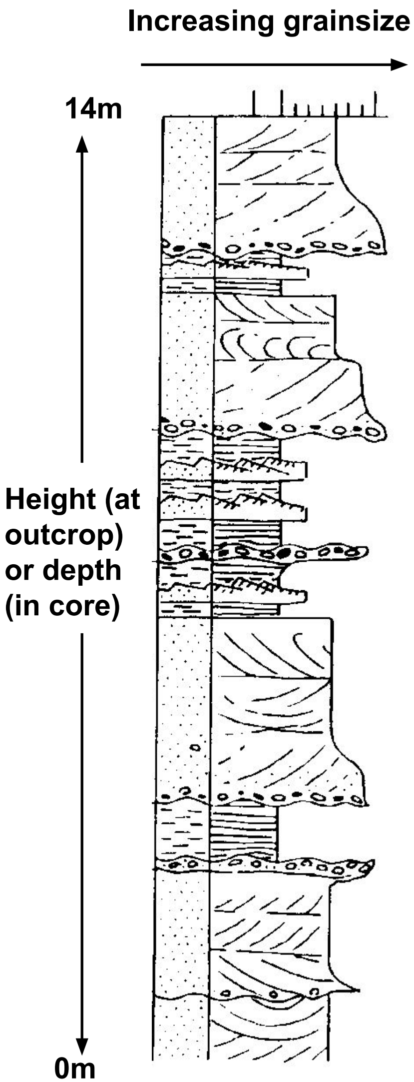
Drawing graphic sedimentary logs

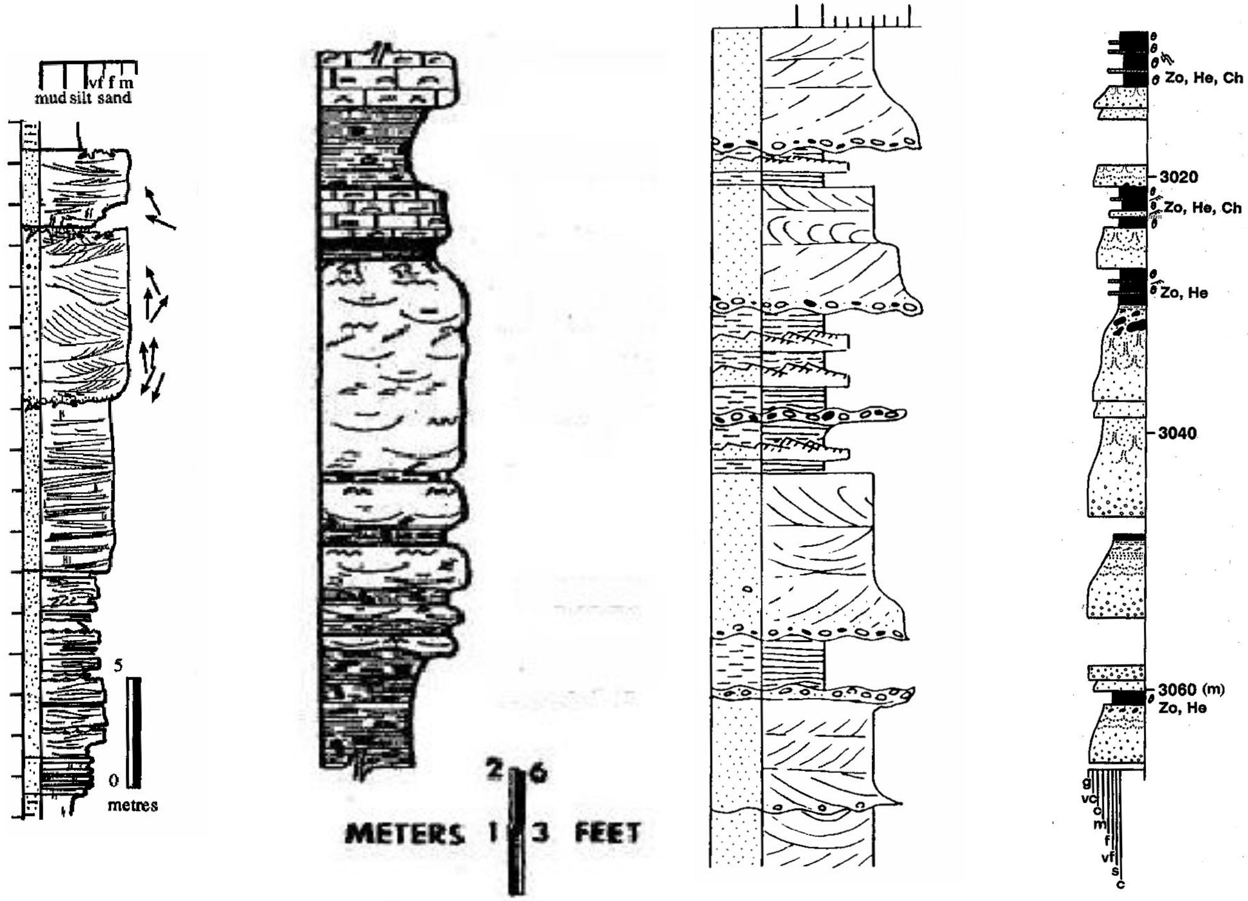


For many decades, graphic sedimentary logs have been a vital method of recording and reporting sedimentary successions, whether they are at outcrop or in the subsurface (core).

Before graphic logs were developed and refined in the 1970s, sedimentary successions were illustrated by parallel-sided lithological/stratigraphic columns showing little more than the lithology. Features such as grain size and sedimentary structures were described in writing alongside the lithology, so that it was very difficult to get an understanding of the succession without laboriously reading long, and often turgid, descriptions.

This changed dramatically with the development of graphic logs that recorded such characteristics as grain size, sedimentary structures, palaeocurrent direction and fossil content, as well as the lithology. For the first time, it was possible to visualise a sedimentary succession at a glance. As an old English saying goes, ‘a picture is worth a thousand words’ and this is never truer than in the case of sedimentary logs.

The variability of sedimentary logs



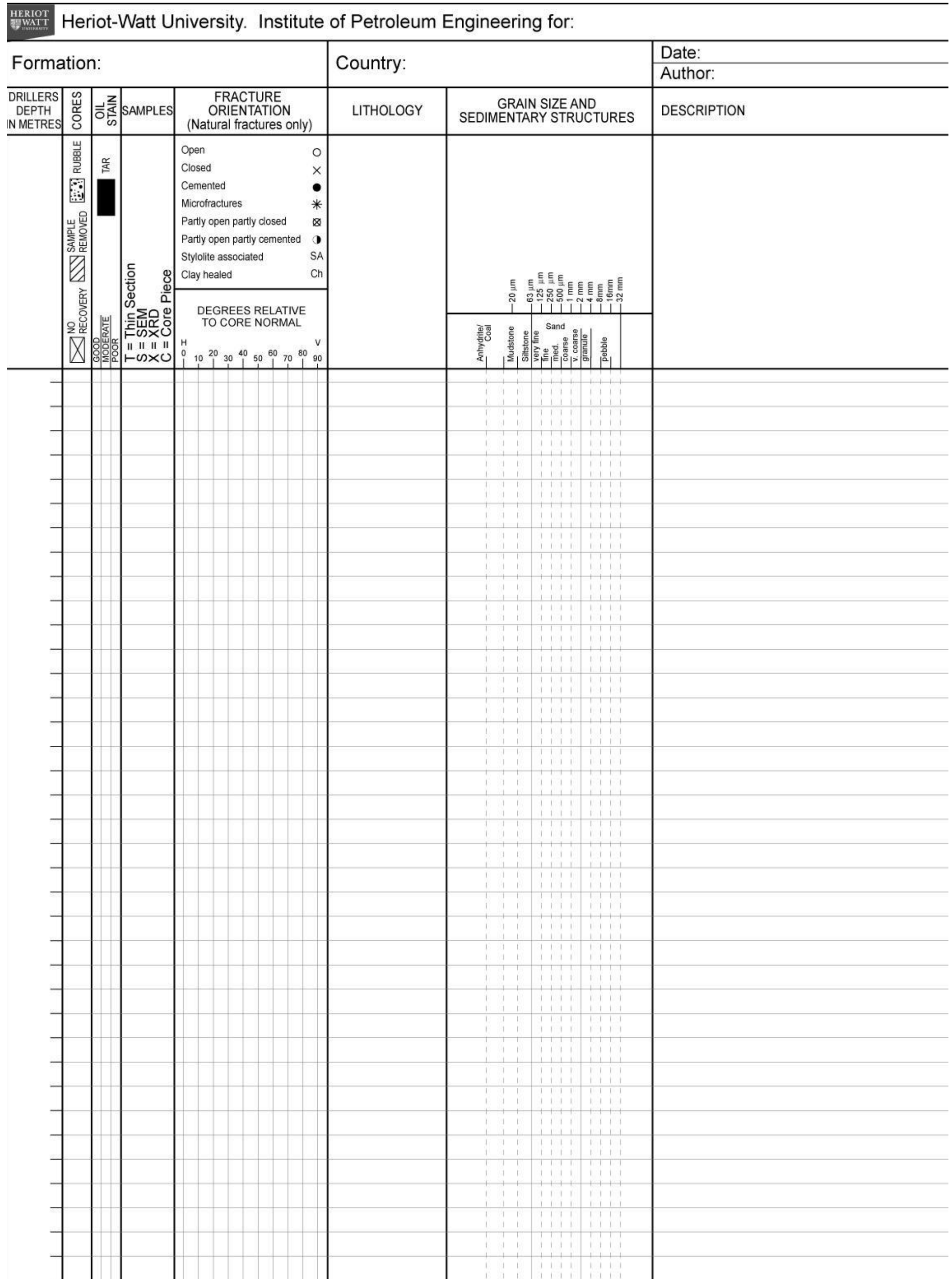
The four logs on the left illustrate that there is no standard way or drawing a sedimentary log. However, the majority of styles have a lot in common.

Because sediments accumulate vertically, sedimentary logs are ideally developed from the base upwards, and this is the norm for logging at outcrop. However, when logging core, many sedimentologists start at the top. This will be discussed further when we learn the technique of sedimentary logging. However, it doesn’t matter how the log is drawn, as long as the result is a good description of the rocks.

Sedimentary logging

The logging sheet on the right is a typical sheet used for logging sedimentary successions in core or at outcrop.

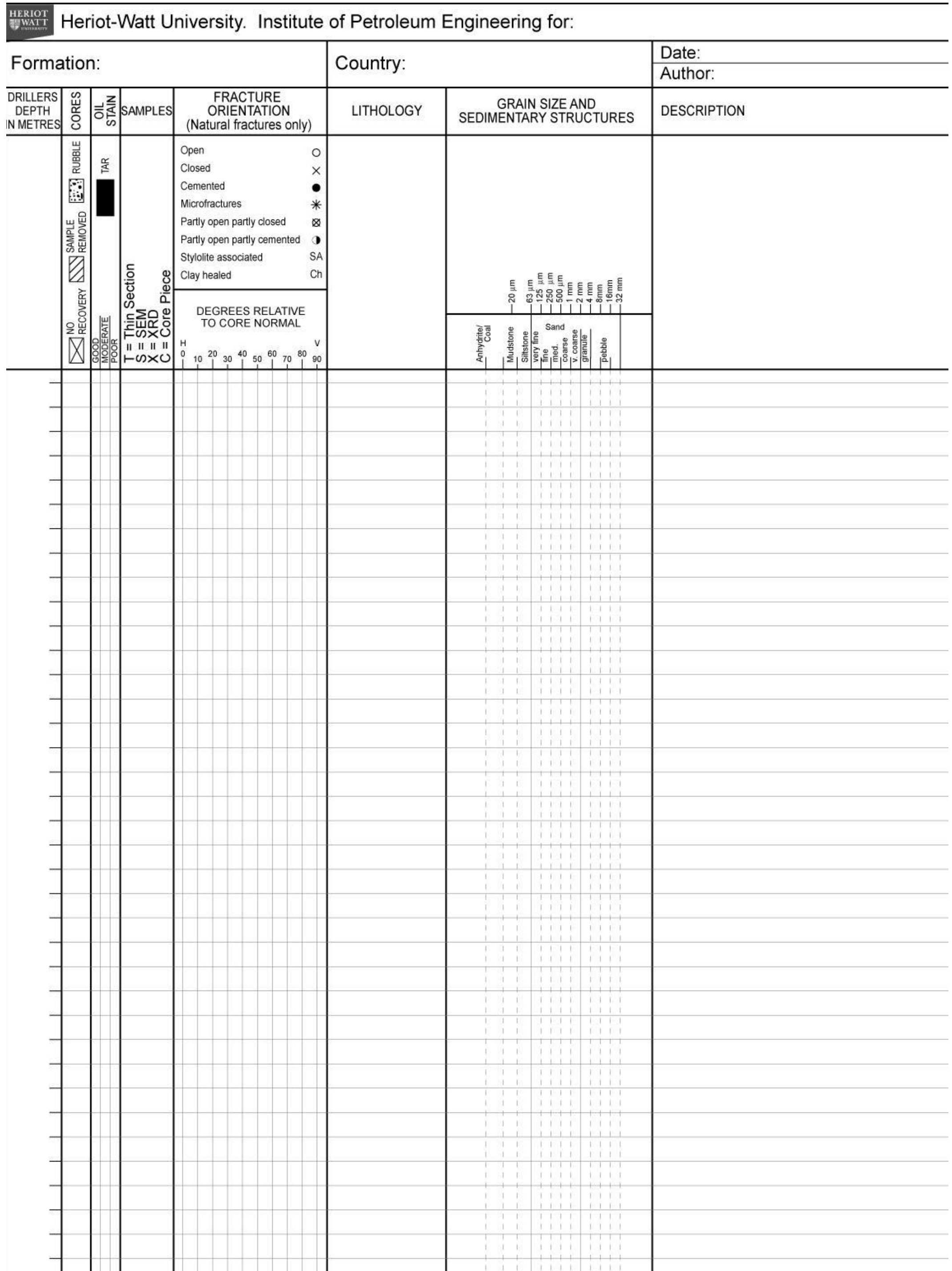
This sheet is based on one developed over many years by the sedimentology specialists at Robertson Research in North Wales. As such, it has a long track record, and works well for most kinds of rocks.



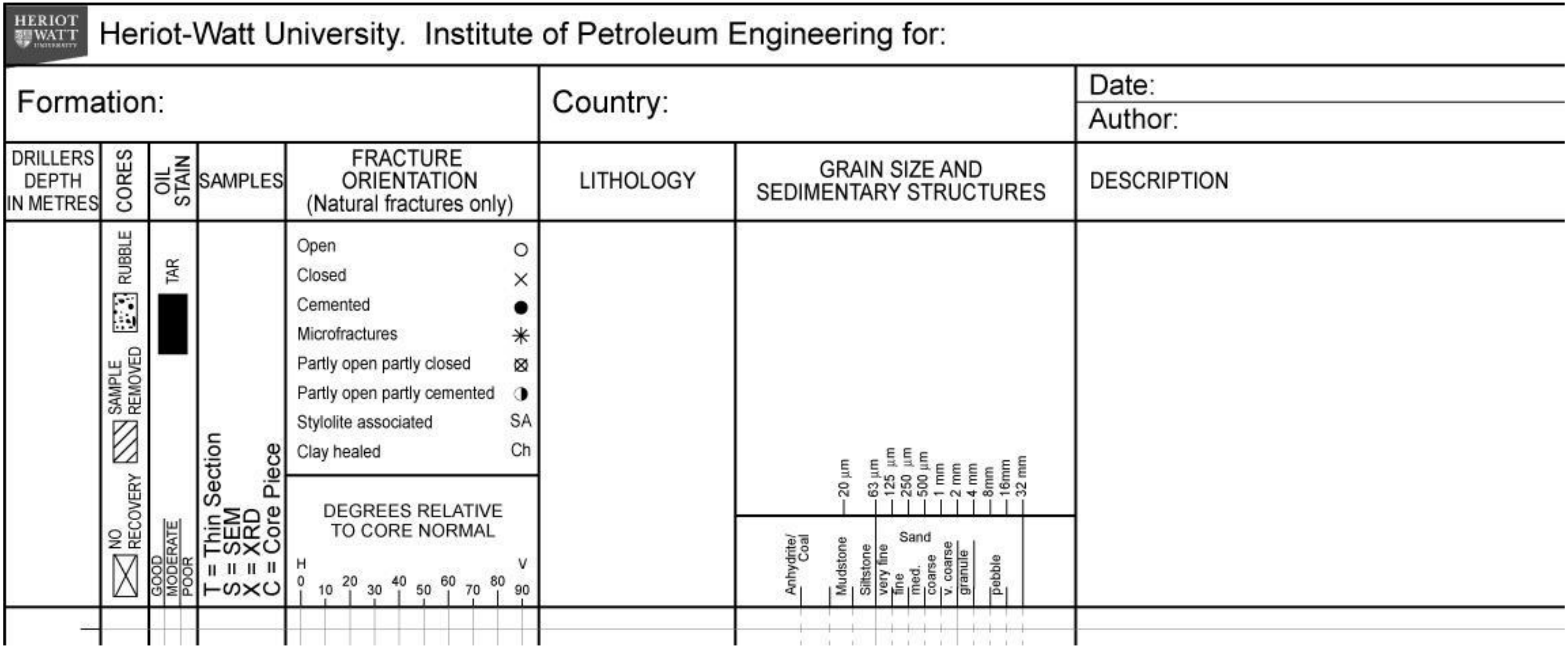
The logging sheet

This sheet was designed for metric wells, and any outcrops which were measured in metres. The spacing between the horizontal lines is 0.5cm. The most common logging scale is 1:50, or 2cm to 1m, which means that there are four 0.5cm intervals per metre. Logs at other scales can, of course, be drawn. For example, 1:200 would be one interval per metre and 1:20 ten intervals per metre.

This sheet cannot be used for logging in feet. This requires the spacing between horizontal lines to be measured in fractions of an inch, not mm. Such sheets do, of course, exist.



Typical logging sheet header



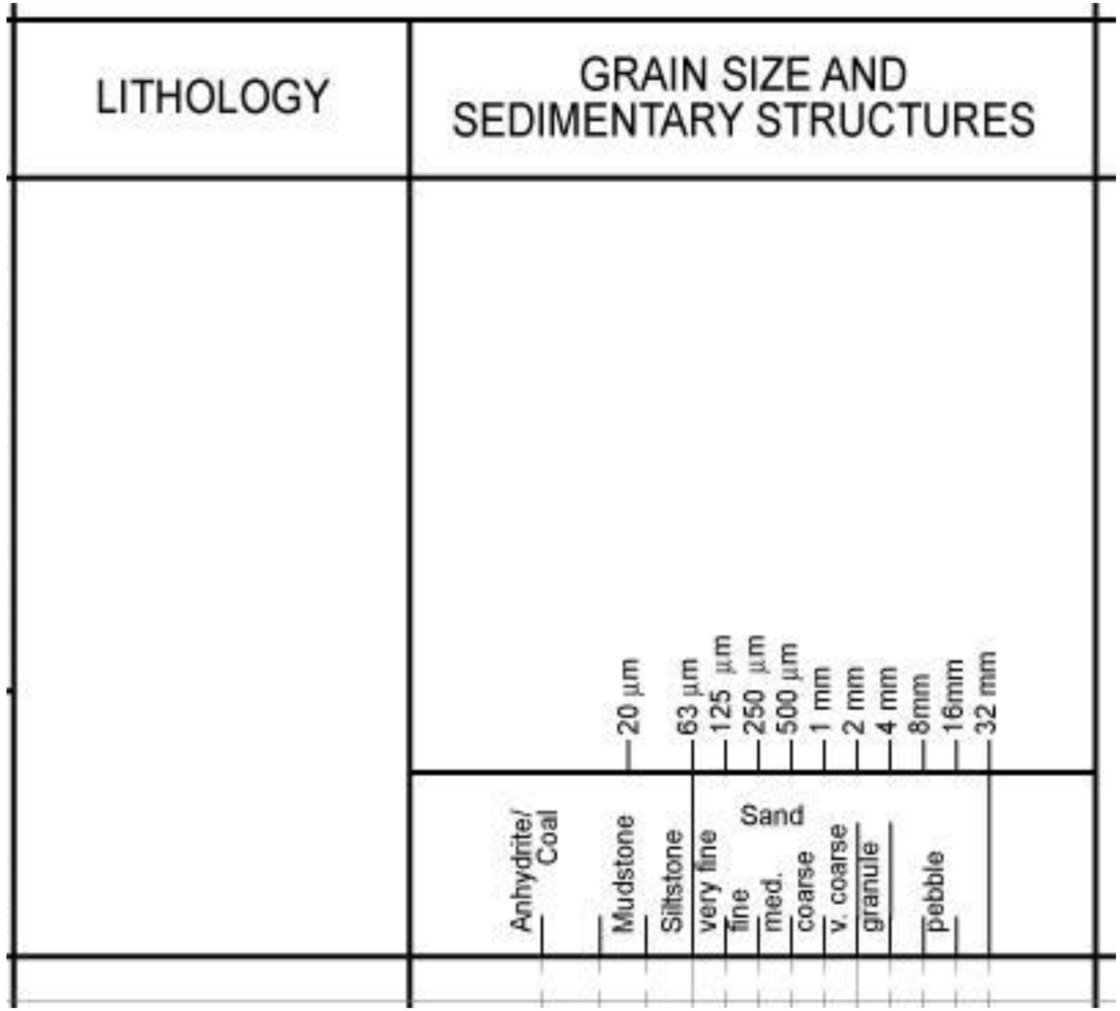
The most important columns on the logging sheet are the depth column and the lithology and grainsize/sedimentary structures pair.

The first thing, when starting the log, is to annotate the depth scale (or height for outcrops). As discussed, for a scale of 1:50, there will be four intervals per metre. Write the appropriate depths in the depth column. When you have done this, check to ensure that you have got it right (any sedimentologist who has spent much time logging core or at outcrop will have got it wrong at least once!). A logging sheet in portrait orientation on A4 paper will allow slightly more than 10m to be logged at 1:50. At this scale, 10m of core should be 20cm long on the paper. Check it before you spend a lot of time drawing a log at the wrong scale!

Lithology and Grain-size scale

The lithology is recorded in a parallel-sided column, using fairly standard symbols (see later). As well as the basic lithology (sandstone, mudstone, limestone etc.), you should also record anything that would have an impact on the wireline log response (e.g. clays minerals in sandstones, cemented intervals, coals etc.). This is to allow the core depths to be correlated with the wireline log depths.

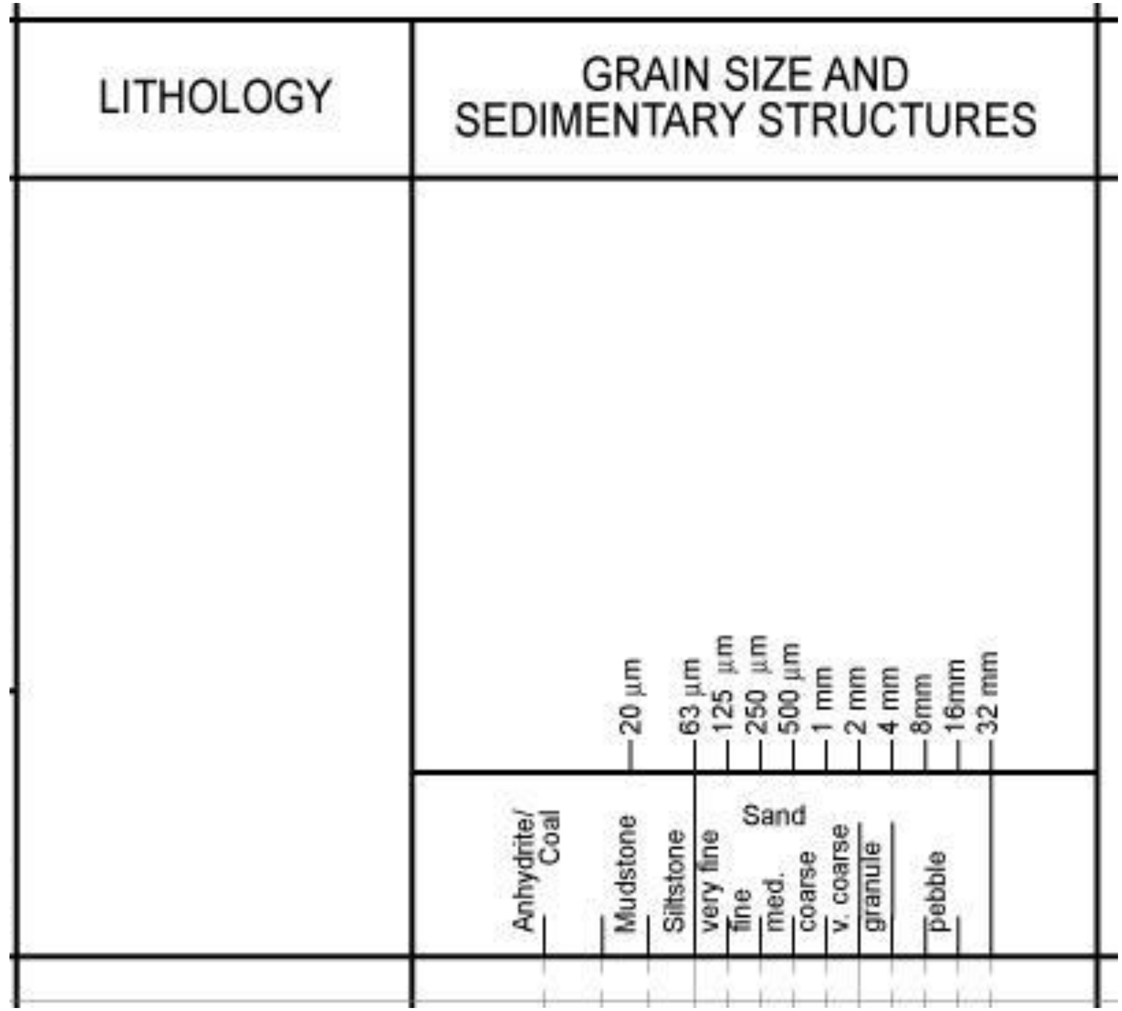
To the right of this is the grain-size column. Because fine lithologies, such as mudstone, may have distinctive features (e.g. sandy laminae, slumps, ripple form sets etc.) within them, it is important to give mudstones and siltstones enough width for these to be drawn.



The grain-size scale is based on the phi scale, with 5 intervals for sand/sandstone. Remember that grain-size is a continuum, so that medium sandstone (for example) should plot at the middle of the interval. Fine/medium sandstone would plot on the boundary between the two grain sizes.

More on the grain-size scale

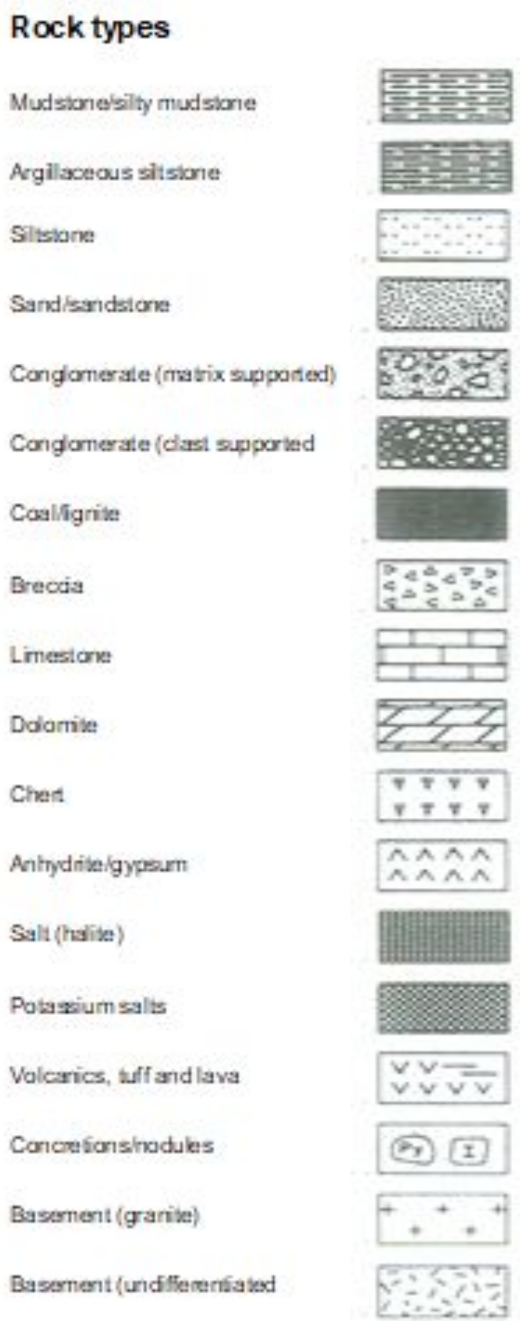
Strictly speaking, there should be 4 divisions for siltstone on the phi scale. However, because it is impossible to resolve these with the naked eye, most logging sheets have relatively narrow columns for siltstone and mudstone. Once sediments become this fine, they generally consist of a mixture of silt-sized grains of quartz, feldspar etc. and finer clay minerals. Because of this, many sedimentologists prefer to divide the fine sediments into argillaceous siltstone (when the silt is dominant) and silty mudstone when the clay minerals are dominant.



The scale above stops at pebbles of 32mm (3.2cm) diameter. If coarser grains exist (for example in a conglomerate). The scale can be extended to the right.

As its name suggests, the grain-size scale is for granular sediments. Any sediments (or other rock types) that do not consist of discrete grains cannot really be plotted on the grain-size scale. Note that, on the scale above, anhydrite and coal are given an arbitrary position on the grainsize scale.

Lithological symbols



The lithological symbols shown here are not as clear as they might be. The best version of the logging legend that I have is, unfortunately, in my office at Heriot-Watt, which is inaccessible during the Covid 19 crisis.

On a sedimentary log, it is usual to mark a change of lithology symbol by a horizontal line at the appropriate depth.

Note that, as there is only one symbol for sandstone, a change from, for example, medium sandstone to fine sandstone is not marked by a horizontal line.

Sedimentary structures

Planar lamination

Trough cross bedding

Tabular cross bedding

Graded bedding

Bimodal lamination

Current-ripple cross lamination

Wave ripple cross lamination

Adhesion ripples

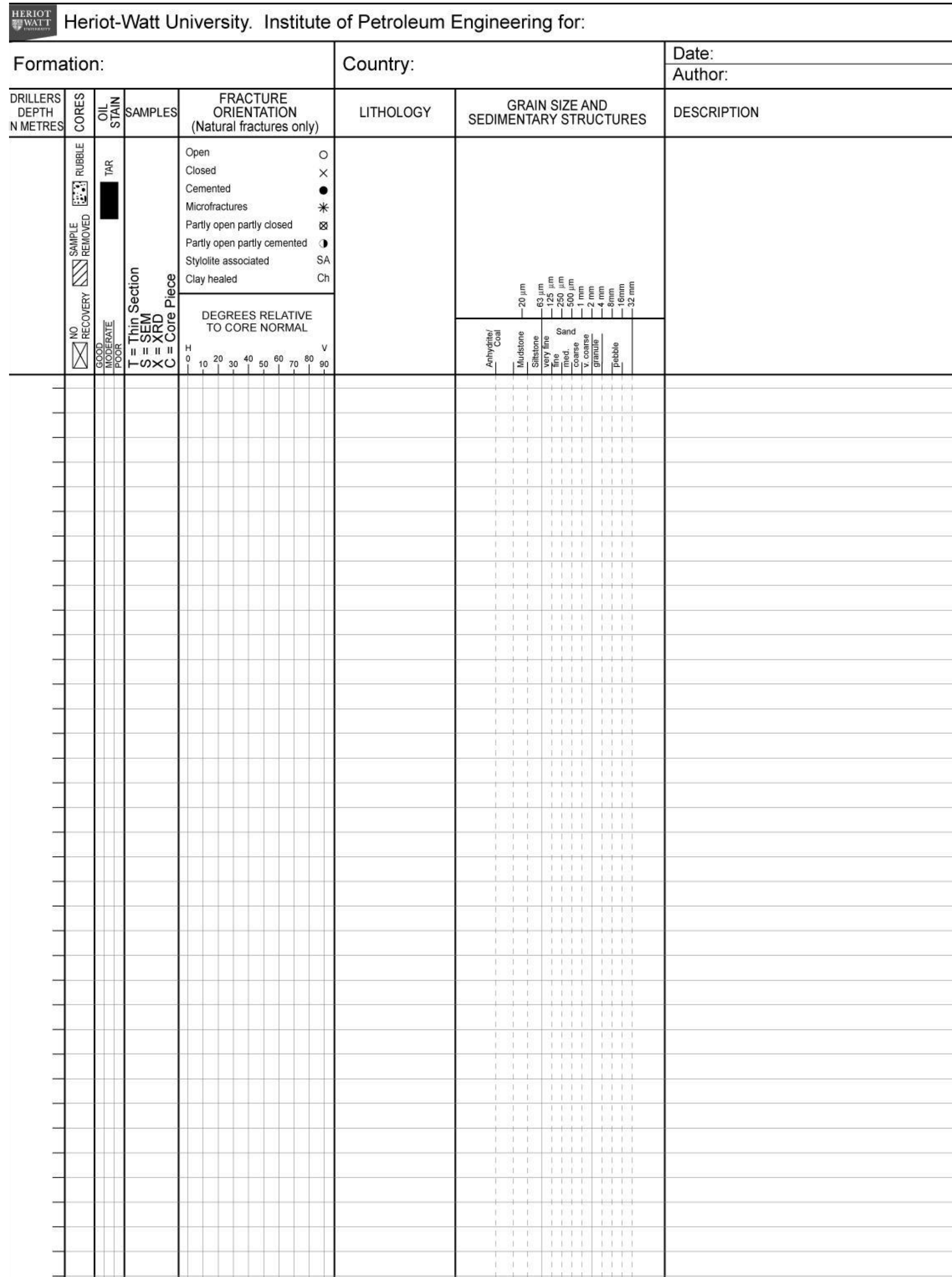
As on the previous slide, the symbols here are quite blurred.

Note also that these symbols need to be up-dated. The recommended symbols are shown on later slides

Demonstration of drawing a sedimentary log

When teaching in the classroom, I would normally draw a representative log to show how it is done. For many years, I used an overhead projector and an acetate sheet printed with a blank logging sheet. In 2019, for the first time, I used a smart computer monitor to do the same thing in PowerPoint.

Unfortunately, all my old acetate sheets are stuck in my office, and I only have the example from last year. The intelligent pen used for this exercise is less precise than a normal pencil or pen, and so some of the symbols are a bit clumsy. However, they are the best we have, and are shown in red on the following slides. I have added comments to clarify some of the points.


Heriot-Watt University. Institute of Petroleum Engineering for:

Formation:
Country:
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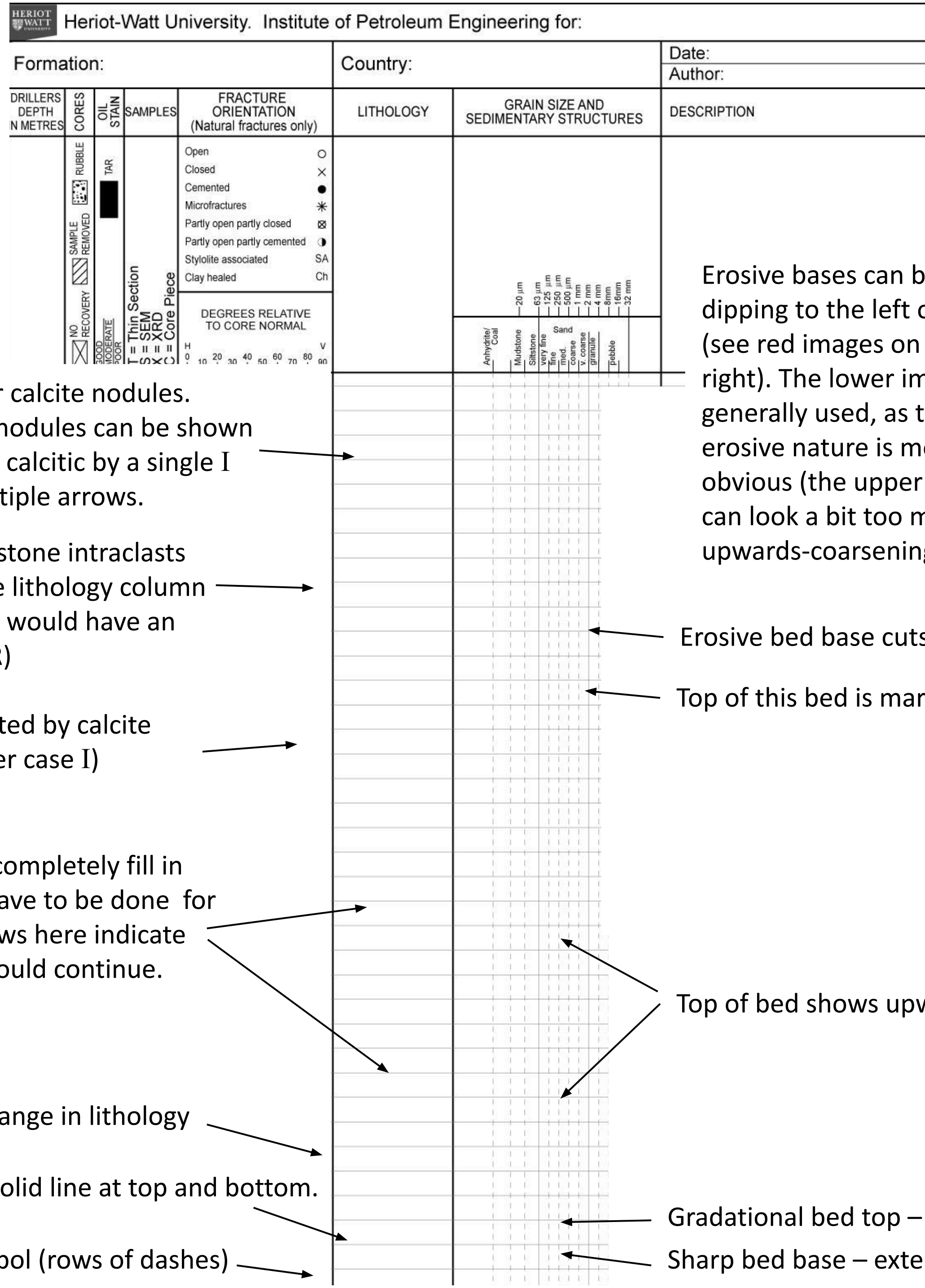
Author:

DRILLERS DEPTH N METRES | CORES | OIL STAIN | SAMPLES | FRACTURE ORIENTATION (Natural fractures only) | LITHOLOGY | GRAIN SIZE AND SEDIMENTARY STRUCTURES | DESCRIPTION

RUBBLE
SAMPLE REMOVED
NO RECOVERY
TAR
GOOD
MODERATE
POOR
T = Thin Section
S = SEM
X = XRD
C = Core Piece
Open
Closed
Cemented
Microfractures
Partly open partly closed
Partly open partly cemented
Stylolite associated SA
Clay healed Ch
DEGREES RELATIVE TO CORE NORMAL
H V
0 10 20 30 40 50 60 70 80 90
20 µm
63 µm
125 µm
250 µm
500 µm
1 mm
2 mm
4 mm
8mm
16mm
32 mm
Anhydrite/ Coal
Mudstone
Siltstone
Sand
very fine
fine
med.
coarse
v. coarse
granule
pebble

Let's look first at the grain-size curve, bed bases etc., and the lithology column



Irregular calcite nodules. Several nodules can be shown as being calcitic by a single I and multiple arrows.

Angular mudstone intraclasts (shown in the lithology column because they would have an impact on GR)

Interval cemented by calcite (shown as upper case I)

It is not always necessary to completely fill in the lithology (though it will have to be done for final presentation!). The arrows here indicate that the lithology symbols should continue.

Again, solid line marks change in lithology

Sandstone symbols. Note also solid line at top and bottom.

Silty mudstone/shale symbol (rows of dashes)

Erosive bases can be shown dipping to the left or right (see red images on the right). The lower image is generally used, as the erosive nature is more obvious (the upper image can look a bit too much like upwards-coarsening).

Erosive bed base cuts down by about 40cm

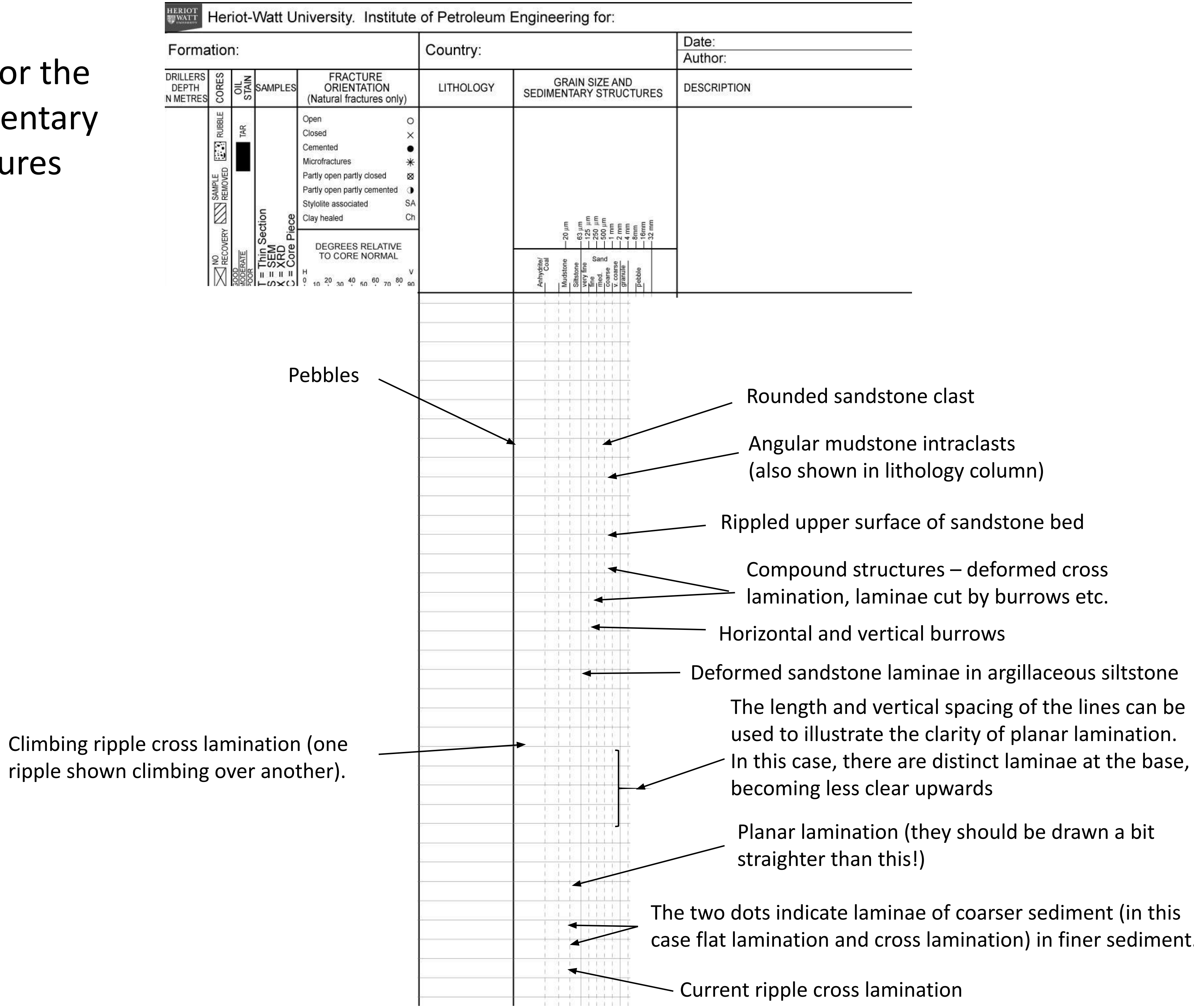
Top of this bed is marked by current ripples

Top of bed shows upwards-fining over several cms

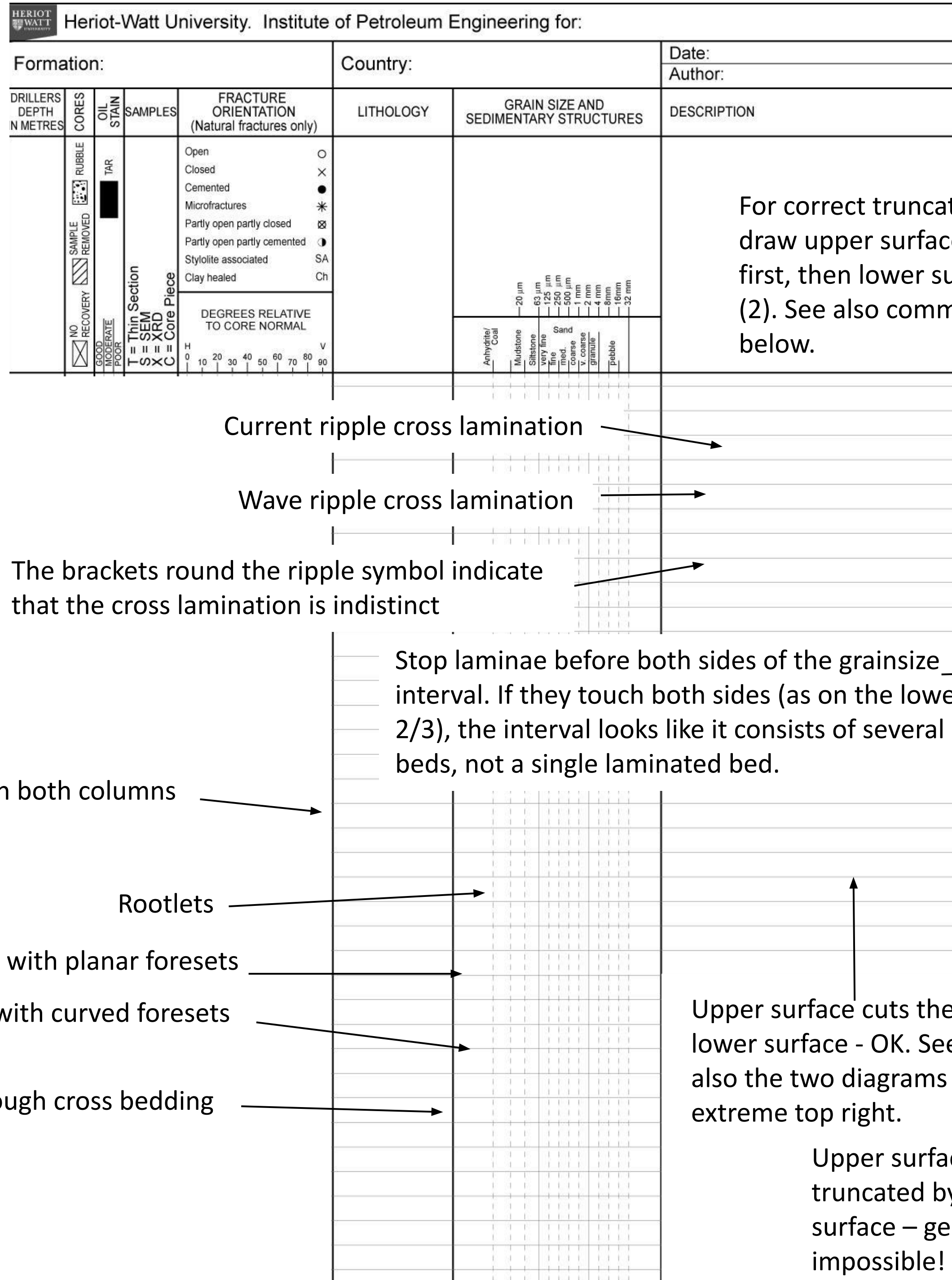
Gradational bed top – does not extend across column

Sharp bed base – extends right across grain-size column

Now for the sedimentary structures



More on sedimentary structures, etc.



For correct truncation, draw upper surface (1) first, then lower surface (2). See also comments below.

Current ripple cross lamination

Wave ripple cross lamination

The brackets round the ripple symbol indicate that the cross lamination is indistinct

Stop laminae before both sides of the grainsize interval. If they touch both sides (as on the lower 2/3), the interval looks like it consists of several beds, not a single laminated bed.

Coal – draw as black in both columns

Rootlets

Tabular cross bedding with planar foresets

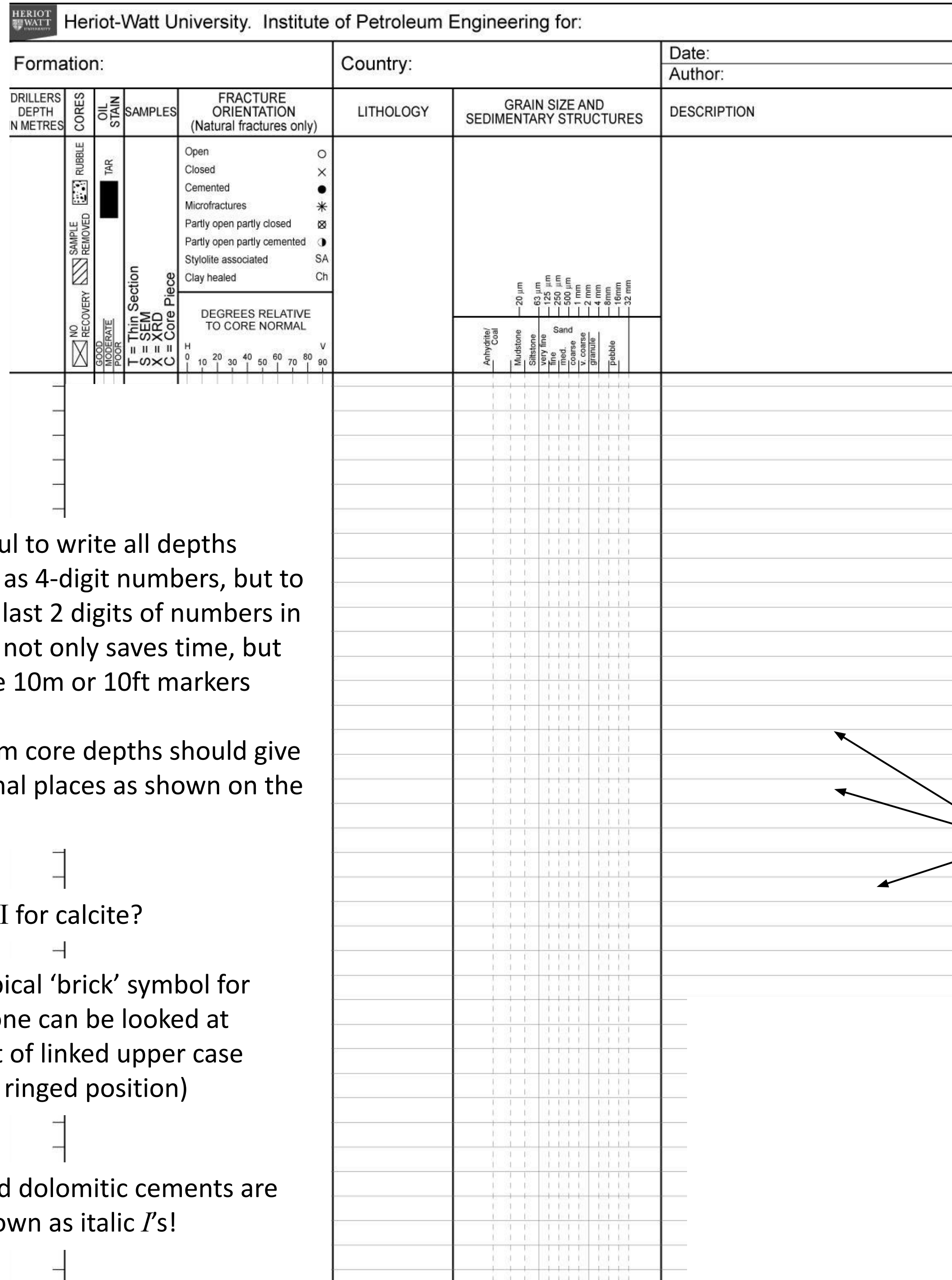
Tabular cross bedding with curved foresets

Trough cross bedding

Upper surface cuts the lower surface - OK. See also the two diagrams at extreme top right.

Upper surface is truncated by the lower surface – geologically impossible!

Some more bits and pieces



Depths

It may be useful to write all depths ending in zero as 4-digit numbers, but to only write the last 2 digits of numbers in between. This not only saves time, but also makes the 10m or 10ft markers more clear.

Top and bottom core depths should give as many decimal places as shown on the core boxes.

Why do we use I for calcite?

The typical 'brick' symbol for limestone can be looked at as a set of linked upper case I's (see ringed position)

And dolomitic cements are shown as italic *I*'s!

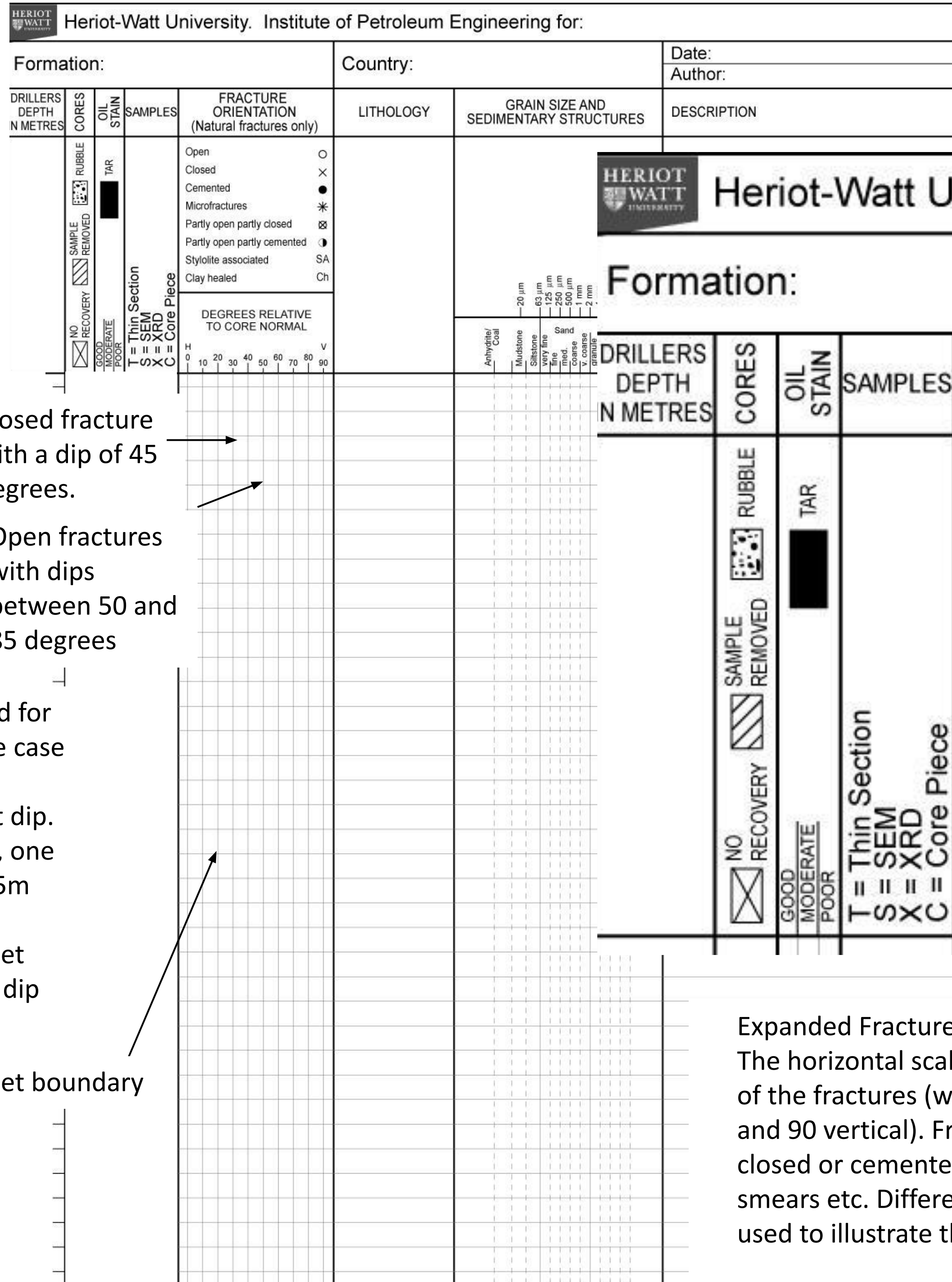
Rounded intraclasts are represented by an oval with a single shale tick within it. Intraclasts can also be angular or deformed, and subtle changes of symbol can illustrate this.

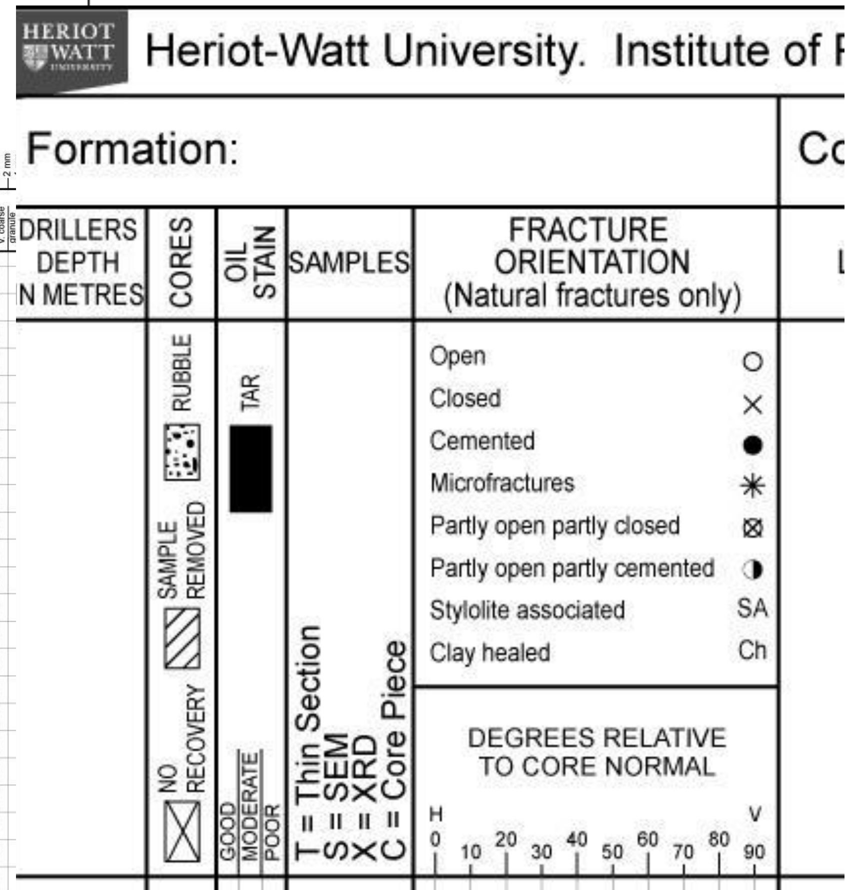
Try not to draw the foresets too steeply – remember that they should not be more than 36 degrees for subaqueous bedforms. In this example, the foresets in the lowest set of cross bedding are two steep, but the upper two examples are OK.

Some of the more obscure columns!

Fractures can be very important in reservoirs, so it is important to record their nature. The header for the fracture column is expanded on the right.

The same column can be used for other inclined features. In the case of aeolian dunes, it may be relevant to record the foreset dip. This example shows two sets, one 3.5m thick and the other 1.75m thick. They both show a downwards decrease in foreset dip, with a sudden change of dip at the set boundary.

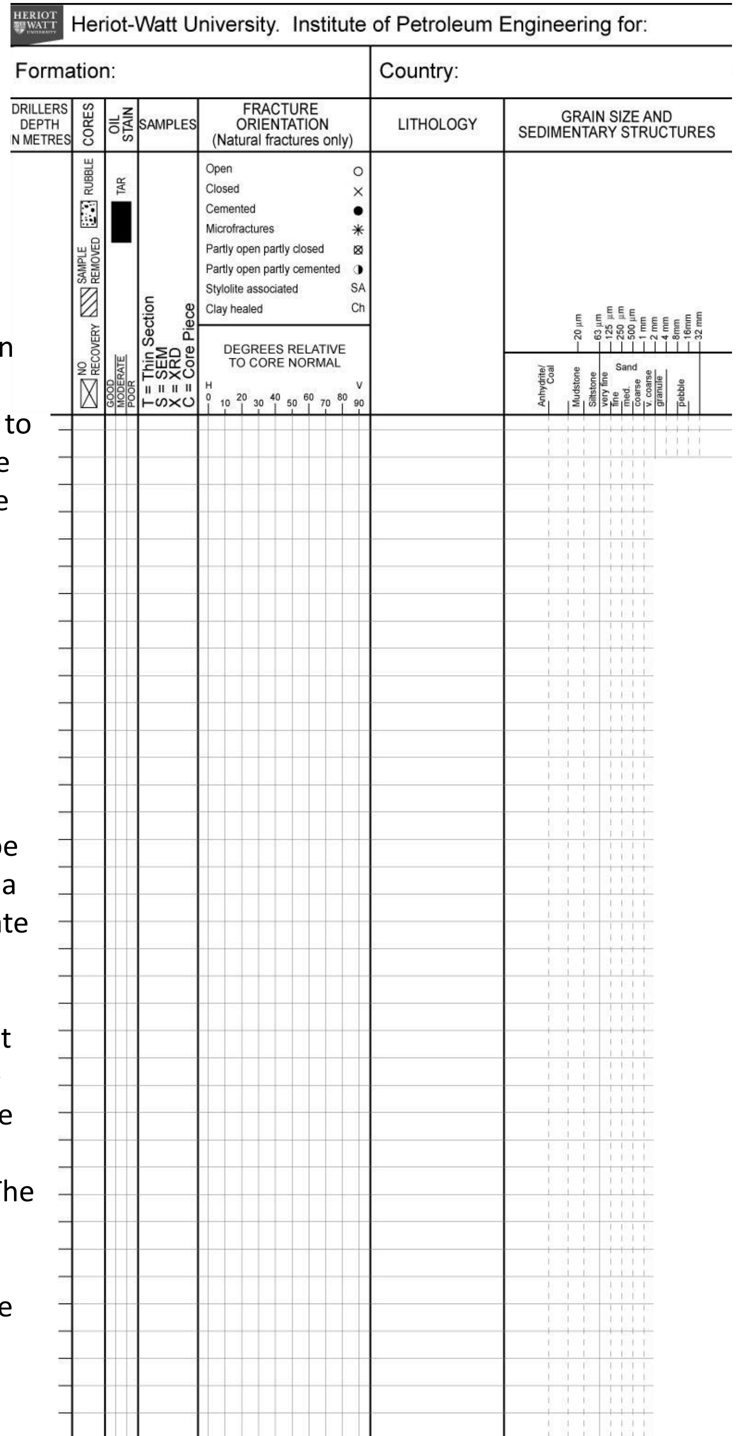


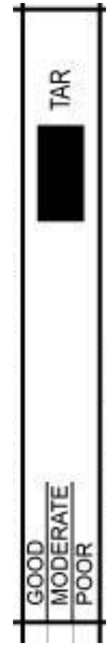


Expanded Fracture Orientation column. The horizontal scale is to show the dip of the fractures (with 0 being horizontal and 90 vertical). Fractures can be open, closed or cemented, and may have clay smears etc. Different symbols can be used to illustrate this (see above).

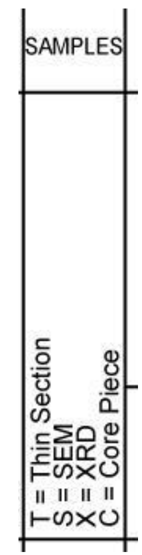
Yet more obscure columns!

The first column after the depth column is used to record the state of the core. The core may be missing, either because it was removed as a preserved sample or because it was not recovered. The core may be present, but in a very broken state ('rubble'). It is important to record this, as it should indicate your confidence in your observations. The degree of damage can be indicated by the width of the rubble symbol.





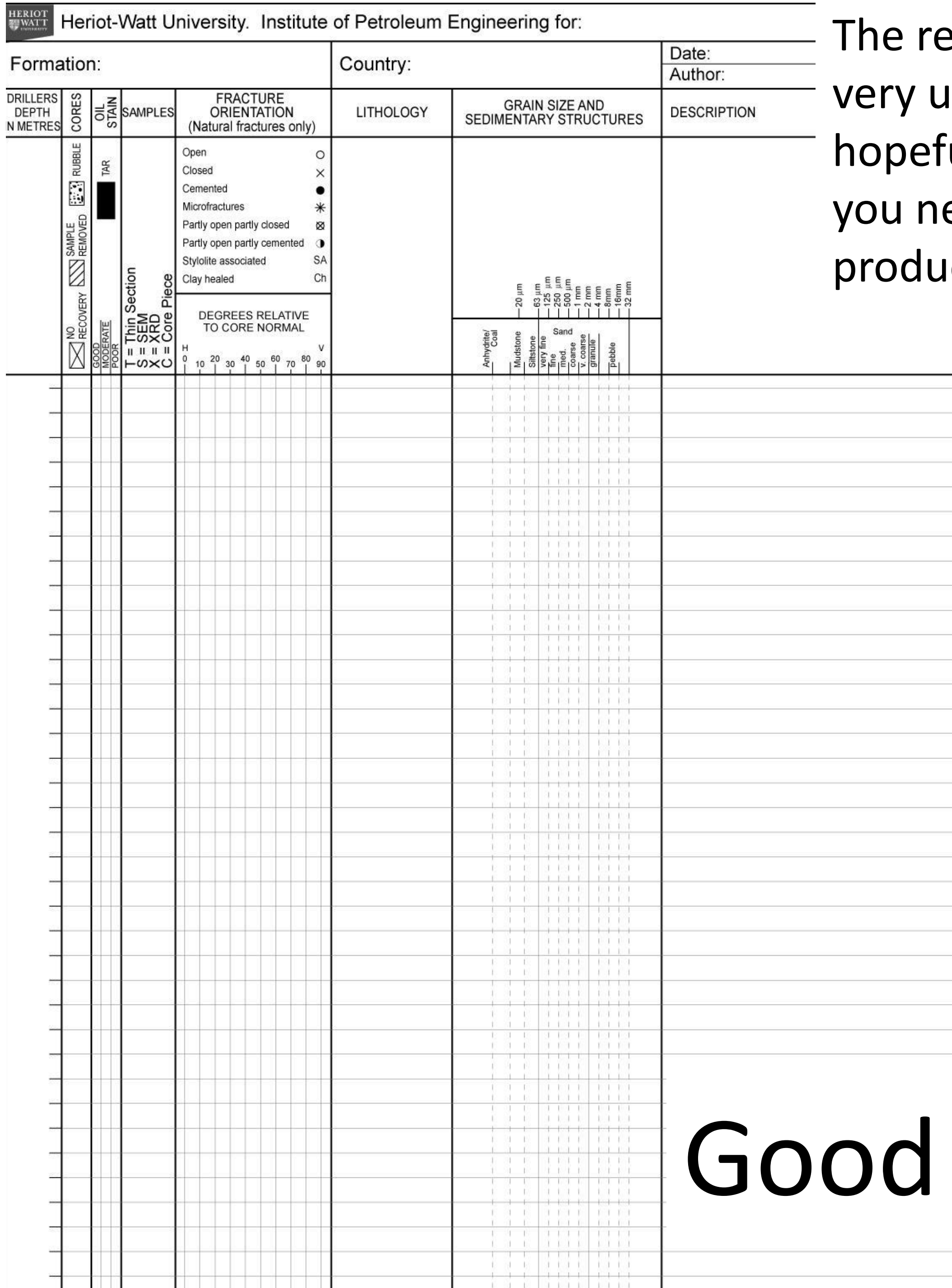
The second column is for the oil stain. If the oil stain is recorded alongside the sedimentary log, it may indicate which grain size or facies shows the strongest oil stain.



The third column is to record where samples have been taken. These may include samples for petrographic thin sections, SEM or XRD analysis, or mudstones for micropalaeontology or palynology.

All cores are different, and it is acceptable to modify the logging sheet to suit your purpose. For example, in aeolian successions (or other terrestrial rocks), it may be relevant to record the colour, which gives an indication of the oxidative state. In this demonstration, I have indicated the degree of red ('R') and grey ('G') in the sample column, as no samples were being taken.

All of this was drawn very rapidly to illustrate the techniques of logging.



The resulting log was very untidy, but it hopefully illustrates what you need to know to produce your own log.

Good luck!