National Exams May 2013

04-Geol-A7, Applied Geophysics

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM.
   Any non-communicating calculator is permitted.
3. Answer all FOUR (4) of the questions in Part I.
   Answer any THREE (3) of the questions in Part II.
   All questions in Part II are of equal value.
4. The value of each question is indicated at the start of the question. The exam will be graded out of a total of 71 marks.
5. The clarity and organization of your answers are important.
6. Some questions require you to indicate part of your answer on the exam paper itself. **Therefore, be sure to write your name or ID number on this paper and return it with your answer booklet.**

Part I: Answer ALL FOUR questions in Part I.

1) (12 marks)
Explain briefly (two or three sentences, with an equation or labelled sketch if helpful) the meaning of **FOUR** of the following terms and include a comment on their significance in geophysics:
(a) shear wave
(b) remanent magnetization
(c) acoustic impedance
(d) Bouguer Anomaly gravity (map or profile)
(e) induced polarization
(f) self-potential

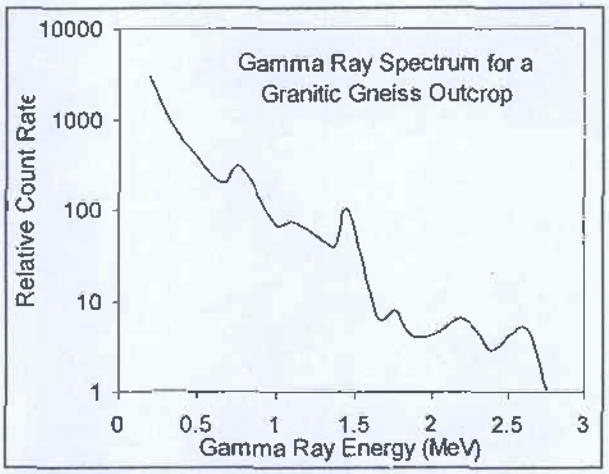
2) (15 marks) For each of the applications listed below, indicate (i) the primary geophysical method that should be used, (ii) why that method is particularly appropriate, and (iii) one or more important limitations of the method that should be considered:
(a) screening bedrock, in areas of proposed highway rock cuts, for the presence of disseminated and/or massive sulphide mineralization that could yield acid rock drainage;
(b) reconnaissance exploration for iron ore deposits in a large (50 by 50 km) area;
(c) imaging stratigraphy (i.e. layering) within a surficial sand and gravel deposit up to 40 m thick that is being considered for development as an aggregate resource;
(d) imaging the structure of a folded and faulted salt layer that lies between clastic rock formations at depths of 500 – 1500.
(e) exploration for fresh groundwater in sand channels buried beneath clay-rich sediments.

3) (7 marks) ***Answer on this exam paper***

(a) What are the three types of radioactivity produced by natural decay processes in rocks? Why are only gamma rays measured in airborne radiometric surveying?

(b) The gamma ray spectrum shown below was measured with a multi-channel spectrometer on a granitic gneiss outcrop.

(i) What causes the peaks in the spectrum? Label the three peaks would be measured to gauge radioactivity in the potassium (K), uranium (U) and Thorium (Th) decay series.

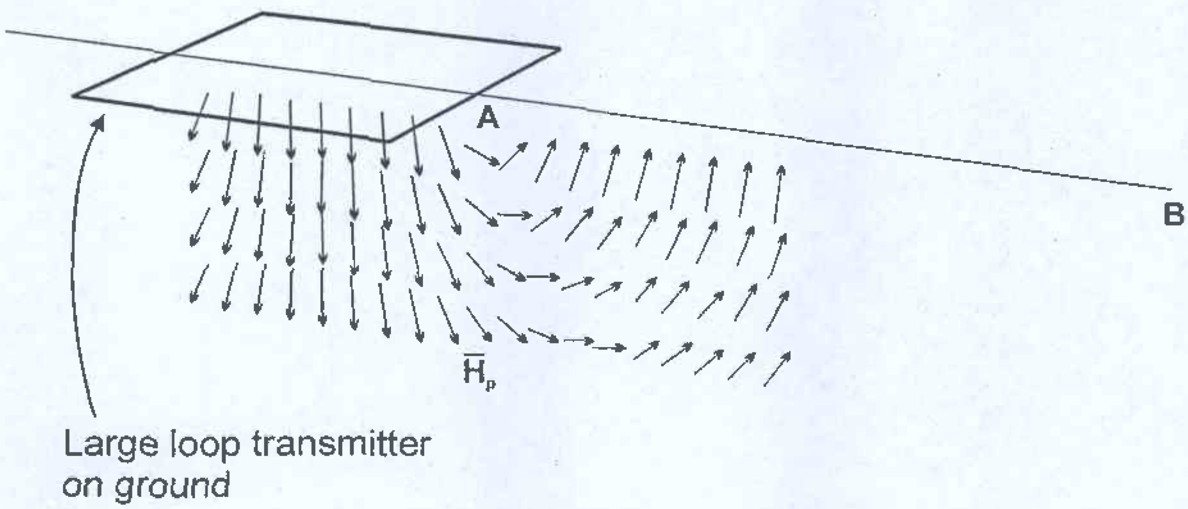


(ii) What type of correction would have to be applied to the potassium gamma ray count before it could be converted to an estimate of the % potassium in the gneiss?

4) (7 marks)

The figure below depicts a large loop EM transmitter and the primary magnetic field $\overline{H}_p$ that it produces. (Only the subsurface field is shown.)

a) Indicate the direction of current flow in the transmitter loop.
b) Draw two rectangular plates, representing thin sheet-like conductive bodies with dimensions slightly smaller than those of the transmitter loop, on the diagram. Draw one plate that is very weakly coupled to the primary field, and a second that is very strongly coupled.
c) Suppose the primary field is abruptly terminated by shutting off the current flow in the loop. Sketch (i) the eddy current pattern that would immediately develop in the strongly coupled plate, and (ii) the secondary field pattern ($\overline{H}_s$) that these eddy currents would produce.
d) Sketch a profile of the vertical component of the secondary field (H_{sz}) that you would expect to observe immediately after current shut-off along a survey line extending from point A to B on the earth's surface.



Part II: Answer any THREE of the questions in Part II.

5) (10 marks)

(a) Describe, with the aid of diagrams, the difficulties that could arise in trying to detect a "thin" middle layer in the 3-layer model below using three different methods:

(i) vertical electrical (resistivity) sounding;

(ii) seismic refraction;

(iii) seismic reflection.

In each case, you should sketch the expected geophysical response (i.e. the vertical electrical sounding curve for (i), the first arrival time-distance graph for (ii), and the synthetic seismogram for (iii)), *showing how the response would change as the middle layer became very thin*. When sketching the synthetic seismogram, assume that the two interfaces have comparable reflection coefficients.

surface

$v_1 = 800$ m/s	$\rho_1 = 100$ ohm·m
$v_2 = 1500$ m/s	$\rho_2 = 2$ ohm·m
$v_3 = 3000$ m/s	$\rho_3 = 50$ ohm·m

(b) Explain why the interpretation (inversion) of vertical electrical sounding data would probably yield an ambiguous result for the resistivity of the middle layer even if it was thick enough to be clearly detected. (*Hint*: consider the principle of equivalence.)

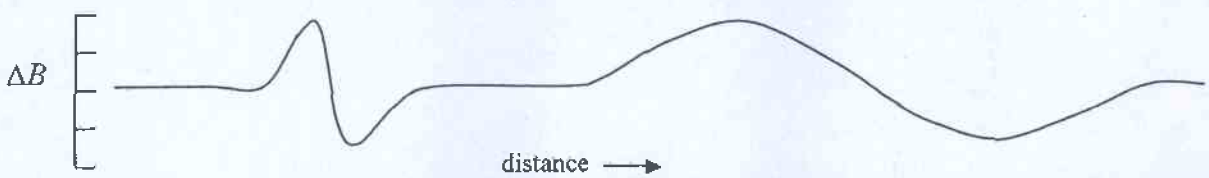
6) (10 marks)

(a) Two magnetic anomalies are shown in the profile below. Both are caused by sources having the same shape, size and direction of magnetization.

(i) Which anomaly is associated with the shallower source? Why?

(ii) Which anomaly is associated with the source having the stronger magnetization? Why?

(iii) How could you estimate the depth to each body based on the profile shape alone?



(b1) List the advantages or benefits and disadvantages or limitations of each of the following magnetic field instruments:

(i) proton precession magnetometer

(ii) fluxgate magnetometer

(iii) magnetic gradiometer

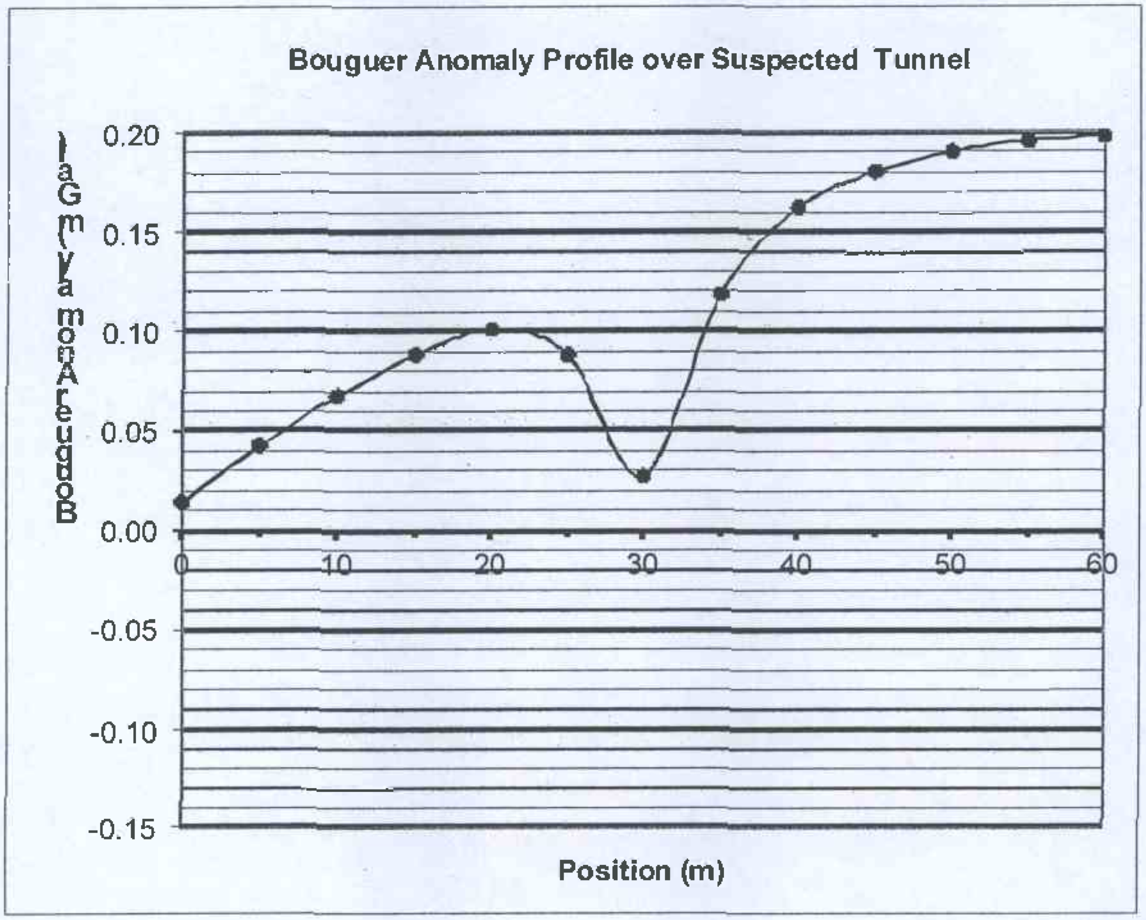
7) (10 marks)

Gravity readings taken over the suspected location of a tunnel yielded the Bouguer Anomaly profile shown on the attached graph. Assume that the tunnel may be modelled as horizontal cylinder, oriented perpendicular to the line and that the bedrock has a density of 2500 kg/m^3.

a) Draw, on the same graph, your estimate for regional field, and the residual anomaly that would remain after subtraction of the regional.

b) Use the residual anomaly and the depth rule for a horizontal cylinder $z = x_{1/2}$ to calculate estimates for the radius and depth to *top* of the mine tunnel assuming it is filled with air. (You'll also need the equation for gravity effect of a horizontal cylinder given below.)

c) Is there any way to infer from the gravity data whether the tunnel is more likely air or water-filled? Explain your answer with the help of the equation given for the gravity effect of a horizontal cylinder.



Formulas and Constants

1 m/s^2 = 10^5 mGal

Gravity effect of a horizontal cylinder: $\Delta g = 2\pi a^2 \rho G \frac{z}{r^2}$

where a is radius of the cylinder,
z is the depth to its axis,
r is the distance from observation point to cylinder axis
ρ is the density contrast
and $G = 6.672\times10^{-11}$ Nm^2/kg^2 is the unviversal gravitational constant.

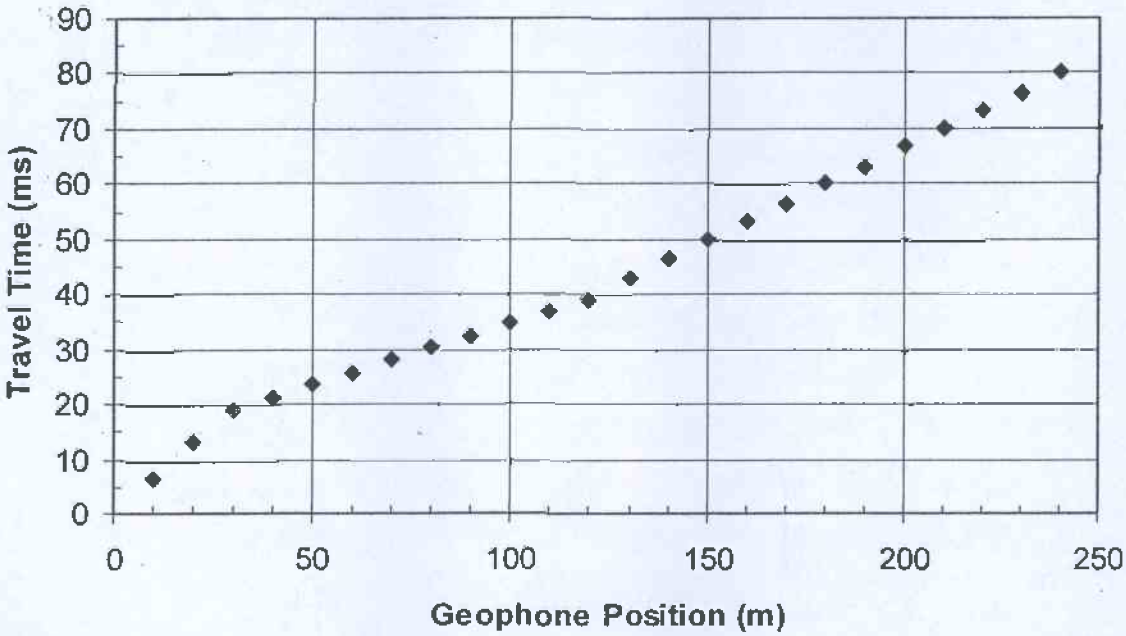
8) (10 marks) Answer parts **(a)**, **(b)** and **(d)** on this exam paper.
The figure below shows the first-arrival time vs distance graph obtained using one shotpoint (at position 0 m) and 24 geophones during a seismic refraction survey. The ground surface was horizontal and the near-surface geology is thought to consist of glacial till overlying bedrock.

(a) (2 marks) Calculate the apparent velocities represented by the three straight line segments on the time-distance graph.

(b) (3 marks) Sketch, in the space below the graph, *two* particular earth models that could account for the observed travel time pattern: (i) model 1 having a horizontal bedrock surface underlying the left hand side of the survey line, and (ii) model 2 having a horizontal bedrock surface underlying the right-hand side of the survey line. *Label the velocities* of each of the layers in your models.

(c) (4 marks) Assuming that model 1 is correct, calculate the depth to bedrock. (Recall that the formula for arrival time of a critical refraction from a single horizontal layer at depth z is given by $T(x) = \frac{2z\cos\theta_c}{v_1} + \frac{x}{v_2}$.)

(d) (1 mark) Assuming that model 1 is correct, sketch, on the time-distance graph, the travel time pattern you would expect for a reverse shot located at position 250 m.



9. Marking Scheme

1. 10 marks total (4 items, 2.5 marks each)
2. 15 marks total (3 items, 5 marks each)
3. 5 marks total (5 marks per section)
4. 10 marks total (3 marks for each method discussed in part (a), 1 mark for part (b))
5. 10 marks total (2, 1, 2, 1, and 4 marks for parts (a) - (e) respectively)
6. 10 marks total (2, 3, 4 and 1 marks for parts (a) – (d) respectively)
7. 10 marks total (3 marks for each part, plus 1 for any especially well done part)
8. 10 marks total (4, 1, 2 and 3 marks for parts (a) – (d) respectively)

Exam Total: 70 marks (for Questions 1 – 3 and any 4 of the remaining 5 questions)