

Comparison of geophysical
techniques to determine depth to
bedrock in complex weathered
environments of the Mount Crawford
region, South Australia

Thesis submitted in accordance with the requirements of the University of
Adelaide for an Honours Degree in Geophysics

Thomas James Fotheringham
November 2013



THE UNIVERSITY
of ADELAIDE

COMPARISON OF GEOPHYSICAL TECHNIQUES TO DETERMINE DEPTH TO BEDROCK IN COMPLEX WEATHERED ENVIRONMENTS OF THE MOUNT CRAWFORD REGION, SOUTH AUSTRALIA**GEOPHYSICAL COMPARISON OF BEDROCK DEPTH****ABSTRACT**

Geophysical techniques have the ability to characterise the subsurface and define the depth to bedrock. The non-destructive nature and relatively cheap costs of geophysical surveying compared to drilling make it an attractive tool for subsurface analysis. Many studies have utilized geophysics to interpret soil features such as clay content, water content, salinity, textural properties and bulk density. Further work has been done to map the regolith-bedrock boundary. Previous work has been conducted in the Mount Crawford region using remote sensing based techniques to determine depth to bedrock. Comparisons between the effectiveness of different geophysical techniques at determining depth to bedrock have not previously been undertaken in similar environments. Fieldwork was undertaken along three transects chosen to represent different geological environments. Three geophysical apparatus were compared: Electrical Resistivity (ER), Frequency Domain EM (FDEM) and Ground Penetrating Radar (GPR). A simultaneous soil sampling program was conducted to provide ground truthing. The work in this study reveals the strengths and weakness of the three geophysical techniques at determining depth to bedrock in complex weathered environments of the Mount Crawford region, South Australia. The study reveals differences in the responses of the three geophysical techniques at each of the transects. The GPR was found to be largely unsuitable due to rapid attenuation of the signal. Resistivity and FDEM appeared to show similar variations in the models generated, with differences in the resolution and depth of investigation relating to intrinsic differences between the two systems. Qualitative analysis of the data suggests resistivity provides the strongest correlations with drill refusal depths. The FDEM appeared to display similar trends to the resistivity data and the system offers faster data acquisition, however the inverted model displays lower resolution. The data suggests that bedrock along the surveyed transects is highly weathered and relatively conductive compared to overlying regolith.

KEYWORDS

Bedrock, resistivity, DualEM, GPR, comparison, Mount Crawford, geophysics

TABLE OF CONTENTS

List of Figures and Tables (Level 1 Heading) 3

Introduction 5

Background and Geology 7

 Background 7

 Regional Geology 8

 Local Geology 9

 Transect 1: Rocky paddock 9

 Transect 2: Chalkies 10

 Transect 3: Canham rd 11

Methods and Theory 11

 Electrical Resistivity method 11

 Frequency Domain Electromagnetics (FDEM) method 14

 Ground Penetrating Radar method 16

 Soil analysis method 17

Results and Comparisons 18

 Transect 1: Rocky Paddock 18

 Transect 2: Chalkies 20

 Transect 3: Canham Rd 23

 Transect 1: Rocky Paddock Comparisons 26

 Transect 2: Chalkies Comparisons 27

 Transect 3: Canham Rd Comparisons 29

Discussion 31

 Transect 1: Rocky Paddock 33

 Transect 2: Chalkies 35

 Transect 3: Canham Rd 37

Conclusions 39

Acknowledgments 41

References 42

Appendix A: detailed Methodology 45

Appendix B: transect 1 (Rocky Paddock) soil data 49

Appendix C: Transect 2 (Chalkies) soil data 55

Appendix D: Transect 3 (Canham Rd) soil data 67

LIST OF FIGURES AND TABLES (LEVEL 1 HEADING)

Figure 1: Location map of the study area is shown by the green triangle. The three transects, all of which are located within the Mount Crawford Forest region, South Australia are displayed on the satellite map image. Transect1 (Rocky Paddock) is represented by the blue line, transect 2 (Chalkies) by the red line and Transect 3 (Canham Rd) by the blue line. Eastings and northings (WGS 84, zone54S) are displayed for reference location.	7
Figure 2: Topography of the Rocky Paddock transect generated from differential GPS data collected at each of the drill-holes (shown by diamonds) along the transect. The data have been smoothed. The transect was orientated in a northeast-southwest direction, with geophysical surveying and drilling starting at the north-eastern end of the transect.....	9
Figure 3: Topography of Chalkies transect generated from differential GPS data. The data have had a 5 point smoothing filter applied. Geophysical surveying and drilling was conducted in a west to east direction.....	10
Figure 4: Topography of the Canham Rd transect generated from differential GPS data. The data have had a 5 point smoothing filter applied. Geophysical surveying was carried out in an east to west direction, while drilling was conducted in a west to east direction.	11
Figure 5: Schematic diagram of the field set-up for a surface survey using the FlashRES64 resistivity system (modified from FlashRES64 user manual, 2013). Dotted lines represent the electrode cables.	13
Figure 6: Geophysical models generated through the processing of data collected at Transect 1:Rocky Paddock. a) shows the 2-D depth section generated from the inversion of the resistivity data. b) shows the 2-D depth section generated from the inversion of the DualEM-421 data. c) shows the processed GPR data collected using the 500 MHz antenna. Drill-holes have been overlayed and labelled on a), b) and c).....	19
Figure 7: Transect 1 drill-hole data generated from the soil analysis program. a) shows the moisture content (weight %) of the soil samples. b) shows the EC 1:5 values (microSiemens/m) measured for the <2mm fraction of the soil samples.	20
Figure 8: Geophysical models generated through the processing of data collected at Transect 2:Chalkies. a) shows the 2-D depth section generated from the inversion of the resistivity data. b) shows the 2-D depth section generated from the inversion of the DualEM-421 data. c) shows the processed GPR data collected using the 500 MHz antenna. Drill-holes have been overlayed and labelled on a), b) and c).	22
Figure 9: Transect 2 drill-hole data generated from the soil analysis program. a) shows the moisture content (weight %) of the soil samples. b) shows the EC 1:5 values (microSiemens/m) measured for the <2mm fraction of the soil samples. Drill-hole 1 is at 0m and drill-hole 25 is at 580m.	23
Figure 10: Geophysical models generated through the processing of data collected at Transect 3 (Canham Rd). a) shows the 2-D depth section generated from stitching two consecutive inversions of the resistivity data. b) shows the 2-D depth section generated from the inversion of the DualEM-421 data. c) shows the processed GPR data collected using the 500 MHz antenna. Drill-holes have been overlayed and labelled on a), b) and c).	25
Figure 11: Transect 3 drill-hole soil data plots generated from the soil analysis program. a) shows the moisture content (weight %) of the soil samples. b) shows the EC 1:5 values (microSiemens/m) measured for the <2mm fraction of the soil samples. Drill-hole 1 is at 0m and drill-hole 18 is at 340m.	26
Figure 12: Inverted 2-D depth sections of (a) resistivity and (b) DualEM data collected over Transect 1. Plots use the same colour scale and depth parameters for direct comparisons between the two techniques. Drill-holes have been overlain to display known drill refusal depths.	27

Figure 13: Inverted 2-D depth sections of (a) resistivity and (b) DualEM data collected over Transect 2. Plots use the same colour scale and depth parameters for direct comparisons between the two techniques. Drill-holes have been overlain to display known drill refusal depths. 28

Figure 14: Inverted 2-D depth sections of (a) resistivity and (b) DualEM data collected over Transect 3. Plots use the same colour scale and depth parameters for direct comparisons between the two techniques. Drill-holes have been overlain to display known drill refusal depths. 30

Figure 15: Interpretation of bedrock using known drill refusal depths as well as the interpreted response of bedrock in the inverted resistivity and DualEM-421 depth sections. a) shows the interpreted bedrock of Transect 1: Rocky Paddock. b) shows the interpreted bedrock of Transect 2: Chalkies. c) shows the interpreted bedrock from drill refusal at Transect 2: Chalkies if the drill-holes that penetrate the top conductive layer (DH 3,6,7,10, 16 and 22) are removed. d) shows the interpreted bedrock of Transect 3: Canham Rd. 32