

# USE OF ELECTRICAL RESISTIVITY IMAGING TO MAP SHALLOW COAL SEAMS AT ANVIL HILL, NSW

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ACARP is partly funding an investigation into the merit of Electrical Resistivity Imaging to map economic changes in coal seams. Centennial Coal made available an area adjacent to a proposed bulk sample site at their Anvil Hill prospect (EL5552) near Denman in the Hunter Valley, where the Great Northern and Fassifern seams lie at depths of 15 to 30m. Two faults were inferred from drilling at this site, with the coal upthrust (removed) between them.

Seven parallel lines of ERI data have more clearly delineated the zone of coal faulted out and suggested fault orientations. Prior to that, the information was limited to boreholes between 50 and 250 metres apart. A more exact measure of resources is therefore now available for mine planning purposes.

ERI also successfully imaged a dyke at another site within the Anvil Hill Project area. The image shows the dyke is dipping to the west and indicates adjacent in-seam silling.

Anvil Hill is showing the potential for ERI to provide significant information between drill holes, especially for areas where seismics will not work due to seam shallowness or high-velocity overburden. It is also expected to assist in delineating changes to coal properties such as determining the LOX line, particularly in structurally disturbed regions. This exploration tool is less costly than seismics and more environmentally friendly largely due to the lack of clearing in most settings and no requirement for drilling shotholes.

## Introduction

Subsurface Imaging conducted a test of the Electrical Resistivity Imaging (ERI) technique at the Centennial Coal exploration site at Anvil Hill, NSW. Figure 1 shows the location. The purpose was to show the ability of ERI to map economically significant changes in coal seams. This is part of an ACARP project led by SSI. Other participants include Adelaide University and Geostudi Astier (of Italy). Centennial Coal contributed to the survey costs and provided significant support in the form of geological knowledge.

The Anvil Hill site was chosen for its geological complexity; the shallowness of the coal and the planned establishment of a bulk sample pit enabling the ERI results to be tested against the real geology.

The Test Pit area includes two east-west faults, with the coal being removed between these faults by up-faulting. The coal is also weathered as it shallows towards the southern fault.

A second area was also surveyed across a known dyke.

### Geology

The 2 sites were specifically chosen at Anvil Hill to document the ability of ERI to map changes in the coal seams. The sites are not considered typical of the Anvil Hill deposit.

#### Site 1

The Fassifern seam enters the southern edge of Site 1 at 20.5 m depth and 9 metres thickness. The Great Northern seam is at 14.5 m depth and 3.5 m thickness. The two seams shallow towards the north, until they are up-faulted between boreholes PAHOH17 and PAHOH19. The seams reappear to the north, in boreholes PAHOH22 and PAH22. The seams become progressively more weathered to the north of PAHOH 20.

The coal seams are associated with other high resistivity layers, such as Tertiary sands and gravels sourced from erosion of overlying Triassic strata.

#### Site 2

A simple sub-vertical dyke extends from depth to near-surface. Silling is suspected in the shallow coal seams. The dyke and sill will coke the coal, lowering its resistance. Weathered dyke material normally has a low resistivity compared with coal and sandstone.



Figure 1 Anvil Hill Locality

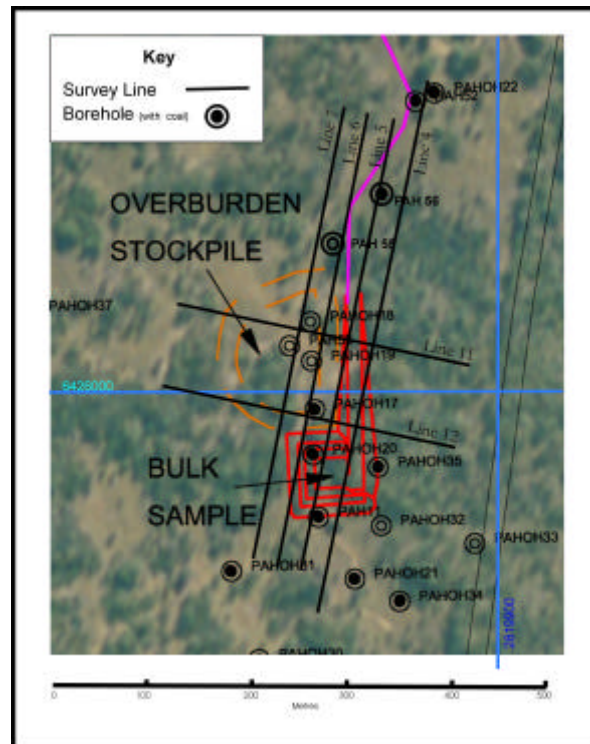


Figure 2 Site 1 Location at Anvil Hill

## ***Forward Modelling***

The site geology, developed from pre-test boreholes, enabled forward modelling to be undertaken for likely scenarios. Professor Stewart Greenhalgh, of Adelaide University, led the forward modelling effort. The principal scenarios were reviewed by Geostudi Astier.

### **The Scenarios**

Five scenarios were inverse-modelled using computer algorithms developed by University of Adelaide. They were:

1. Two seams of varying inter-burden and depth of cover
2. One seam faulted by varying throws at varying depths. Seam removal (or sub-cropping) was also tested
3. One seam with varying degrees of dip
4. One seam thickening and thinning
5. Dyke intrusion, with silling

### **The arrays**

Forward modelling was performed for 4 electrode arrays. These are standard arrays used in ERI and electrical resistivity soundings.

1. Wenner: good for mapping horizontal layers, with an intermediate depth of investigation
2. Dipole Dipole: good for mapping shallow and laterally changing features
3. Pole-Dipole: good for detecting lateral changes, at intermediate to deep depth of investigation.
4. Pole-Pole: good for detecting large scale, deep structures

### **Results of Forward Modelling**

The dipole –dipole and pole-dipole electrode configurations can be used in surface resistivity surveys to image shallow coal seams and associated geological obstacles like faults and dyke, even when the data are contaminated by noise of 2 % to 10%. However, resolution is limited and the images are significantly blurred, especially when compared with seismic images. For targets deeper than about 40 m, the image bears little resemblance to the actual structure, and is highly prone to mis-interpretation.

Faulting is generally discernible by the vertically-extensive low-resistivity zone around the fault area. Dykes and sills are likewise discernible.

In general the modelling suggests a tight control is required on the probable resistivity of the coal and host rocks in order to correctly discern the seams. ERI, as modelled, consistently over estimated both the depth to coal and its thickness.

Sensitivity to low noise levels was tested for various scenarios and found to be immune when noise less than 5% of signal, but fell over gracefully above 10% noise

Table 1 shows the results for each array for the two principal scenarios for Anvil Hill. Modelling showed ERI is unable to separately image two seams unless the interburden is of similar magnitude to the depth to the top seam. Thin units will be represented by a composite resistivity layer.

**Table 1 Accurate Depth of Investigation by Array.** Forward Modelling indicates the arrays will uniquely reflect the geological scenario to the given depth. The Fault model required the array to show two separate layers, separated by the correct throw. Experience shows the Wenner array will detect fault zones due to the low resistivity present, but may not indicate the correct throw.

<b>Array</b>	<b>Fault model</b>	<b>Dipping Model</b>
Wenner	Poor depth determination	20 metres
Dipole-Dipole	20 metres	40 metres
Pole Dipole	40 metres	20-40 metres
Pole Pole	40-60 metres, noisy	Poor depth determination

## Data collection

Eight survey lines were collected (see Figure 2). Lines 1, 2 and 3 were not collected. Lines 4 to 7 were parallel lines over the Test Pit at Site 1. Lines 11 and 12 were orthogonal tie lines. The electrode spacing was a uniform 5 metres. The remote poles were at 400 metres north or south, as appropriate, from Line 4. Line 4 was 555m long. Lines 5, 6 and 7 were 475 metres long and offset 40 m south relative to Line 4. (IE electrode 1 on Line 5 was adjacent to electrode 9 on Line 4. Lines 11, 12 were 315 m long.

Lines 31 and 32 were parallel and 315 m long at Site 2.

Data quality varied between lines and arrays. The cause was likely to be sandy, resistive surface soils and intense rain. Surveying was paused several times during rain and thunder events. Surveying could not resume until the self-potential had stabilised (moving ground water following rain generally causes erratic changes in the self potential of the earth).

Lines 4, 7 and 31 were surveyed with Wenner, Dipole-Dipole, Pole-Dipole and Pole-Pole.

Lines 5, 6 and 12 were surveyed using Wenner and Pole-Pole arrays.

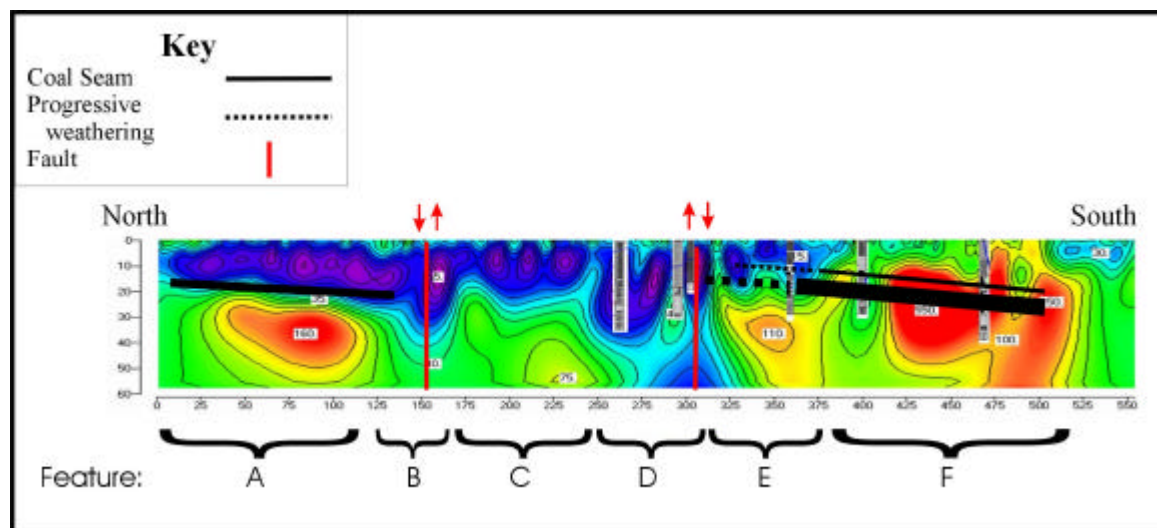
Lines 11 and 32 were surveyed using Wenner, Dipole-Dipole and Pole-Pole arrays

## Results

### Site 1: *Faulting and Weathering*

There are six features in the resistivity results that appear to be consistent and common across the 6 survey lines of Site 1. Consistency increases the confidence in interpretation.

The features reflect changes in the resistivity of the ground. The features cannot be uniquely interpreted as changes in lithology without independent geological information. For example, a lateral decrease in resistivity may be due to either 1) the sub-cropping of a coal seam; 2) the sub-cropping of a sandstone overburden; 3) a fault; or 4) the alteration of the coal to a low-resistivity unit.



**Figure 3** Features as interpreted on the Pole-Dipole results for Line 4

The features are, from the north:

- A. A high resistivity Layer at 20 m depth on Line 4, deepening to 27 metres at Line 7. This is interpreted to be the Fassifern coal seam (supported by boreholes PAHOH22 and PAH52). The increase in depth between Lines 4 and 7 could be due to a 5 to 7 degree dip, or to an increase in the depth of weathering of the coal seam.
- B. A sharp, discrete, vertically extensive decrease in resistivity. This is interpreted as a fault, up thrown to the south (removal of coal seam) (supported by boreholes PAH56 to the north, PAH55 to the south).
- C. Moderate resistivity layer at about 25 metres depth. This was initially interpreted to be a coal layer without an overlying high resistivity layer. Borehole PAH55 showed it to be a non-coal unit.
- D. Sharp, major decrease in resistivity extending to depth. Interpreted as a fault, up thrown to the north (supported by boreholes PAHOH18, PAHOH19 and PAH53 to the north, PAHOH17 to the south).

- E. An area of moderate resistivity, increasing to the south, and merging with Feature F at about the same depth. Interpreted to be weathering / alteration of the coal seams (increased depth of weathering to the north), or sup-cropping (supported by boreholes PAH53, PAHOH17 and PAHOH20).
  
- F. An area of high resistivity at the southern end of the survey area. Interpreted to be the Great Northern and Fassifern coal seams (supported by boreholes PAH11, PAHOH17 and PAHOH20). Small high resistivity zones extending to surface are interpreted to be small pockets of Tertiary sandstones or conglomerate.

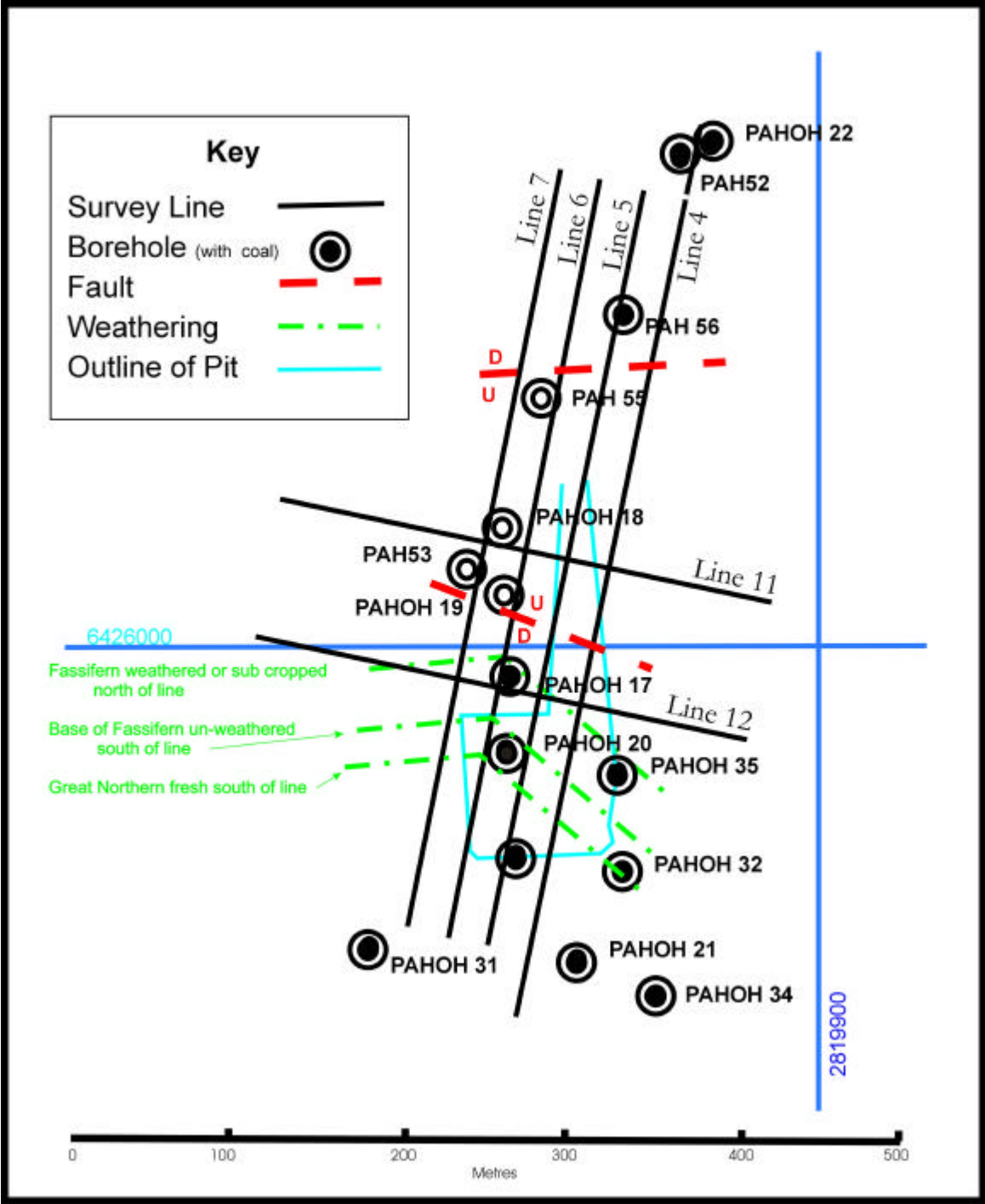


Figure 4 Map showing commonality of interpretation across all Lines at Sire 1

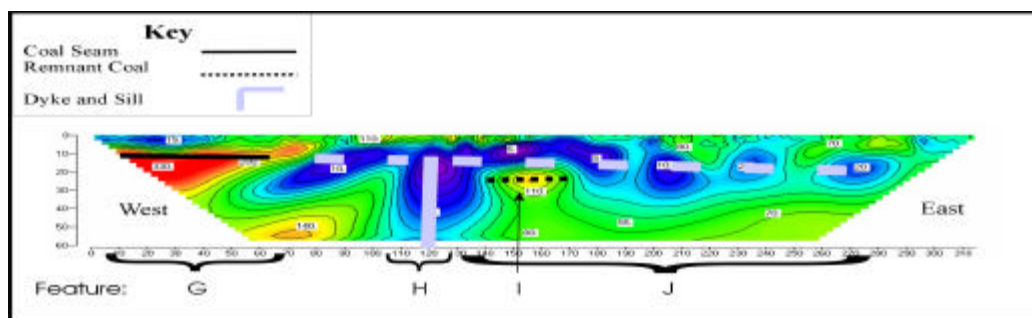
## Site 2: Dyke and possible Sill

Lines 31 and 32 were run approximately West East across a shallow valley.

All arrays, other than Wenner, indicated a body of low resistivity rising from depth and extending laterally at a depth of about 15 metres.

The common features were, from the left on the images:

- G. A high resistivity zone at 10 to 20 metres depth. The resistivity decreases to the right. This is interpreted to be a seam of fresh coal that is progressively oxidised or coked as it approaches Feature H.
- H. A low resistivity area extending from depth to about 10 metres. This is interpreted to be an extensive dyke.
- I. Small, discrete zones of moderate resistivity underneath Feature I. These are interpreted to be remnant coal indicating partial silling.
- J. A horizontal band of low resistivity. This is interpreted to be sill material.



**Figure 5** Features as interpreted on the Pole-Dipole results for Line 31.

## Discussion and Conclusions

The Electrical Resistivity Imaging technique has correctly identified faulting, volcanic dykes and associated silling in shallow coal seams at Anvil Hill.

Weathering, oxidation and dipping seams were also identified with the assistance of geological information from boreholes. The survey showed that ERI cannot uniquely interpret what changes in resistivity mean in terms of coal quantities or properties.

As a minimum, ERI can provide drilling targets, identify features and provide more accurate locations and strike directions for structural features. A second, iterative interpretation, melding the new drilling information will generally yield a comprehensive description of the coal seams for the area. ERI will typically enable the geologist to accurately interpolate the extent of features identified in boreholes (such as stacking, removal, oxidation).

ERI has provided valuable information on the extent of features seen in boreholes, such as the loss of coal through up faulting. The ability of ERI to assist the generation of accurate assessments of reserves in this shallow coal deposit has been demonstrated even in structurally complex locations.

Melding good geological information with the geophysical data produced by the Electrical Resistivity Imaging technique will help to describe economically important changes in coal seam properties particularly in the loxline region.

## **Acknowledgements**

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