dump.

Methods:

Powder X-ray Diffraction PXRD

Scanning Electron Microscopy SEM- EDS

Reflected Light Optical Microscopy RLOM

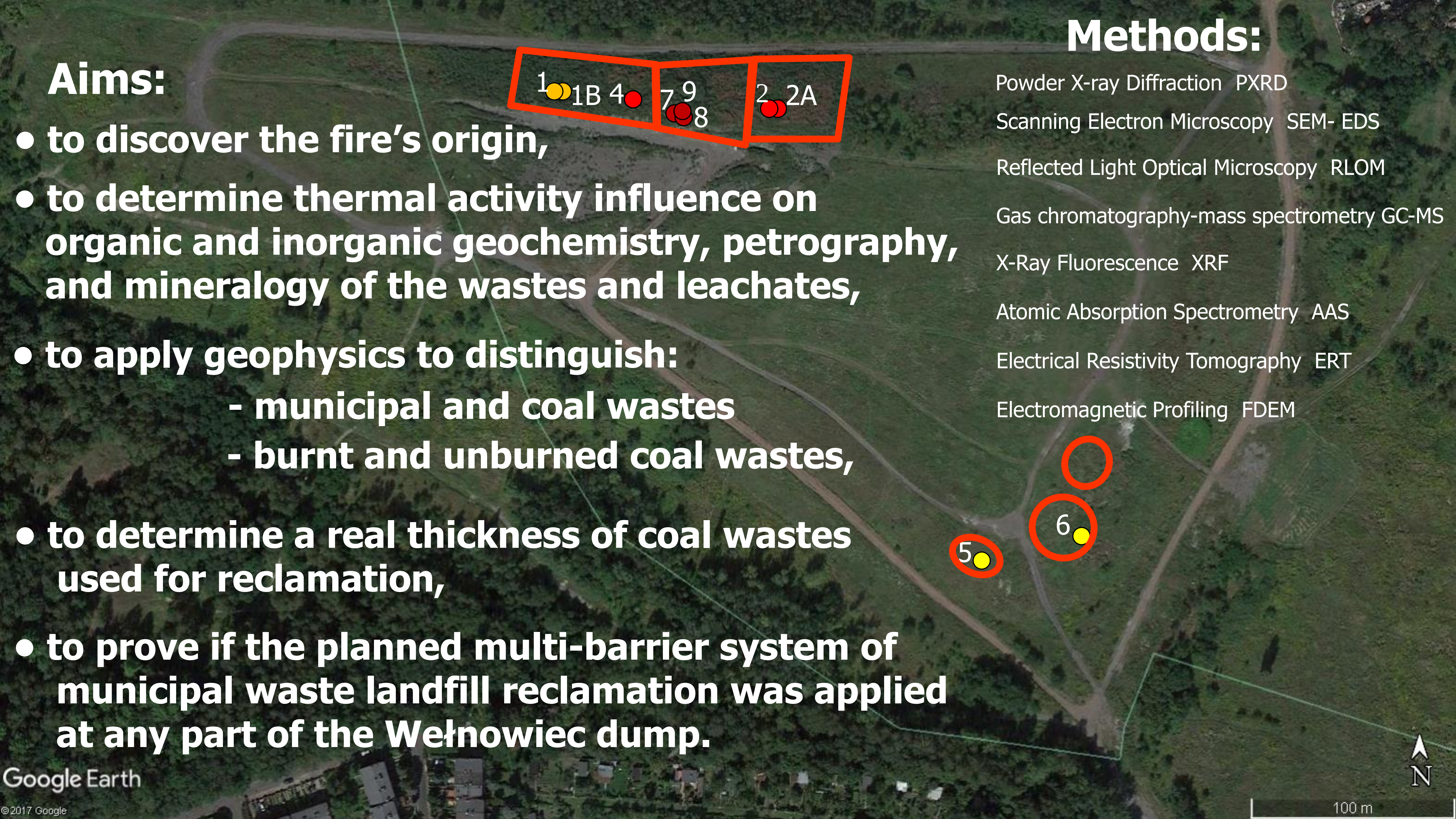
Gas chromatography-mass spectrometry GC-MS

X-Ray Fluorescence XRF

Atomic Absorption Spectrometry AAS

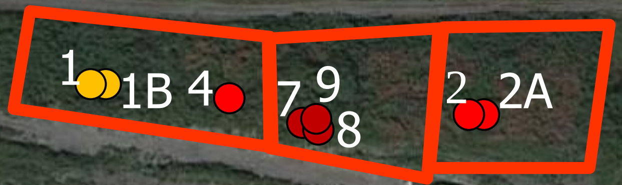
Electrical Resistivity Tomography ERT

Electromagnetic Profiling FDEM



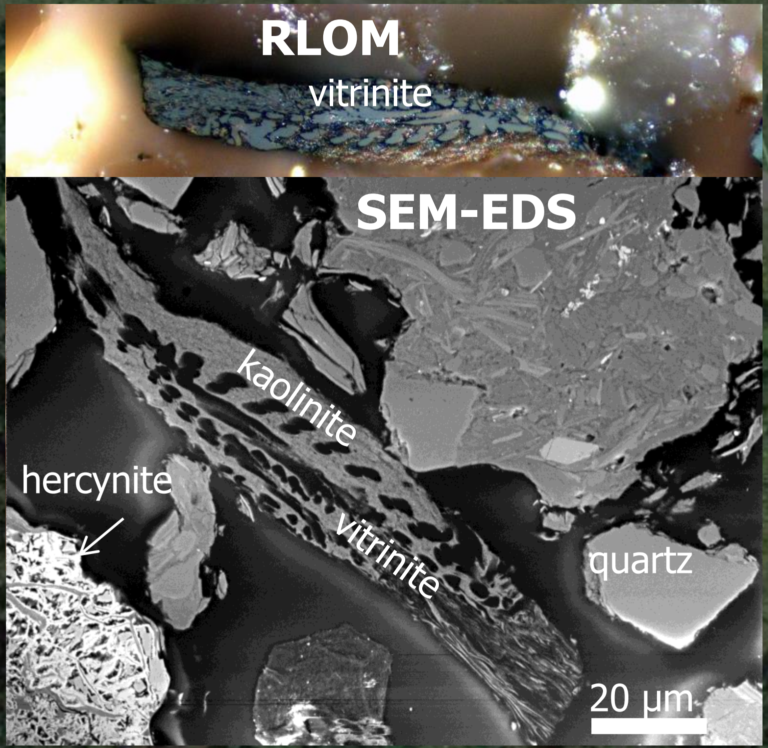
ZONE I - INITIAL

is located at the edges of active zones, where fire overtakes new volume of the coal wastes



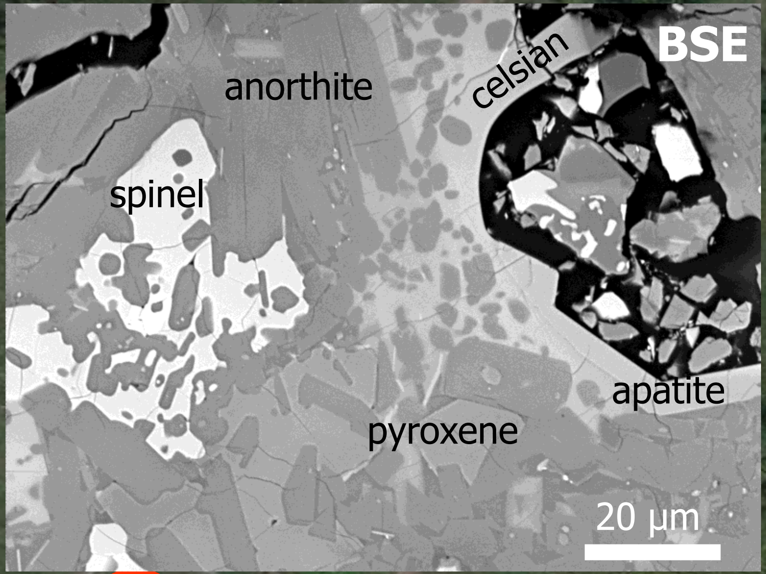
ZONE O - OVERBURNED

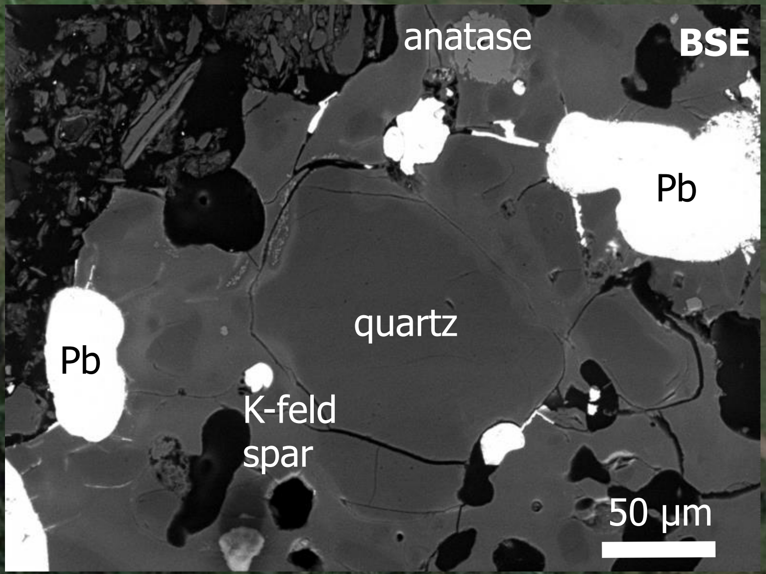
characterize in temperatures being high for a long time, up to 800-900°C and higher; the zone was accessible thanks to fire-extinguishing works



ZONE A - ACTIVE

is located within areas where fire has never been extinguished and the temperature has reached 400-500°C at the surface in the exhalation flues





ZONE F - FORMER

were short termed and fire was not intensive there; temperatures oscillated between 70-100°C, with maximum of 460°C lasting only up to 1-2 months

Google Earth

N

100 m

Mineralogy...

Thermal zones	initial		active			former		overburned		
	1	1B	2	2A	4	5	6	7	8	9
...minerals of wastes										
quartz SiO_2	XXX	XXX	XXXX	XXXX	XXXXX	XXXXX	XXXXX		X	X
illite /muscovite $KAl_2(AlSi_3O_{10})(OH,F)_2$	XXXX	XXXX	XXXX	X	XX	XX	X			
biotite $K(Mg,Fe)_3(AlSi_3O_{10})(F,OH)_2$	EDS						EDS			
kaolinite $Al_2Si_2O_5(OH)_4$	XX	XX	XX		XX	XX	XX			
dickite				XX						
chlorite $(Mg,Fe)_5Al(Si_3Al)O_{10}(OH)_8$	XX	XX								
clinochlore $Mg_5Al(Si_3Al)O_{10}(OH)_8$			X		XX	XX	X			
microcline $KAlSi_3O_8$	XX	XX	EDS	XXX	XX		XX			
orthoclase $KAlSi_3O_8$						XX				XX
coal	EDS	EDS	EDS	EDS	EDS	EDS	EDS			EDS
...combusted phases										
cristobalite SiO_2									X	
celsian $(K, Ba)AlSi_3O_8$								EDS		
plagioclase $(Na, Ca)AlSi_3O_8$	X				X	EDS	XX			
anorthite $CaAl_2Si_2O_8$								XXXX		XXXX
cordierite $Mg_2Al_3[AlSi_5O_{18}]$									XXXXX	
corundum Al_2O_3				EDS						
mullite $Al_6Si_2O_{13}$			XX						XXX	
olivine group $(Fe, Mg)_2SiO_4$								XX		
augite								XXX		XXX
hematite Fe_2O_3		?	EDS	EDS				X	X	X
magnesioferrite $MgFe_2O_4$								X		
magnetite $FeFe_2O_4$		?	EDS						X	
hercynite $FeAl_2O_4$	EDS		EDS					EDS		
spinel $(Mg, Fe)Al_2O_4$		EDS			?			?		X
calcite $CaCO_3$		EDS	EDS	X	trace	EDS				
dolomite $CaMg(CO_3)_2$						EDS				
hydroxyapatite $Ca_5(PO_4)_3(OH)$		EDS	EDS	EDS	Cl-EDS	EDS		X		
gypsum $CaSO_4{\cdot}2H_2O$				XX						
sal ammoniac NH_4Cl				X						
glass		?	EDS	EDS	EDS	EDS		EDS		EDS
...minerals in traces										
calcite $CaCO_3$		EDS	EDS	X	trace	EDS				
dolomite $CaMg(CO_3)_2$						EDS				
zircon $ZrSiO_4$	EDS	EDS			EDS					
monazite-(Ce) $(Ce,La)PO_4$	EDS									
anatase TiO_2	EDS				EDS					
lead Pb				EDS	EDS					
iron Fe									EDS	
chalcopyrite $CuFeS_2$									EDS	
ZnS					EDS					

Chemistry [mass %]

Element	Cause / mode of occurrence	initial	active	former	overburned
Si	carbonates, sulfates, depletion in quartz	24.80	19.43	26.30	22.20
Ti	affinity to anatase and zircon	0.56	0.43	0.42	0.37
Al	carbonates	5.85	4.05	4.71	5.03
K	depletion in muscovite and K feldspar	2.81	1.67	2.91	1.74
Sb	hercynite? coal? plagioclase? ZnS, chalcopyrite	0.10	0.05	0.23	0.07
In		0.65	0.49	0.63	0.39
Sc		0.01	0	0.01	0
Fe	Fe oxides	1.64	2.74	1.49	7.24
Mn	Fe oxides	0.03	0.05	0.03	0.17
Mg	augite	0.33	0.47	0.24	1.42
Ca	calcite, augite, anorthite	0.27	2.68	0.29	4.68
P	apatite	0.15	0.30	0.14	0.25
Sr	celsian	0.01	0.03	0.01	0.05
Ba	celsian	0.06	0.10	0.09	0.53
Se	ZnS, lead, gypsum, coal	0	0.01	0	0.01
Ce		0.01	0.05	0.03	0.09
Pr		0	0.04	0.03	0.05
Nd		0.01	0.04	0.04	0.14
Sn	affinity to Fe oxides	0	0.01	0	0.03
Te		0.21	0.38	0.22	0.60
I	sal ammoniac	0	0.02	0	0.01
S	gypsum, ZnS	0.19	1.47	0.14	0.14
Cl	salammoniac, chlorapatite	0.05	0.59	0.05	0.06
Zn	ZnS	0.01	0.10	0.02	0.01
Pb	combusted Pb	0	0.07	0	0
V	affinity to illite	0.03	0.02	0.02	0.01
Cr	affinity to chlorite and spinel	0.03	0.06	0.03	0.02
Co	affinity to Fe oxides	0.01	0.02	0.01	0.04
Rb	affinity to illite	0.01	0.01	0.01	0.01
Ge	affinity to Fe oxides	0.11	0.06	0.11	0.17

initial & former >> active & overburned

active & overburned >> initial & former

active

no correlation

absent elements: As, Cd, Hg, Hf, Nb, Ta, Th, U, Br, Rh, Ag, Ir, Pt, Au, Ga, Cs, Tl, W, Mo, Ni, Cu, Y, La, Dy

Leachates [mg/kg]...

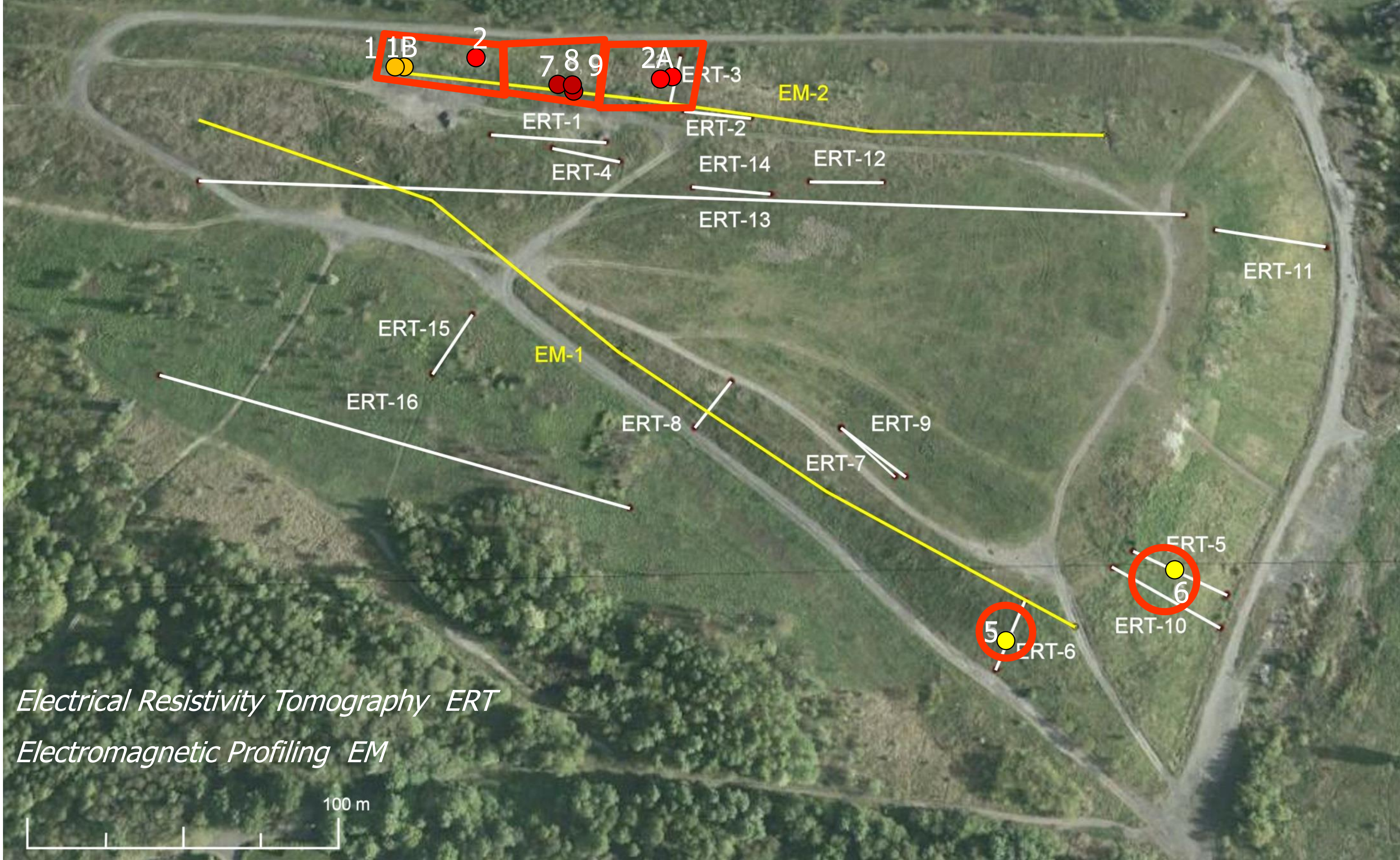
...major elements

		initial	active	former	overburned
Mg	rock	3310	4737	2375	14160
	leachate	30	411	45	175
	%	*0.90*	*15.03*	*1.93*	*1.19*
K	rock	28050	16667	29050	17423
	leachate	193	466	212	202
	%	*0.66*	*3.42*	*0.75*	*1.41*
Ca	rock	2660	26823	2850	46783
	leachate	165	7160	427	4660
	%	*5.32*	*14.88*	*17.52*	*10.30*
Mn	rock	259	543	303	1657
	leachate	0.00	8.3	0.00	0.47
	%	*0.00*	*1.53*	*0.00*	*0.03*
Fe	rock	16400	27400	14850	72433
	leachate	0.26	0.19	1.0	0.79
	%	*0.00*	*0.00*	*0.01*	*0.00*
total	rock	50680	76170	49430	152500
	leachate	387.48	8040.53	685.28	5039.00
	%	*0.76*	*10.56*	*1.39*	*3.31*

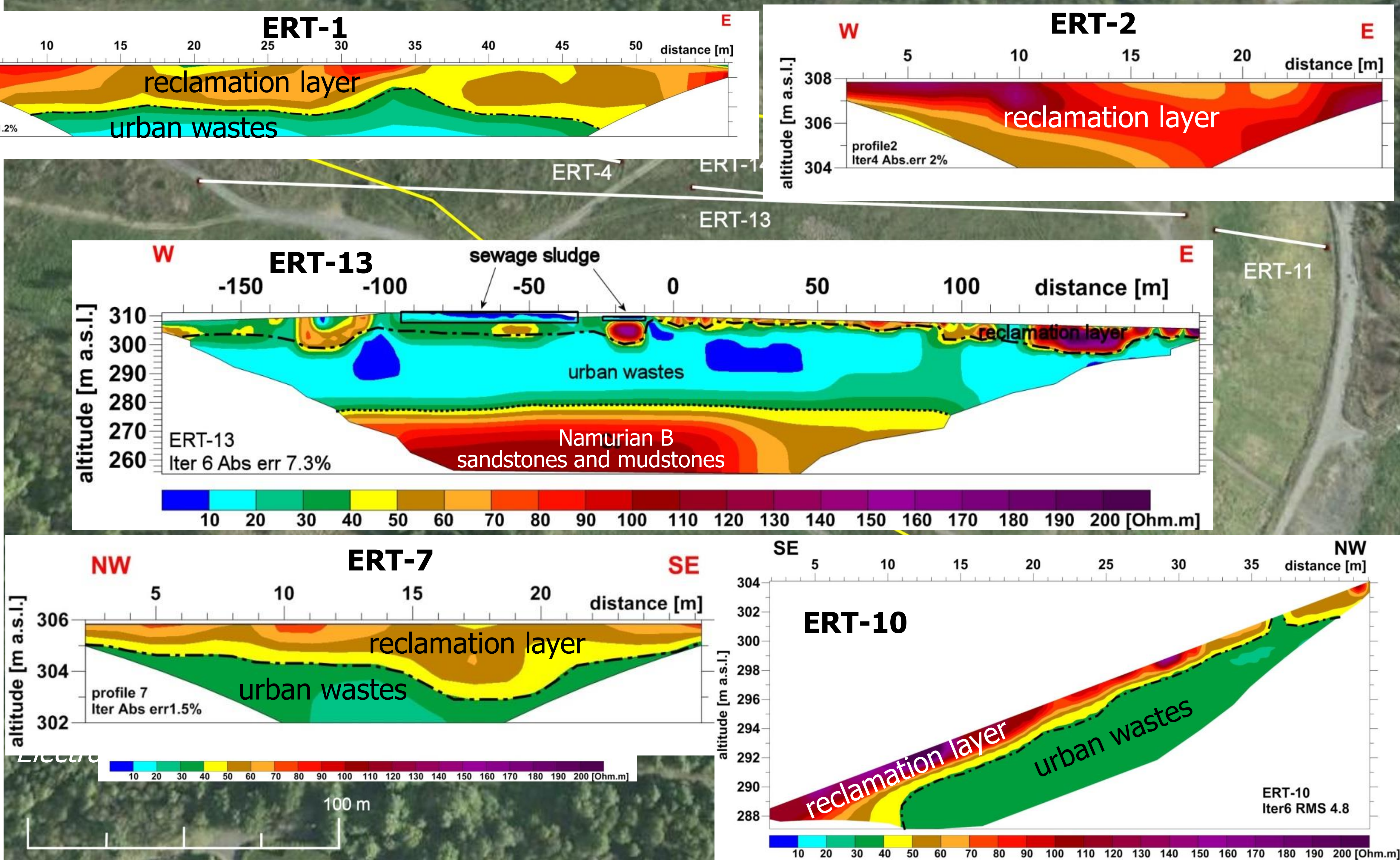
...minor elements

		initial	active	former	overburned
Ni	rock	202	277	202	233
	leachate	-	0.22	-	-
	%	-	*0.11*	-	-
Cu	rock	87	168	78	135
	leachate	0.35	0.52	0.63	1.67
	%	*0.40*	*0.40*	*0.90*	*1.46*
Zn	rock	82	985	155	81
	leachate	0.06	1.49	0.25	0.33
	%	*0.08*	*0.22*	*0.25*	*0.48*
Cd	rock	15	25	9	21
	leachate	-	-	-	-
Pb	rock	31	651	50	27
	leachate	-	-	-	-
Co	rock	118	209	115	370
	leachate	0.06	0.11	0.15	0.13
	%	*0.05*	*0.04*	*0.12*	*0.04*
total	rock	534.00	2285.33	607.50	866.33
	leachate	0.48	2.31	1.03	2.12
	%	*0.09*	*0.10*	*0.17*	*0.25*

Geophysics


1
1B
2
7
8
9
2A
ERT-3
EM-2
ERT-1
ERT-2
ERT-4
ERT-14
ERT-12
ERT-13
ERT-11
ERT-15
EM-1
ERT-16
ERT-8
ERT-9
ERT-7
ERT-5
6
ERT-10
5
ERT-6
Electrical Resistivity Tomography ERT
Electromagnetic Profiling EM
100 m

Geophysics


ERT-1
W
E
distance [m]
altitude [m a.s.l.]
reclamation layer
urban wastes
profile 1
Iter8 Abs err. 1.2%
ERT-2
W
E
distance [m]
altitude [m a.s.l.]
reclamation layer
profile2
Iter4 Abs.err 2%
ERT-4
ERT-13
ERT-11
ERT-13
W
E
sewage sludge
distance [m]
altitude [m a.s.l.]
reclamation layer
urban wastes
Namurian B
sandstones and mudstones
ERT-13
Iter 6 Abs err 7.3%
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 [Ohm.m]
ERT-7
NW
SE
distance [m]
altitude [m a.s.l.]
reclamation layer
urban wastes
profile 7
Iter Abs err1.5%
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 [Ohm.m]
100 m
ERT-10
SE
NW
distance [m]
altitude [m a.s.l.]
reclamation layer
urban wastes
ERT-10
Iter6 RMS 4.8
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 [Ohm.m]

Przegląd Geologiczny, vol. 61, nr 12, 2013

Przebieg i przyczyny endogenicznego pożaru węgla kamiennego na zrekultywowanym składowisku odpadów komunalnych w Katowicach

Justyna Ciesielczuk[1], Janusz Janeczek[1], Stefan Cebulak[1]


J. Ciesielczuk


J. Janeczek


S. Cebulak

The cause and progress of the endogenous coal fire in the remediated landfill in the city of Katowice. Prz. Geol., 61: 764–772.

A b s t r a c t. Slopes of the abandoned municipal waste landfill in the city of Katowice remediated in 1998 have been thermally active since 2007. The thermal activity was caused by spontaneous coal combustion within the sub-surface (0.5–1.5 m below ground level) layer of coal mine waste used for engineering the landfill. Exploitation of biogas from the landfill prior to thermal events may have enhanced exothermic oxidation of coal waste. The smoldering is the prevalent and persistent form of coal combustion in the landfill and is responsible for high emissions of CO (up to 3%), CO_2 (>18%), methane and a suite of gaseous hydrocarbons. Attempts to extinguish coal fire did not prevent the advance of smoldering front at a rate of tens of metres per year.

Keywords: *coal waste, smoldering fire, municipal waste landfill, Katowice, Poland*

DE GRUYTER OPEN

Environmental & Socio-economic Studies

environ

DOI: 10.1515/environ-2015-0057

Environ. Socio.-econ. Stud., **2015, 3, 2: 1-10**

Plant occurrence on burning coal waste – a case study from the Katowice-Wełnowiec dump, Poland

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journal homepage: www.elsevier.com/locate/coal

Thermal history of coal wastes reflected in their organic geochemistry and petrography; the case study: The Katowice-Wełnowiec dump, Poland

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A R T I C L E I N F O

Keywords:
Self-heating
Coal waste
Macerals
Geochemical markers
Aromatic hydrocarbons

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journal homepage: www.elsevier.com/locate/coal

Structure and thermal history of the Wełnowiec dump, Poland: A municipal dump rehabilitated with coal waste

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A R T I C L E I N F O

Keywords:
Self-heating
Thermal zones
Coal wastes
Electrical resistivity tomography (ERT)
Conductivity profiling (FDEM)
Mineralogy
Geochemistry

A B S T R A C T

The Wełnowiec municipal dump, Katowice, Poland, rehabilitated with coal waste, is self-heating and igniting. This paper presents a novel application of the use of electrical- and resistivity geophysical methods in the investigation of burning coal waste to help explain why the heating occurred. Geoelectrical methods allowed the internal structure of the dump to be revealed, and the municipal wastes and their rehabilitation cover containing coal waste to be differentiated. Instead of a planned 2.2-m-thick multi-barrier system, the cover consists of irregularly distributed material of varying thickness (< 1 to 8 m) and organic carbon content (> 5%). This caused the fire to arise 3–4 years after the coal waste deposition. In areas where the rehabilitation layer is < 3 m

CONCLUSIONS

- why did the fire start? **5 times exceeded the volume of coal wastes!**
- how does thermal activity influence the chemistry and mineralogy of the wastes and leachates? **strongly!**
- can we apply geophysics to distinguish:
  - municipal and coal wastes **yes**
  - burnt and unburned coal wastes? **no**
- what is a real thickness of coal wastes used for reclamation? **from 1 up to 10 m**
- was the planned multi-barrier system of municipal waste landfill reclamation applied at any part of the Wełnowiec dump? **no**

Geological methods can complete recent stories as well...

April 21, 2023