

# **Estimating depth to bedrock in weathered terrains using ground-penetrating radar: a case study in the Adelaide Hills**

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

Dylan Cremasco

November 2013



THE UNIVERSITY  
*of* ADELAIDE

## **TITLE**

Estimating depth to bedrock in weathered terrains using ground-penetrating radar: a case study in the Adelaide Hills

## **RUNNING TITLE**

Bedrock depth estimation using ground-penetrating radar

## **ABSTRACT**

Ground-penetrating radar (GPR) is a geophysical technique that is commonly applied to a variety of subsurface investigations, with the capability to determine depth to bedrock under favourable soil conditions. This study was conducted at three different physiographic regions that represent typical terrains in the Adelaide Hills. At each site, GPR surveys were conducted along traverses using 100, 250, 500 and 800 MHz antennae. A drilling program was conducted concurrently with the GPR survey to provide baseline bedrock depths for comparison. Electrical resistivity and electromagnetic surveys were also conducted along each traverse to determine subsurface conductivity and secondary bedrock depth estimates. The GPR results for all antennae were compared to determine the frequency that provided the best depth estimation. Rapid attenuation of GPR signal at all frequencies was observed, resulting in shallower than expected investigation depths. At two of the sites, GPR signal penetration depth was increased in areas that were highly resistive. The 800 MHz antennae displayed the highest resolution of estimated bedrock contacts in these resistive areas, and were subsequently compared to drill refusal depths using a paired  $t$  test. GPR estimation depths and drill refusal in electrically resistive areas strongly correlated at two of the sites, while the third site showed no correlation. Across all three transects bedrock depths were underestimated by 74% on average. This underestimation is attributed to signal attenuation, which appears to be caused by a combination of increased conductivity, clay content and the presence of iron oxides in the soil profile. Without further investigation it is difficult to quantify these factors on attenuation in the area. The results of this study suggest that GPR surveys are not suitable for bedrock depth estimation in Adelaide Hills-type terrains.

## **KEYWORDS**

Ground-penetrating radar, bedrock depth, Adelaide Hills, site productivity, soil profile, attenuation

**TABLE OF CONTENTS**

List of Figures.....	3
List of Tables.....	4
1. Introduction .....	6
2. Geological setting .....	10
2.1. Regional tectonic history .....	10
2.2. Local geology.....	11
2.3. Study area .....	12
2.3.1. Site 1: Rocky Paddock.....	12
2.3.2. Site 2: Chalkies Line.....	13
2.3.3. Site 3: Canham Road .....	14
3. Equipment theory.....	16
3.1. Ground-penetrating radar.....	16
3.2. Electrical resistivity.....	20
3.3. Electromagnetics .....	21
4. Methods.....	22
4.1. Ground-penetrating radar.....	22
4.2. Electrical resistivity .....	23
4.3. Electromagnetics .....	24
4.4. Drilling and soil analysis .....	25
5. Observations and results.....	26
5.1. Site 1: Rocky Paddock.....	27
5.2. Site 2: Chalkies Line .....	32
5.3. Site 3: Canham Road .....	38
6. Discussion.....	43
6.1. GPR Signal Attenuation .....	45
6.1.1. Signal scattering .....	45
6.1.2. Soil conductivity.....	46
6.1.3. Clay content.....	47
6.1.4. Iron oxide content.....	48
6.2. Signal attenuation summary.....	49
7. Conclusions .....	50
8. Acknowledgments.....	51
9. References .....	51
Appendix A: Detailed methods .....	55

Appendix B: Soil Analysis Data.....	60
Appendix C: GPR radargrams for Site 1.....	75
Appendix D: GPR radargrams for Site 2 .....	80
Appendix E: GPR radargrams for Site 3.....	85

## **LIST OF FIGURES**

Figure 1: Locality map of the three survey lines within the Mount Crawford Forestry Reserve.....	13
Figure 2: Topographic cross-section of the traverse at Site 1 (Rocky Paddock) .....	14
Figure 3: Topographic cross-section of the traverse at Site 2 (Chalkies Line). .....	15
Figure 4: Topographic cross-section of the traverse at Site 3 (Canham Road).....	15
Figure 5: Schematic diagram of potential radio wave propagation paths generated by a GPR transmitter. ....	16
Figure 6: Cross-section of the Site 1 traverse. Drill hole locations and depths are marked relative to regional topography.....	27
Figure 7: Comparative plot of processed ground-penetrating radar data for Site 1 (Rocky Paddock).....	28
Figure 8: Comparison plot for Site 1 .....	30
Figure 9: Cross-section of the Site 2 traverse. Drill hole locations and depths are marked relative to regional topography.....	32
Figure 10: Comparative plot of processed ground-penetrating radar data for Site 2 (Chalkies Line) .....	33
Figure 11: Comparison plot for Site 2 .....	35
Figure 12: Cross-section of the Site 3 traverse. Drill hole locations and depths are marked relative to regional topography. ....	38
Figure 13: Comparison plot of processed ground-penetrating radar data for Site 3 (Canham Road).....	39
Figure 14: Comparison plot for Site 3 .....	41

**LIST OF TABLES**

Table 1: Operational parameters of all GPR antennae used at each site..... 23

Table 2: Receiver array orientations and depths of investigation for the DualEM-421 instrument. .... 24

Table 3: Paired *t*-test to establish mean value and Pearson correlation between drill refusal depth and GPR bedrock depth estimates at Site 1..... 31

Table 4: Paired *t*-test to establish mean value and Pearson correlation between drill refusal depth and GPR bedrock depth estimates at Site 1, using only data from locations in areas with large scale resistive subsurface. .... 31

Table 5: Paired *t*-test to establish mean value and Pearson correlation between drill refusal depth and GPR bedrock depth estimates at Site 2..... 37

Table 6: Paired *t*-test to establish mean value and Pearson correlation between drill refusal depth and GPR bedrock depth estimates at Site 2, using only data from locations in areas with large scale resistive subsurface. .... 37

Table 7: Paired *t*-test to establish mean value and Pearson correlation between drill refusal depth and GPR bedrock depth estimates at Site 3..... 43

Table 8: Paired *t*-test to establish mean value and Pearson correlation between drill refusal depth and GPR bedrock depth estimates at Site 3, using only data from locations in areas with large scale resistive subsurface. .... 43