Electrical Resistance Study Using Geothermal Steel Casings as Long Electrodes

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Outline

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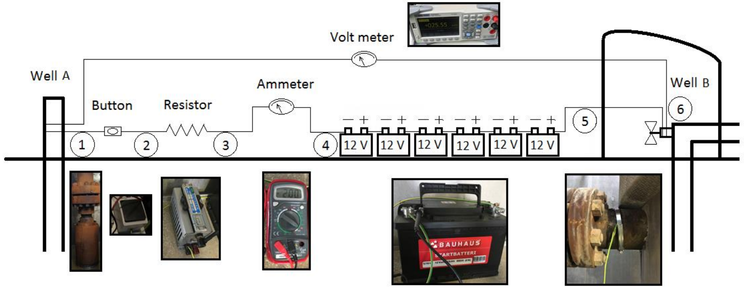
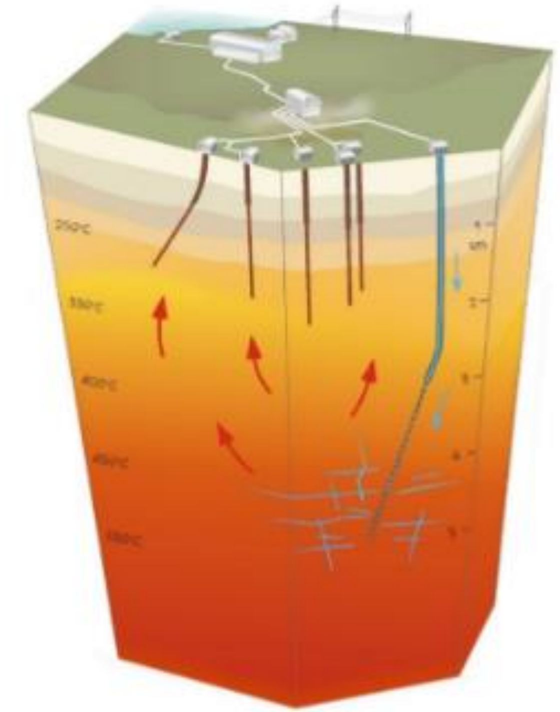


Objective

Characterize fractures using time-lapse electrical resistivity with water injection

Transfer current deeper into the subsurface by using steel casings as electrodes



Source: iddp.is

Fracture Characterization Method

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Estimate fracture connectivity with an inverse analysis using direct current electric potential measurements during water injection

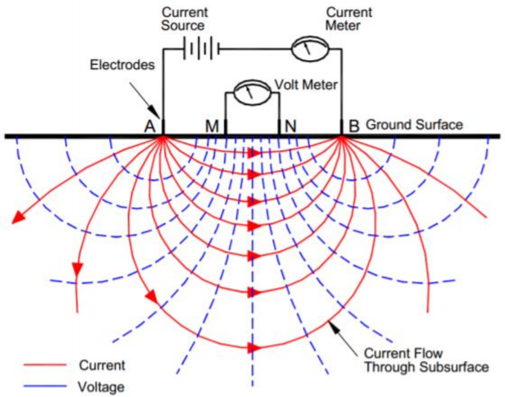
If water with less electrical conductivity than brine is injected into a geothermal reservoir, electrical potential in the field will increase as the injected water fills fracture paths

Time-lapse electric potential data is related to the connectivity of the fracture network

Materials	Resistivity [ohm-m]
Pure water	1,000,000
Natural waters	1-1,000
Sea water	0.2
Saline water (20%)	0.05
Clay	5-150
Gravel	480-900
Limestone	350-6,000
Sandstone (consolidated)	1,000-4000
Igneous rock	100-1,000,000

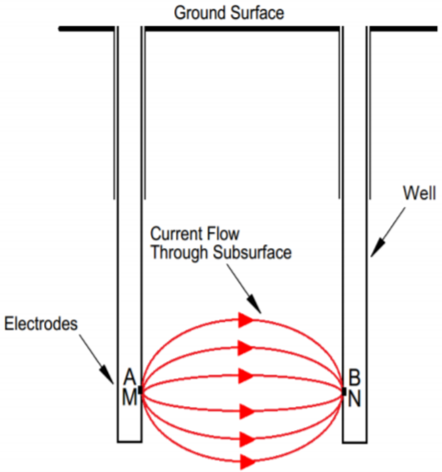
Electrical Resistivity Surveys

General configuration:



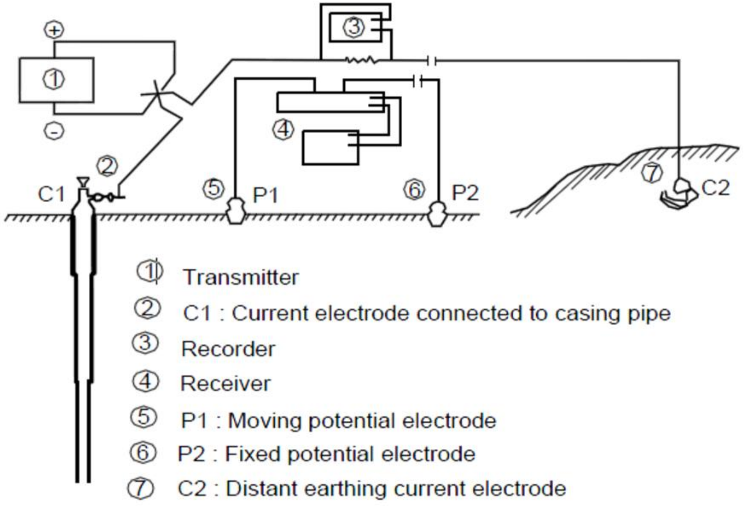
Source: Northwest Geophysical Associates

Cross-well resistivity survey:



Source: Daniels and Dyck (1984)

Mise-A-La-Masse method:

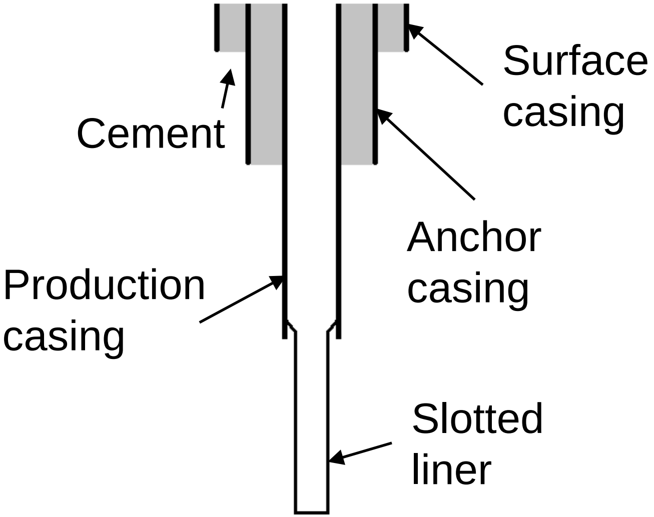


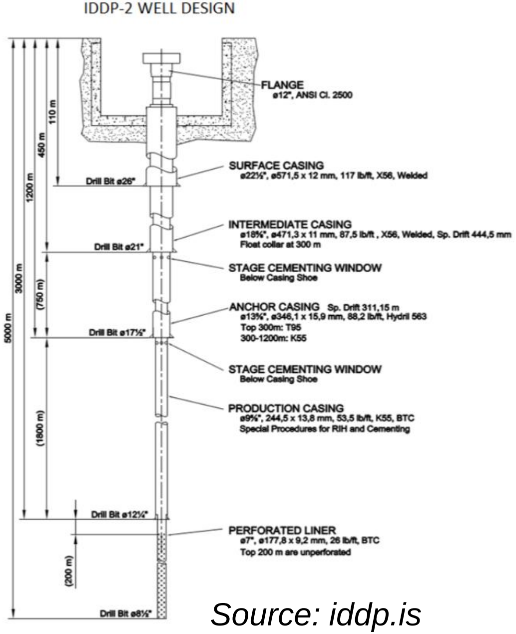
Source: Mustopa et al. (2011)

Using Steel Casings as Electrodes – Proof of Concept

Does the current flow from the production casing to the anchor casing and from there to the ground?

No indication, high resistance measured between production and anchor casings





Source: iddp.is

Using Steel Casings as Electrodes – Proof of Concept

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Does the current flow via surface pipelines from one well to another?

Sometimes, in some cases the resistance through the surface pipelines is lower than the resistance through the ground

Using Steel Casings as Electrodes – Proof of Concept

How do steel casings compare to using surface electrodes?

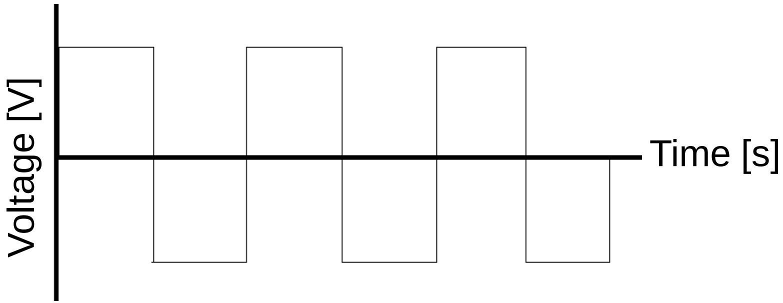
Current travels deeper into the ground when steel casings are used.
Resistance was much higher when steel signs were used as surface electrodes.
Contact resistance between surface electrodes and the ground can be high.

Using Steel Casings as Electrodes – Proof of Concept

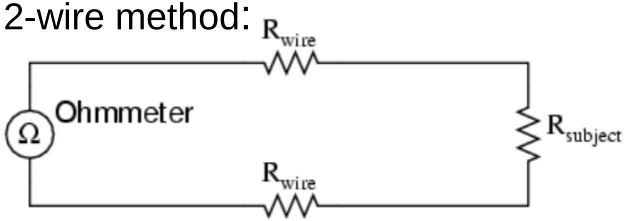
What about noise in the measured data?

4-wire method necessary

Square wave current to reduce noise

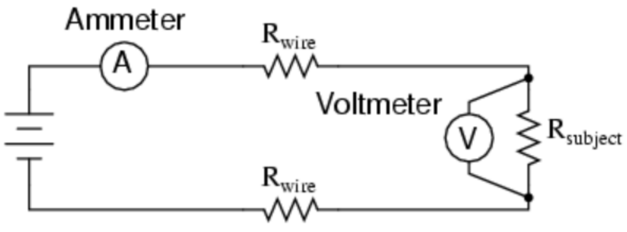


2-wire method:



Ohmmeter indicates $R_{wire} + R_{subject} + R_{wire}$

4-wire method:



$$R_{subject} = \frac{\text{Voltmeter indication}}{\text{Ammeter indication}}$$

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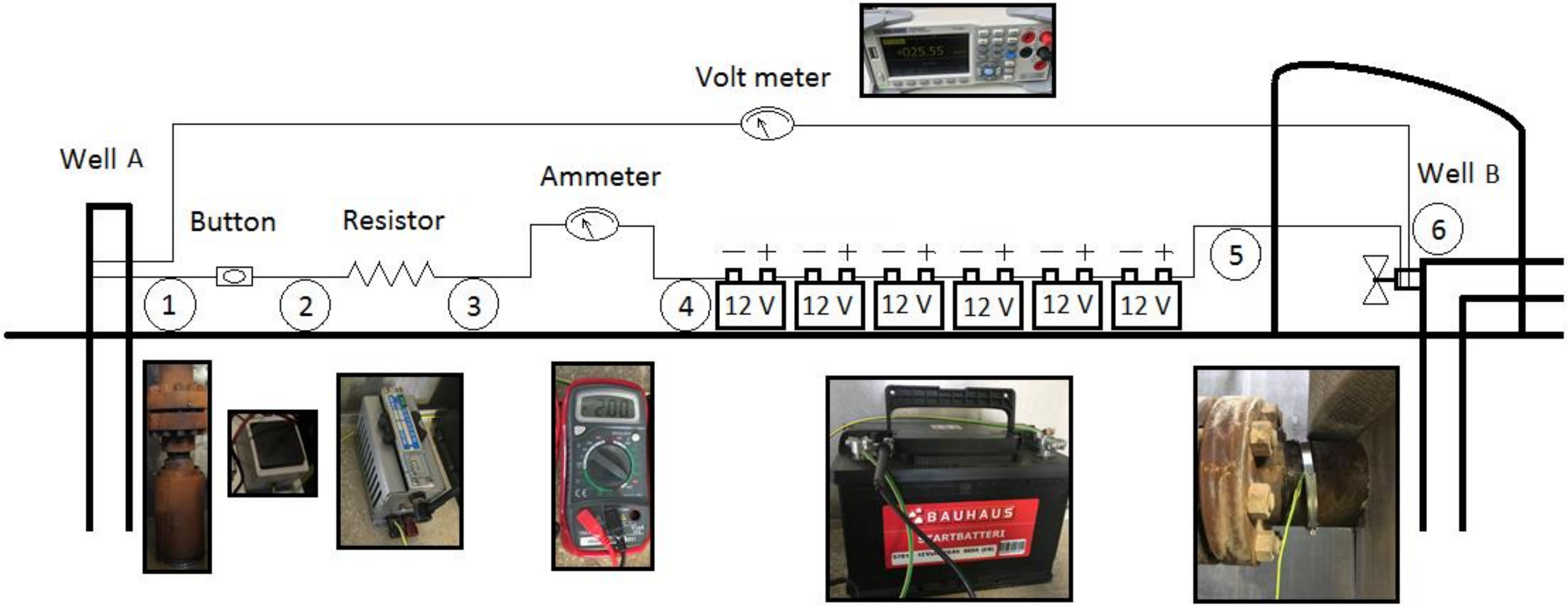
Measurement Set-Up



Preliminary Results – Resistance Between Well-Pairs

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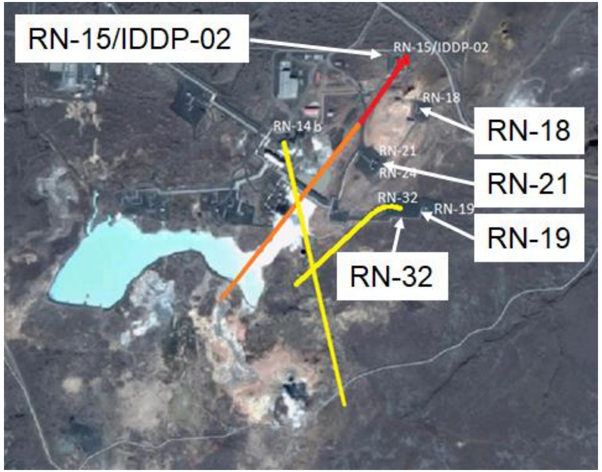
RN-32 not connected to any other wells via surface pipelines

Current traveling along the steel casing of well A into the subsurface, through water-filled fractures and up the steel casing of well B



Well A	Well B	Voltage [mV]	Current [A]	Calculated resistance [mohm]
RN-32	RN-19	18.69	5.89	3.17
RN-32	RN-18	20.05	4.86	4.12
RN-32	RN-21	10.25	4.86	2.11

Summary

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Resistance measured between well pairs indicates that current travels through water-filled fractures from one casing to another

Current travels deeper into the ground when casings are used as electrodes instead of surface electrodes

Acknowledgements

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HS Orka

Thank you!