

## UNCONFORMITIES, CROSS SECTIONS AND GEOLOGICAL MAP DESCRIPTIONS

### Topography and geology

Read Chapter 2, pages 11-13, of the text by Rowland et al (2007) if you have not already done so. In this week's lab we will use the relationships explained in this section to make inferences about the geology of the Grand Canyon area.

Sometimes the combination of topography and geology can produce map patterns that are quite complicated, with patches of one unit surrounded by others. An **inlier** is an exposure of older strata surrounded by younger, whereas an **outlier** is an exposure or erosional remnant of younger strata that are completely surrounded by older. The relationship is indicated in Figure 1, wherein (a) represents a cross-section through an eroded succession of strata, units 1 to 3 being oldest to youngest, and (b) shows the corresponding map. On Map 1, an inlier of shale occurs at X and an outlier of limestone at Y.

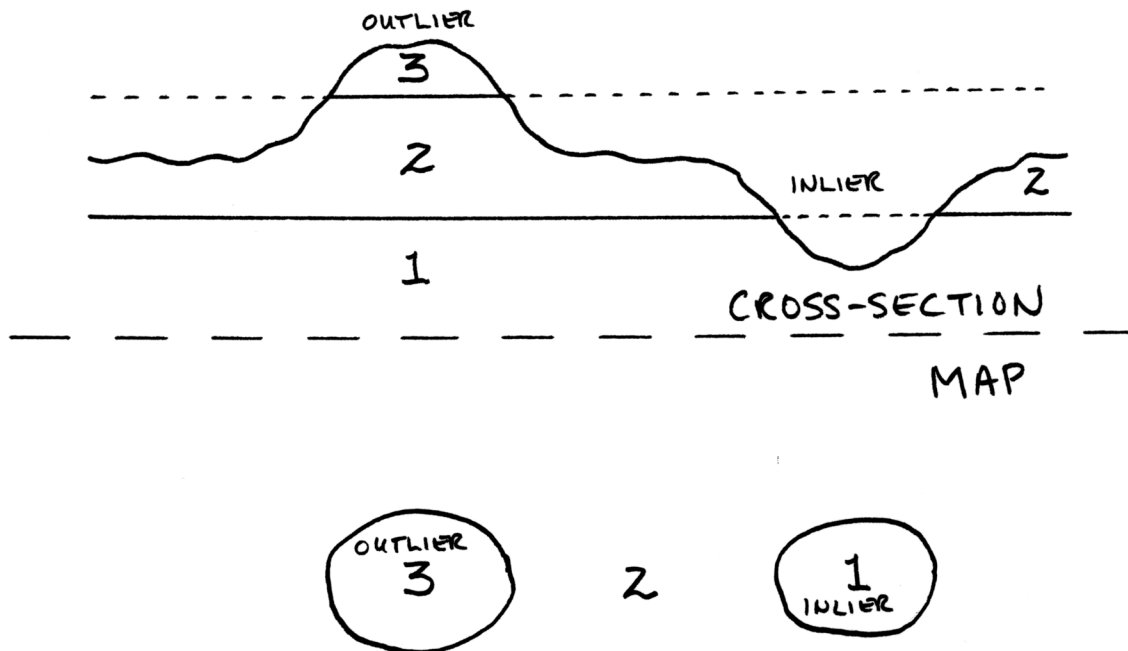


Fig. 1. Cross-section (a) and map view (b) showing how the relationship between older and younger units develops for inliers and outliers; oldest unit is 1, youngest is 3. Inlier of 1 is exposed through overlying unit 2 by erosion, which surrounds it in map view; similarly outlier of unit 3 is an erosional remnant, underlain by unit 2 and thus surrounded by it in map view.

### Unconformities

In order to understand an area like the Grand Canyon, we need to understand its history. Despite the exceptional record preserved in the canyon area, there are still major gaps in its geologic history. **Unconformities** are ancient surfaces of erosion and/or non-deposition that indicate a **gap or hiatus** in the stratigraphic record.

An unconformity may be represented on a map by different type of line than that used for other contacts, and in cross-section is shown by a wavy or crenulated line.

Subtle unconformities are very important in the analysis of sedimentary successions. A **sequence** is a package of strata bounded both above and below by unconformities. It may be that an unconformity is a sequence boundary, but that determination depends on finding another unconformity in the succession, either higher up or lower down stratigraphically.

## Angular unconformities

An **angular unconformity** is seen in the angular **discordance** between older, generally tilted or more strongly deformed strata below, and younger, horizontal or less strongly deformed strata above (Fig. 2). Of course, subsequent tilting of the entire succession could alter the orientations, but there will still be a discordance between strata above and below the unconformity. Bedding in the younger sequence tends to be parallel to the plane of unconformity, or more nearly so.

Structure contours on the younger strata above the unconformity by definition will not coincide with those on the older strata below; either the strike or the dip, or both, will differ.

## Disconformities

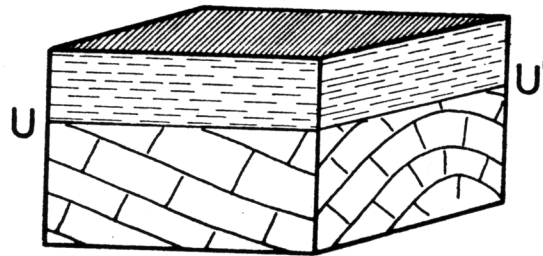


Fig. 2. Block diagram of an angular unconformity UU'.

A **disconformity** is a contact between parallel strata whose ages are significantly separated (Fig. 3b). How can it be recognized? One may discern the erosion surface by observations of such features as stream channels, buried soil profiles, and pebbles/conglomerates. If the only evidence for a gap is from detailed paleontological investigation, the surface is a **paraconformity**. In either case, structure contours for strata both above and below the unconformity will be parallel and will have the same spacing.

## Nonconformities

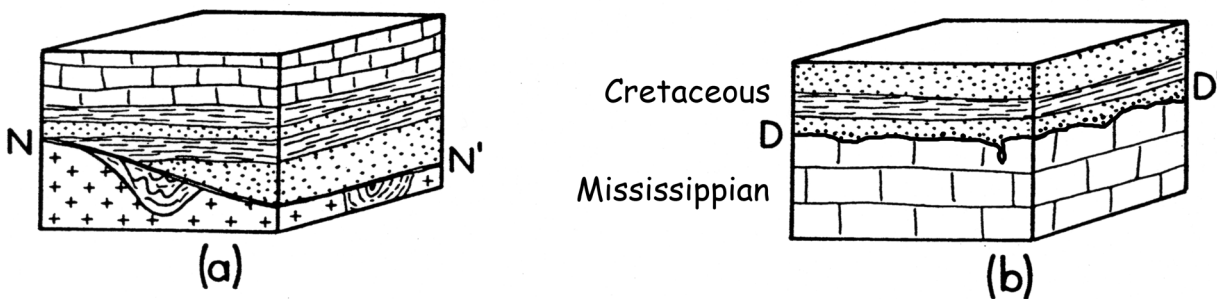


Fig. 3. (a) Block diagram of a nonconformity NN'. (b) Block diagram of a disconformity DD'.

The term **nonconformity** is used to describe the contact between **younger** sedimentary strata deposited upon an eroded surface of **older** crystalline (igneous or metamorphic) rocks (Fig. 3a) in which distinct layers cannot easily be recognized. (In other words it is impossible to say whether the unconformity is angular or not.) Be careful to distinguish a nonconformity from an **intrusive contact**. At a **nonconformity**, *younger sedimentary rocks* were deposited on an *older intrusion*. Typically there may be pebbles of weathered intrusive rock in the sedimentary rocks. At an **intrusive contact**, it is the intrusion which is younger. Surrounding *older sedimentary rocks* may show baking (thermal metamorphism), and the *younger intrusion* may contain pieces (xenoliths) of the older sedimentary rocks. Although an intrusive contact may be strongly discordant, it is not any kind of unconformity.

## Onlap and overstep

In a sedimentary succession containing an unconformity, the beds may show either onlap or overstep or both (Figure 4). In that part of the succession **above** an unconformity, younger beds **onlap** older beds if they extend beyond them geographically. The onlap relationship is generally produced by progressive burial of an unconformity by a process called transgression (defined as landward movement of the shoreline), and is confined to those strata above the unconformity. The **overstep** relationship exists **across** the unconformity, and is seen where younger beds above an unconformity truncate or directly overlie strata (in whole or in part) of that part of the succession below the unconformity. In Figure 4, Y onlaps X, for example, and Y oversteps R onto S (in two places, due to folding of S) and T.

## Paleogeologic Maps and Subcrops

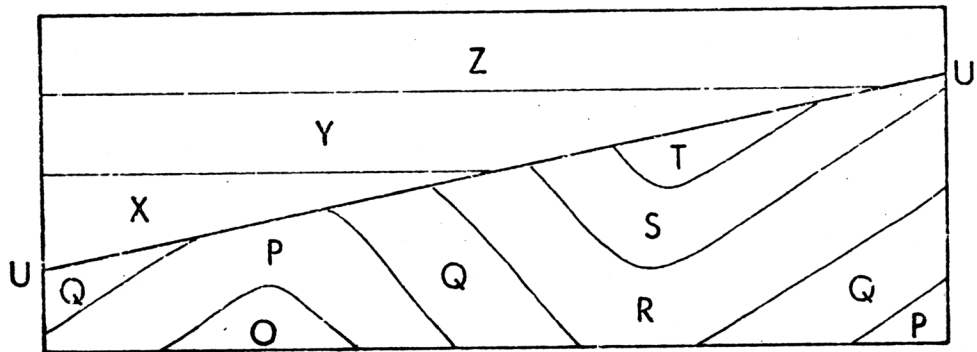


Fig.4. Cross-section of an angular unconformity  $UU'$ , showing onlap and overstep.

If exposures of rock at the present-day erosion surface are referred to as outcrops, then rocks that were exposed at ancient erosion surfaces that are now buried are referred to as **subcrops**. Given that buried surfaces of erosion are unconformities, it follows that subcrops represent those rocks directly below an unconformity. If we strip away all the rocks above an unconformity, we can produce a map of the subcropping units, and this would constitute a **paleogeologic map**. In effect, it is a map of the geology as a prehistoric geologist would have recorded it just before renewed deposition began to bury the ancient erosion surface. If we consider the cross-section of Figure 4, a paleogeologic map showing the distribution of rocks prior to deposition of units X-Z would show the eroded exposure of the folded succession O-T.

The intersection of a plane representing the erosion surface and a geological surface below the unconformity is the **subcrop limit** of that older surface. It can easily be determined by finding the intersections between corresponding structure contour on the unconformity and the older surface. The subcrop limit is the boundary between a region where the older surface is preserved below the unconformity, and a region where it was eroded. In the first region, the unconformity structure contours are higher than the older surface; in the second, the structure contours on the unconformity show it is lower.

In practical terms, there are many hydrocarbon traps at subcrop limits of reservoir rocks below angular unconformities in the Western Canada Sedimentary Basin. Lighter oil and gas migrate in the up-dip direction through buried reservoirs, until they encounter impermeable younger rocks above an unconformity. The search for such an occurrence is called a **subcrop play** in the petroleum industry.

## Topographic profiles and cross-sections

Topographic profiles show the shape of the Earth's surface in a view that simulates a vertical slice through the landscape. Topographic profiles may be constructed by noting where topographic contours cross the line of the

profile. You may remember the technique for drawing a topographic profile from EAS 100, but in case you need a reminder, the steps are described in pages 34 - 36 of the text by Rowland et al. (2007). On a cross-section, the ratio of the vertical scale to the horizontal scale, expressed as a fraction, is the **vertical exaggeration**. If the vertical and horizontal scales are equal the section is said to have a **natural scale**.

A vertical **cross-section** showing the trace of a geologic surface may be constructed in exactly the same way by noting where structure contours cross the line of section. Where a natural scale has been used and the line of section is perpendicular to the strike of a geologic surface, the plunge of its trace on the cross-section equals its true dip. On natural-scale vertical sections oblique to strike, the plunge of this trace is called the **apparent dip** (Figure 5). It is possible to demonstrate that true dip is **always** greater than apparent dip

In a cross-section through a succession containing an angular unconformity, there is no possible orientation of the cross-section that will show true dip for both the underlying and overlying parts of the succession, unless they both have the same strike. Cross-sections with vertical exaggeration show neither true nor apparent dip, although these can be calculated using trigonometry.

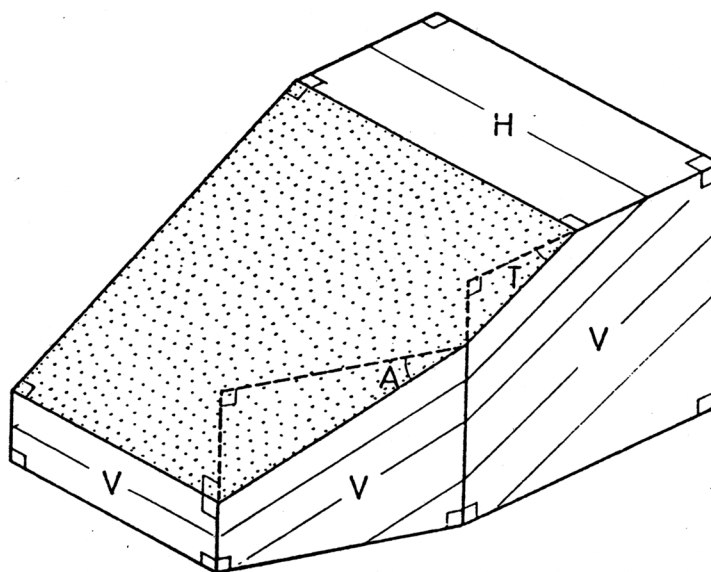


Fig. 5. Block diagram illustrating the difference between the true (T) and apparent (A) dip of the stippled plane. Planes labelled H and V are horizontal and vertical, respectively, and right angles are labelled in the usual way.

### Three point problems

Structure contours may be drawn for a planar surface if we know its elevation at three points. This is known as a 'three point problem'. The procedure is also described in the manual by Rowland et al (2007) on page 14.

You need three points of known location and elevation: a low point (A), a high point (C), and an intermediate point (B), all plotted on a map (Fig. 6). Connect the high and low points on the map with a line AC. This allows you to locate a fourth point D, on that line, which will be at the same elevation as the intermediate of your initial three points. The distance of D along AC is proportional to the height differences

$$\text{Length AD} = (\text{Length AC}) \times (\text{Elevation difference AB}) / (\text{Elevation difference AC})$$

Connect D to B, to generate a horizontal line that lies within the plane. This is, of course, a structure contour or strike line.

To determine the dip, you need to use trigonometry. (You cannot measure the dip from the map because the dip lies in the vertical plane, not the plane of the paper, which is horizontal.) Draw a perpendicular line from the

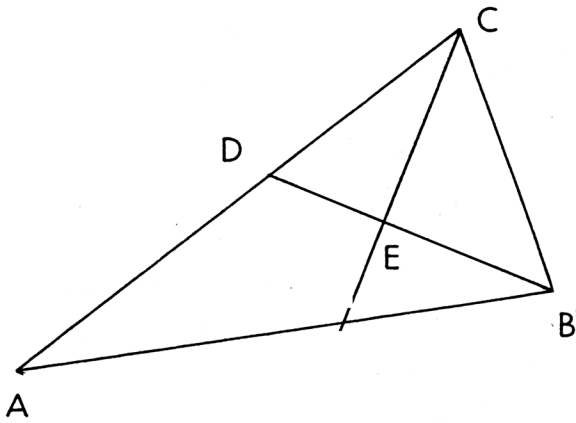
structure contour to either the high or the low point. In the diagram it is drawn from the contour at E to through the high point C,. The dip ( $\delta$ ) can then be calculated:

$$\tan \delta = \text{elevation difference } BC \div \text{horizontal distance } EC$$

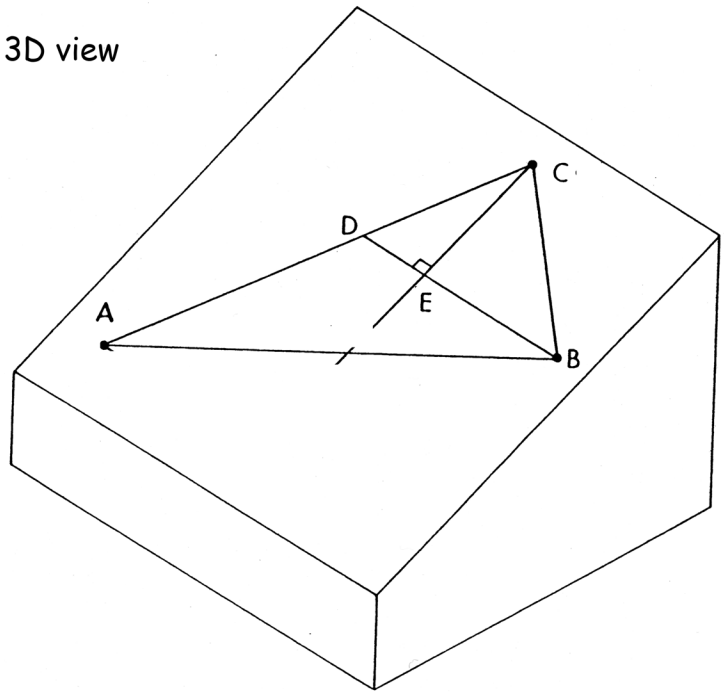
Structure contours for round-number contours (200 m, 300 m etc) may then be constructed by locating points (P) at round-number elevations. The position of a point P at a given elevation may be determined by

$$\text{horizontal distance } PC = \text{elevation difference } PC \div \tan \delta$$

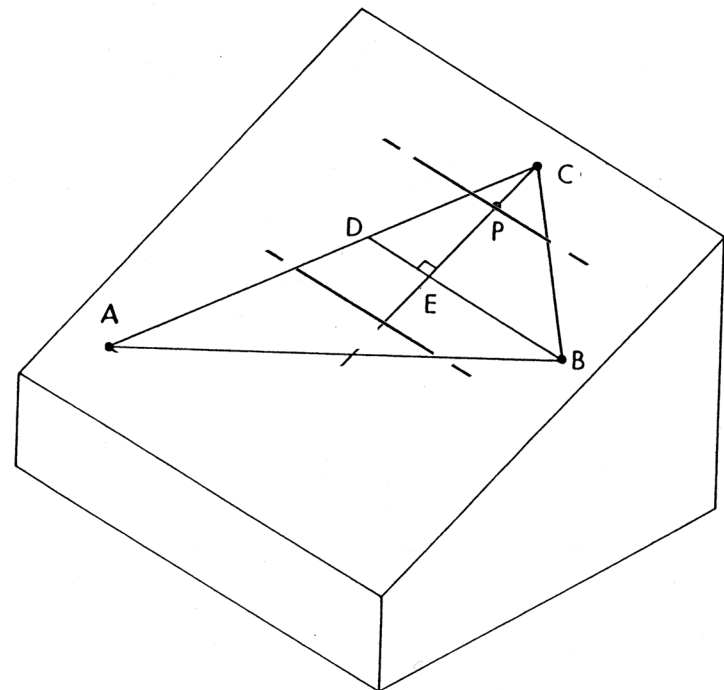
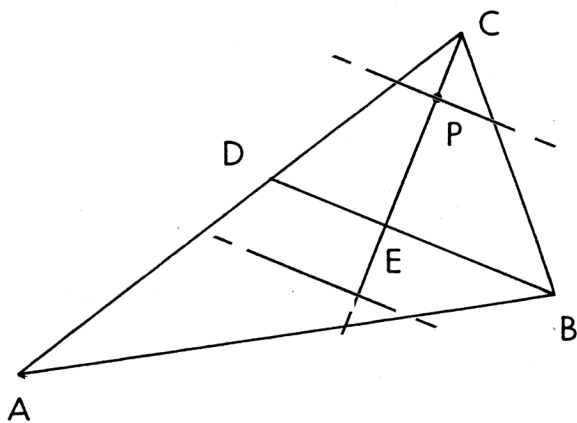
Map view



3D view

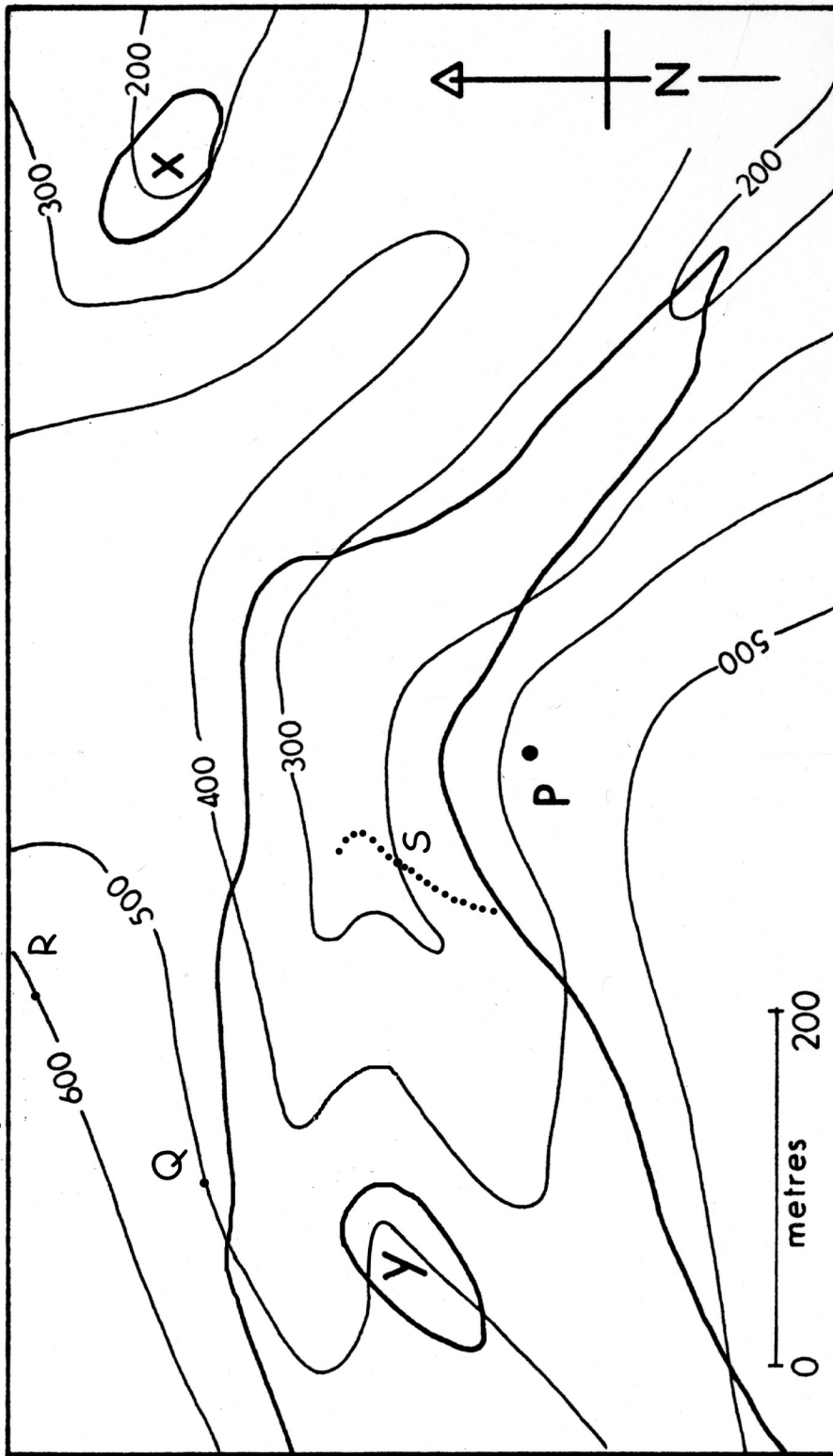


Step 1



Step 2

Fig. 6. Map and block diagram illustrating solution of three-point problems. A, B and C are three points at different elevation on the surface. Map view on the left, 3-D view on the right. Step 1 shows the location of a fourth point D at the same elevation as the middle point B. Step 2 shows the construction of 'round-number' contours parallel to BD.



Map 1. Contour interval 100 m.