scattered plant remains, which evidently represents riverborne sandbanks, this suggesting that the higher land bordering the delta flats had been uplifted leading to more rapid erosion. As the impetus of this uplift died away the sand became finer and eventually swamp forest again spread over the delta, giving rise to another coal seam. Usually beneath the coal seam is a bed called the seat-earth, either clay, then called 'fire-clay', or sandstone, then called 'ganister'; this bed is the soil in which the coal plants grew and their roots are characteristically found in it. Seat-earth has had many of the fluxing materials, such as alkalis, removed by the plants and is therefore relatively infusible; this makes it valuable for manufacture of fire-bricks and furnace linings.

Such a rhythmic unit of sedimentation is called a *cyclothem* and the Coal Measures are essentially composed of such cyclothems scores of times repeated. Note that only a very small part of the Coal Measures is actually coal; and even so the plant debris was in some cases removed by erosion before the overlying shale was deposited, so that the same rhythms of sedimentation may be found but with practically no coal seams at all; this is the case with much of the widespread Coal Measures of Ireland and the uppermost parts of the Coal Measures of England and Wales. Likewise in many cyclothems the marine episode is missing.

Chapter 8 *Map: Fig. 14*

The Armorican Mountain-building

As mentioned above, the highest parts of the Coal Measures in most of the British coal fields are barren of coal; the beds here are usually red sandstones and red shales, with some conglomerates, hence the miners' term 'Barren Red Beds' for these horizons. In the Midland coal fields these pass up into really coarse conglomerates and breccias. Another important point is that marine bands cease to occur about halfway up the Coal Measures. All these facts point to increasing uplift of the British area, with uplands which had been subject to tropical weathering (to give the red colouring) undergoing increasingly rapid erosion. The next beds that can be dated are of Upper Permian age and rest with violent unconformity on the Carboniferous.

All these phenomena are due to the occurrence of another major period of mountain-building, the Armorican (or Hercynian) orogeny, similar in scale to the Caledonian. These folding movements began in the south of Europe well back in Carboniferous times but the main phase reached southern Britain towards the end of the Upper Carboniferous. The southern geosyncline was obliterated and transformed into a folded mountain chain stretching across what is now southern Ireland, southern England and Brittany. The Devonian and Carboniferous sediments in Devon and Cornwall show complex structures, including intense isoclinal folding, well seen on the coast near Bude, and major northward thrusting. Most of the shales have been metamorphosed to slate. The shelf-sea rocks on the margin show similar, but less intense, structures, as in the northwardly thrust anticlines of

the Mendip Hills and of the south coast of Wales, especially in Pembrokeshire. These structures plunge eastwards beneath the younger rocks of south-east England, where they are undoubtably present at depth.

The general effect was to produce folding along approximately east-west trends in the area of the Upper Palaeozoic geosyncline and its immediate northern margins (Fig. 13). Further north this period of tectonic movement produced broader, more open folds, some approximately east-west or NE–SW, like the Rossendale and Bowland folds of Lancashire, but also some important ones with a north-south trend. Examples of these are the Pennine Anticline, between Lancashire and Yorkshire, and the associated Derbyshire Dome; and the Malvern Hills with their associated north-south folds. There is clear evidence that some of the north-south folds, at least those of the Malvern area, were formed about halfway through Coal Measure times as an early folding phase, before the main phase with its east-west folds had begun.

One important result of these two directions taken by the Armorican folds is the breaking up of the uniform sheet of Coal Measures into the separate coal fields seen today, all of which are, broadly speaking, down-warped syncline-type Armorican structures.

The Armorican orogeny, like the Caledonian, was closely followed by the intrusion, among the folded sediments, of granites—those of Dartmoor, Bodmin Moor and the other granites of Cornwall down to Lands End and the Scilly Islands. Associated with the granites was an important phase of mineralization, when the tin and copper deposits of Cornwall and Devon were formed; and most of the lead and zinc veins found in the Carboniferous Limestone (as in the Mendips, Derbyshire and Cumberland) also date from this period.

Chapter 9 *Map: Fig. 15*

The Permo-Triassic Desert Environment

IT is usually difficult to separate clearly the Permian system from the Triassic in Britain. The Permian is regarded as the last period of the Upper Palaeozoic era and the Triassic as the first of the Mesozoic era because of a considerable difference in the fossil faunas seen where these periods are represented by fully marine strata; the Permian fauna is broadly reminiscent of the Carboniferous, while the Triassic fauna is in many respects a foretaste of the Jurassic. In Britain both periods are almost everywhere represented by non-marine and poorly fossiliferous deposits; even where marine Permian occurs it has a restricted and not very typical fauna. Hence both periods are often lumped together as the *New Red Sandstone*—the group of dominantly non-marine strata coming above the Carboniferous just as the Old Red Sandstone is the group of dominantly non-marine strata coming below it.

This treatment emphasizes the similarity between the Old and the New Red