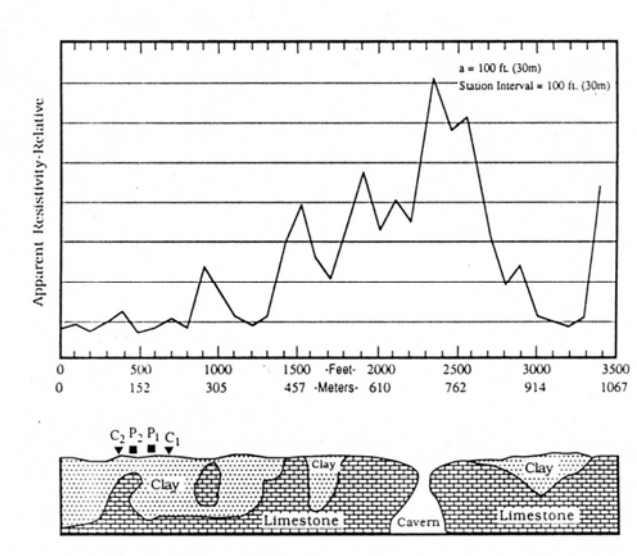
B7 Applications of DC resistivity exploration

- Modern DC resistivity surveys collect data for generating a 2-D or 3-D geoelectric model of the Earth. A simple 1-D analysis does not often yield results that are satisfactory.
- Also see reviews by Ward (1990) and Pellerin (2002)

B7.1 Cave detection



- Caves show up as **high resistivity zones** in a Wenner array profile over karst terrain.
- What other geophysical methods could be used for cave detection?

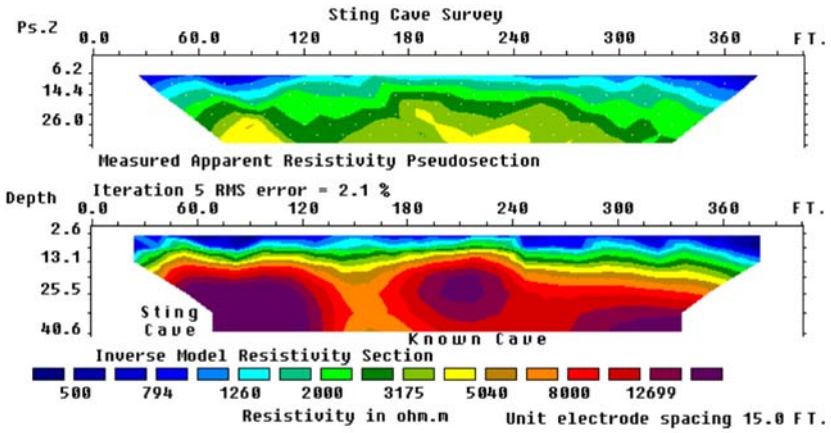
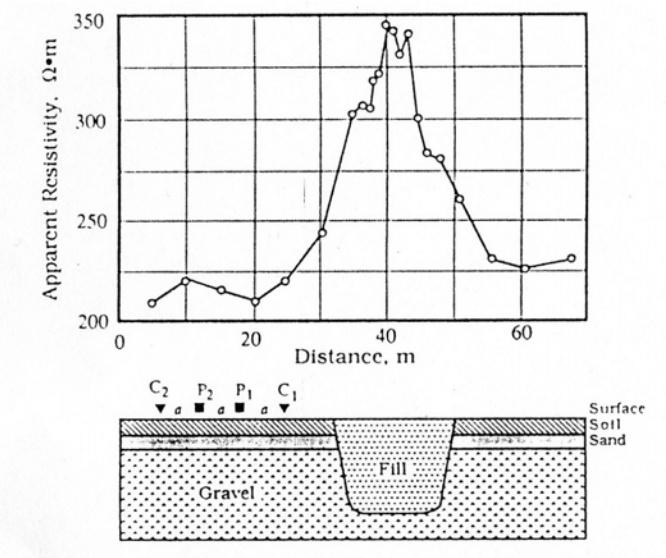


Figure 18. The observed apparent resistivity pseudosection for the Sting Cave survey together with an inversion model. The time taken to invert this data set on a 90 Mhz Pentium computer was 98 seconds (1.6 minutes), while on a 266 Mhz Pentium II it took 23 seconds.

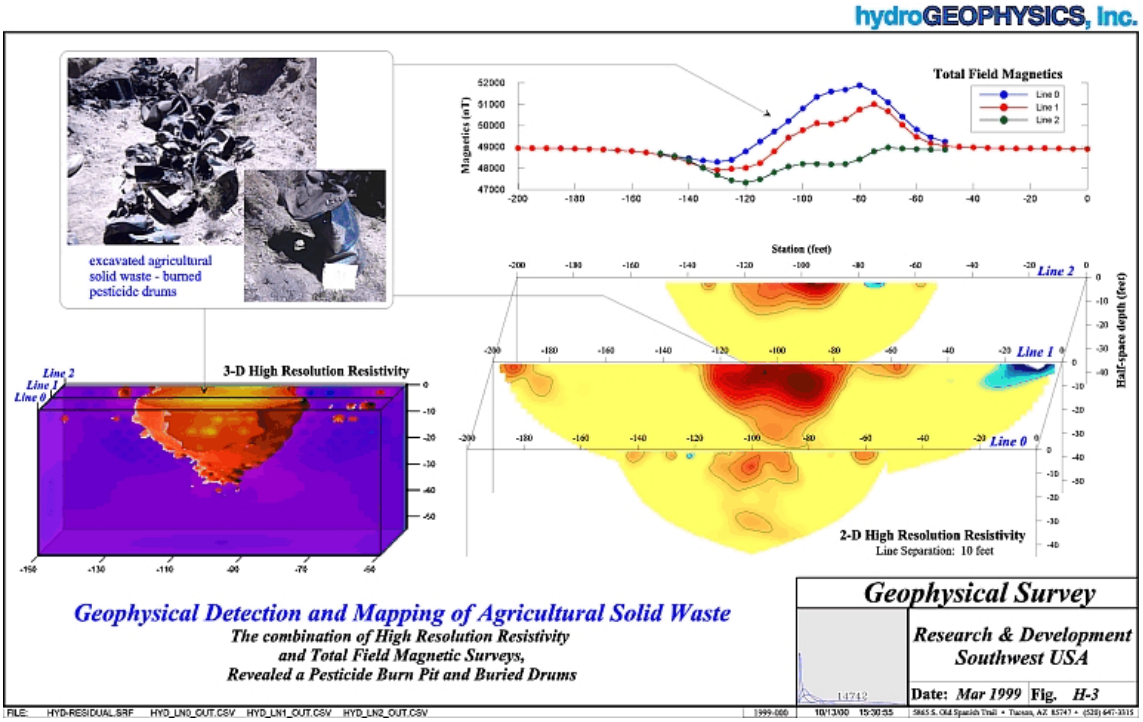
- This DC resistivity survey detected both a known cave and discovered a new (larger) cave that was called the Sting Cave. Figure courtesy of M.H. Loke

B7.2 Environmental geophysics

B7.2.1 Locating and mapping waste dumps



- Here the fill has a higher resistivity than the surroundings. What could be the content?

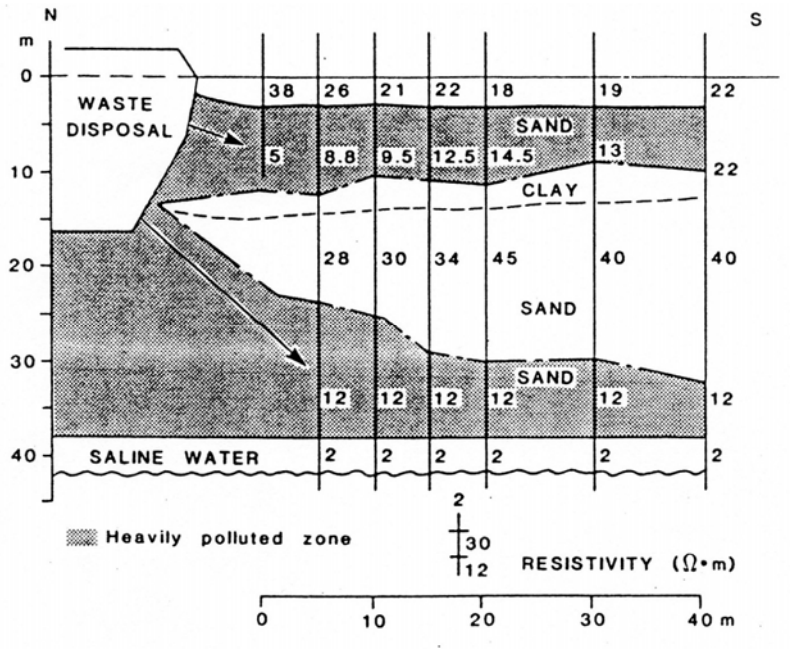


- A second example of locating a waste pit from www.hydrogeophysics.com. Both DC resistivity and magnetic field measurements were used and revealed the presence of 55-gallon drums containing pesticides.

- In other cases the landfill will be a low resistivity zone. Why?

B7.2.2 Mapping contaminant plumes

Conductive plume: (low resistivity) often due to saline water, heavy metals
Resistive plume: hydrocarbons, CCl_4 and DNAPLS (dense non-aqueous phase liquids)



- Example from a landfill near Utrecht in the Netherlands.

- Contaminated fluids leak into two layers that are characterized by a low resistivity

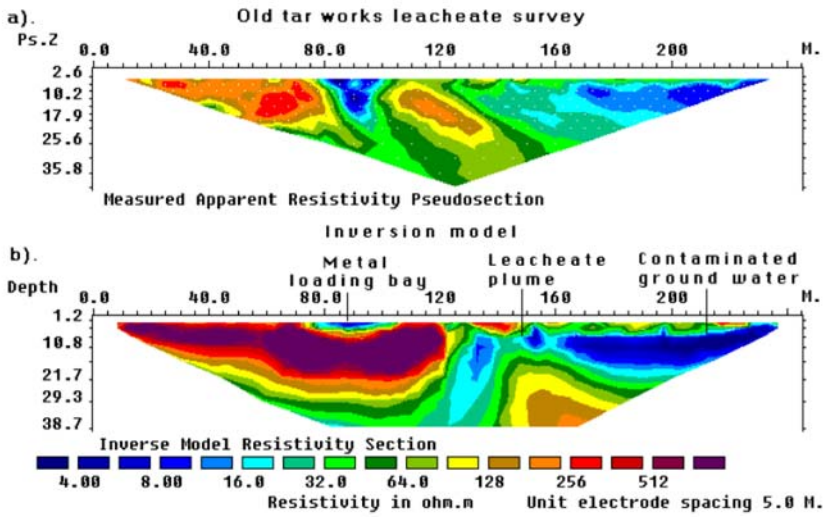
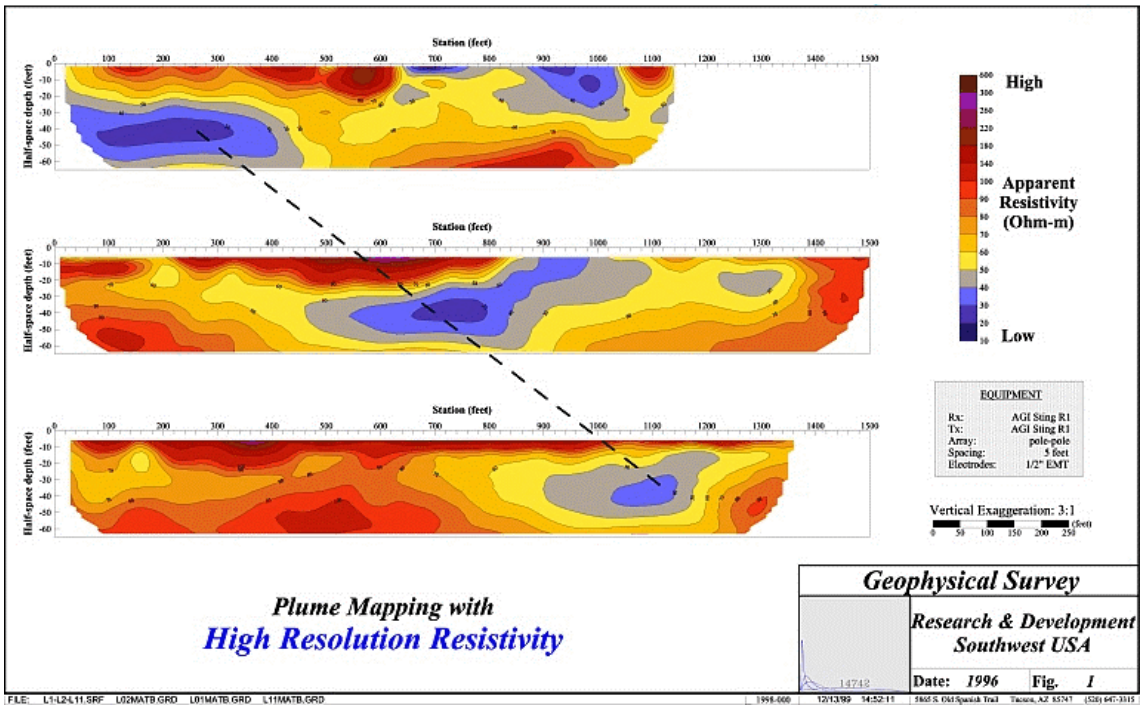


Figure 20. (a) The apparent resistivity pseudosection from a survey over a derelict industrial site, and the (b) computer model for the subsurface.

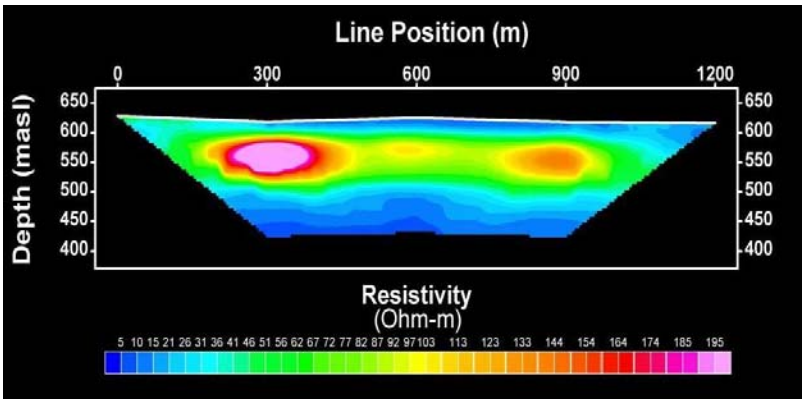
- Note that contaminants leak from surface at the edge of a metal loading dock (shows up as a low resistivity zone). Figure from Loke (2004).



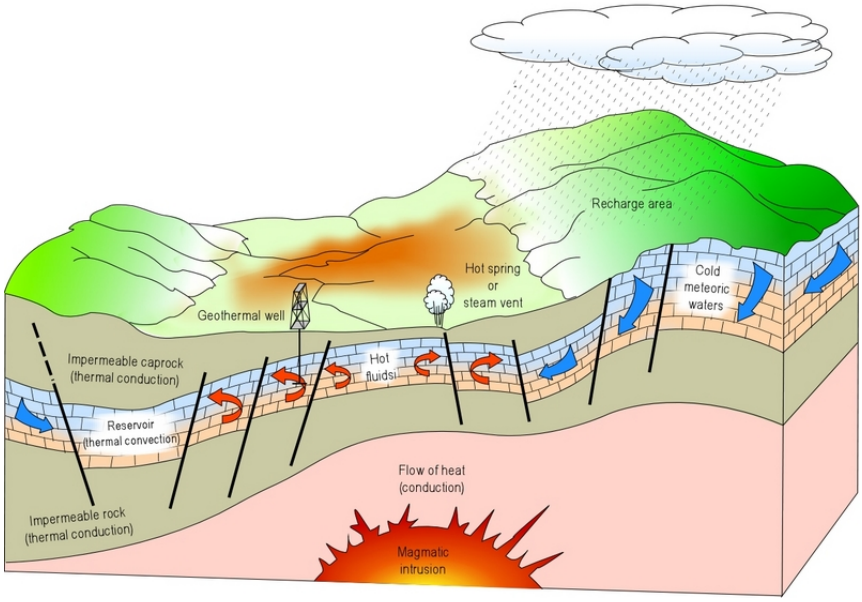
- Image of a low resistivity plume moving through the ground. Measurements made at three separate time intervals. From www.hydrogeophysics.com

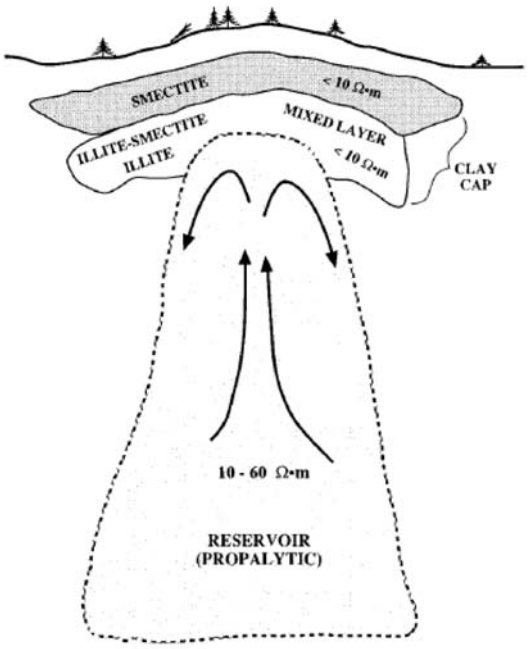
B7.3 Hydrocarbon exploration

- Shallow gas exploration. Natural gas can accumulate close to the surface in paleochannels Example from Northern Alberta. Data courtesy of Komex International



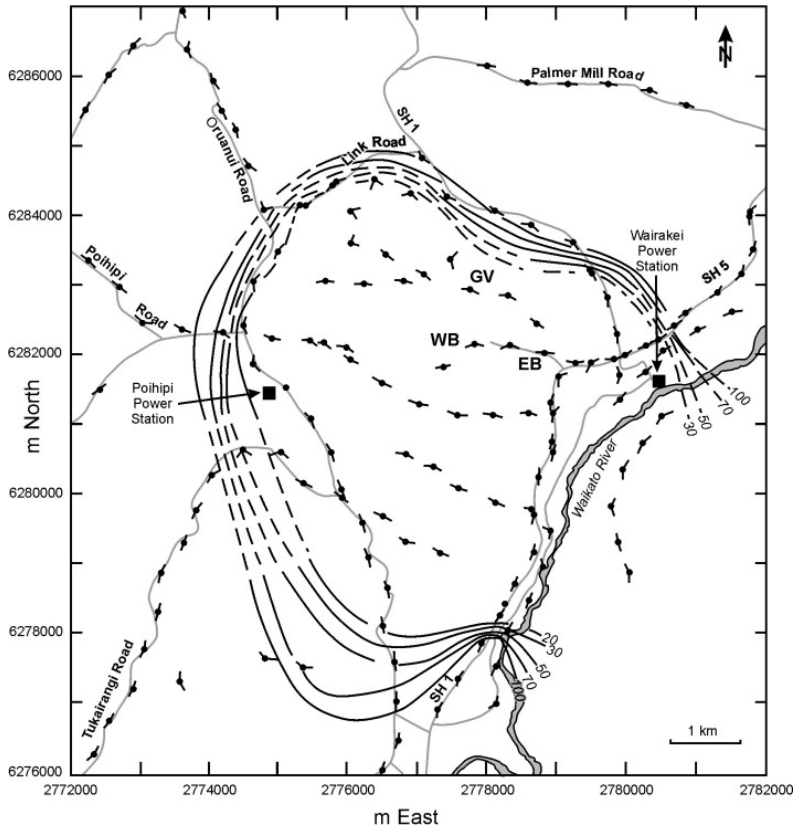
B7.4 Geothermal exploration





Pellerin et al., (1996)

- A geothermal reservoir is generally a low resistivity zone, owing to the presence of saline fluids. The hydrothermal circulation and high temperatures often form a low resistivity clay cap above the reservoir.
- DC resistivity exploration can be used to locate the clay cap and reservoir.

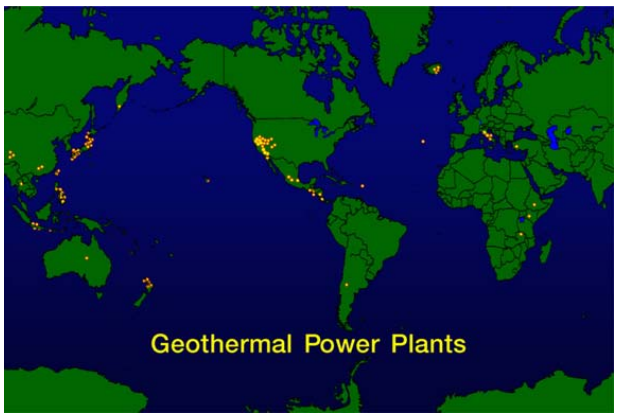


- Example above shows Schlumberger sounding with AB/2 = 1000 m from the Wairakei geothermal field in New Zealand (Bibby et al., 2009)

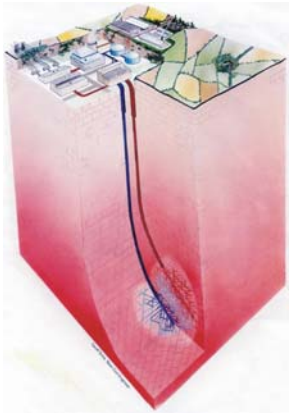
- Note that when a geothermal reservoir is depleted, the clay cap will remain making exploration more complicated.
- Electromagnetic exploration can be used to map geothermal reservoirs

Country	**1990**	**1995**	**2000**
Argentina	0.67	0.67	0
Australia	0	0.17	0.17
China	19.2	28.78	29.17
Costa Rica	0	55	142.5
El Salvador	95	105	161
Ethiopia	0	0	8.52
France	4.2	4.2	4.2
Guatemala	0	33.4	33.4
Iceland	45	50	170
Indonesia	145	310	590
Italy	545	632	785
Japan	215	413	547
Kenya	45	45	45
Mexico	700	753	755
New Zealand	283	286	437
Nicaragua	35	70	70
Philippines	891	1227	1909
Russia (Kamchatka)	11	11	23
Thailand	0.3	0.3	0.3
Turkey	20.6	20.4	20.4
USA	2775	2817	2228
Total	**5832**	**6833**	**7974**

http://iga.igg.cnr.it/geo/geoenergy.php



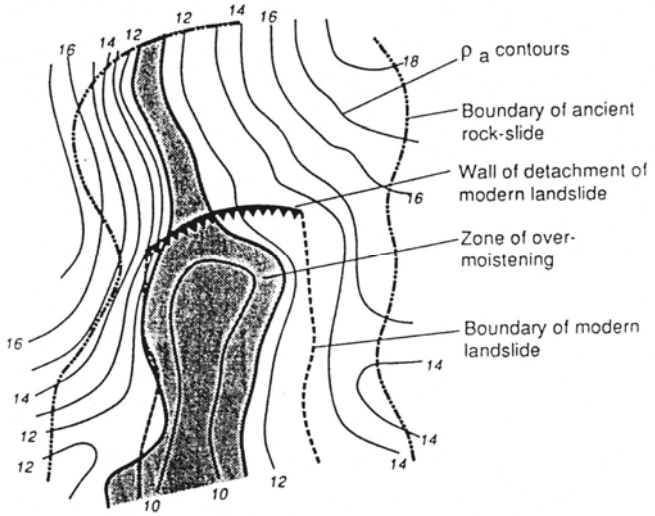
More details *http://geothermal.marin.org/GEOpresentation/*



Hot dry rock projects

B7.5 Geotechnical applications

- Evaluating the hazards posed by landslides. Results of profiling with a Wenner array on a grid of points can show low resistivity areas that may be due to enhanced water flow



- Detailed study in a region where landslips begin and are triggered by a zone of water saturation. Note that topography has been included in the model. Figure from Loke (2001) and Loke (2004)

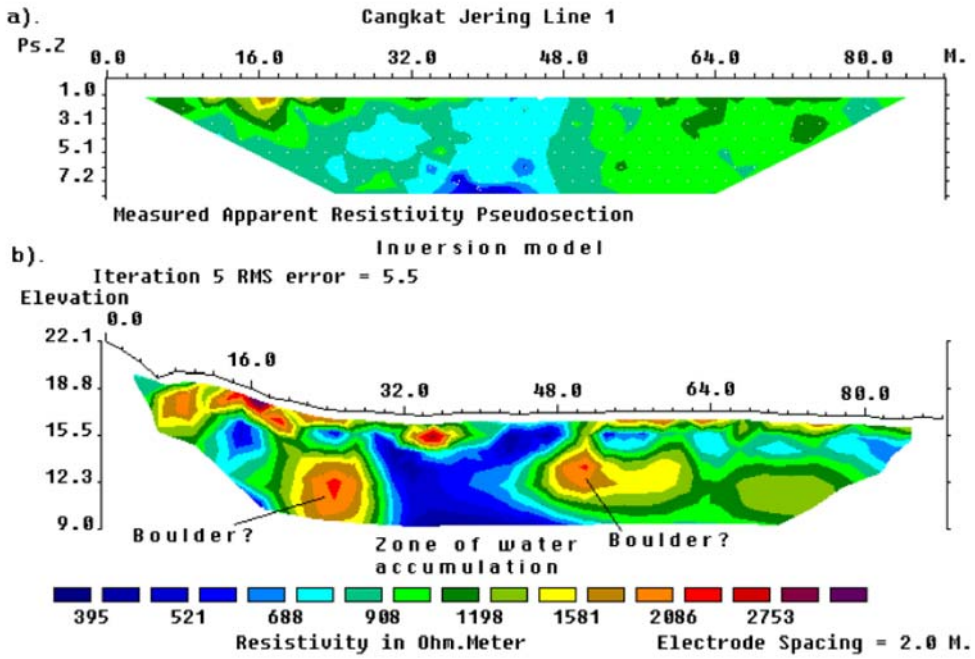
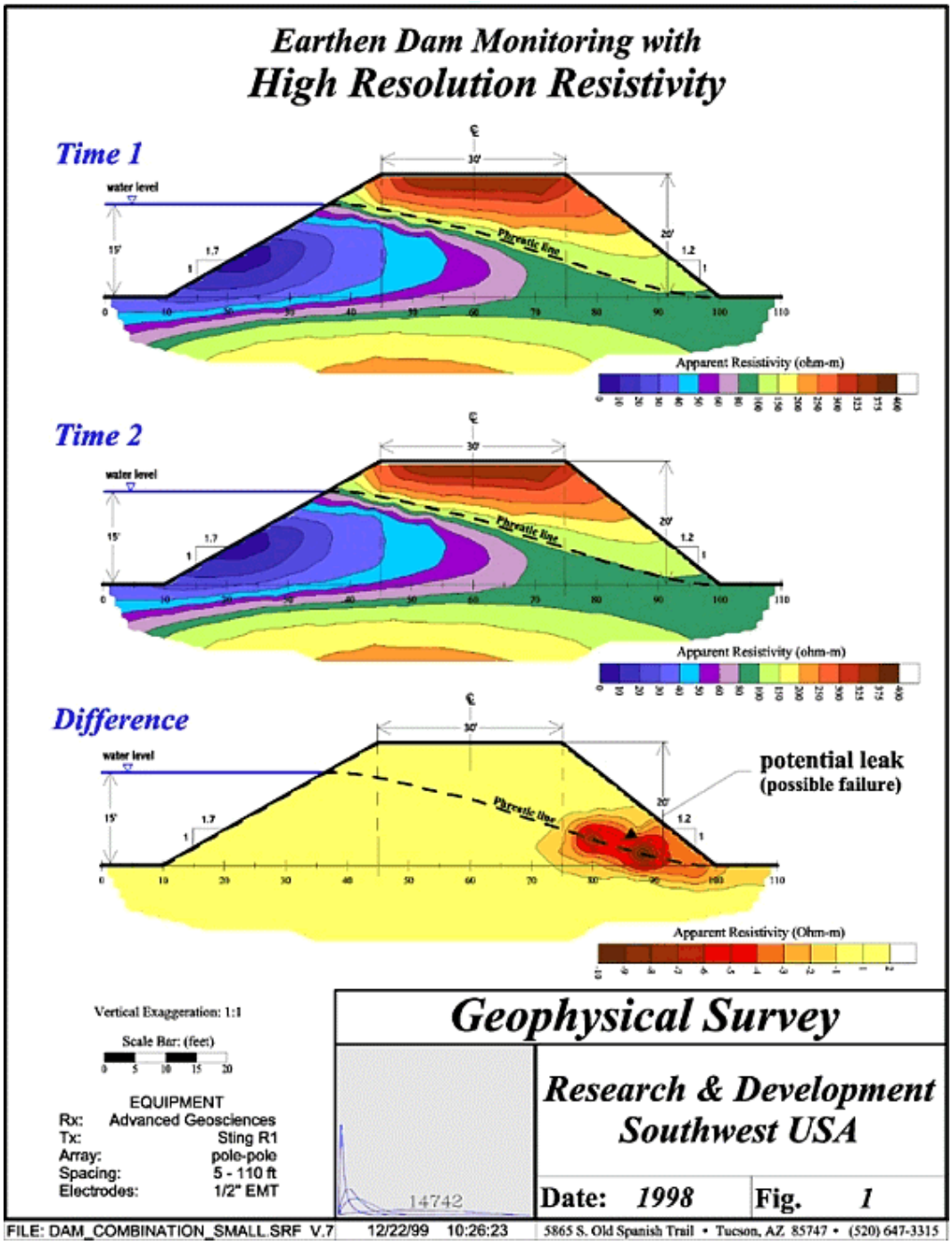


Figure 19. (a) The apparent resistivity pseudosection for a survey across a landslide in Cangkat Jering and (b) the interpretation model for the subsurface.

- Monitoring Earth dams for leaks
- Shows that time variations can be measured. Important that electrodes are placed in same locations on each survey. If possible, the electrodes can be left in place.

Figure from http://www.hydrogeophysics.com/services/safetynet.html



B7.6 Groundwater studies

- Infiltration study showing time variations described by Barker and Moore (1998)

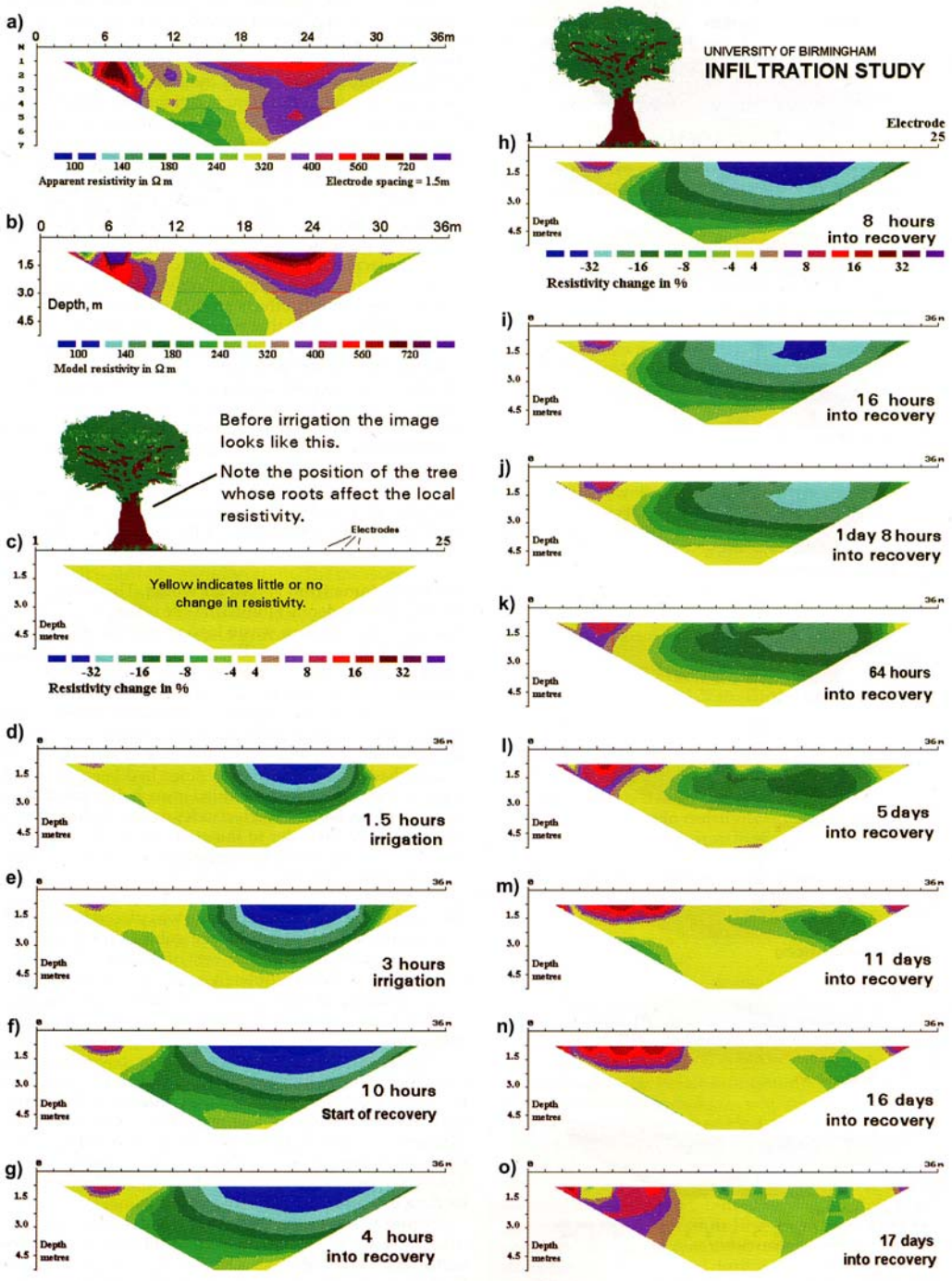


Figure 2. (a) Apparent resistivity pseudosection measured over sand and gravel with electrode spacing of 1.5 m; (b) resistivity produced from the inversion of (a); (c)-(o) difference images measured during infiltration and recovery phases of the study.

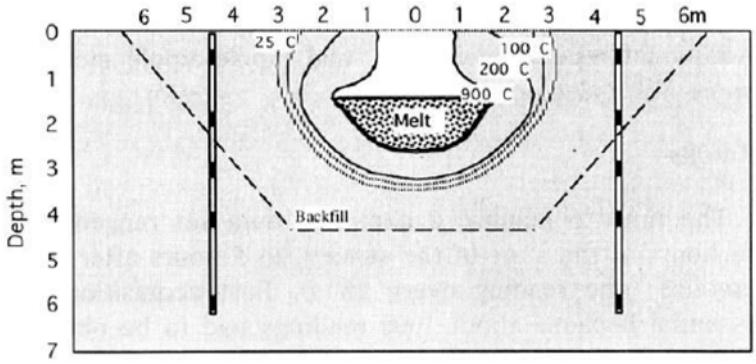
- Monitoring the flow of water in the ground and hydrogeology

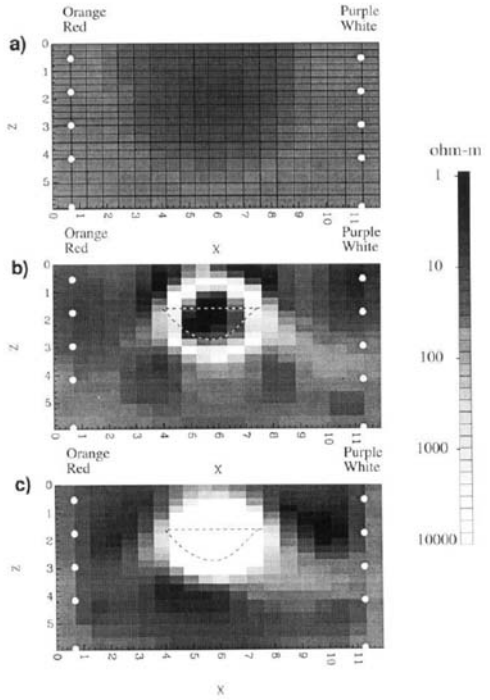
B7.7 Monitoring in-situ vitrification of radio active waste

- Spies and Ellis (1995) describe a pilot study to see if ground contaminated with radionuclides could be vitrified, to immobilize the contamination and stop it seeping into aquifers.

- A 3D DC resistivity survey was chosen to monitor the site as the sand was heated, became molten and then solidified.

- It is expected that the molten rock would have a low resistivity and that the glass would have a high resistivity.





(a) Pre-melt (b) maximum amount of melting. The melt body has a low resistivity but is surrounded by a high resistivity halo caused by a zone of heated (dry) sand (c) post-melt. The melt has frozen to glass and has a high resistivity.

B7.8 Mineral exploration

Many types of mineral deposit have a low electrical resistivity that is caused by the presence of mineralization. Certain minerals such as sulphides are also polarisable.

DC resistivity surveys in mineral exploration routinely measure induced polarization as well as apparent resistivity data.

See the separate section for notes about **induced polarization (IP)**

Links

Geophysical methods for mineral exploration
http://gsc.nrcan.gc.ca/mindep/method/geophysics/index_e.php

Case studies from Hydrogeophysics
http://www.hydrogeophysics.com/sampleprojects/sampleprojects.html#resistivity

RES2DINV software, tutorials and case studies
http://www.geoelectrical.com/

More about Induced polarization
http://www.cflhd.gov/agm/geoapplications/SurfaceMethods/934InducedPolarization.htm

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Barker, R., and J. Moore,, The application of time□lapse electrical tomography in groundwater studies, The Leading Edge, 17 , no. 10, 1454-1458, (1998)

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Pellerin, L., J. M. Johnston and G. W. Hohmann, A numerical evaluation of electromagnetic methods in geothermal exploration, *Geophysics*, **61**, 121-130, 1996.

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Ward, S.H., 1990. Resistivity and induced polarization methods. In: Ward, S. (Ed.), Investigations in Geophysics no. 5: Geotechnical and Environmental Geophysics, vol I. Society of Exploration Geophysicists, Tulsa, pp. 147–189.