Transgressive-regressive cycles; Pebbley Beach Formation, Sydney-Bowen Basin

Author: Steve Abbott*

Introduction

Sedimentary rocks of the Sydney-Bowen Basin are exposed in the coastal cliffs of southern New South Wales. At Point Upright (Figure 1), the strata exposed in the cliff belong to the Pebbley Beach Formation. This formation is Permian in age, marine in origin and comprises alternating units of dark coloured mudstone and lighter coloured sandstone (Figure 1). The sandstones were deposited in shallow water while the mudstones were deposited in relatively deep water. Such vertical alternation between shallow and deep marine sediments is common in sedimentary basins. This case-study aims to explain how vertical changes in sedimentary rock type and environment can result from the repeated landward (transgression) and seaward (regression) movement of the shoreline. The alternation of sandstone and mudstone created by transgression and regression is important because earth resources that occur in the pore spaces of sandstone (e.g. oil, gas, ground water) are trapped there by impermeable mudstone.

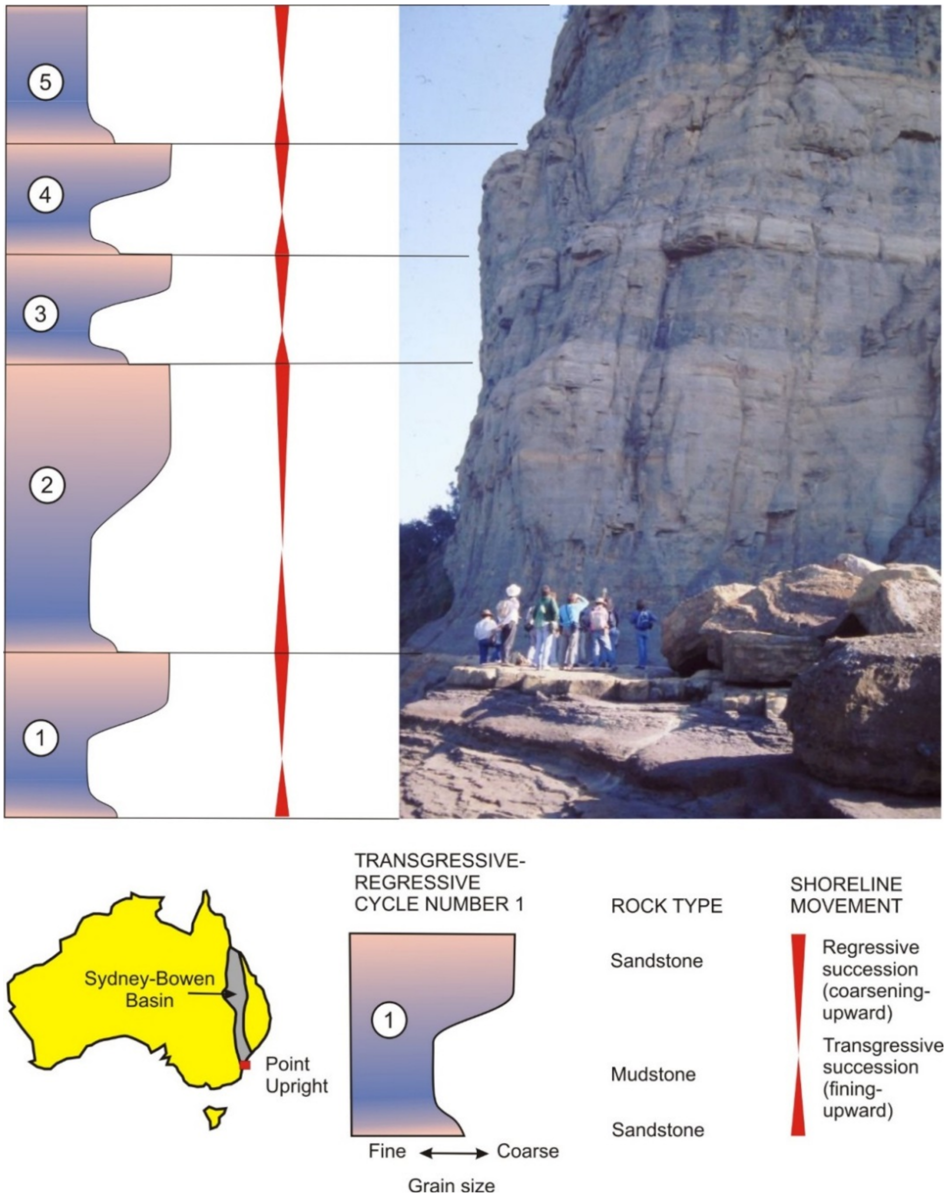

Figure 1. The Pebbley Beach Formation exposed in the coastal cliff at Point Upright, near Durras North, NSW.

Main content

When a river delivers its load of sediment to the shoreline, wave energy acting on the shoreline winnows out the fine grained mud, leaving the larger grains of sand on and near the beach. Offshore in deeper water, beyond the reach of waves, mud settles on the sea-floor. A lateral change occurs in sediment type and environment, from shoreline sand to offshore mud. Such lateral change in sediment and environment is also observed as vertical changes in ancient strata. The vertical alternation of sandstone and mudstone results from transgression and regression of a shoreline.

During shoreline transgression (Figure 2, Time 1 to 4), the shoreline moves towards the land and the sedimentary environments "follow" the shoreline. As transgression continues, perhaps over a distance of tens of kilometres, offshore mud is deposited on top of sandy shoreline sediments. If a sediment core was collected from the deposited sediment, there would be a vertical change from sand at the bottom of the core into mud at the top of the core. Transgression of the shoreline occurs during sea-level rise.

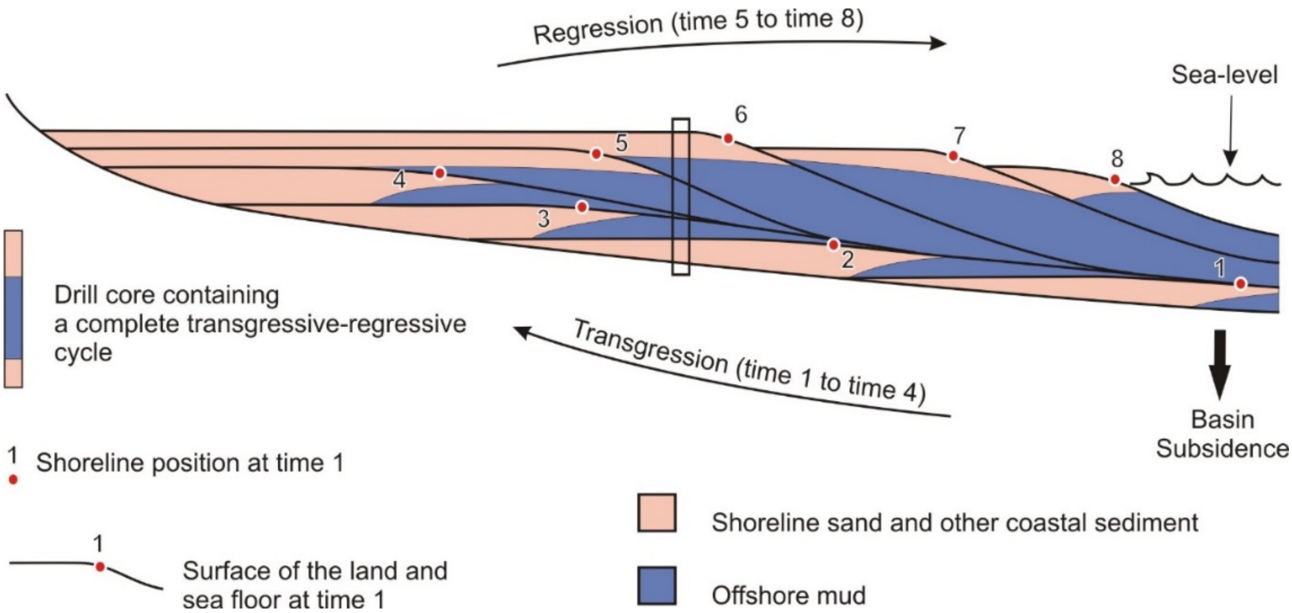

Figure 2. Illustration showing how transgression and regression of the shoreline deposits a transgressive-regressive sedimentary cycle. Such cycles may extend horizontally for several tens of kilometres, and range from a few metres to a few hundred metres in thickness.

During shoreline regression (Figure 2, Time 5 to 8), the shoreline moves towards the ocean and the sedimentary environments "follow" the shoreline in a seaward direction. Shoreline sand is deposited on top of offshore mud. If a sediment core was collected of these sediments, there would be a vertical change from mud at the bottom of the core into sand at the top of the core. Regression of the shoreline usually occurs during sea-level fall. However, if there is a very high rate of sediment supply to the shoreline, such as occurs at a delta, regression may also occur during sea-level rise.

The sediment deposited during a complete transgression and regression is referred to as a transgressive-regressive cycle. Each transgressive-regressive cycle at Point Upright commences with a thin sandy interval overlain by dark grey mudstone. This is the transgressive "fining-upward" part of the cycle. The mudstone in the middle of the cycle then grades upward into sandstone and this is the regressive "coarsening-upward" part of the cycle. Five transgressive-regressive cycles are visible in the cliff at Point Upright (Figure 1).

Shoreline transgression and regression occurs in response to rising and falling sea level, respectively. An important mechanism of sea level change is the alternate melting and freezing of polar continental ice. Water added to the ocean derived from melting ice causes sea-level rise and shoreline transgression. On the other hand, when water is removed from the ocean as polar ice-caps grow, sea-level falls and shoreline regression occurs. The alternate melting and freezing of continental ice is caused by climate variation. The second main mechanism of sea-level change is uplift and subsidence of the sedimentary basin floor arising from plate tectonic movements. Uplift of the basin floor results in shoreline regression, while subsidence results in transgression. The transgressive-regressive cycles seen in the cliff-face at Point Upright were deposited during the Permian Period. The Permian is one of several parts of Earth history characterised by transgressive-regressive cycles driven by climate variation.

Transgressive-regressive cycles can play an important role in the concentration of Earth resources such as oil, gas, and groundwater. These resources are found in the pore spaces between grains of permeable sandstone. The impermeable mudstone units that surround such sandstones act to trap these resources. Thus oil and gas traps are made up permeable sandstone (termed reservoir rock) and impermeable mudstone (seal rock). In the case of groundwater, the water-bearing sandstone is referred to as an aquifer while the surrounding impermeable mudstones are called aquicludes. In recent years, porous sandstones sealed by mudstone have been investigated as places where human-produced carbon dioxide can be injected and stored.

References

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*Steve Abbott is a geologist with considerable experience in academic research, undergraduate teaching, geological mapping and industry exploration with particular experience in basin analysis and sedimentology.

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Student activity

Figure 3 shows the stratigraphy of part of the Binthalya Formation. The rock types and environments of deposition are similar to the Pebbley Beach Formation at Point Upright. Study Figure 3 and complete the following activities.

a) Look for fining-upward and coarsening upward trends and mark them on the right-hand side of Figure 3. One has been completed for you to use as a guide.

b) Mark on Figure 3 the boundaries between transgressive-regressive cycles. One has been completed for you to use as a guide. Number the cycles.

c) If transgression and regression of the shoreline to form each cycle took 40,000 years, how many years did it take for the strata shown in Figure 3 to be deposited?

d) On Figure 3, indicate with an asterisk the intervals that might be good ground water aquifers. Which one of these is the best aquifer (Hint: think about the relationship between grain-size, porosity and permeability)? Write a short paragraph to justify your answer.

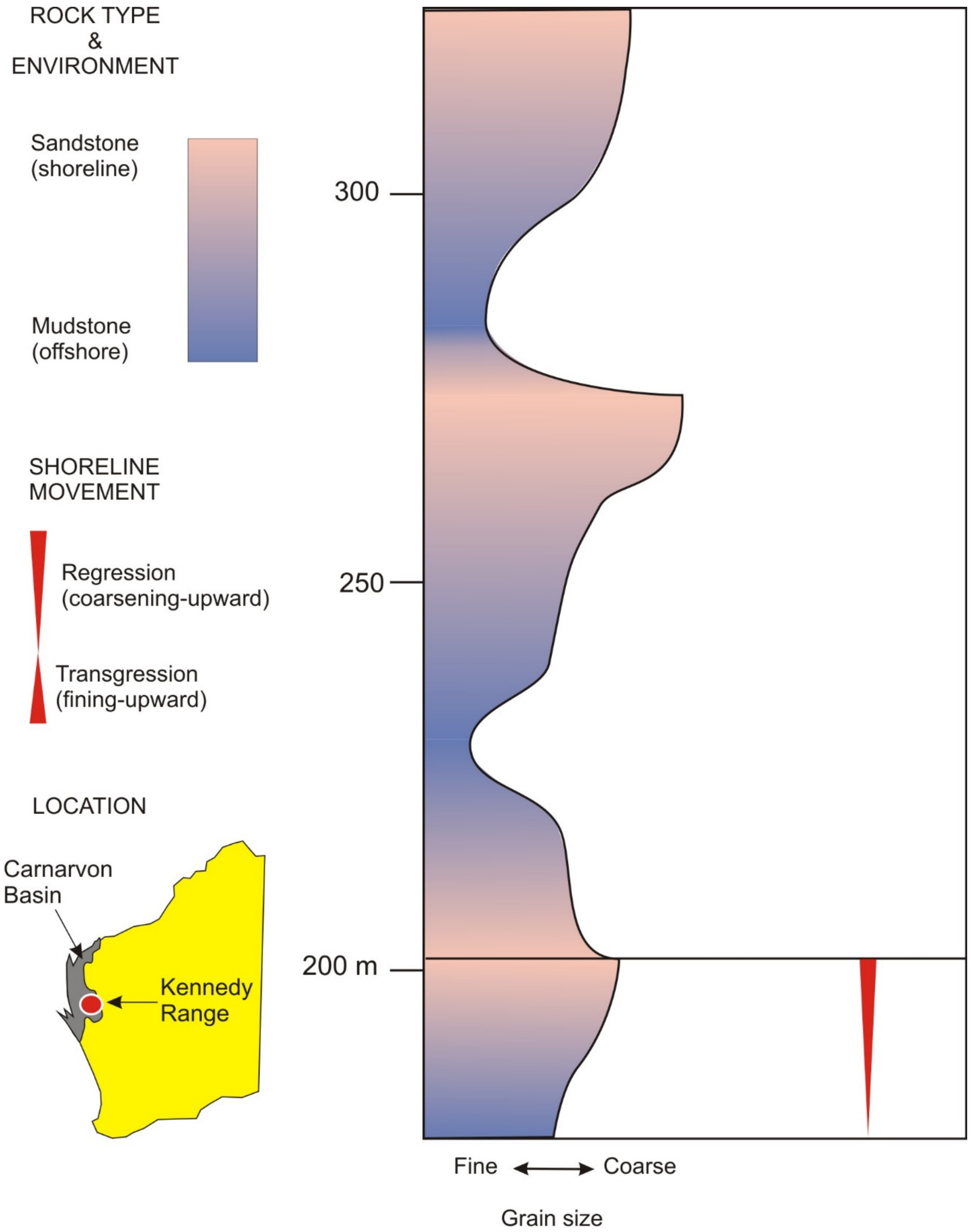

Figure 3. Stratigraphy of part of the Permian Binthalya Formation (much simplified) exposed in the Kennedy Range, Carnarvon Basin, Western Australia.

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