

Name:

UNIVERSITY
of
OTAGO



Te Whare Wānanga o Ōtāgo

DEPARTMENT OF GEOLOGY

GEOL 252

**FIELD STUDIES AND
NEW ZEALAND GEOLOGY**

Map Exercise Book

2016

The following exercises guide you in progressive steps through the analysis and interpretation of geological maps. This is an introductory course that will give you basic, fundamental skills. The course will build upon the work you did in the first few lab classes in GEOL 112 and you should review those lab classes. To help you some of these exercises are repeated here (“revision” exercises).

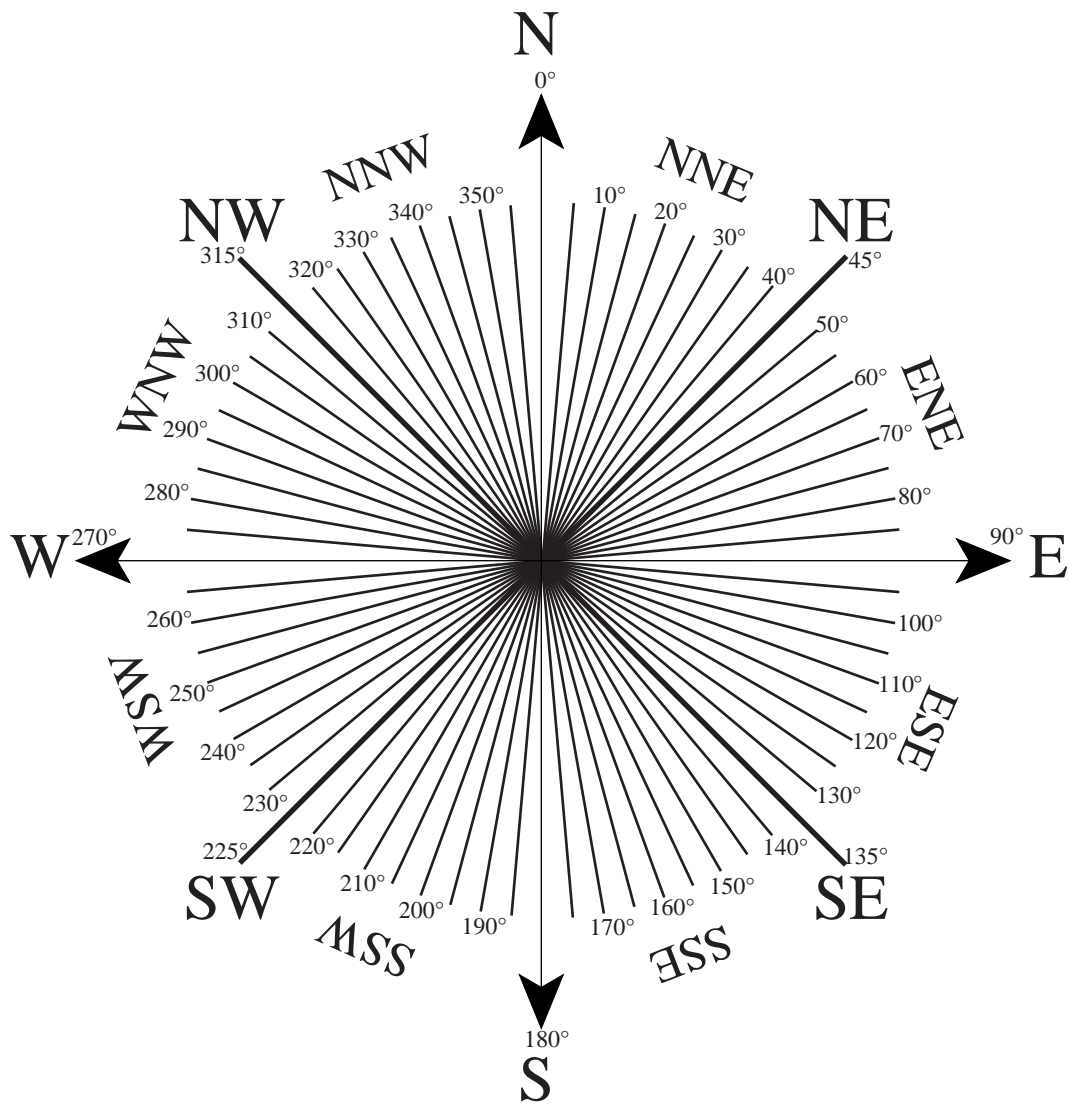
It is a requirement that you write down your answers and sketch your drawings in the booklet provided. This will allow corrections, and will be a useful guide for your reference and future assessments. We will collect these books for assessment from students who achieve marginal marks in the practical examination.

We may not necessarily conduct the exercises in numerical order. The exercises will help you to learn techniques that can be applied to any geological map, but they will also introduce you to the regional geology of some areas of the South Island.

The map component will be assessed by an exam that will comprise some simple exercises, equivalent to problems in the revision exercises, a problem equivalent to Map Exercise 5 and a harder question- which does not correspond exactly to any given exercise and will require you to think! An example exam and a couple of examples of the harder question are at the end of this booklet.

Try to find the connections between what you see mapped in different areas and the regional geology synthesized in the course document you will have (**A brief introduction to the geology of the South Island**) in terms of basement terranes, Cenozoic sedimentary cover sequences, and the age and character of regional tectonic events.

Compass Directions

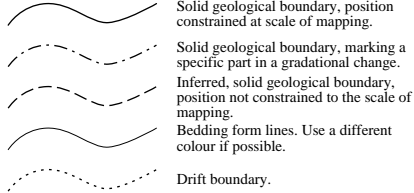


Geological Mapping Symbols

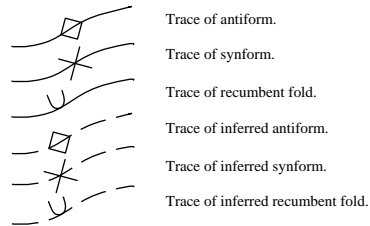
Traces of planes

Do not use a ruler. For inferred lines, degree of uncertainty can be shown by spacing of dashes.

Boundaries



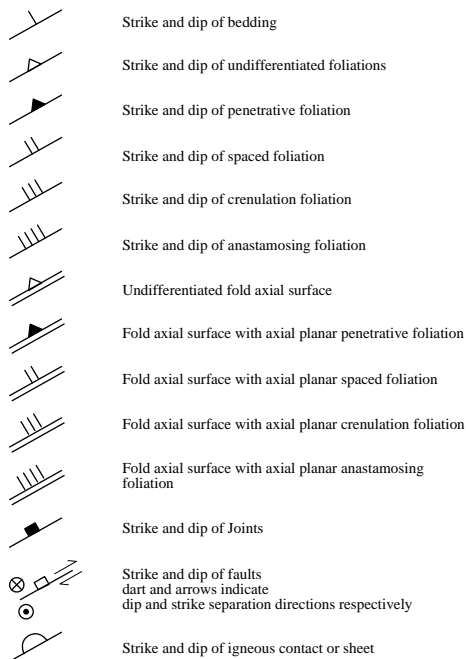
Fold axial traces



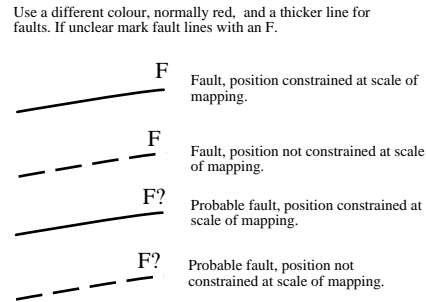
Structural Measurements

Planar measurements

Mark the dip in degrees as near to dip tick as possible. Where space permits mark the strike in degrees (3 figs) at the correct end of the strike line. Draw strike line at the precise orientation measured. The intersection of the dip tick and strike line should be positioned on measurement point.

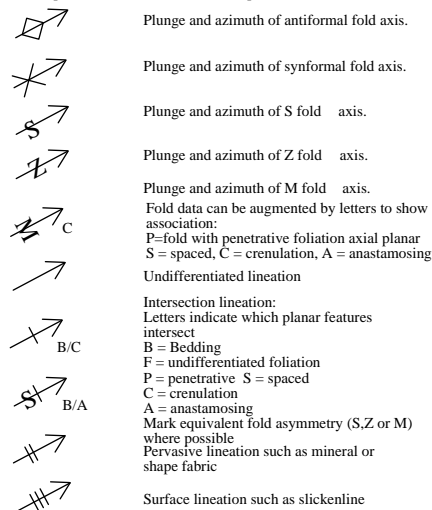


Faults

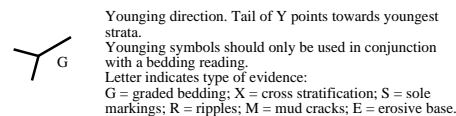


Linear measurements

Mark the plunge in degrees and where space permits the azimuth (3 figs). Mark both as close to the arrowhead as possible. Draw approx. length in the precise azimuth direction measured. The tip of the arrow should be positioned on the measurement point.

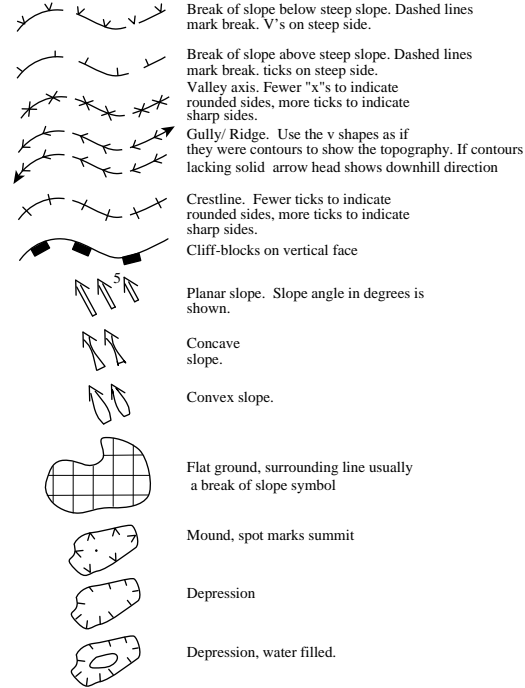


Other symbols



Topographic Features

Usually in a different colour.



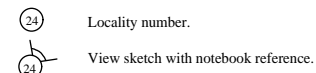
Multiple measurements and structural chronology

Where a sequence of structures is identified at a locality, the relative chronology of these is marked with Roman numerals. An example is shown here.



For multiple measurements, locate the earliest structure (normally bedding) and position on the measurement point. Other measurements should be clustered closely enough that they are clearly from the same locality.

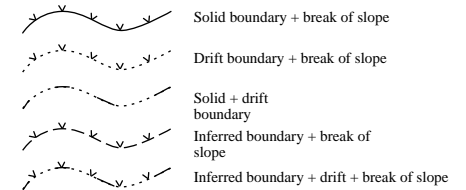
Notebook Cross-Reference



Practical Considerations

Line combinations

To prevent problems of superposing lines, the portions of which are indistinguishable at the scale of mapping, line types can be combined. Examples of combinations of break of slope are shown below. Similar combinations can be made with gully symbols and crestlines.

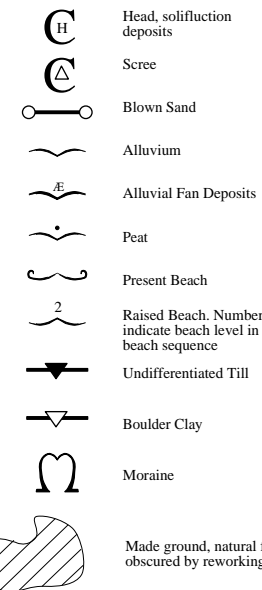


Lithological Symbols

Geological constraints:

S	sandstone observed
Sh	shale observed

Drift:



Glacial movement indicators

Mark azimuth of flow at arrow head.



GEOL252

Some notes on use of structural symbols on maps.

Use standard symbols wherever possible. Sometimes you will need to adopt a symbol for a different use or invent new symbols.

Symbols should be precisely located (unless impossible because of multiple measurements- we will cover this later). For planar data the intersection of dip tick and strike line should correspond precisely to the measurement locality. For linear data the point of the arrow should correspond precisely to the measurement locality.

Symbols, unlike boundaries, should always be ruled with a straight edge. All the symbols on a single map should be exactly the same size. For planar data the strike line must be in the correct orientation and the dip tick, which is significantly shorter than half the strike line length, should be perpendicular to the strike line. For linear data the arrow must be parallel and pointing to the azimuth.

Strike values of planar data may be omitted. If they are not omitted they must be written next to the correct end of the strike line. Dip measurements must be marked next to the dip tick (except for horizontal or vertical measurements)

Azimuth values of linear data may be omitted. Plunge values must be written next to the arrowhead. If azimuth values are not omitted the plunge and azimuth must be written in standard form (eg 23/061) next to the arrowhead.

Some notes on use of colouring on maps.

Use standard colours (get experience of looking at geological maps) wherever possible. Use a letter to clarify each lithology.

Superficial deposits can be:

- Left uncoloured
- Coloured pale yellow
- Coloured the same as underlying solid
- Coloured the same as underlying solid, but more faintly than where there is solid outcrop.

Colour should be applied evenly without pencil/brush marks

Colour should be feint rather than heavy

Colour associated with a particular lithology should abut the boundaries of that lithology but must not cross those boundaries.

REVISION (Structure) contours of planar surfaces

Contours (including topographic contours and structure contours) that represent planar surfaces will be:

1. Straight
2. Parallel
3. Equally spaced (for equal height differences).

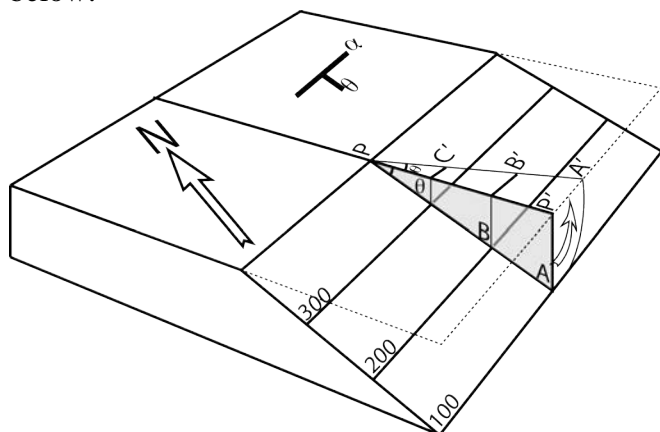
Graphical approaches.

You must learn and understand graphical methods* for:

- a. Drawing structure contours that correspond to a given strike and dip
- b. Calculating strike and dip from structure contours.

*These problems can also be solved using trigonometry and you should derive the appropriate trigonometrical equations (they are simple). Remember and use the graphical solutions as these will always enable you to derive the trigonometry. Rote use of trigonometry (without drawing up the triangles) will usually lead to errors.

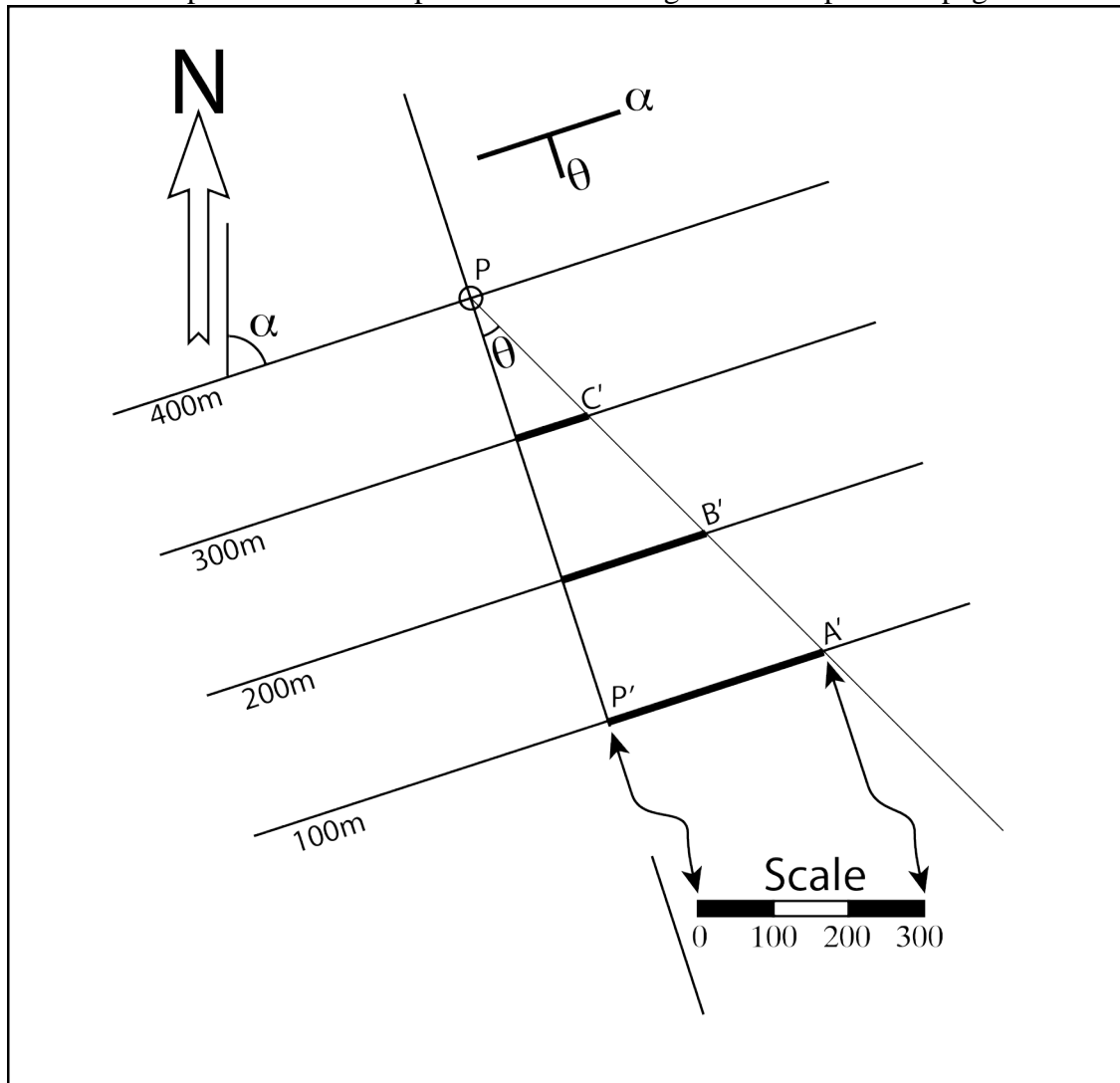
The graphical approach involves visualizing and drawing a cross section through the dipping planar surface at the point of measurement. The visualization relevant to the next few sections is shown below:



In this case we imagine a vertical cross section that passes through the measurement point (P) of a strike and dip. The section line is oriented perpendicular to strike (so that it shows true dip). This is the plane P-P'-A on the 3D diagram above. The dip is θ . In the graphical construction we imagine rotating the cross section 90° around line P-P' so that it lies in the horizontal (map) plane: A rotates onto A', B onto B' etc.

a. Drawing structure contours that correspond to a given strike and dip

This is the map view that corresponds to the 3D diagram on the previous page.



Given a strike of α and a dip of θ measured at point P and a height of P (400m in this case):

- Draw a structure contour parallel to strike through point P and label with the height at P (400m).
- Draw a line perpendicular to the strike, also passing through point P.
- Draw a line so that the angle between this and the line perpendicular to the strike is θ (angle of the dip). See the 3D diagram on the previous page to understand why we've done this.
- Use the scale bar of the map to find a line that lies parallel to the strike and has a particular length (10m, 100m, 1000m, 300m etc) between the intersection with the lines drawn in steps 2 and 3. In this example the line P'-A has length 300m parallel to strike. P'-A must lie on a structure contour that is either 300m higher or lower than the structure contour that passes through P. In this case we are down dip of P so this must be the 100m structure contour. 200m and 300m structure contours can be completed by dividing length P-P' by three. Alternatively 200m could have been measured to B' or 100m to C'.

- b. Calculating strike and dip from structure contours (refers to fig on previous page)
- i. Measure the strike angle α with a protractor.
 - ii. Draw a line perpendicular to the structure contours.
 - iii. Pick two points (P and P') where the line crosses structure contours.
 - iv. Calculate the height difference (ΔH) between P and P'. Measure distance equivalent to ΔH from P' along the structure contour using the map scale - this is the line P'-A' on the figure (300m long at map scale).
 - v. Draw a line that joins A' to P- then measure the dip angle θ with a protractor.
 - vi. Easy as.

GEOL252. Revision Exercise 1: Structure Contours of planar surfaces

Materials you should have in addition to this sheet:

A practical sheet with 6 boxes a-f.

The aims of this practical are:

1. To ensure students understand how structure contours of planar surfaces relate to the dip and strike of the surface.
2. To show how three known points can be used to construct structure contours of planar surfaces.

In box a: Draw structure contours for a planar geological surface of orientation 010 30W and at an altitude of 600m at point P.

In box b: Draw structure contours for a planar geological surface of orientation 117 10S and at an altitude of 200m at point P.

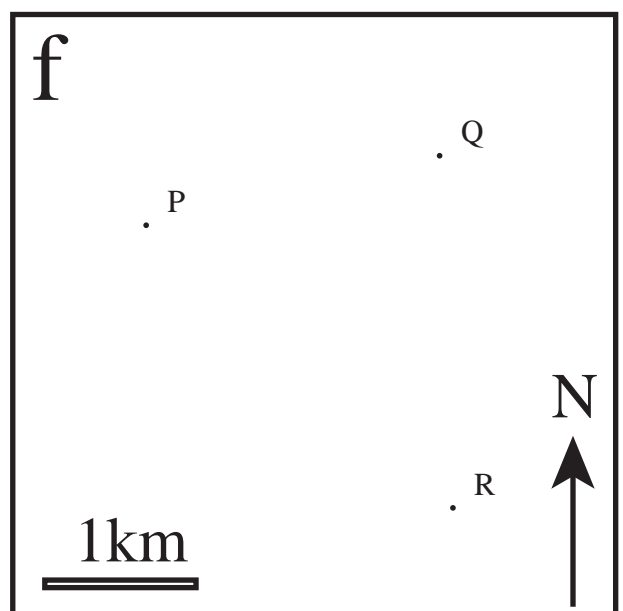
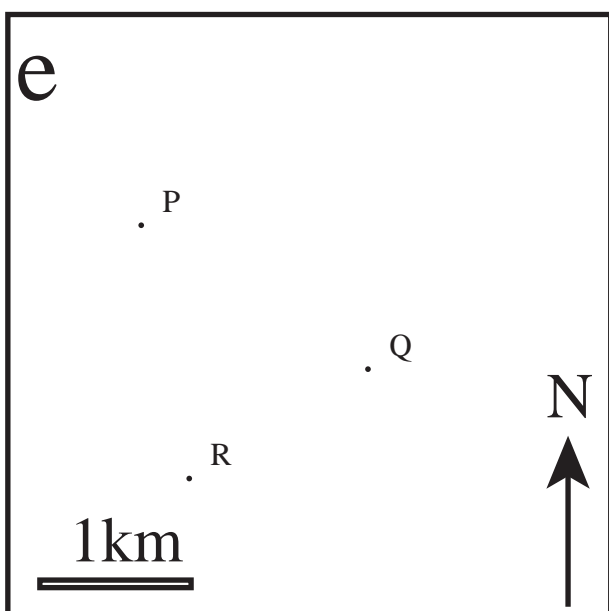
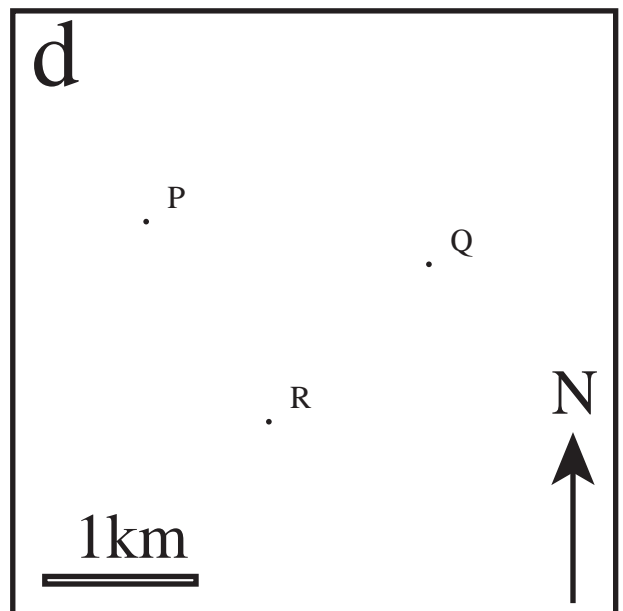
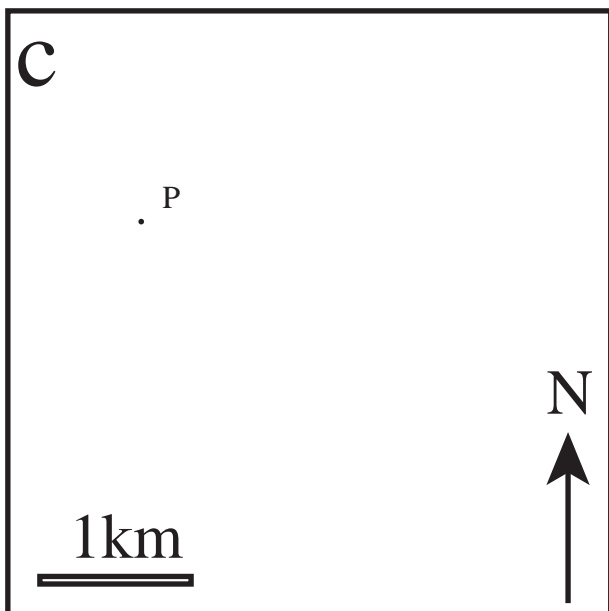
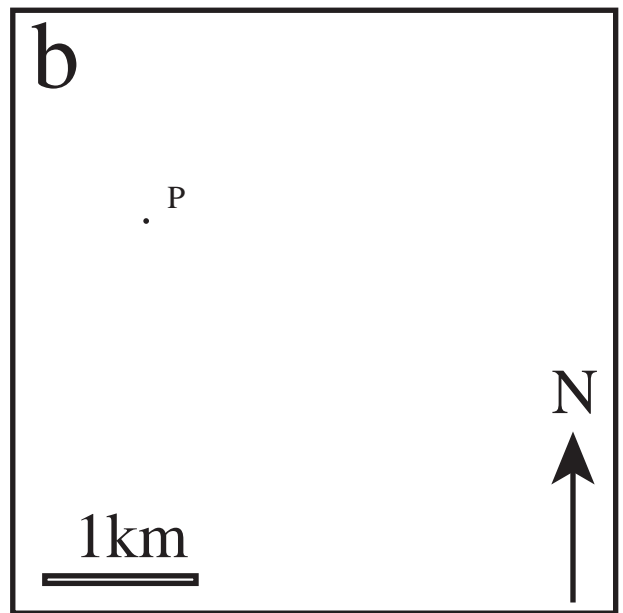
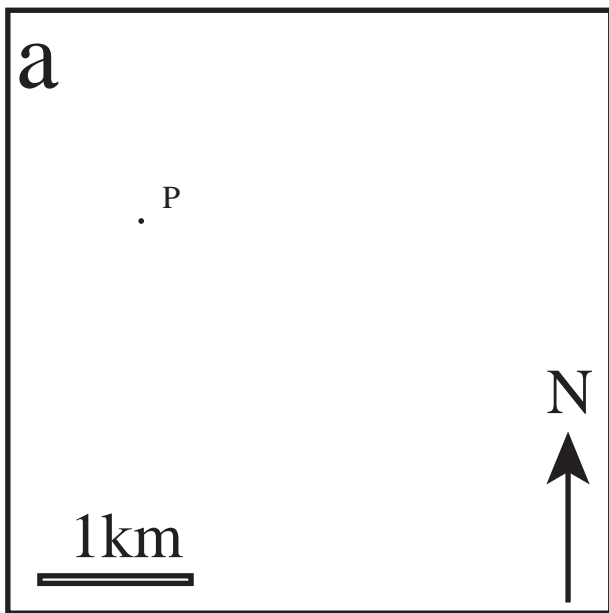
In box c: Draw structure contours for a planar geological surface of orientation 071 52N and at an altitude of 1100m at point P.

In box d: Draw structure contours for a planar geological surface with an altitude of 600m at point P, 500m at point Q and 700m at point R. Calculate the strike and dip of the surface.

In box e: Draw structure contours for a planar geological surface with an altitude of 600m at point P, 900m at point Q and 700m at point R. Calculate the strike and dip of the surface.

In box f: Draw structure contours for a planar geological surface with an altitude of 1214m at point P, 1127m at point Q and 890m at point R. Calculate the strike and dip of the surface.

GEOL252 Revision Exercise 1



GEOL252 Revision Exercise 2: Interactions of structure contours of planar surfaces and topography

Materials you should have in addition to this sheet:

A practical sheet with 6 boxes a-f.

The aims of this practical are:

1. To ensure students understand how structure contours of planar surfaces interact with topography

In each of boxes a to d:

The structure contours relate to a perfectly planar coal bed. Draw the outcrop pattern of the coal (ie a line joining all outcrop points). Calculate the strike and dip of the coal and draw a symbol on the map to show this.

In box e: A perfectly planar coal bed outcrops at P and is horizontal. Draw the outcrop pattern of the coal. A basalt dyke, that cuts the coal, outcrops at Q and has strike and dip 165 90. Draw the outcrop pattern of the dyke.

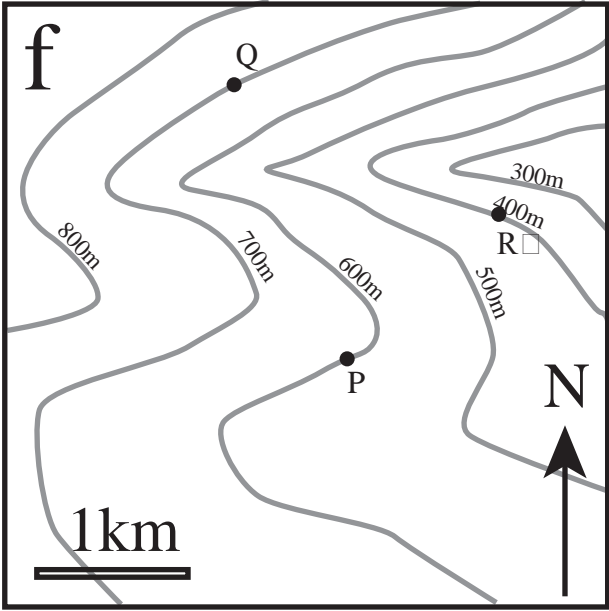
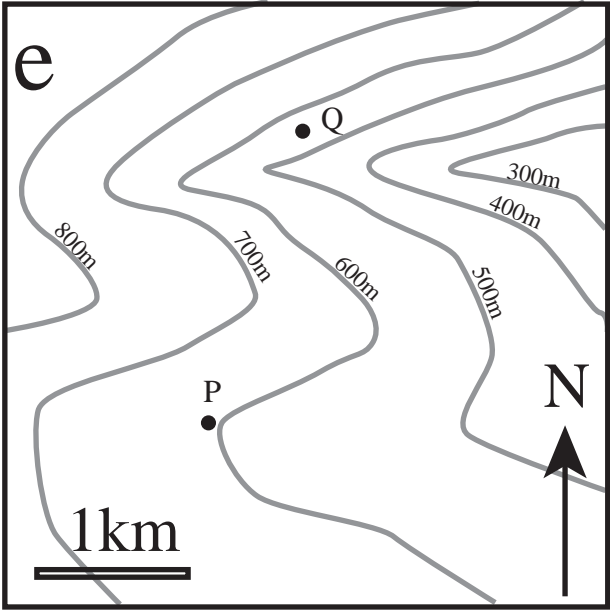
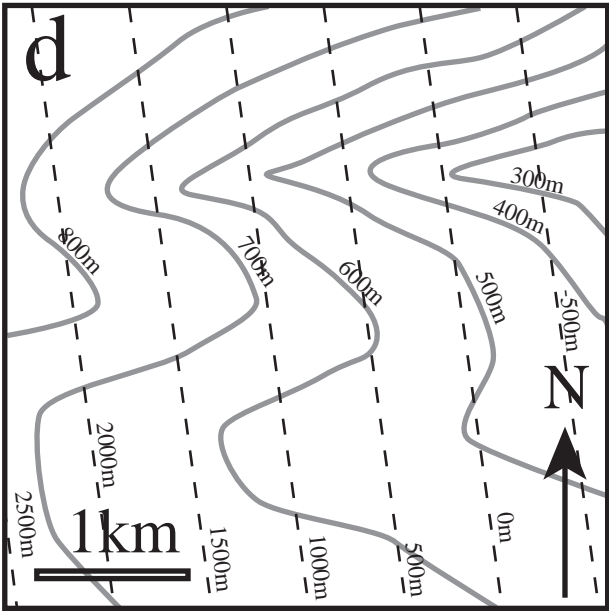
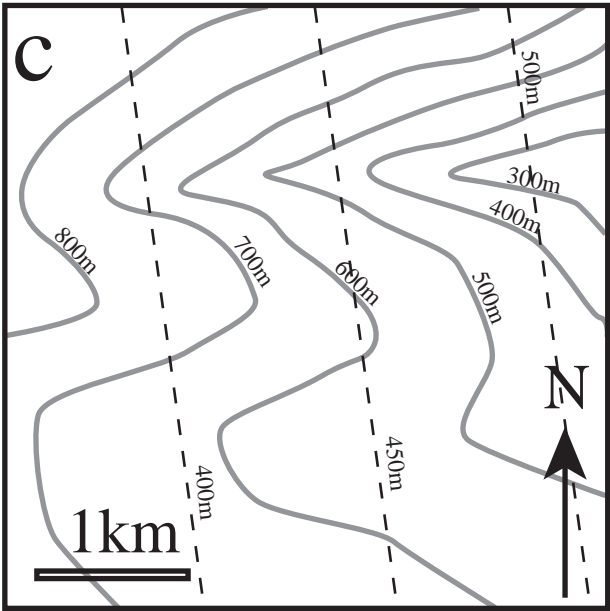
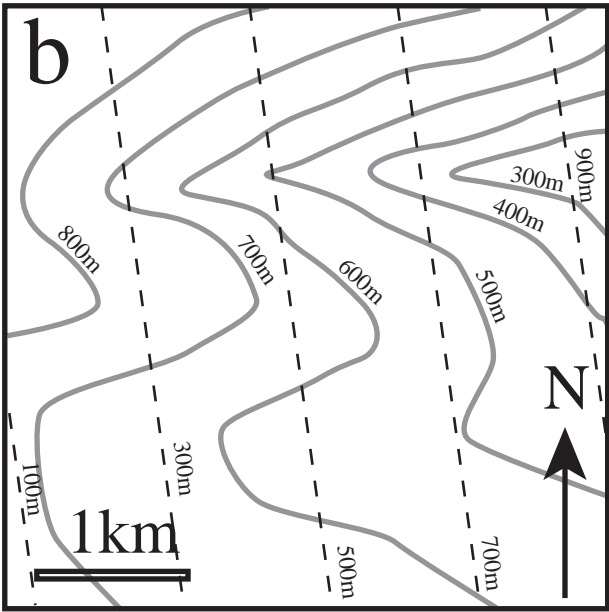
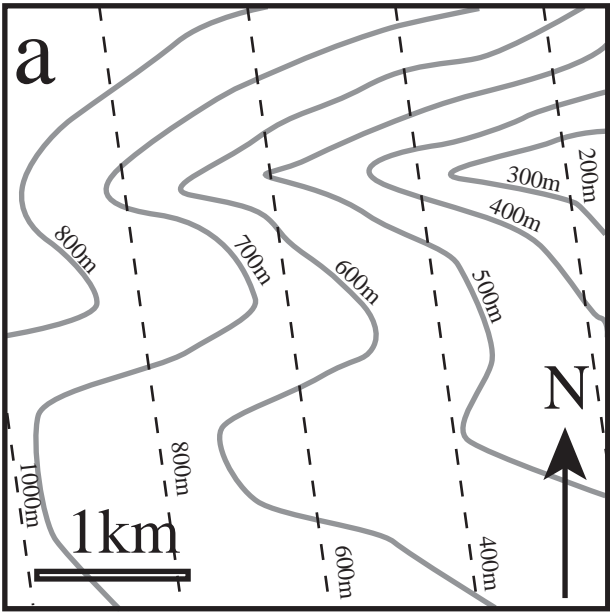
In box f: A perfectly planar coal bed outcrops at P, Q and R. Draw structure contours for the coal. Draw the outcrop pattern of the coal. Calculate the strike and dip of the coal and draw a symbol on the map to show this.

From the outcrop patterns in the exercises

- make a general statement about the relationship between the dip of a planar surface (such as a coal bed) and its outcrop pattern in areas with variable topography.
- make a general statement about the relationship between the dip direction of a planar surface (such as a coal bed) and the outcrop pattern observed when the surface crosses a valleys or ridges.

GEOL252 Revision Exercise 2

Topographic Contours
Structure Contours



GEOL252 Revision Exercise 3: Constructing structure contours and calculating strikes and dips from outcrop patterns of planar contacts.

Materials you should have in addition to this sheet:

A practical sheet with 6 boxes a-f.

The aims of this practical are:

1. To show students how to construct structure contours from outcrop patterns and to use these structure contours to calculate strikes and dips.

In each of boxes a to f:

The complete outcrop pattern of a perfectly planar coal bed is shown. Draw structure contours for the coal. Calculate the strike and dip of the coal and draw a symbol on the map to show this.

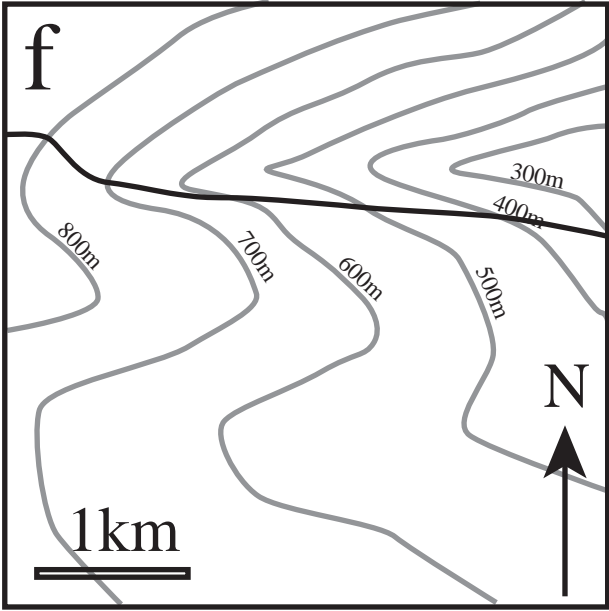
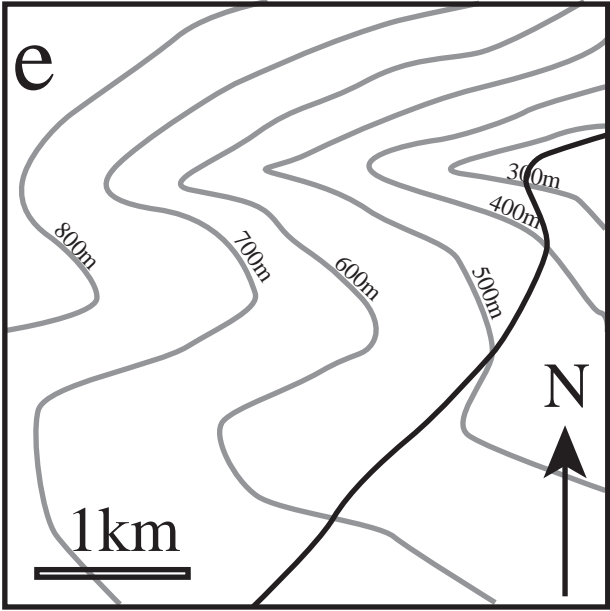
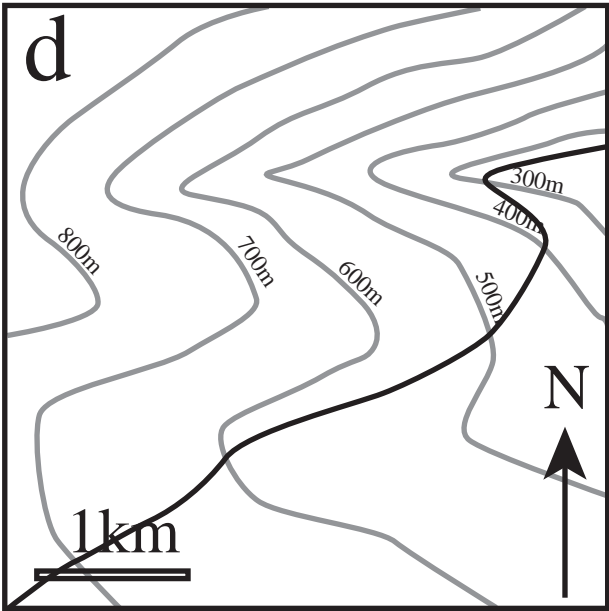
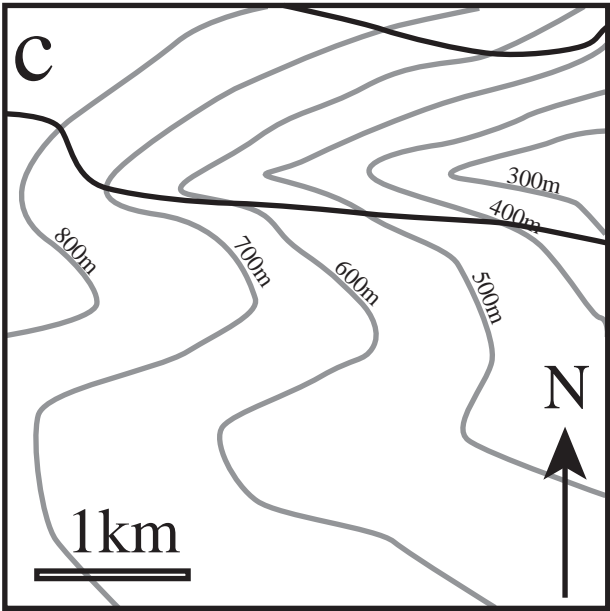
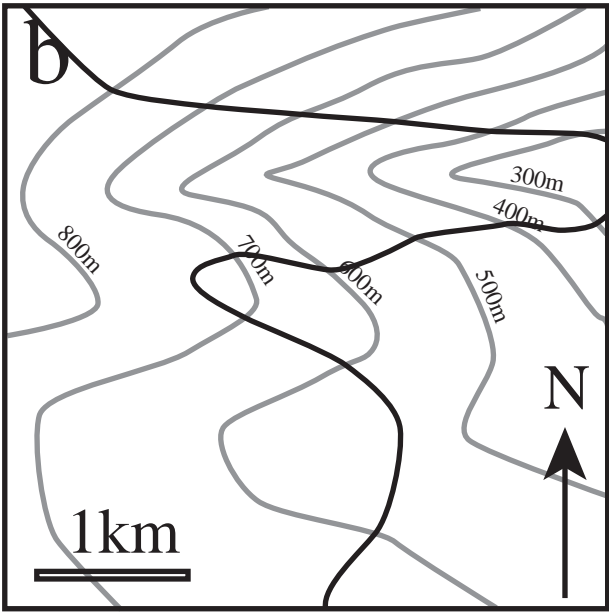
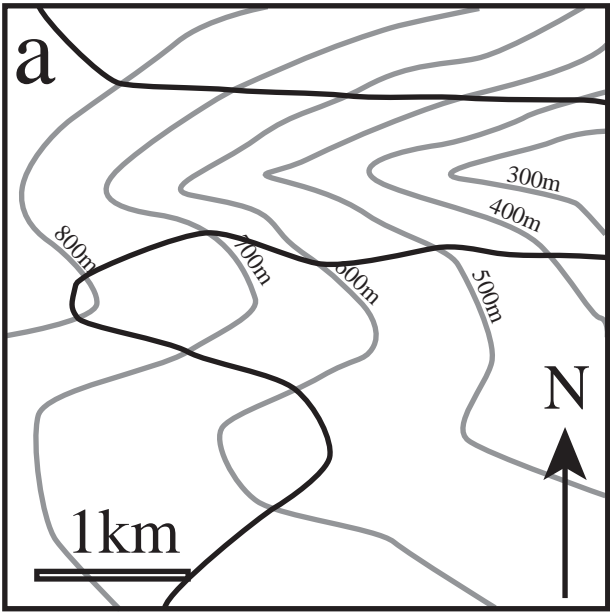
Hints:

Structure contours for a planar contact must be straight, parallel and equally spaced (for equal height difference).

- So if the outcrop crosses the same contour at more than one place you can draw the first structure contour, then use a point where the outcrop crosses a different contour to draw a second structure contour parallel to the first. etc
- Sometimes the outcrop will not cross the same contour twice. So use the three point method. Find three points on the outcrop of known height.

GEOL252 Revision Exercise 3

Topographic Contours
Coal outcrop



GEOL252 Revision Exercise 4: Lithology and Lithostratigraphy

Materials you should have in addition to this sheet:

- A sheet labelled field map
- A sheet labelled final map

The aims of this practical are:

1. To illustrate the difference between lithology and lithostratigraphy.
2. To illustrate the principles of establishing stratigraphic nomenclature

When a geologist starts making a field map the initial mapping is of lithology. As mapping proceeds, and perhaps follow-up work (e.g. palaeontology) is completed, the geologist will gradually learn about the stratigraphy. The map should evolve so that lithological mapping gives way to lithostratigraphic mapping. The final map, wherever possible, should comprise lithostratigraphy. A map should never have two different keys: a common undergraduate mistake is to have one key of lithology and one of lithostratigraphy.

A field map (not a good one as there are few data and the key is incomplete) of an area of 100% exposure is provided. All the mapped units young in the same direction. They form a continuous succession with no tectonic breaks or repetitions.

Colour the field map and key according to **lithology**. All units of one lithology have the same colour, irrespective of their position in the stratigraphy.

Complete the GVS on the final map by assigning formal stratigraphic names and symbols (this has been started for you). Colour the final map, section and GVS according to **lithostratigraphy**. Different lithostratigraphic units have different colours that relate to their position in the stratigraphy.

For the purpose of this exercise formal stratigraphic names should have the following structure:

Location Rocktype Formation

Where:

- The 'Location' is a permanent feature that lies in the outcrop area (or lies nearby the outcrop area) of the formation.
- The 'Rocktype' is as simple as possible: one word preferably.
- The word 'Formation' is used
- All elements start with capitals

Correct: Hangman's Gorge Limestone Formation.

Wrong: Richie McCaw Limestone Formation.

Wrong: Dead Sheep Limestone Formation.

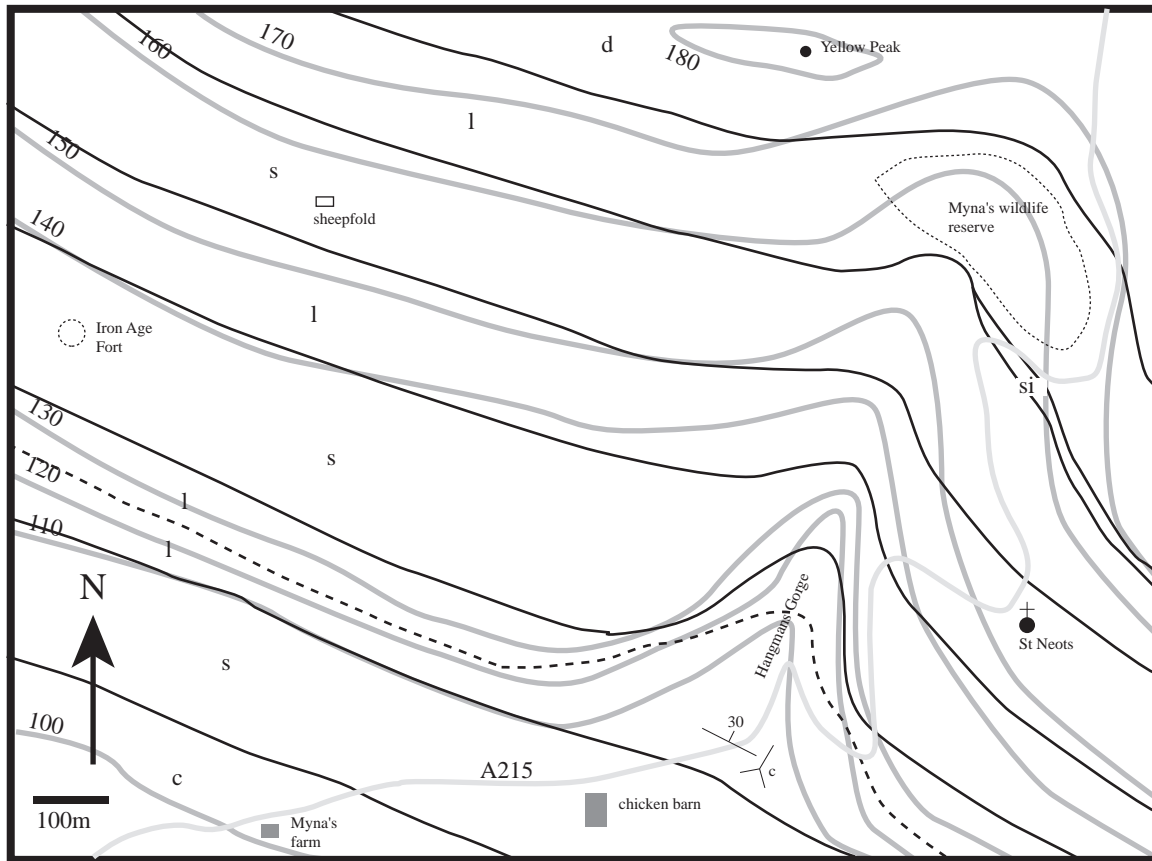
Wrong: Hangman's Gorge Limestone

Wrong: Hangman's gorge limestone formation.

Wrong: Hangman's Gorge Crinoid rich, Quartz bearing, Reddish Biomicrite Formation.

GEOL252 Revision Exercise 4

Field Map



Lithologies

d	dolomite	si	siltstone	s	sandstone
c	conglomerate	l	limestone		

— geological boundary

— contours (metres)

— road

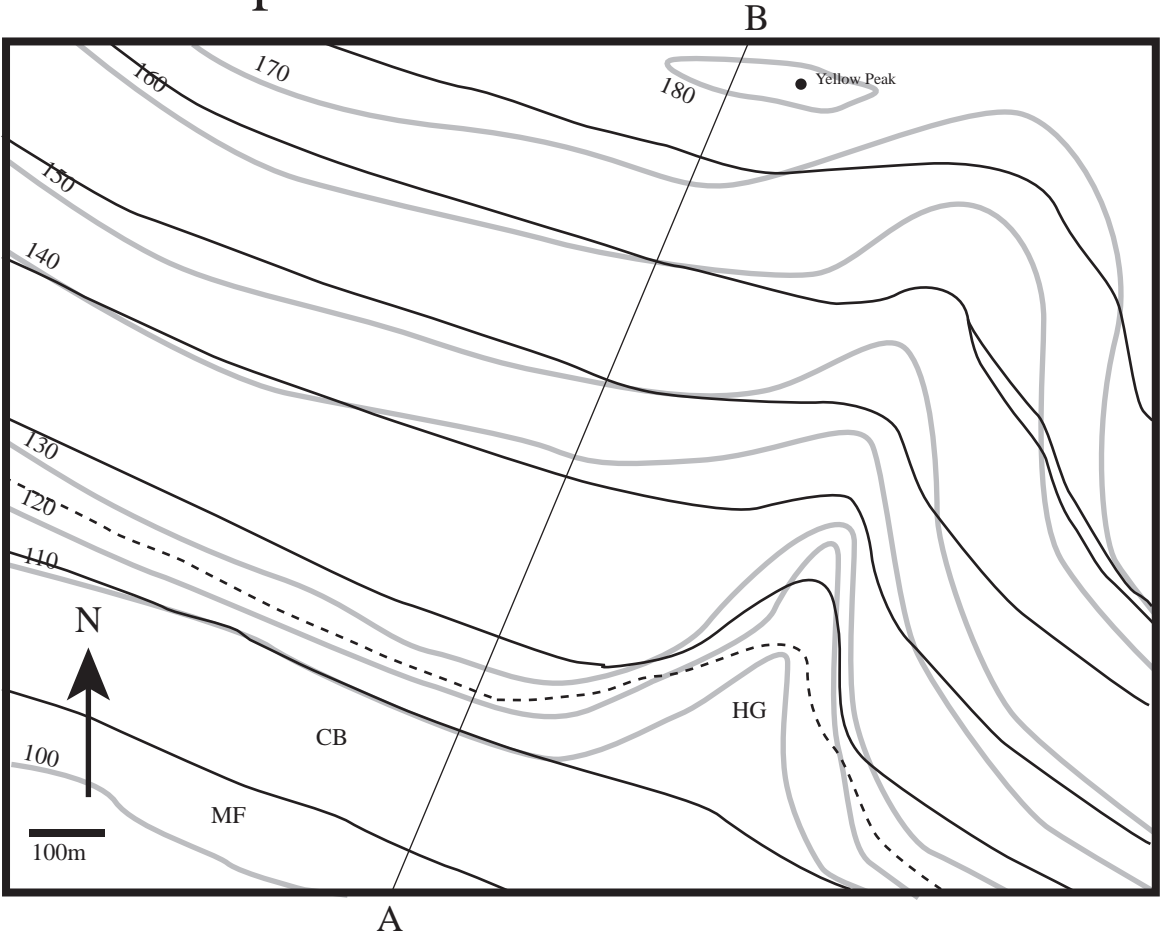
- - - coral rich bed

30° Strike and Dip of Bedding

c Younging defined by corals

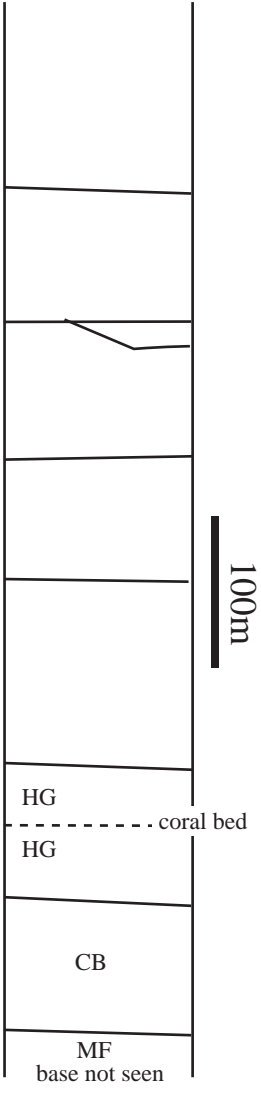
GEOL252 Revision Exercise 4

Final Map

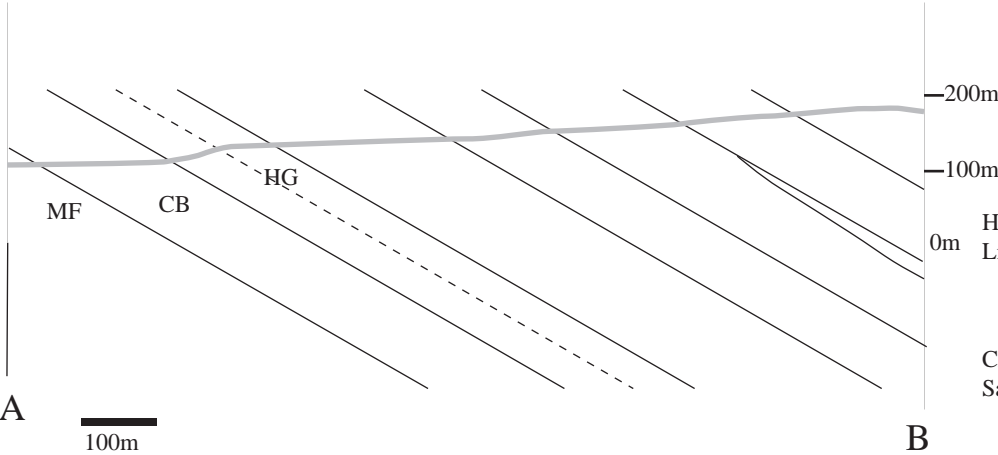


- geological boundary
- contours (metres)

GVS



Cross Section



- Hangmans Gorge Limestone Formation
- Chicken Barn Sandstone Formation
- Myna's Farm Conglomerate Formation

GEOL252 Map Exercise 1: Interaction of structure contours and topography

Materials you should have in addition to this sheet:

A map showing topographic and structure contours.

Graph paper.

The aims of this practical are:

1. To show that the superposition of a topographic contour map and a structure contour map, of a particular geological surface, enables constraint of :
 - i. the outcrop of the geological surface (where it intersects the surface and maybe exposed if not covered by superficial deposits).
 - ii. the areas of the map where the geological surface has been eroded away.
 - iii. the areas of the map where the geological surface is buried.

The map shows topographic contours and structure contours for a thin coal. Highly fractured limestones overlie the coal. Impermeable shale lay below the coal.

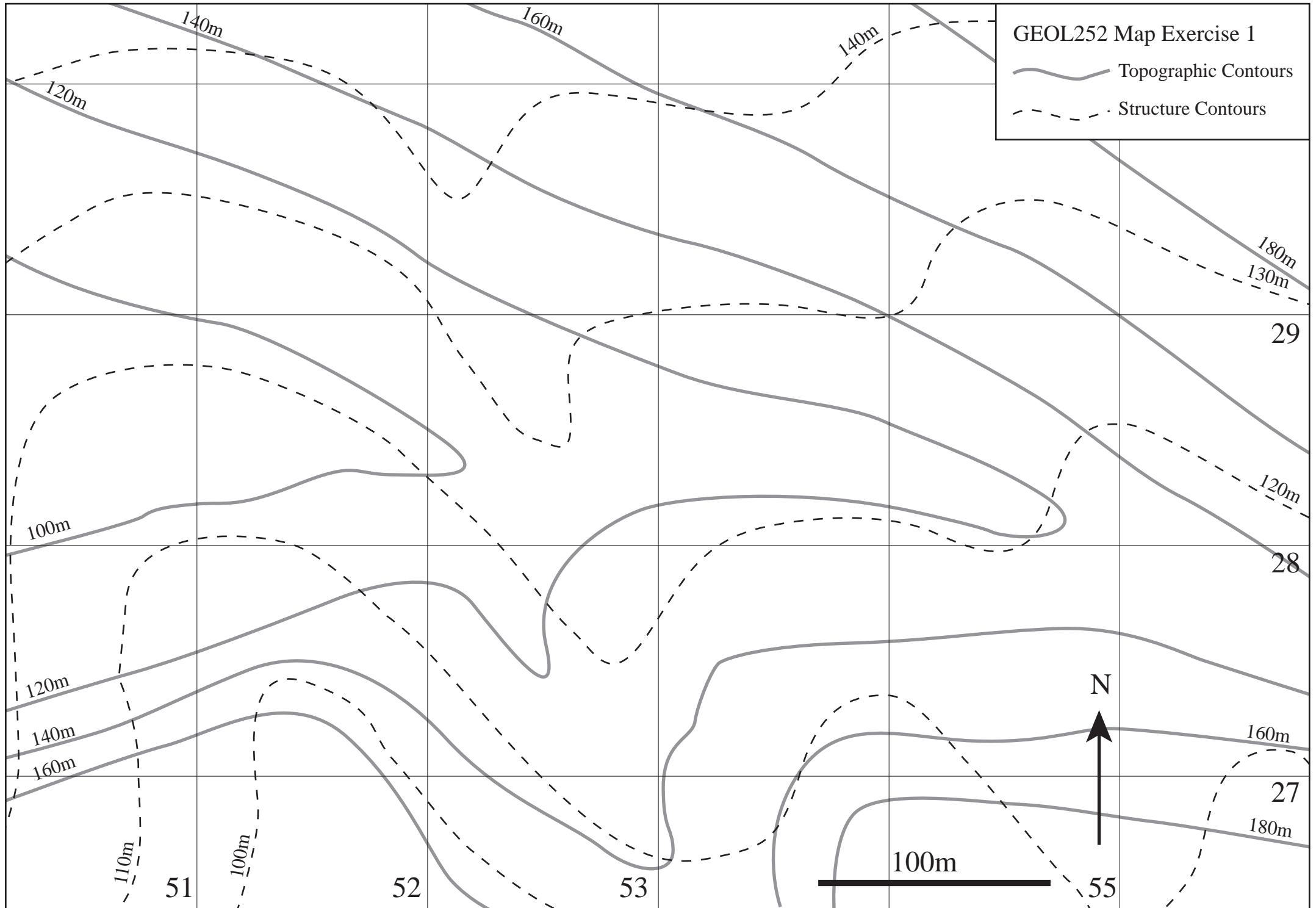
When you make marks on the map, make sure they are labelled unambiguously. Otherwise you will find it difficult to understand your work when you come to review it.

1. Describe (in no more than a few lines) the topography of the area.
2. Describe (in no more than a few lines) the geometry of the coal.
3. Draw one N-S profile (with no vertical exaggeration), between (5176 2650) and (5176 3030), to show both the surface topography and the coal. Identify, on the profile:
 - i. regions where the coal is buried
 - ii. regions where the coal has been eroded away
 - iii. points where the coal outcrops (ie it is at the surface)
4. Draw a profile (with no vertical exaggeration), between (5016 2708) and (5500 2848), to show both the surface topography and the coal. Identify regions i) to iii) (as above) on this profile. Be careful. This profile is much trickier than the last. In places you may need to draw segments of contours and structure contours interpolated between the data that are already on the map (e.g you will need to sketch segments of 110, 115, and 117.5m contours in grid square (52 27)). You will need your pencil to be very sharp.
5. The two profiles will show that the coal outcrops at some points along the profiles. Mark these on the map as points. Can you see any way to identify other points where the coal outcrops, but without drawing profiles? Mark on the map as many outcrop points as you can. You should be able to increase the number of outcrop points by drawing segments of contours and stratum contours interpolated between the data that is already on the map.
6. The coal must define a line where it intersects the topographic surface. All the outcrop points you have constrained must lie on this line. Use the outcrop points you have to draw the line that shows the outcrop of the coal. You may need to locate more outcrop points to complete this task with precision.
7. Under what circumstances can the line showing outcrop cross contours (either topographic or structure contours)?
8. Locate on the map the most likely locations of springs.

GEOL252 Map Exercise 1

Topographic Contours

Structure Contours



GEOL252 Map Exercise 2: Cross sections in simple stratigraphy

Materials you should have in addition to this sheet:

A practical sheet with a map

Graph Paper

The aims of this practical are:

1. To show students how to construct a simple geological cross section from a map
 2. To show students how to construct a simple generalized vertical succession (GVS)
-
1. Draw the structure contours for the contact between units C and D on the map. Go back to revision exercise 3 (or it's equivalent in GEOL112 if you don't know what you are doing) Make sure each structure contour is labelled (e.g. C-D1000)
 2. What is the likely geometry of the C-D contact in three dimensions: A planar surface? (if so what is the strike and dip), a dome? a basin? a ridge? etc
 3. Draw a topographic profile through point P along a line in the orientation most suited to showing the true dip of the C-D contact. Do not use any vertical exaggeration. Use the structure contours to draw the C-D contact on the same profile. Draw a solid line for the C-D contact where it is buried below the surface, and a dashed line where it is above the surface (and eroded away).
 4. Draw the structure contours for all the other contacts on the map. If you do not make sure each structure contour is clearly labelled you will end up with a useless mess.
 5. How do the structure contours of the various contacts relate to each other and what does this tell you about the relative orientation of the contacts?
 6. Use the structure contours to put all of the contacts onto the profile (including those that are above the topographic surface along the whole length of the profile. You now have a geological cross section through the map.
 7. How do the thicknesses of units on the cross section compare with outcrop widths on the map? Do either of these represent the true thickness?
 8. Use the thicknesses on the cross section to draw up a GVS (a column of 1-3cm width) to show the stratigraphic succession and the true thicknesses of the units. Use a vertical scale of 1:10,000.

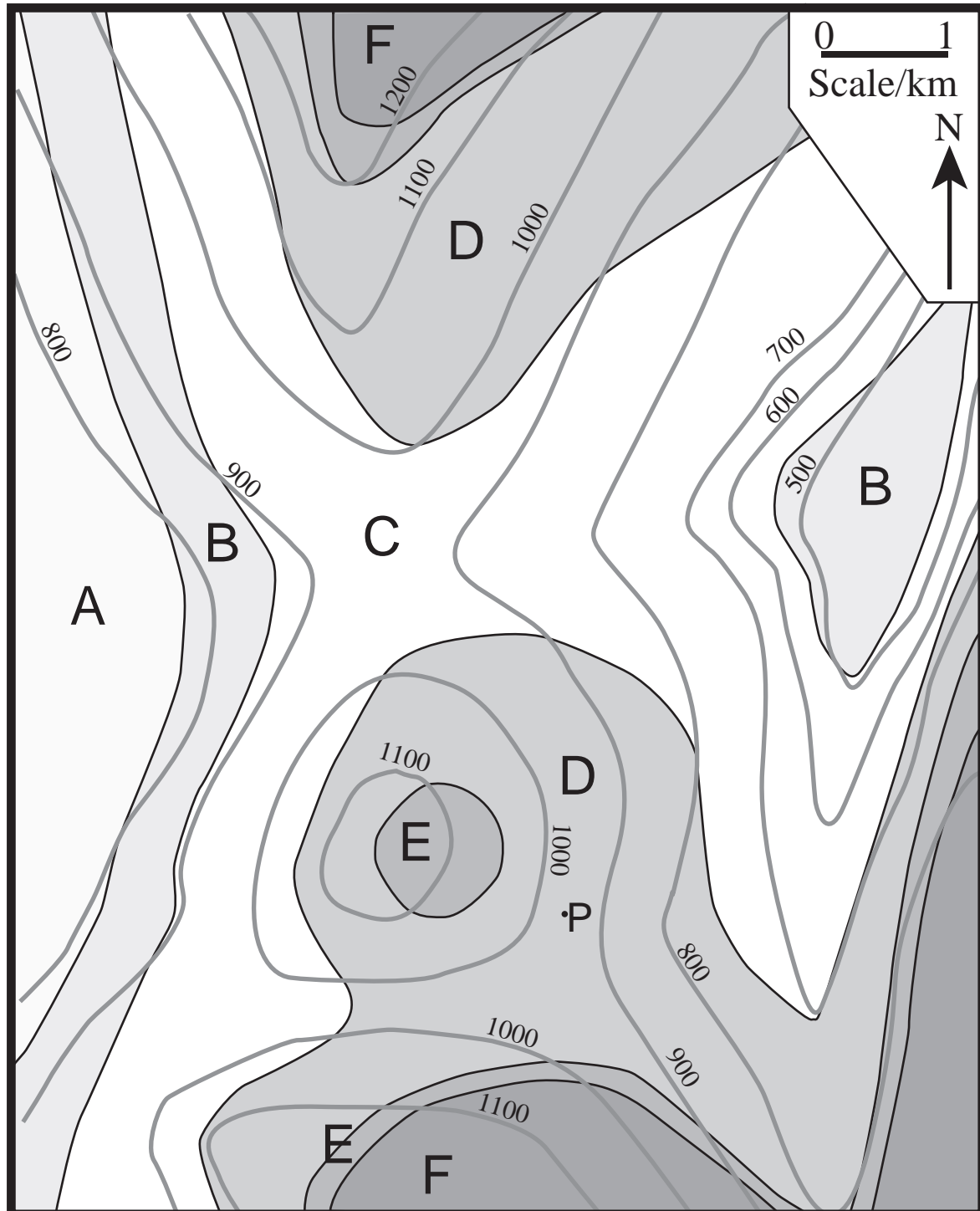
GEOL252

Map Exercise 2

 Topographic contours- heights in metres

 Geological contacts

A-F Geological Mapping Units



GEOL252 Map Exercise 3: Assessing strike and dip from geological maps

Materials you should have in addition to this sheet:

- A copy of the Te Anau Downs Geological Map (Sheet D42AC, part D43. 1:50,000). Contours are hard to read and are in metres. Contour intervals west of the lake are 150m. East of the lake contour intervals are 30m up to 450m then 150m above this. **Please do not mark the maps.**
- Black and white copies (in this labbook) of parts of the map. Use these to do the exercises together with the map to give you better context and to provide the key.

The aims of this practical are:

1. To demonstrate that three point techniques can be applied to the interpretation of real geological maps. (if you have forgotten all about the 3 point approach go back to revision exercises 1, 2 and 3 or their equivalents in your GEOL112 work)
2. To emphasise the importance of understanding how dipping features interact with topography.
3. To show that rules governing the interaction of surfaces and topography apply equally to a variety of geological features, including beds, intrusions and faults.

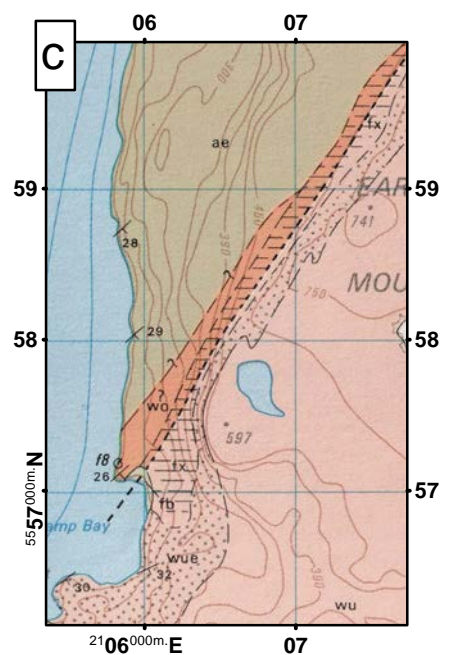
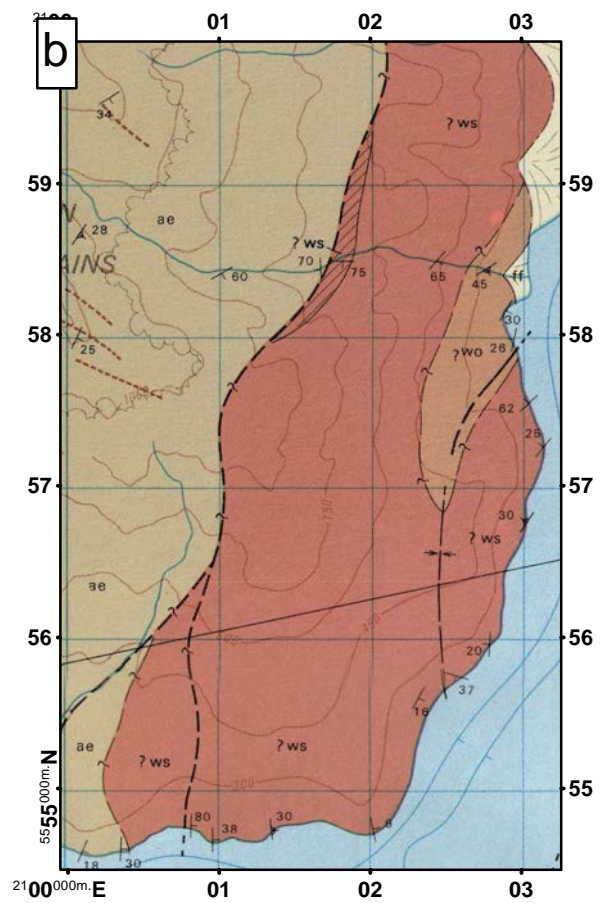
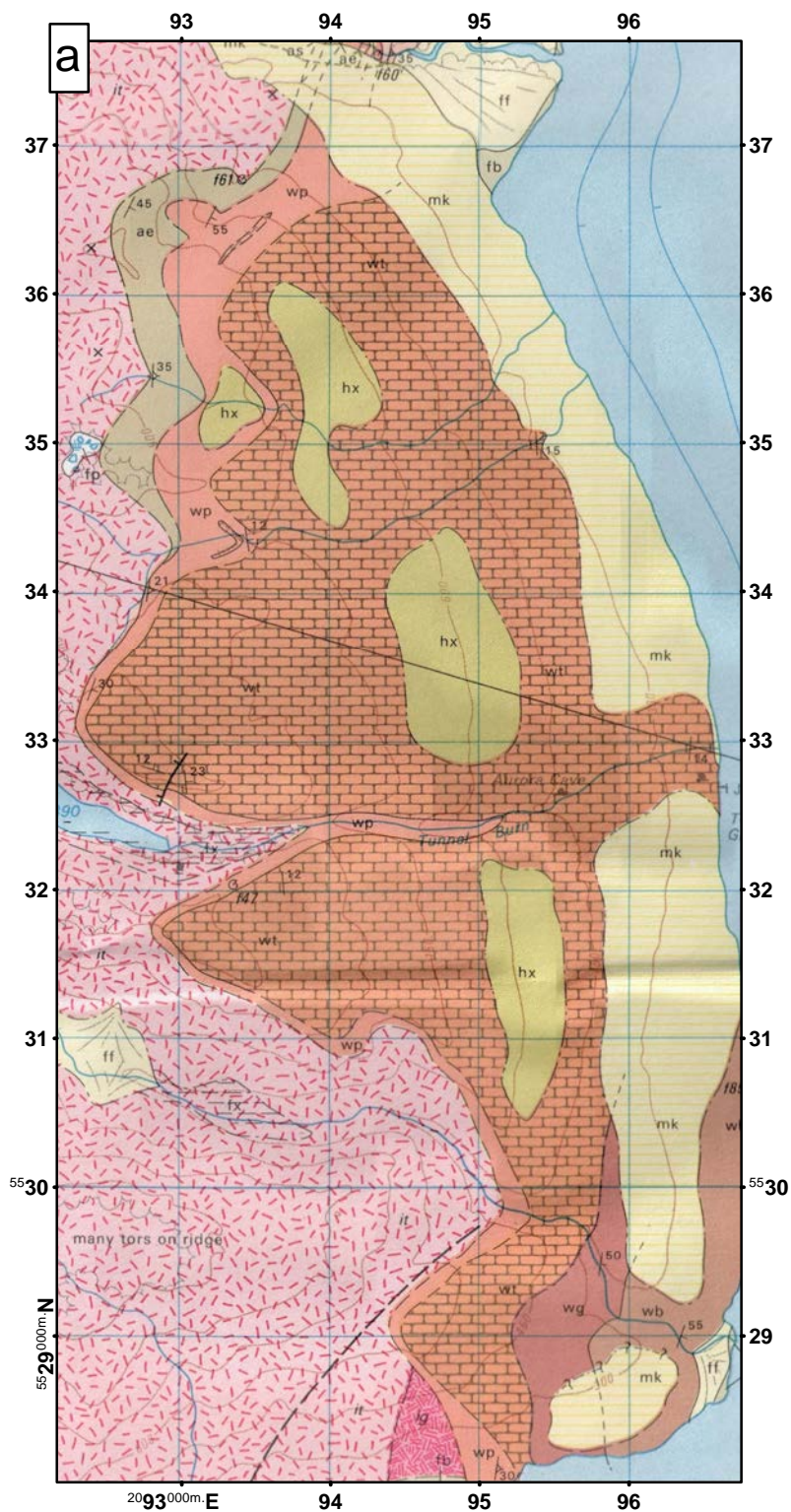
For each the features listed below (a-e):

1. From the relationship of the outcrop to topography, make a rapid assessment of whether the feature is sub-horizontal, dips shallowly, moderately or steeply or is sub-vertical. Assess which way the feature dips.
 2. Use three points to calculate the strike and dip. Use the tracing paper for this. Start by marking three points where the heights of the outcrop are constrained. Use these to draw up structure contours and calculate the strike and dip from these (go back to exercises 1, 2, 4 and 5 if you are stuck)
-
- a. The base of the Tunnel Burn Formation (wt) between (95 28) and (94 36). Best place is in the area immediately south of the Tunnel Burn.
 - b. The faulted contact of the Stuart Formation (ws) and the Earl Mountain Sandstone Formation (ae) between (01 57) and (02 59). Do not include any of the contact south of (01 57) – see if you can work out why.
 - c. The faulted contact of the Turret Peaks Formation (wue, wu) and the Boyd Creek Formation (wo) between (06 57) and (07 59)
 - d. The base of the Marakura 2 Till Member (mk₂t) in the area within ~3km of (07 45)
 - e. The base of the Turret Peaks Formation (wu) between (93 47) and (99 52). Be careful with this one. I suggest you do the exercise three times on different parts of the contact (South, central and North).

Check how your calculations compare with your rapid assessments.

Compare your calculations with colleagues who may have used a different three points. How do the answers vary? Can you explain any variation?

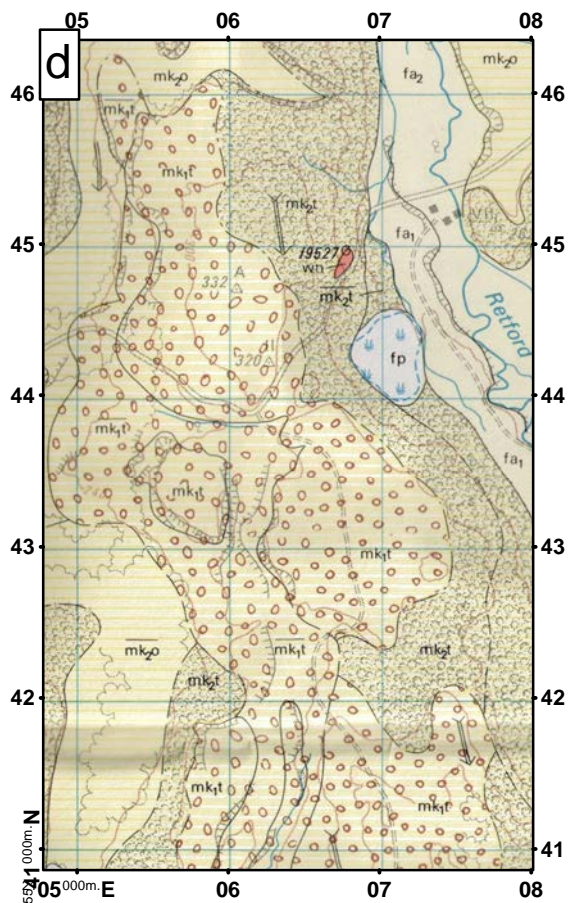
Under what conditions will the three point approach fail?



GEOL252

Map Exercise 3

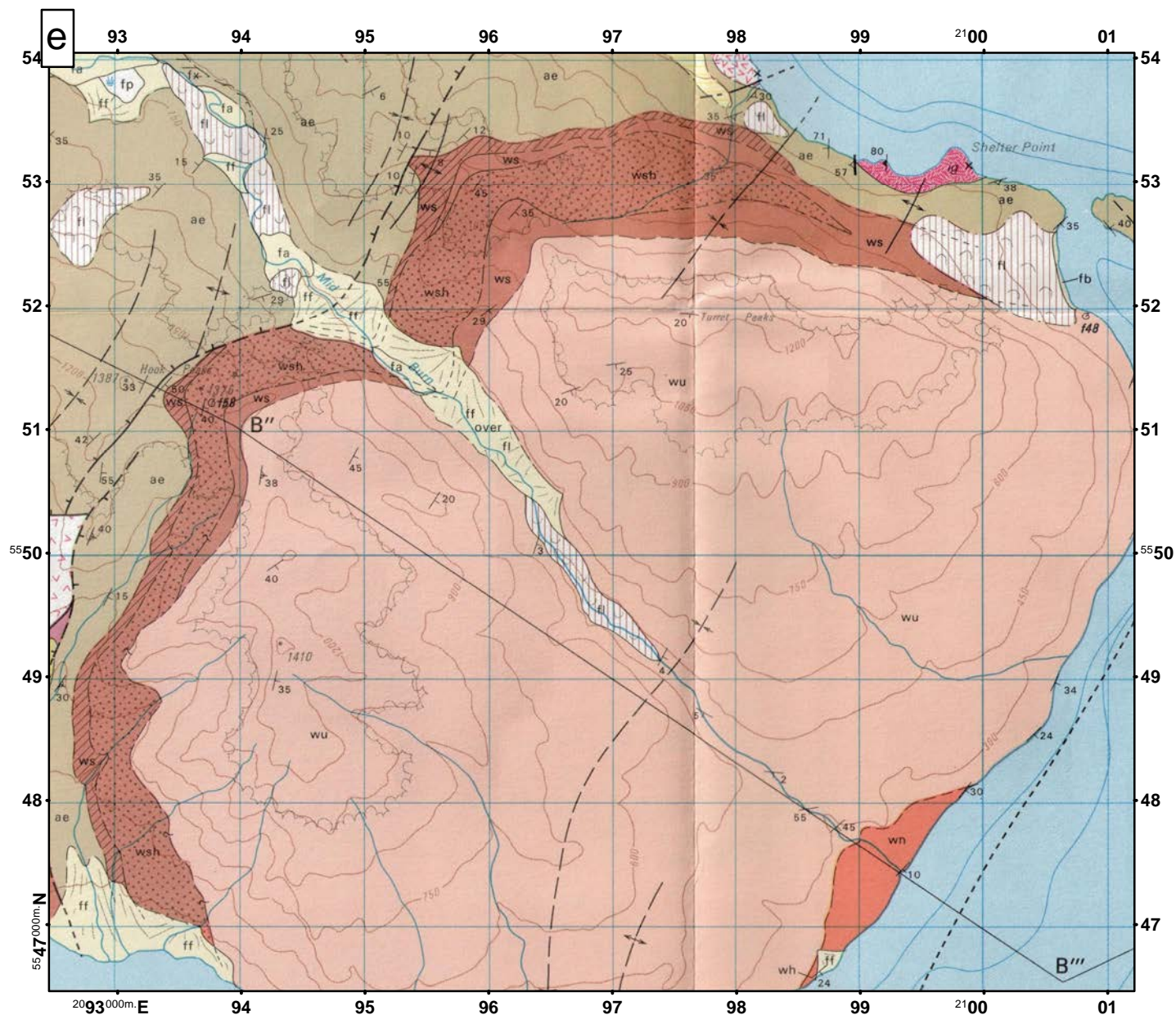
Do your work on these, but makesure you look at the original map



GEOL252

Map Exercise 3

Do your work on these,
but make sure you look
at the original map



GEOL252 Map Exercise 4: Cross sections and stratigraphy on geological maps:

Materials you should have in addition to this sheet:

- A copy of the Te Anau Downs Geological Map (Sheet D42AC, part D43. 1:50,000). Contours are hard to read and are in metres. Contour intervals west of the lake are 150m. East of the lake contour intervals are 30m up to 450m then 150m above this. **Please do not mark the maps.**
- Tracing paper
- Graph Paper

The aims of this practical are:

1. To introduce students to rapid map assessment.
 2. To give practice in drawing a cross section from a geological map.
 3. To show how map patterns may relate to stratigraphy
-
1. In 5 minutes try and draw a sketch map to show the main geological elements of the map. Successful sketch maps do not break down the map to more than a few (≤ 5) geological elements.
 2. Understanding the map is dependent on understanding the nature of contacts. Have a look in particular at the base of the Earl Mountains Sandstone Formation (ae) around ($^{20}91$ $^{55}56$). What is the nature of this contact? Are there any other contacts of this nature? What do they tell you?
 3. Draw one cross section (with no vertical exaggeration) from to ($^{20}90$ $^{55}57$) to ($^{21}00$ $^{55}49$). The topography should be included on the cross section and the inferred geology above and below topography should be shown.
 4. From the cross section, draw a GVS (See revision exercise 4) with a vertical scale of 1:10,000.

GEOL252 Map Exercise 5: Cross sections in less simple stratigraphy

Materials you should have in addition to this sheet:

A practical sheet with a map

The aims of this practical are:

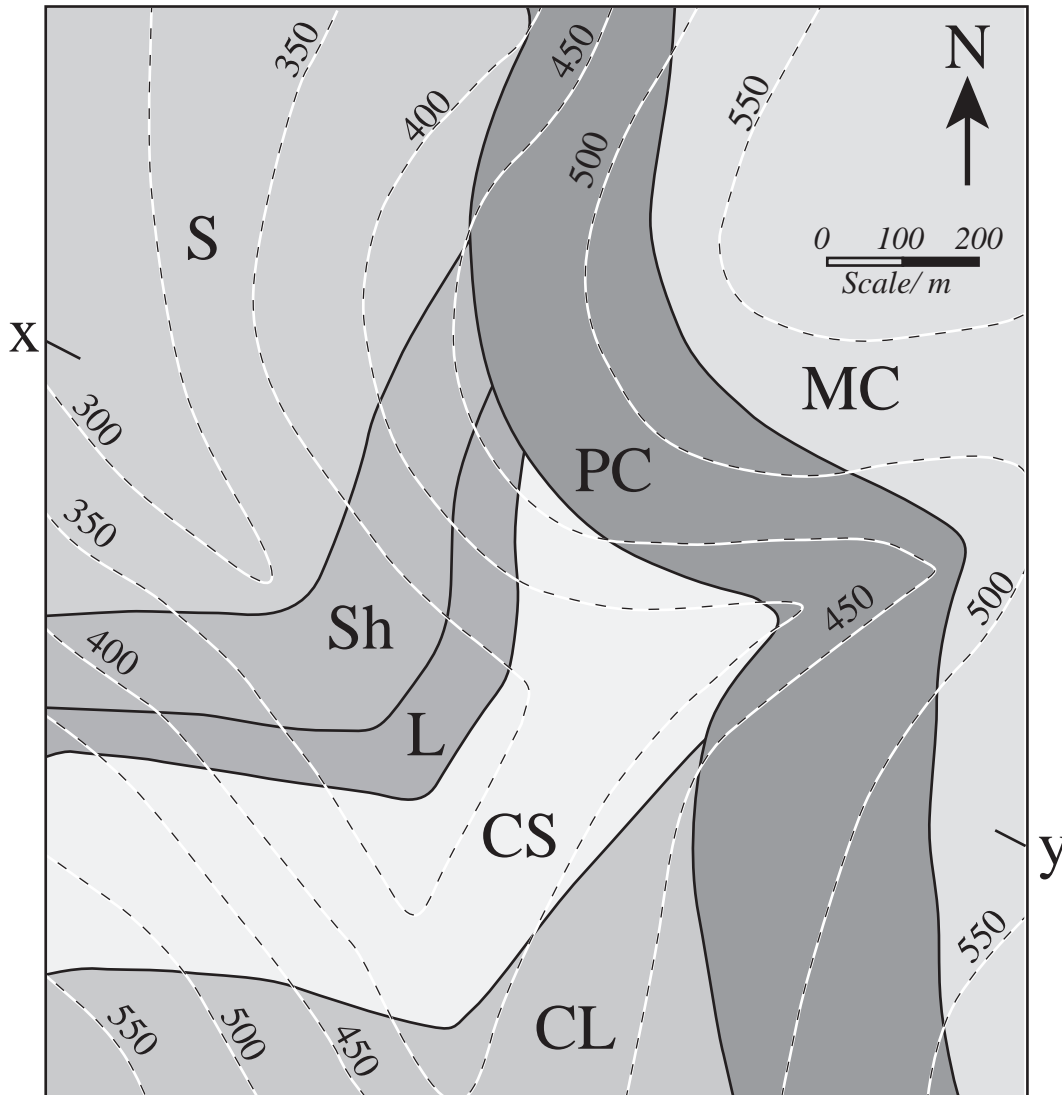
1. To give students experience in constructing a geological cross sections in maps with some stratigraphic complications
2. To show students how to construct a generalized vertical succession (GVS) where stratigraphy is not straightforward
3. To illustrate how maps can be used to understand more generally subsurface geology.

Note that a large part of the final examination will ask you to draw an accurate cross section and construct a GVS for a map, which is very similar to this one. You will not be given step by step instructions in the examination. Alternative maps are provided so that you can practice.

1. Draw structure contours (at least 2) for the contact between PC and MC on the map. Make sure each structure contour is labelled (with the contact it relates to and the height).
2. Draw structure contours for the CS–CL contact on the map. Make sure each structure contour is labelled.
3. How do the structure contours of the PC–MC contact and the CS–CL contact relate to each other and what does this tell you about their relative orientations.
4. Draw the structure contours for all the other contacts on the map. If you do not make sure each structure contour is clearly labelled (with the contact it relates to and the height) you will end up with a useless mess. What are the relative orientations of the contacts? How many families of orientations of contacts are represented on the map?
5. Draw a topographic profile along the line X–Y. Do not use any vertical exaggeration. Use the structure contours to draw all geological contacts on the same profile. Be particularly careful: some of your contacts will intersect- use the map to help you understand what must happen, on the cross section, in each of these cases.
6. What is the significance of the contact beneath unit PC.
7. Draw (two) extra cross sections (on another sheet of paper) to show the true thickness of the units. Use the thicknesses on these cross sections to draw a GVS (generalised vertical succession) to show the stratigraphic succession and the true thicknesses of the units. Use a vertical scale of 1:5,000 on the GVS.
8. The contact of Sh and L contains a rich Zn deposit. The money question- show where there this deposit is in the subsurface and where it is absent. You will need to think quite hard about what to do under PC and MC. You might look at this again after doing exercise 6.

GEOL252 Map Exercise 5

Column for
GVS

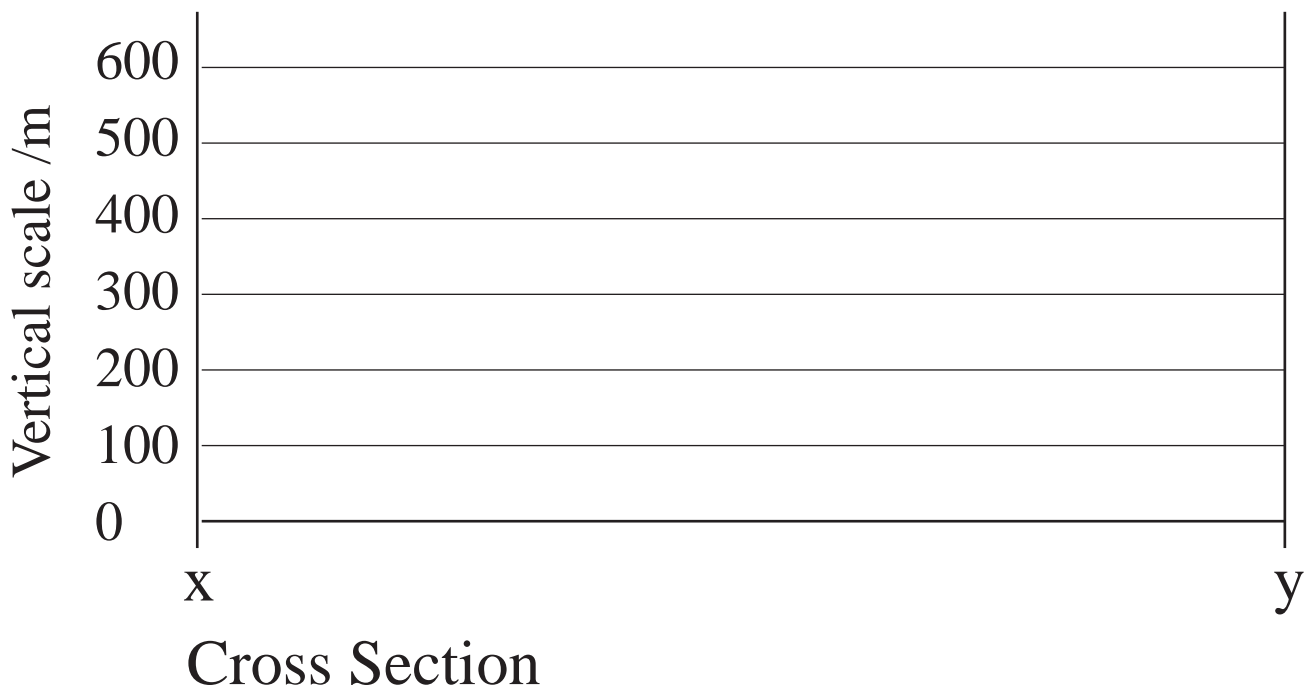
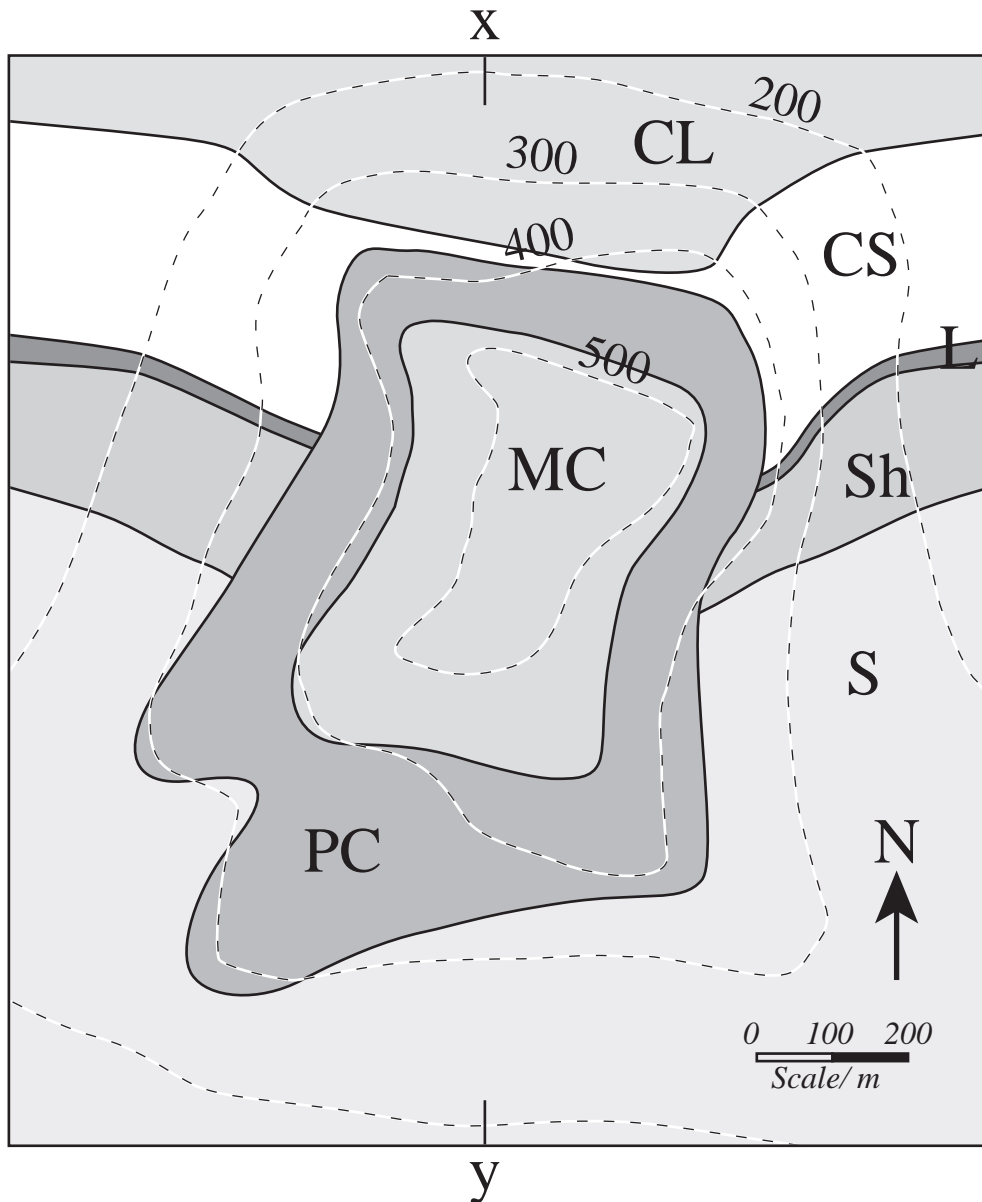


Cross Section

GEOL252 Map Exercise 5

Alternate Map for Practice

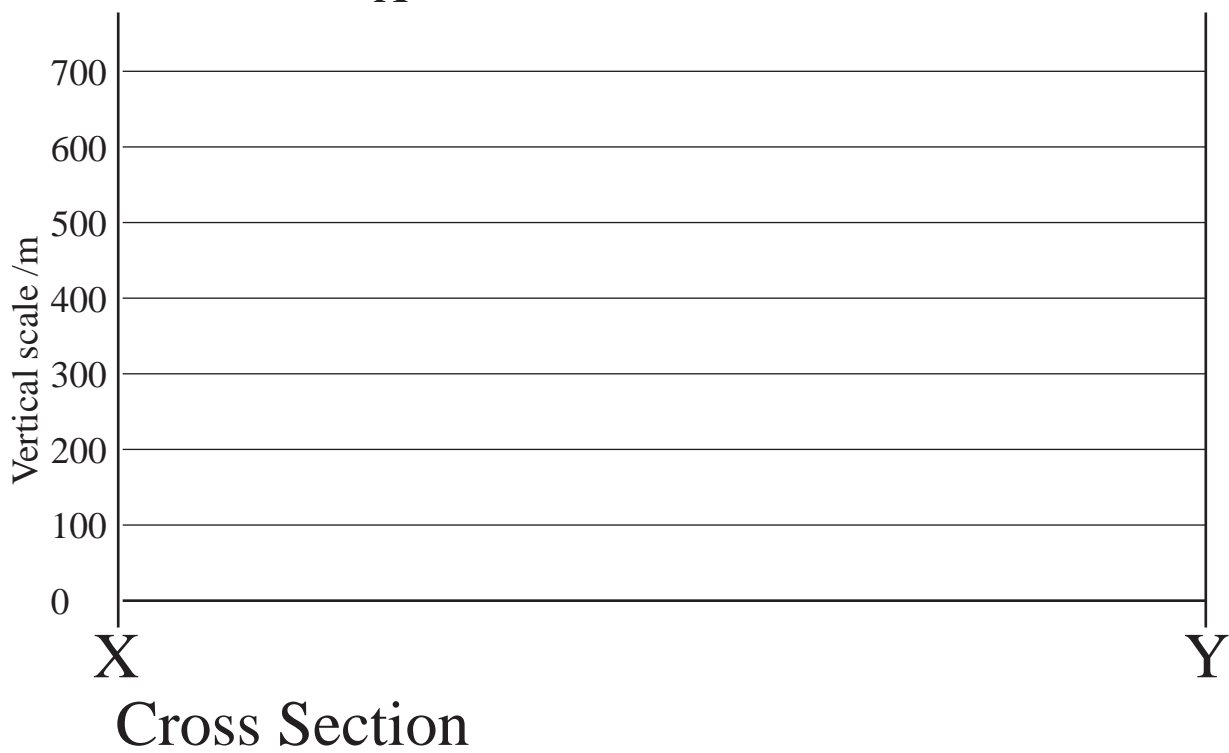
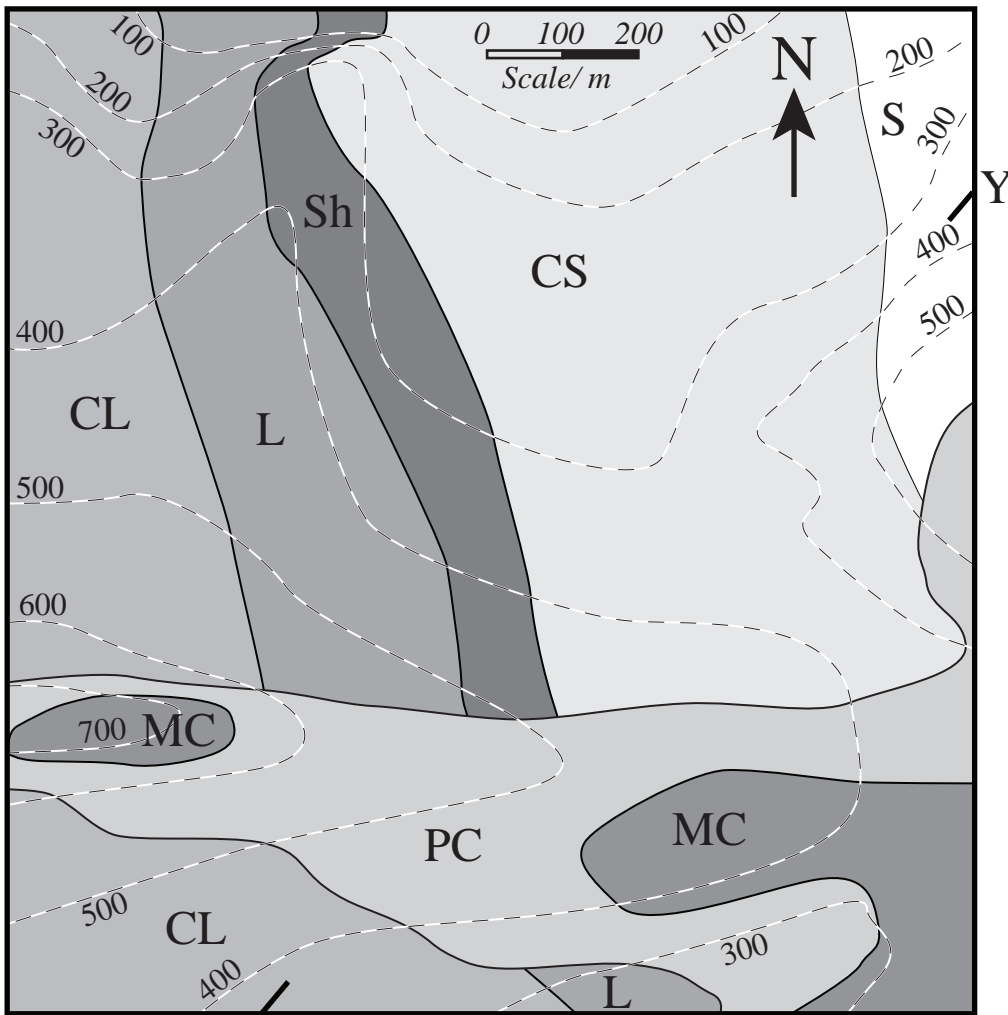
Column for
GVS



GEOL252 Map Exercise 5

Alternate Map for Practice

Column for
GVS



GEOL252 Map Exercise 6: Subcrop/ resource assessment

Materials you should have in addition to this sheet:

A practical sheet with a map

The aims of this practical are:

1. To show how to define “subcrop”- that is the intersection of a geological boundary with a buried surface.
2. To give students some very basic experience in resource evaluation as could be applied to water, mineral or hydrocarbon exploration or to environmental waste management.

You have been contracted as a consultant to assess the resource potential for a company interested in bidding for licences to extract high-grade anthracite coal from an area shown in the map (the location is top secret). Three licence areas (shown as A,B and C) are up for grabs. The licence requires that underground, rather than open pit mining is conducted and that the company remediates the area after coal extraction. The company has provided the geological map with the following explanatory notes:

- The target coal (marked on the map) is a high-grade anthracite (density 850 kg/m^3) valued at \$100 per tonne. The vertical thickness (rather than true thickness) measured at exposures of the coal is 3m.
- The coal is in a sequence of dipping sandstones and siltstones underlying an unconformity. Shallowly dipping basalt lavas overlie the unconformity.
- Mine infrastructure establishment costs for each individual licence area should be estimated at \$50 million dollars.
- Remediation costs for each individual licence area should be estimated at \$50 million dollars.
- Extraction costs should be estimated at \$40 per tonne for coal up to 500m below the surface and \$80 per tonne for coal between 500m and 1000m below the surface. Extraction at depths greater than 1000m costs more than the value of the coal.

You should provide advice how much money the company will offer for each licence area. The company has instructed that it is not interested in an area unless it can clear a profit of \$50 million. You are new in the job and a little unsure how to proceed so you have asked your boss for some help- he has provided the following advice.

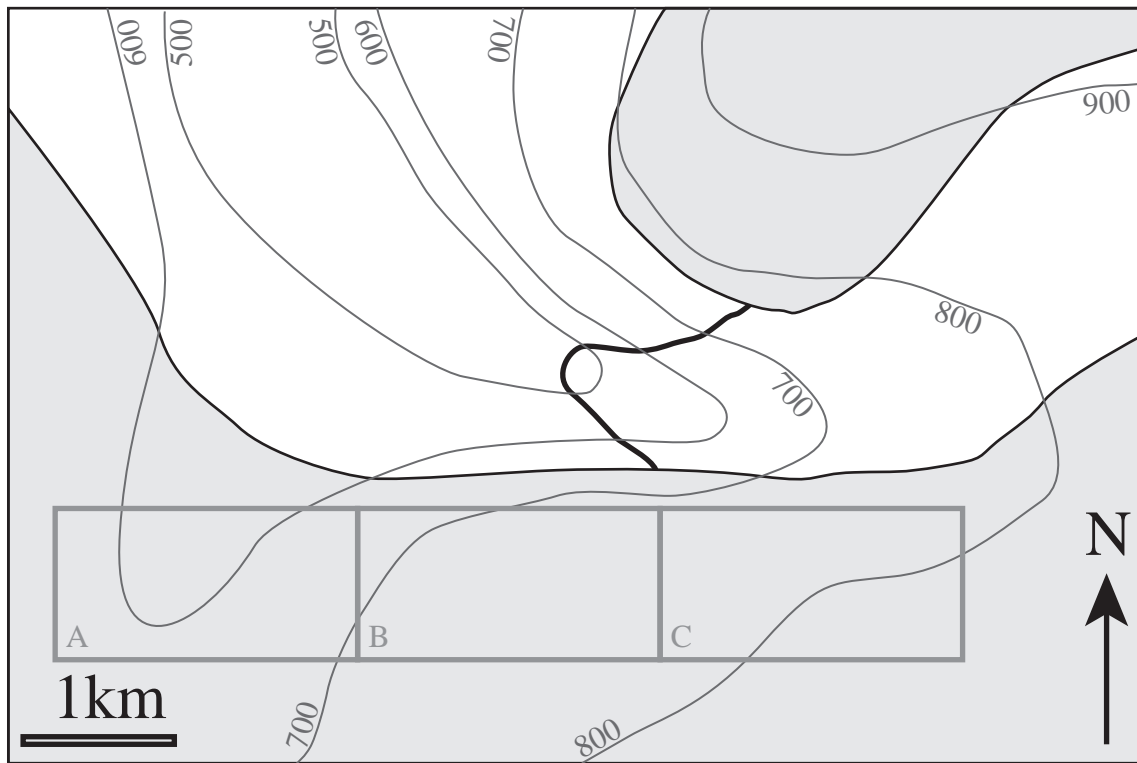
1. Draw structure contours for the coal.
2. Draw structure contours for the unconformity (base of the basalt)
3. Draw the “subcrop” of the coal on the unconformity. This is where the coal would be exposed if the basalt were all removed (ie where the coal intersects the unconformity). To do this find points where structure contours for the coal intersect structure contours of the same height for the unconformity (base of basalt).
4. Colour areas of the map where coal is underground (rather than eroded away).
5. Eliminate licence areas where there is no coal.
6. Calculate the volume and mass of coal under other licence areas.
7. Estimate the depths below surface of the coal in each licence area by comparing the heights of crossing topographic contours and coal structure contours.
8. Estimate the profit that can be made in each licence area and the maximum bid that will leave \$50 million profit.

You can do the subcrop analysis on exercise 5: go back and give it a go.

GEOL252 Map Exercise 6

Topographic
Contours

coal
basalt



GEOL252 Map Exercise 7: Getting to grips with non-planar surfaces

Materials you should have in addition to this sheet:

- A practical sheet with a map

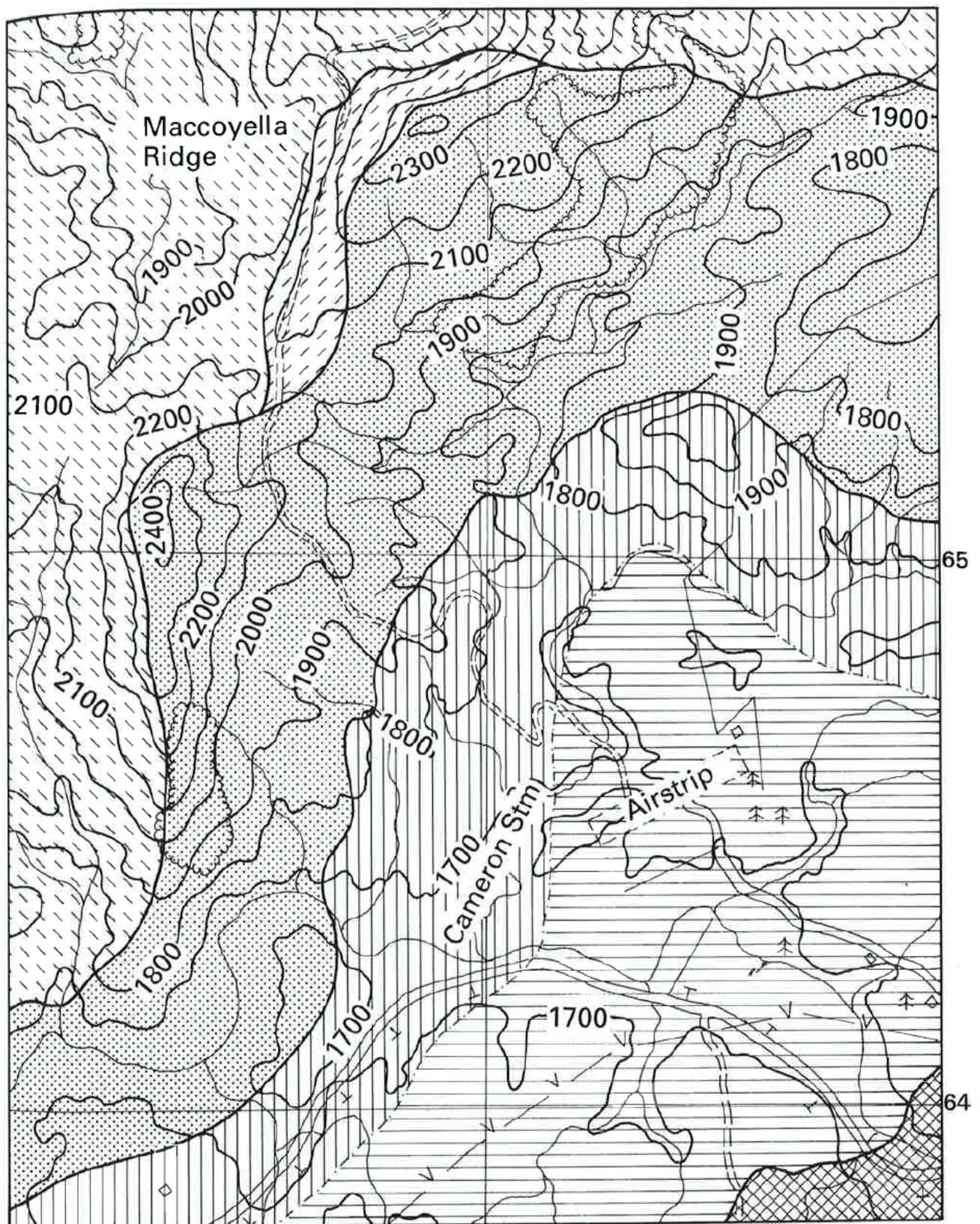
The aims of this practical are:

1. To provide some techniques for drawing structure contours for non planar surfaces

This practical is modified from Maltman, A. Geological Maps An introduction. Wiley 1998.

1. Identify the younging direction on the map.
2. Use the three point technique at five or six discrete locations along the outcrop of the base of the Tewere sandstone in order to calculate the strike and dip. Mark strike and dip symbols on the map.
3. Use the results of the three point problems, and any other data to construct a series of structure contours for the base of the Tewere sandstone. Draw structure contours between 1700m and 2400m (at least) with 100m intervals.
4. Describe the geometry of the base of the Teewere sandstone. What geological explanations might there be for this form.

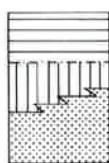
Remember that in nature, very few structure contours are straight because very few geological surfaces are perfectly planar.. We utilize straight structure contours in simple problem maps to aid understanding. Now we are back closer to reality. The three point technique is the key to real maps. With this you can assess whether surfaces may be planar or not and you can often analyse non planar surfaces.



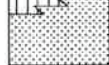
Key (youngest rocks at top)



Rakauro Formation



Kareware Siltstone
(contains *Aucelina cf gryphaeoides*)
(contains *Aucelina euglypha*)



Tewere Sandstone



Koranga Sandstone



Torlesse Supergroup

0

81

1

Scale/ km

GEOL 252

Map Exercise 7



GEOL252 Map Exercise 8: Greymouth Map

Materials you should have in addition to this sheet:

- A copy of the Greymouth Geological Map (Sheet S44. 1:63,360). **Please do not mark the maps.**
- Tracing paper
- Graph Paper

The aims of this practical are:

1. To introduce students to rapid map assessment.
 2. To give practice in drawing a cross section from a geological map with complex structure.
 3. To understand complex map geometries.
-
1. In 5 minutes try and draw a sketch map to show the main geological elements of the map. Successful sketch maps do not break down the map to more than a few (≤ 5) geological elements.
 2. Draw one cross section (with no vertical exaggeration) from Greymouth (720 870) to south of Kokiri (900 820). The topography should be included on the cross section and ultimately the inferred geology above and below topography should be shown. Initially just include the units that appear on the section line. You may simplify things by grouping all the members of the Paparoa Coal Measures into a single unit.
 3. Draw a second cross section from (800 830) to (880 000)
 4. Use the second section and the published sections on the map to help fill out the geology above and below topography on your first section.
 5. In Groups of 3 or 4, draw or build a simplified 3D model of the area covered by your sections. Prize for the best one.

GEOL252 Map Exercise 9: Faults

Materials you should have in addition to this sheet:

- “Characterising a Fault”: an explanation sheet containing a geological map and some analysis on copies of the map.
- A practical sheet with a map

The aims of this practical are:

1. To give students a better appreciation that the map patterns of faults, particularly map separations, can be misleading.
2. To ensure students understand the differences between fault:
 - a. separations (map strike, dip, vertical and stratigraphic)
 - b. throw and heave
 - c. displacement
3. To give students practice in defining the strike and dip of a fault and defining the hangingwall and footwall.
4. To give students some practice in calculating strike and dip separations for an offset planar feature.
5. To give students practice in calculating fault displacement when a fault offsets two non-parallel planar features.

Using the explanation sheet “Characterising a Fault”:

Look at the geological map (a). A fault cuts two different planar features (a coal layer and a basalt sheet). One description of the fault is to measure the “map separation”: this is the distance between the intersection of a layer on one side of the fault and the intersection of the fault with the same layer on the other side of the fault. The map separation of the basalt sheet is the distance between the centre of the two small circles (400m) shown in the repeat of a small part of the map in (b). The map separation for the coal is more complex- there are two answers (!)- neither of which is the same as the 400m map separation for the basalt.

- Why are the map separation values different for differently oriented layers (the basalt and coal)?

More useful measures of the “offset” of a planar layer on a fault are:

- **strike separation:** this is the horizontal movement, parallel to the strike of the fault, that would move the hangingwall from a restored position (pre-fault: so that the layer in the hangingwall is in the same plane as that in the footwall) to its current position. In order to find this for the coal, I have drawn up (in c) structure contours for the fault and structure contours for the coal on either side of the fault. These enable me to draw up the traces (“subcrop”) of the footwall (fw) and hangingwall (hw) coal on the fault (trace = line where structure contours of the fault intersect structure contours of coal at the same height: some of these are shown as circles for the hangingwall coal and triangles for the footwall coal in c.). I can then measure the movement parallel to the fault structure contours that would lay the hangingwall trace on the footwall trace (1740m). The movement needed in the hangingwall, to move the coal from a position lined up with the footwall coal to its current position is dextral. So the strike separation is 1740m dextral. The strike separation for the basalt sheet is calculated in the same way in d.
- **dip separation:** this is the movement parallel to the dip of the fault that that would move the hangingwall from a restored position to its current position. I use the same construction I used to calculate strike separation but I add my usual construction to find the dip of the fault (on the right hand end of the fault structure contours in c. The line that connects the intersections of hangingwall and footwall traces with a line drawn an angle equal to the dip (35° in this case) away from the normal to the structure contours, gives the dip separation (420m in this case). The movement needed in the hangingwall, to move the coal from a position lined up with the footwall coal to its current position is normal. So the dip separation is 420m normal. The dip separation for the basalt sheet is calculated in the same way in d.

- **throw** and **heave** are old miners terms that refer to the vertical and horizontal offset of the hangingwall trace on the fault relative to the footwall trace on the fault. These are the vertical and horizontal vector components of the dip separation and are calculated, for the coal, on the right hand side of c. by using a vector triangle.
- **vertical separation** is the vertical movement needed to restore a layer on one side of the fault to be lined up with its equivalent on the other side of the fault. The easiest way to calculate it is to look at the height difference of the structure contours for footwall and hangingwall. In this case the 600m coal structure contour in the footwall (600Cfw) lines up approximately with a 365m contour in the hangingwall giving a vertical separation of 240m normal.
- **stratigraphic separation** is the same as the vertical separation but measured perpendicular to the strike and dip of the unit. It will be a trigonometrical function of the vertical separation and the dip and can be calculated graphically or trigonometrically.

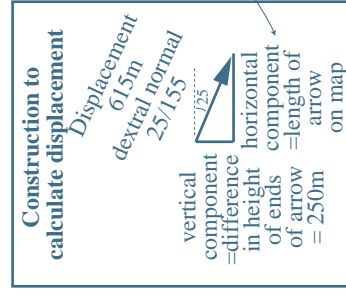
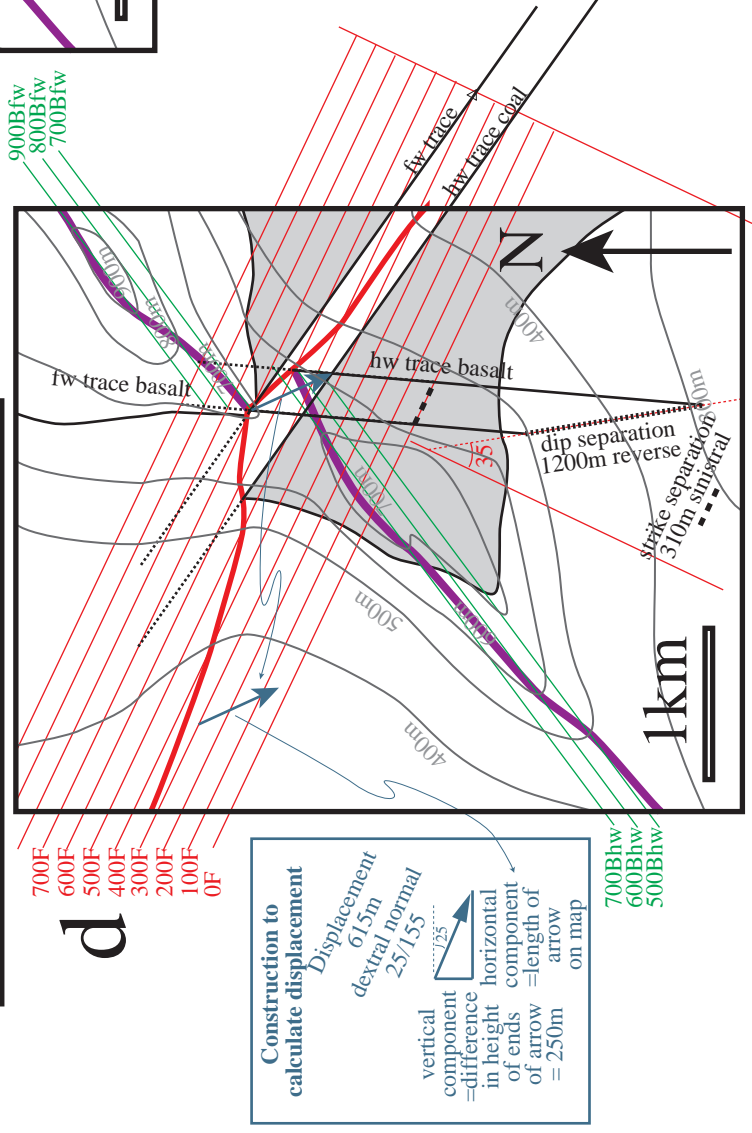
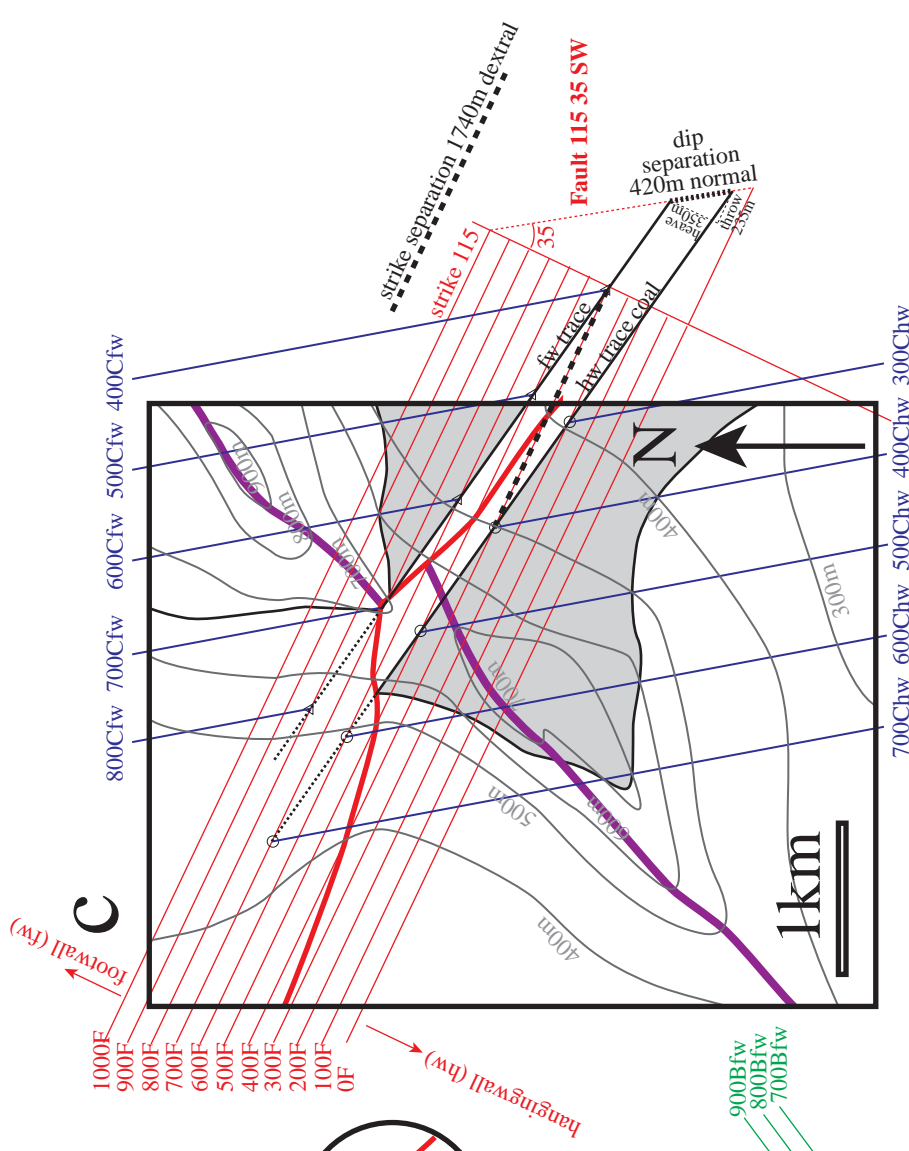
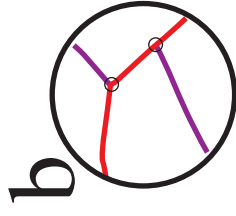
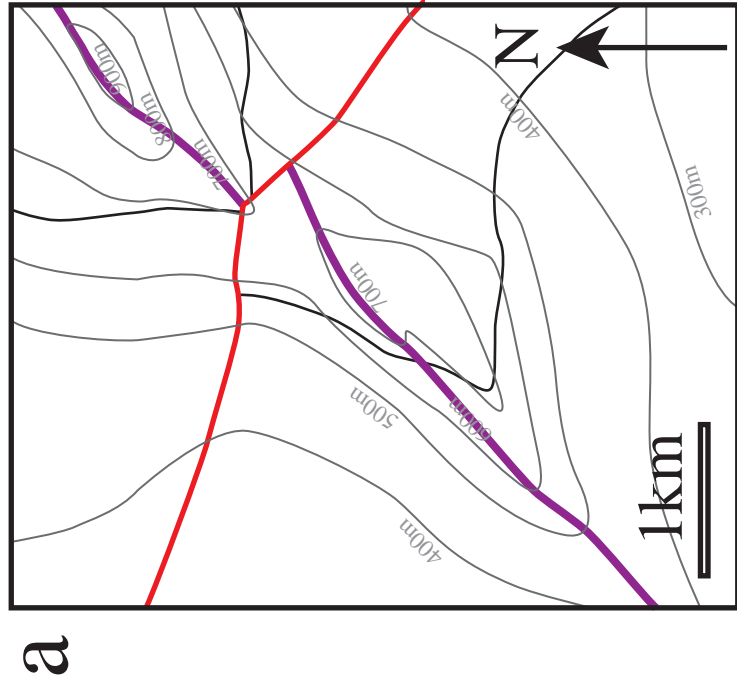
Separations are not necessarily the same as displacement. A strike-slip movement, a dip-slip movement or an infinite number of different oblique slip movements could give the observed separations of the coal. More information is needed to calculate displacement. This information could be a measurement of the fault slip vector (a field measurement of slickenlines on the fault surface for example). If two non-parallel planes are both cut by the fault then the full displacement can be calculated.

- **Displacement** is the vector that fully describes the final position of the hangingwall relative to the footwall. It might represent the movement vector (integrated across geological time rather than in a single earthquake event) –assuming it always moved (in each earthquake) along the same vector. In the example a coal and a basalt sheet are both cut by the fault. In d. I have drawn up traces of both the coal and the basalt sheet on the fault surface. The fault displacement can be drawn as the line that goes from the intersection of the footwall traces of the two planes (coal and basalt sheet) to the intersection of the hangingwall traces of the two planes. This arrow is a bit hard to see in d. so I have pulled it out and re-plotted it on the left hand side of d. The length of the arrow gives the component of displacement in the horizontal (585m) and gives directly the azimuth of the displacement vector (direction of fault motion in horizontal): to get this just measure the bearing- the angle around from North- 155 in this case. Calculating the displacement in the fault plane requires drawing a triangle showing the horizontal and vertical components of the displacement vector. This is done in the box to the left of d. The horizontal component is measured directly from the arrow on the map- 585m in this case. The vertical component comes from the height difference (using the fault structure contours) of one end and the other- 250m in this case. This gives a displacement of 615m. The displacement vector has a plunge of 25/155 (25 measured from the triangle in the box left of d). The motion is oblique with dextral and normal components.

Problem Map

Use the problem map to practice some of the analyses outlined above. In your own time you can go further and do a full analysis.

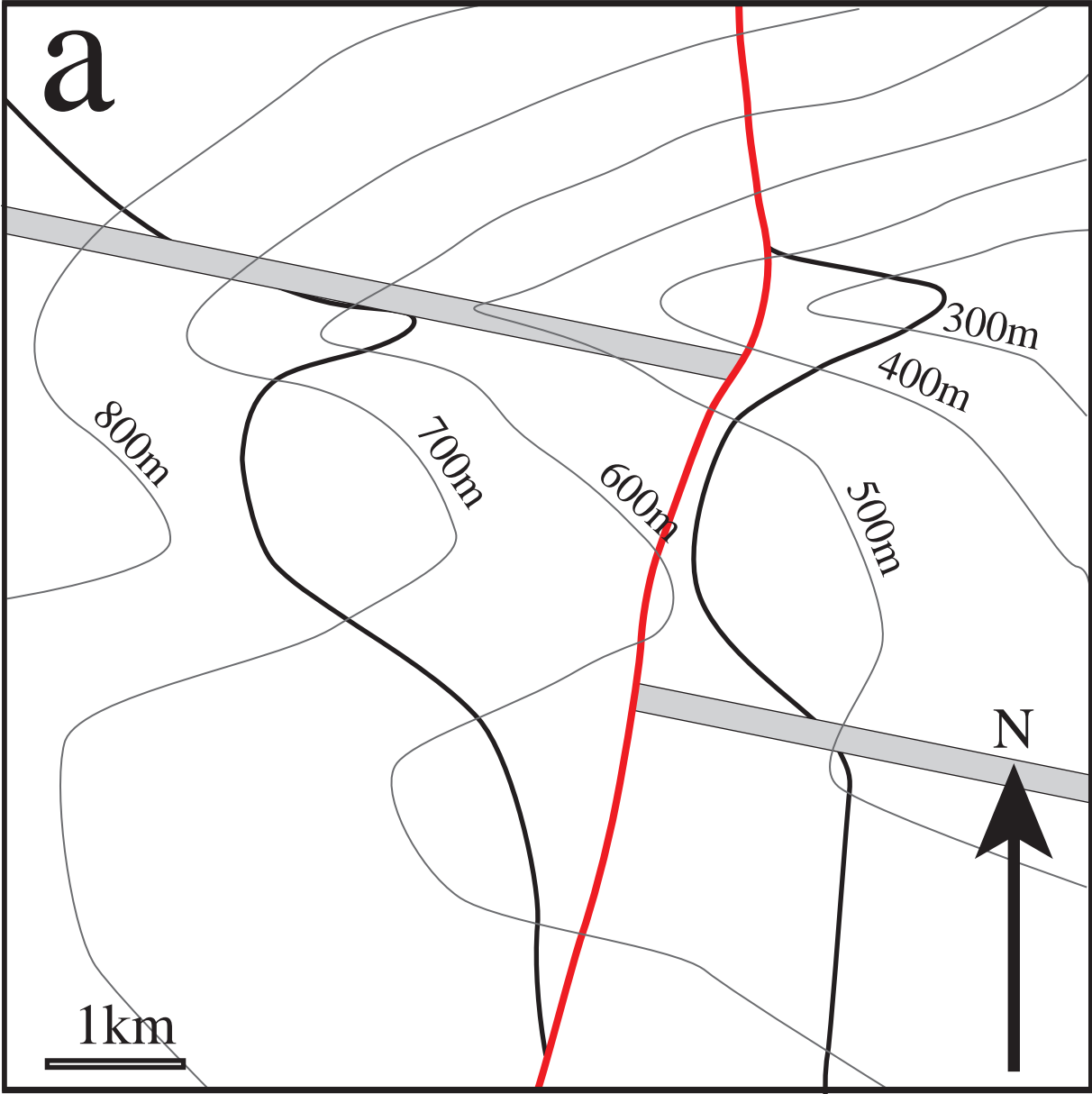
1. Draw structure contours for the fault
2. Calculate the strike and dip of the fault.
3. Work out which side of fault is hangingwall (hw) and which footwall (fw) and label these.
4. Draw structure contours for the coal in the hangingwall and coal in the footwall
5. Mark traces of hangingwall and footwall coal on fault
6. Calculate the strike and dip separations of the coal on the fault. Give both the magnitude and the sense (dextral vs sinistral and normal vs reverse) of the separations
7. Draw traces of the basalt on fault. This has been made easy in this case. Don't try and draw basalt structure contours, just think about the strike and dip of the basalt and how it will project onto the fault. .
8. Draw an arrow to show horizontal component of fault displacement and measure its magnitude.
9. Calculate the displacement in plane of fault. Calculate the plunge and azimuth of displacement vector and give both the magnitude and the sense (dextral vs sinistral and normal vs reverse) of the displacement.



GEOL252 Characterising a Fault explanation for exercise 9

- Topographic Contours
- Fault
- Coal Seam
- Basalt sheet

GEOL252 Map Exercise 9



GEOL252 Map Exercise 10: Cobb Map

Materials you should have in addition to this sheet:

- A copy of the Cobb Geological Map (Sheet S13. 1:63,360). **Please do not mark the maps.**
- Tracing paper
- Graph Paper

The aims of this practical are:

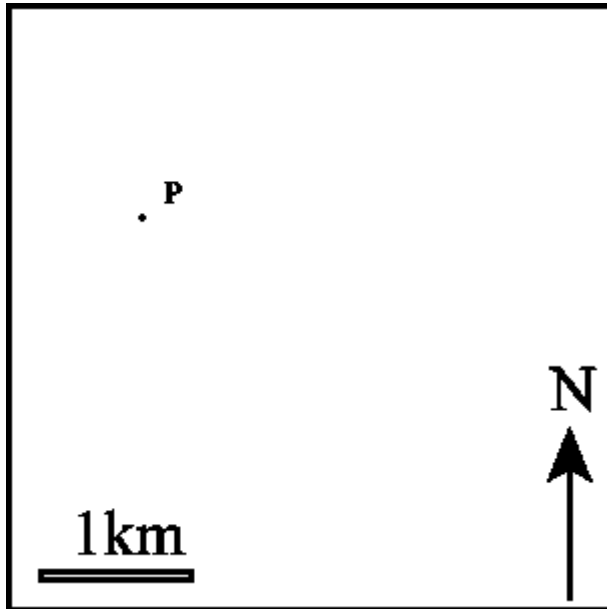
1. To introduce students to rapid map assessment.
 2. To give some experience of dealing with faults on maps.
-
1. In 5 minutes try and draw a sketch map to show the main geological elements of the map. Successful sketch maps do not break down the map to more than a few (≤ 5) geological elements.
 2. Take a look at the unnamed fault at (95 40).
 - a) What is the strike and dip of the fault.
 - b) What are the constraints on the age of this fault?
 - c) What constraints do you have on the fault displacement? You will need to draw a picture of how the boundaries between the Roaring Lion Formation (ar) and the Douglas Formation (gd) project onto the fault plane. That is draw a cross section along the fault trace. Check your answers before proceeding.
 3. Take a look at the diamond fault and answer questions a to c for that. Look closely at the area between (95 48) and (99 50)- you should have a fault parallel section for this part at least. Do not proceed until you have checked your answers.
 4. Work out the age relationships (relative to each other and to geological units) and the kinematics (the constrained senses of movement) of the following Faults: Diamond Fault, Devil River Thrust, Karamea Fault, Anatoki Thrust, Pikikiruna Fault.
 5. Do any of these faults have the potential to be active? What movement senses would you expect?

Name _____

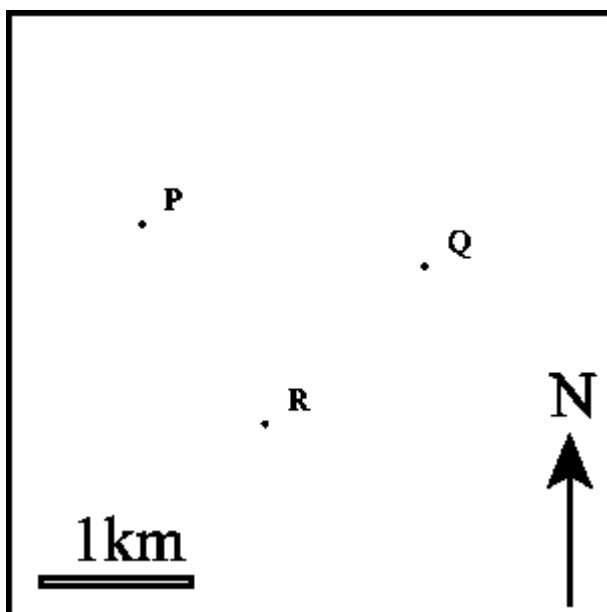
GEOL 252 Map Exam 2013

You have 120 minutes to complete this exam. Show any workings. Put your name on each page. If you use extra sheets of paper put your name on these.

1. (4 MINUTES) In the box below, draw structure contours (draw at least 2) to show the geometry of a planar geological surface with an orientation of 125° 20'SW and an altitude of 600m at point P. Make sure that the structure contours are labelled.

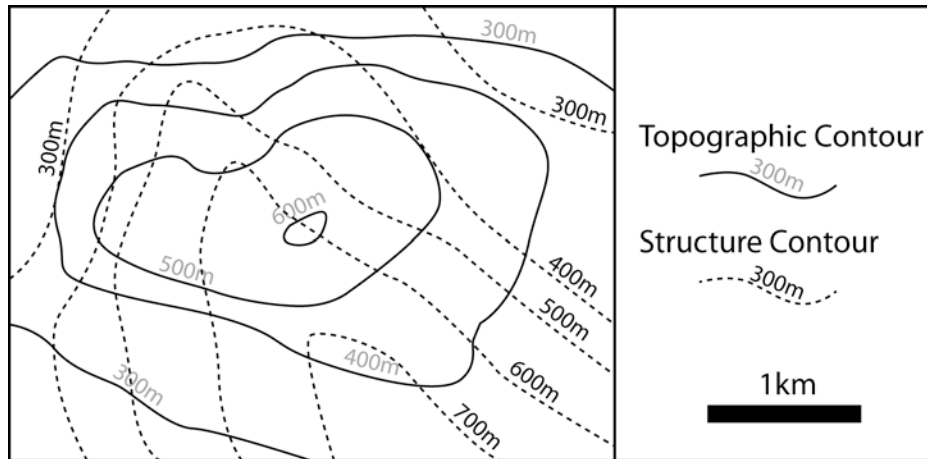


2. (6 MINUTES) In the box below:
- Draw structure contours (draw at least 2) to show the geometry of a planar surface with an altitude of 1000m at point P, 600m at point Q and 500m at point R. Make sure that the structure contours are labelled.
 - Calculate the strike and dip of the surface. Write this out using the convention you have been taught for strike and dip.

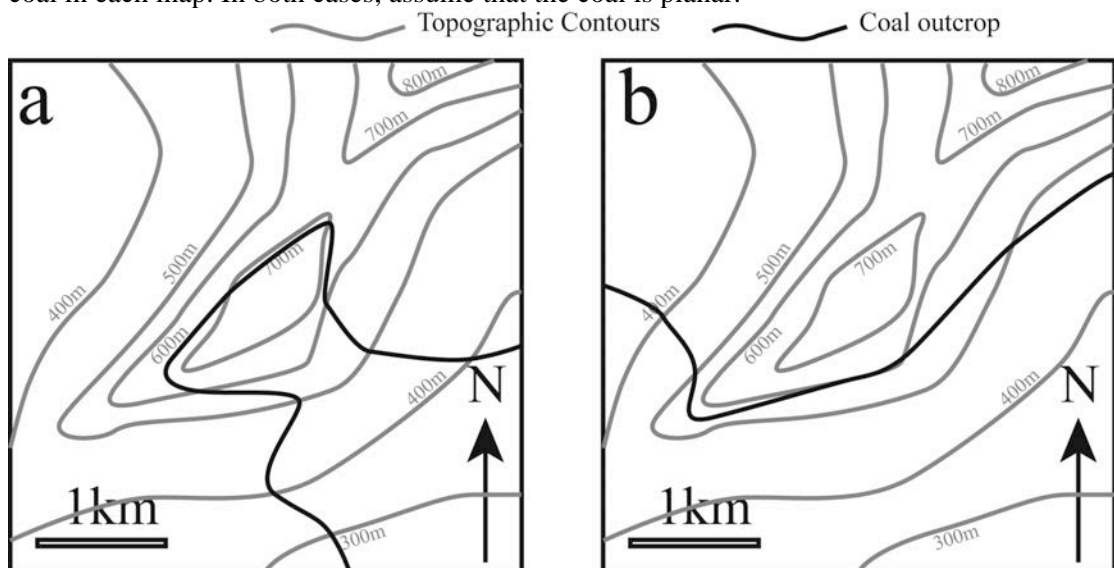


Name _____

3. (10 MINUTES) The map below shows the structure contours of a coal superposed on topographic contours.
- Use the structure contours, together with the topographic contours to draw on the outcrop of the coal.
 - Colour the area of the map where the coal is below the topographic surface.



4. (10 MINUTES) The maps below (a and b) shows the outcrop of a coal superposed on topographic contours. Construct structure contours and calculate the strike and dip of the coal in each map. In both cases, assume that the coal is planar.



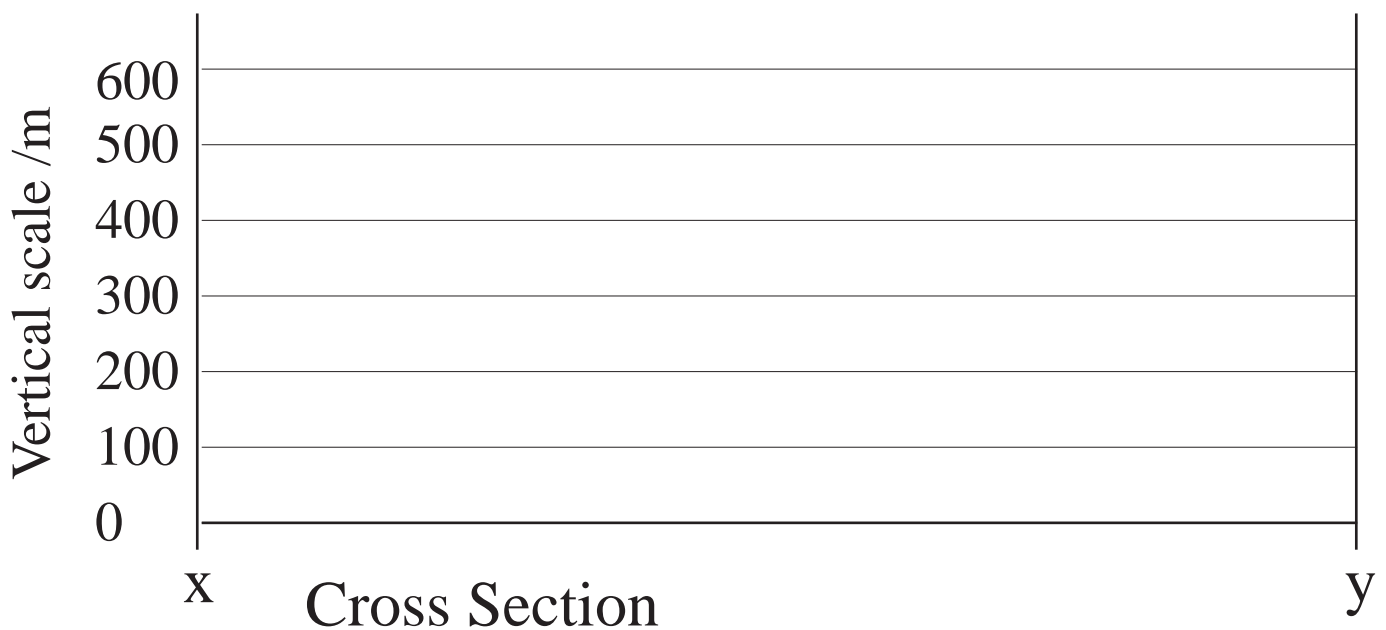
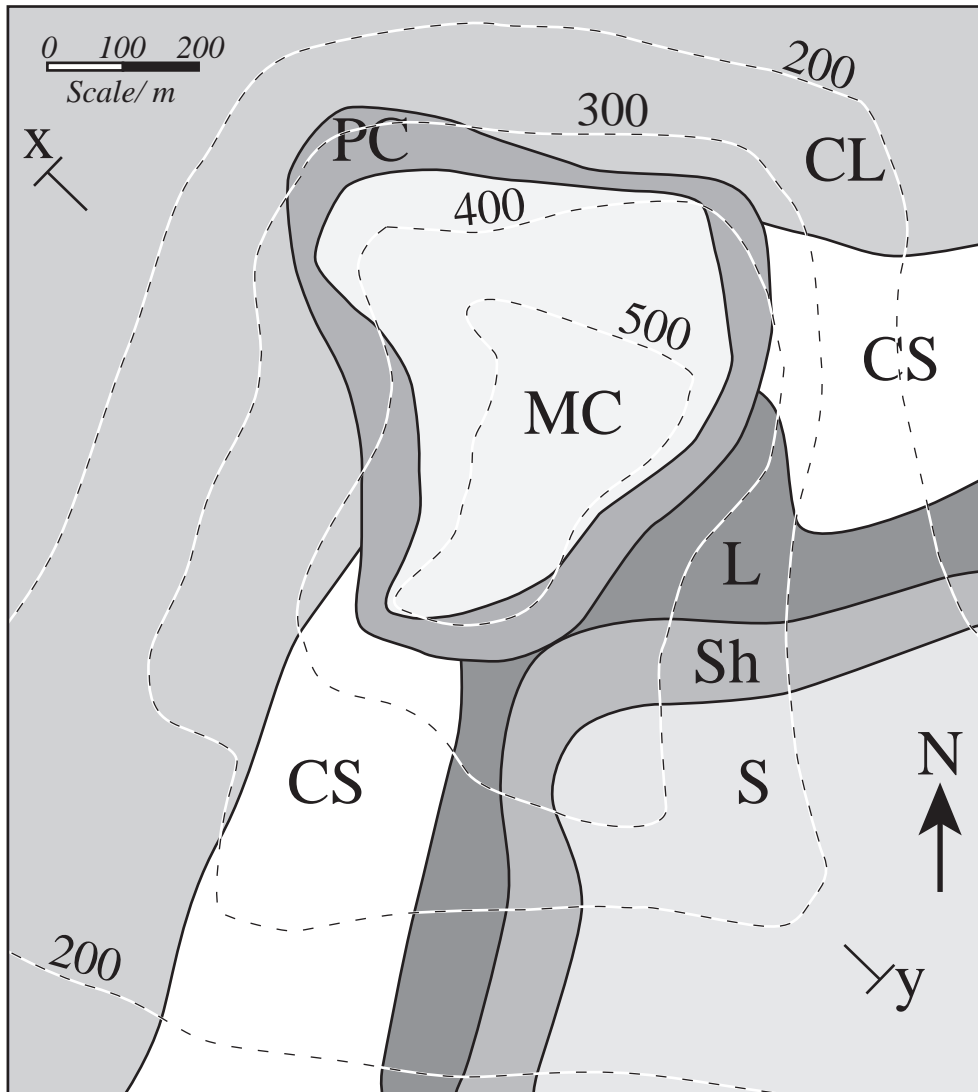
5. (60 MINUTES) The map on the next page shows a simplified geological map with topographic contours (dashed) in metres. S = sandstone, Sh = shale, L = limestone, CS = carbonate sandstone, CL = coral rich limestone, PC = polymict conglomerate, MC = monomict conglomerate. Use structure contours to help you:
- Draw an accurate cross section along line X-Y. Ensure that the cross section shows the topographic profile, the subsurface geology and the eroded geology (above the topographic profile). Draw the cross section on the template prepared at the bottom of the page (or on graph paper if you prefer).
 - Construct a GVS on the panel to the right of the map.

Ensure that structure contours that you mark on the map are neat and are clearly labelled.

Name _____

GEOL252 Map for Question 5 of Exam.

Column for
GVS

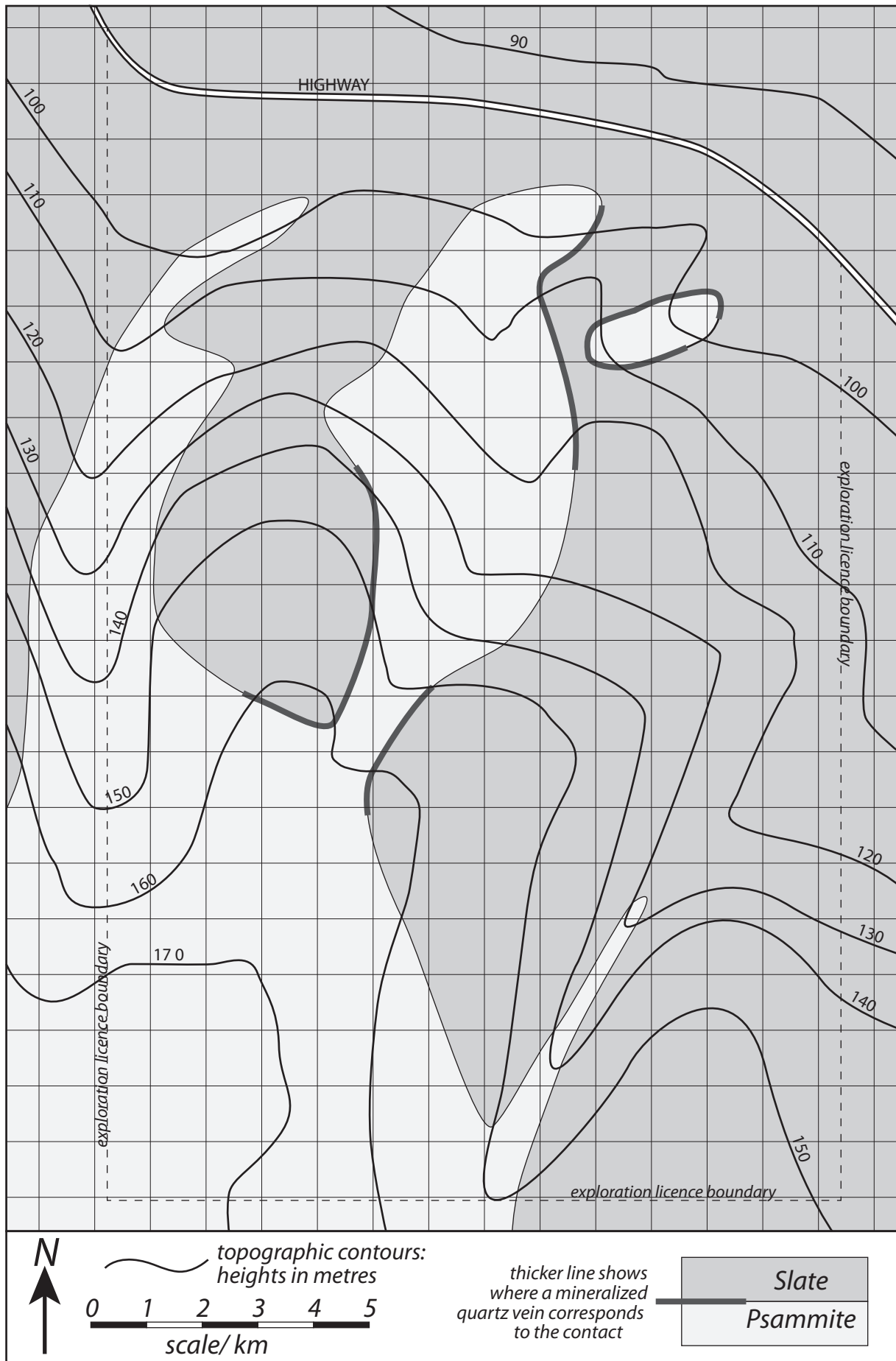


Name _____

6. (30 MINUTES). You have been contracted by a company to assess the gold mineralization in an area they have under licence for exploration. The map on the following page shows the licence area south of the highway. Gold occurs together with sulphides in quartz vein material on the slate-psammite boundary. The map shows the outcrop pattern of the boundary and the places where the boundary is marked by mineralized quartz vein.
- a) Construct structure contours for the slate-psammite boundary. Draw the structure contours in pencil first then use colour/ pen once you have them right. Make sure the structure contours are clearly labelled.
 - b) Describe the geometry of the slate-psammite boundary in the space below.
 - c) Is there a structural control on the mineralization? If so describe the nature of this control.
 - d) Colour the areas on the map under which the mineralized quartz lies (ie all areas where a vertical borehole would intersect the quartz vein).
 - e) The vein generally has a vertical thickness of 1m and assays suggest the mean gold concentration is 20g per tonne (1 tonne= 1000kg). The vein material has a density of 3000kg/m^3 . Calculate the gold reserve (an estimate of the tonnage of gold) in the licence area. Show your workings below- refer to measurements from the map when you use these.
 - f) Gold currently has a value of \$50 per gramme. Calculate the value of the reserve. Show your workings below.
 - g) The company advises you that open surface strip mining (as opposed to underground mining) is economic if less than 10m of overburden needs to be removed. Outline below your advice to the company re mining methods.

Name _____

Map for Question 6 of Geol252 Exam



This is the **Hard** question from the 2014 exam

6. (30 MINUTES). You have been contracted by a company to assess the gold resource in an area they have under licence for exploration. The map on the following page shows the mapped geology, some extra information from historical diggings and the licence area.

Gold occurs in three distinct zones.

- i. As finely disseminated gold together with sulphides in a large planar quartz vein within basement schist
 - ii. as larger gold grains in a zone of supergene enrichment where the quartz vein is close to the unconformity (within 10m of the unconformity).
 - iii. As alluvial gold grains in the conglomerates immediately above the unconformity.
- a) Construct structure contours for the both the vein and the unconformity south of the fault .
 - b) Use the structure contours to show the area(s) within the license area under which the mineralized quartz vein lies (ie all areas where a vertical borehole would intersect the quartz vein).
 - c) The vein generally has a vertical thickness of 1m. The vein material has a density of 3000kg/m^3 . Calculate the tonnage of ore (quartz plus sulphides plus gold) in the licence area related to the vein (ignoring the supergene enrichment). Show your workings below- refer to measurements from the map when you use these.
- d) Assays suggest the mean gold concentration is 10g per tonne (1 tonne= 1000kg) in the vein. Gold currently has a value of \$50 per gramme. Calculate the value of the reserve. Show your workings below.
- e) The company is particularly interested in the area of supergene enrichment. Mark a line on the map to show the location of an open cast channel (ditch) that could be dug to intersect the top of the supergene enrichment zone (where the vein intersects the unconformity) at depths of 20m or less from the surface
- f) The grade of the alluvial gold is poor and the company has little interest in this. However you are intrigued by an area of historical diggings, north of the fault, that follow an extremely gold-rich linear channel on the unconformity surface. You realise that if you calculate the displacement of the fault you could predict where this channel should be on the south side of the fault. Use structure contours for the fault, the unconformity north and south of the fault and the vein north and south of the fault to calculate the displacement (show all your construction on the map: ***make sure it is legible***). Mark where you predict the channel to be (assume it has the same trend as north of the fault). You'll get a huge bonus if you get this right.

Name _____

Map for Question 6 of Geol252 Exam

