Exercise 1 Uplift, weathering and climate (Chapter 2 of *The Cretaceous World*)

You should allow about ½ hour to complete this Exercise, for which you need only to refer to The Cretaceous World*.*

In Section 2.1.1 of *The Cretaceous World*, possible links between uplift, chemical weathering of rocks and climate were noted. In order to explore these links further, it is necessary to consider not only which areas might have experienced uplift, but also what kind of material was then being eroded and weathered.

During continental rifting, the extensional thinning of the lithosphere is accompanied by doming of the molten asthenosphere beneath. Initially, while the asthenosphere is still hotter and relatively less dense than the solid mantle lithosphere (the lower part of the lithosphere), isostatic uplift may ensue. If extension (hence asthenospheric doming) is rapid enough, the isostatic uplift may temporarily exceed the subsidence due to thinning of the crust and result in erosion, especially of the upturned corners of the rift margins and fault-tilted crustal blocks, to yield syn-rifting sediments (e.g., Figure 2.9a in *The Cretaceous World*). Although this does not qualify as mountain-building, it does at least represent one potentially widespread source of sediment for weathering.

Question 1.1 Could parts of the British Isles have experienced the effects of such rift-related uplift during the Cretaceous?

In fact, episodic movements on basement faults in the region, probably related to rifting, continued until late Aptian times, and studies of heavy minerals in Lower Cretaceous sediments in southern England point to prolific uplifted source areas to the north and west. Of course this represents only a small segment of one of the zones of rift-related uplift associated with Atlantic opening (see Section 2.3 in *The Cretaceous World*), and the rocks exposed to erosion were many and varied. Nevertheless, it is worth taking a closer look at some examples to see if their weathering might have impacted on climate.

We'll start by considering two typical examples of the *products* of Early Cretaceous erosion and weathering in southern England, a haematite-cemented pebbly quartz arenite (from the Lower Greensand) and a quartz arenite with authigenic glauconite (from the Upper Greensand).

Question 1.2 What was the mineral composition of the original sediment that was deposited in these two cases?

When deposited, these sediments were thus already at the limit of chemical weathering: they can thus be described as mineralogically very mature. However, before we can comment on the effects of weathering during the Cretaceous, we also need to know about the mineralogy of the rocks that were eroded to yield these sediments.

Question 1.3 Why is this consideration important?

Bearing this thought in mind, let's look at our pebbly quartz arenite again. On closer inspection, we would find that the sorting of grains is poor, with a mixture of pebbles, granules and sand, yet most of the grains show a high degree of rounding and sphericity.

Question 1.4 (a) Given the observations above, what can you infer about the amount of transport experienced by the sediment from its source area to its point of deposition from the degree of sorting? (b) What does the grain morphology suggest concerning the amount of abrasion suffered by the grains?

The implications of the sorting and morphology of the grains might at first seem at odds. However, a simple explanation would be that most of the abrasion suffered by the grains had already occurred in a previous cycle (or cycles) of transport, prior to their incorporation in the source rocks that furnished the Cretaceous sediment. In other words, the source rocks in this instance are likely to have been already texturally mature sedimentary rocks. This is not surprising, as, even today, most of the pre-Cretaceous outcrop in the British Isles, as well as the 'subcrop' underlying the Cretaceous, consists of older sedimentary rocks.

Question 1.5 Some representative examples of the kinds of widespread sedimentary rocks that would have undergone erosion on the Early Cretaceous land surface of the British Isles might include (a) sub-arkosic quartz arenites, (b) fissile mudstones and (c) bioclastic limestones from the

Carboniferous, now (and in the Cretaceous) widely exposed across the Pennines, for example. What contribution could the weathering of each have made to the drawdown of atmospheric CO_2, according to the general equation given in Section 2.1.1 of *The Cretaceous World*?

Although the dissolution of atmospheric CO_2 in water to produce carbonic acid does dissolve limestone, yielding calcium (Ca^{2+}) and bicarbonate (HCO_3^-) ions, the same amount of CO_2 is released again when $CaCO_3$ is next precipitated, so there is no net drawdown, as will be explained in later chapters of *The Cretaceous World*.

The selection of rock types in Question 1.5 has (intentionally) given a somewhat biased result. Weathering of other rock types, such as mineralogically immature siliciclastic sedimentary rocks or silicate-rich igneous and metamorphic rocks would, by contrast, have contributed to CO_2 drawdown. However, the exposure to erosion of these, at least in the British sector of Atlantic rift-related uplift, was not as extensive as that of the common sedimentary rocks discussed in Question 1.5.

The overall lesson to be learned from this Activity, then, is that there is not a simple correlation between uplift and erosion, and the drawdown of CO_2 from the atmosphere. So when considering the relationship, it is necessary to take careful account of the rock types involved. Indeed, in most circumstances it probably requires considerable, even mountain-scale uplift to expose the sorts of silicate-rich rocks that might make a serious contribution to CO_2 drawdown.