PRESENTS

IMAGING WITH ELECTRICITY

WITH SPEAKER ANDY ADLER
PROFESSOR - SYSTEMS AND
COMPUTER ENGINEERING,
CARLETON UNIVERSITY

WEDNESDAY, NOV 2, 2016
6:30-7:30 PM
SUNNYSIDE LIBRARY
1049 BANK ST.

Imaging with Electricity, Andy Adler, 2016/11/02
Tomography
≜ imaging by sections

τόμος tomos, "slice, section"

γράφω graphō, "to write"
X-ray energy and the body
X-ray Computed Tomography — CT or CAT
Ultrasound
Ultrasound energy and the body
Ultrasound — imaging
MRI and the body
MRI — imaging*

* One way to do it
# Images and the body

<table>
<thead>
<tr>
<th>Modality</th>
<th>Energy</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>X–ray</td>
<td>High energy light</td>
<td>Attenuation</td>
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<tr>
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<td>High frequency sound</td>
<td>Reflection</td>
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<td>MRI</td>
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# Images and the body

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<tr>
<td>Electrical</td>
<td>Electricity</td>
<td>Resistance</td>
</tr>
</tbody>
</table>
Ohm's Law

\[ V = IR \]
Ohm’s Law

\[ V = IR \]
Current flow in tissue — Low Frequency
Current flow in tissue — High Frequency
Electrical Impedance Tomography (EIT)

10-day old healthy baby with EIT electrodes

Source: eidors3d.sf.net/data_contrib/if-neonate-spontaneous
EIT – electrical stimulation and measurements

Image with Electricity, Andy Adler, 2016/11/02
Current Propagation

Healthy Adult Male
CT slide at heart

Source:
eidors3d.sf.net/tutorial/netgen/extrusion
Current Propagation

Healthy Adult Male
CT slide at heart

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eidors3d.sf.net/tutorial/netgen/extrusion
Finite Element Modelling
Finite Element Modelling

Simulated Voltages

Voxel Currents
Thorax Propagation

CT Slice with simulated current streamlines and voltage equipotentials
Thorax Propagation

CT Slice with simulated current streamlines and voltage equipotentials
Changing Conductivity

Heart receives blood (diastole) and is more conductive
Changing Conductivity

Heart receives blood (diastole) and is more conductive
Changing Conductivity
Application: Breathing

Chest images of tidal breathing in healthy adult
Application: Heart

EIT Signal in ROI around heart (and ECG)
Lung Heterogeneity

Mechanical Ventilation and EIT monitor

Source: Swisstom.com
Acute Respiratory Distress Syndrome (ARDS)
EIT + Lung State

Imaging with Electricity, Andy Adler, 2016/11/02
EIT + Lung State

Overdistension

Collapse
EIT + Lung State

Overdistension

Collapse
EIT + Lung State

Overdistension

Collapse

Image with Electricity, Andy Adler, 2016/11/02
EIT + Lung State

Overdistension

Collapse
EIT + Lung State

![Diagram showing ventilaory pressure over time with corresponding imaging results.](image)

**Overdistension**

Collapse

**Images A to E**

*Imaging with Electricity, Andy Adler, 2016/11/02*
EIT + Lung State

Overdistension

Collapse

Imaging with Electricity, Andy Adler, 2016/11/02
EIT + Lung State

Overdistension

Collapse

Imaging with Electricity, Andy Adler, 2016/11/02
Blood Pressure via Pulse Transit Time

First breath of life

Source: D. Tingay et al., 2016

Imaging with Electricity, Andy Adler, 2016/11/02
Figure 1. La Soufrière lava dome seen from North-East. The dashed line marks the Eastern segment of the electrode line shown in Fig. 2. The small
Table 1. Description of the measuring electrodes configuration for each pair of stimulating electrodes.

<table>
<thead>
<tr>
<th>Measurement number</th>
<th>West profile</th>
<th>South−East profile</th>
<th>North profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tbody>
</table>

Source: N. Lesparre et al., Geophys J Int, 2014
values for $\alpha_i$ in order to estimate the corresponding values of $\log \tilde{\rho}_i + 1$:

$$\log \tilde{\rho}_i + 1 = f(\varsigma_i + \ldots)$$

The hydraulic pathway below the R1 structure and linking the Tarissan pit (GT on Fig. 9) to the Bains Jaunes hot springs.

For next iterations, the trial values correspond to is done with 13 trial values for the resistivity of $10^6 \Omega$.

Resistivity values span a range of $10^2$ orders of magnitude, varying between 0.2 and 0.5. For next iterations, the trial values correspond to the different resistive anomalies located on the western and southern sides of the cross-section with an average resistivity of $10^2 \Omega$.

...parameters (i.e. number of iterations, cut-off in the L-curve,...). These tests show that several structures located near the northern end of the R1 cross-section may significantly vary, especially the most resistive part of the resistive body that vertically extends up to the summit of the lava dome. This may explain the absence of any activity during the resistivity model test summit La Découverte (Fig. 8; Yasin et al., 2008). In practice, ten iterations are performed and the resistivity cross-section obtained from the inversion of the data set shown in Fig. 6 is displayed in Fig. 8. The resistivity cross-section correspond to summits on the plateau at the top of La Soufrière. The high-conductivity anomalies visible on the summit of the dome indicate a series of promontories visible on the summit of R1 ridge seems to constitute an efficient barrier that practically extends up to the summit of the lava dome. This may explain the absence of any activity during meltwater drainage near the northern end coincides with a dense region that coincides with a dense region of Nicollin et al. (2006) who give a resistivity history of the volcano. However, the chemical tracing soundings performed on the top part of the dome indicate that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with the fact that the peaks visible at the summit agree with...
Excavation tunnels for Evaluation of Nuclear Waste Storage

Figure 4. Mechanisms of breakouts formation after the microtunnel excavation due to strength and stress anisotropy, from Marschall et al. (2006).

respectively, located in the north and south side walls of GA04 at a distance of about 1 m from ring 1 (Fig. 3). Other measurements were made in 2005 March, 2006 April, 2007 September and 2008 April to monitor long timescale variations of the rock electrical resistivity.

The eight data sets analysed in this study were acquired by using the same procedure: an electrical current of 100 mA is injected in

Lesparre et al., Geophys J Int, 195:972–984, 2013
Excavation tunnels for Evaluation of Nuclear Waste Storage

Monitoring the EDZ with resistivity images

Figure 7. Evolution of the average resistivity with time during the process of gallery 04 excavation from 2004 July to 2008 April. North is on the right side.

The limited amount of data available would make a full 3-D inversion of the conductivity distribution hugely under-determined. Consequently, we reconstruct three 2-D conductivity structures, in the planes of the electrodes rings, interpolated along the axis of the gallery segment as described in the Appendix A.

4.2 Global resistivity structure

The resistivity tomograms possess a common global structure with two resistive anomalies located on opposite sides of the gallery (Fig. 7). A first persistent resistive anomaly (PRA1) is located in the 9hr–12hr sector and another one (PRA2) in the 3hr–5hr sector (see Fig. 8 for clock-like positioning). These two resistive structures have a size of about 2 m along the circumference of the gallery and a depth of 1.5 m.

The pattern depicted by the resistivity tomograms is identical to the breakout structure observed in the microtunnel (Fig. 4) and coherent with the high-resolution geological mapping performed during GA04 excavation (Gibert et al. 2006, Fig. 9). In particular, the bedding and the tectonic fault planes near the rings present a similar orientation with respect to the excavations in GA04 start niche and in the microtunnel (Fig. 4). The two resistive anomalies PRA1 and PRA2 may safely be attributed to the presence of highly damaged clay. The resistivity values in these areas are comprised between 20 and 100 \( \Omega \cdot m \) in full accordance with Kruschwitz & Yaramanci (2004) who found resistivities between 16 and 60 \( \Omega \cdot m \) in the damaged zones.

The resistivity at depths >2 m appears almost homogeneous with moderate variations from one period to another. The average resistivity is 11.8 \( \Omega \cdot m \) for a standard deviation of 1.6 \( \Omega \cdot m \). This value falls near the constant background resistivity of 11 \( \Omega \cdot m \) estimated from boreholes measurements. Such resistivity values are in full agreement with those (8 and 16 \( \Omega \cdot m \)) obtained by Kruschwitz & Yaramanci (2004) for the undisturbed Mont Terri Opalinus Clay. Consequently, the resistivity inverted for depth beyond 2 m does not significantly differ from resistivity of undisturbed clay. A low persistent resistivity value of about 8 \( \Omega \cdot m \) is found in the floor zone (5hr–7hr) and probably corresponds to a region of fully saturated rock not solicited by EDZ formation (Fig. 7; Kruschwitz & Yaramanci 2004). The fractures observed on the cores correspond.
Thank you

Ingenious Talk: “Imaging with Electricity"

Wednesday, November 2, 2016
Speaker: Andy Adler

Summary: Technologies which see inside bodies from the outside (using X-rays, ultrasound, MRI) have revolutionized medicine and many other industries. One of the earliest ideas was to create these images with applied electrical currents. Recently improved computer algorithms have created new possibilities for electrical impedance imaging. In this talk, we will look at the kinds of images one can make with this technology, from measuring heart pressure to fluid flows inside active volcanoes.