

## Excursion 4

# Mass Death in Fife

**TIME:** Late Devonian.

**LOCATION:** Dura Den, Fife.

**OBJECTIVES:** To examine the deposits of rivers and sand dunes, and find the cause of a mass kill of fish.

**THE MODERN EVIDENCE:** The sandstones with many crowded fossil fish discovered at Dura Den in Fife in the nineteenth century.

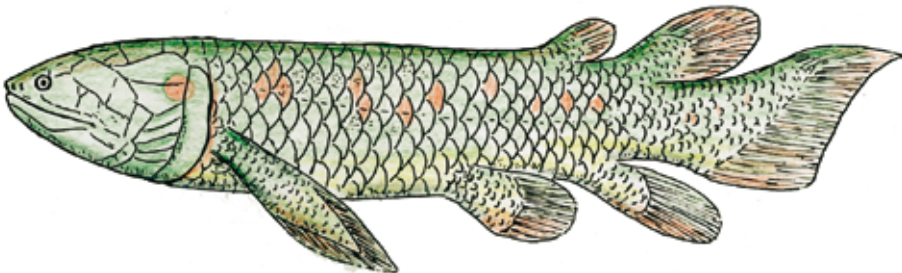
‘Accidental death’ or ‘death by misadventure’ is the likely verdict in court for the animals entombed at many famous fossil sites. Dura Den in Fife is no exception. Fossil fish had been recorded from this area from 1830, and they had been figured by Louis Agassiz in his famous monograph on *Poissons Fossiles du Vieux Grés Rouge* published in 1844. Illustrious geologists of the day took the trouble to examine the fossiliferous sandstones at Dura Den. Charles Lyell, author of *Principles of Geology* visited the area in the company of John Anderson in 1842, and Hugh Miller, author of *The Old Red Sandstone*, also paid a call.

On 16 September 1858, however, the most sensational finds began, when Sir Roderick Murchison, John Anderson, Lord and Lady Kinnaird and a ‘distinguished party from Rossie Priory’ discovered a complete *Holoptychius* one metre long, together with many smaller specimens. Anderson, in his 1859 monograph on Dura Den, also recorded that the landowner subsequently cleared an area from which nearly a thousand fish were ‘lifted from their stony bed of ages’ (Figs 4.1, 4.2 and 4.3). Anderson dedicated his monograph to Lord Kinnaird and Sir Roderick Murchison, and Lady Kinnaird drew the originals of some of the plates, but they are more artistic impressions than anatomically correct drawings.

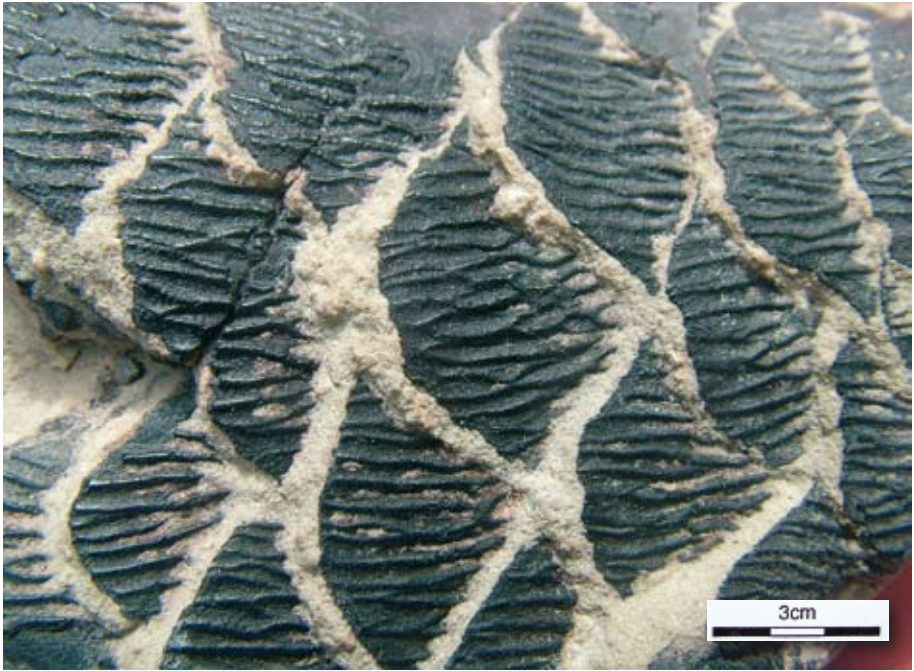
Twenty-four years before the finding of the *Holoptychius* bed, and fifteen metres higher in the rock section, a bedding surface had been identified bearing the remains of creatures of a distinctly problematical nature at the time of discovery. They looked like armoured boxes, covered by bony plates with a distinctive wrinkled ornament. The head, also encased in bony plates, had a single oval



**Fig 4.1** Specimens of *Holoptychius* crowded together in a block of sandstone from Dura Den, Fife. Specimen in St Andrews University Collection. (Photograph courtesy of Stuart Allison.)



**Fig 4.2** Reconstruction of *Holoptychius*.



**Fig 4.3** Detail of characteristic ornament of *Holoptychius* scales in a specimen from Dura Den. Individual scales are 30mm in diameter.

opening like a cyclopean eye gazing upwards, but even more extraordinary were the two sickle-shaped arms attached either side at the front of the body. Rather poorly preserved was the part of the animal that gave the game away; a scaly tail with dorsal and caudal fins emerged from the rear of the armoured body, proving wrong those who considered it to be a crustacean. Underneath the head, weak jaws surrounded an opening that had to be the mouth.

Here was a fish the like of which does not exist today. *Bothriolepis* is now its name, but it was called *Pamphractus* or *Pterichthys* in 1859. In general body plan it clearly resembles *Pterichthyodes*, the ‘winged fish’ of Hugh Miller. The 1858 discovery was more spectacular than the *Bothriolepis* bed. Here the fossil fish were found crowded together on a sandstone bedding plane; the commonest fish was *Holoptychius*, a lobe-finned fish with large sculptured scales and strong jaws with pointed conical teeth—clearly of predatory habit. Along with the *Holoptychius* were other types of fish: a lung fish, *Phaneropleuron*, distantly related to the surviving lung fish species in South America, Africa and Australia. There was also *Eusthenopteron*, a famous fish from the zoological standpoint. Within the lobe fins of this fish there was a skeleton with bony elements arranged in a similar manner to the bones in the limbs of later tetrapods—four-legged animals that walked on

land. Although arguments persist on the details, *Eusthenopteron* is clearly very close to the ancestral line of land-dwelling tetrapods. The most famous and best-preserved examples of *Eusthenopteron* came from lake deposits of similar age at Escuminac Bay in Canada, where they can be seen displayed in the excellent Miguasha Museum. Go there if possible.

The surviving relative of this group of fish, known as the crossopterygians, is the coelacanth *Latimeria*, the ‘living fossil’ discovered off South Africa in 1938. *Latimeria* is probably the last survivor of the coelacanths, a group of fish first recorded in the mid Devonian.

Slabs of the Dura Den fish beds are preserved in several museums including The Natural History Museum in London and The National Museum of Scotland. There are also two rather sad slabs at Aberdeen University, which were formerly mounted in the wall of the teaching lab in Marischal College either side of a small ichthyosaur from the Jurassic. The slabs suffered an act of vandalism some time prior to 1967 when the then professor (a mineralogist) ordered the laboratory attendant to clean the lab, and give the wall-mounted specimens a good scrub to remove the chalk dust and grime that inevitably accumulated in a teaching lab in the chalk-and-duster era. The attendant went to work with great zeal, but unfortunately used a wire brush in an attempt to remove the black bits and reveal the yellow sandstone. The black bits, of course, were the fish scales. Despite the damage the slabs clearly show that the fish are in part preserved in 3D, the round body shapes being partly filled with sand. To achieve this preservation the fish carcass must have dried out to a state hard enough to have allowed sand to enter the cavity within the carcass after the flesh had rotted away.

In the sequence of sandstones at Dura Den there are several levels with desiccation cracks—evidence that there had been water present, but that it had dried up through evaporation. Also within the section are sandstones of fine grain size with the grains well sorted. These are sands sorted by the wind as they were blown across a land surface. Thus we have evidence of fish dying in large numbers in an area where water was apparently only intermittently present.

The fossil fish of Dura Den occur within rocks of the Upper Old Red Sandstone of the Midland Valley of Scotland, and were deposited following a period of erosion that took place in the mid Devonian. Whilst Lake Orcadie was in existence in the north of Scotland, and the Caithness flagstones were being deposited, the Midland Valley was suffering lateral compression. Consequently the rocks of the Lower Old Red Sandstone were folded, faulted, uplifted and subjected to considerable erosion before the start of Upper Old Red Sandstone deposition.

The Upper Old Red sandstones were therefore deposited on an eroded surface of folded and faulted Lower Old Red and older strata. The unconformity between the two can be seen in the cliffs at Arbroath. Coarse-grained sandstones and conglomerates, representing the gravels of alluvial fans, accumulated where rivers dropped their loads of transported debris at valley margins. Broad alluvial plains built up in valleys as the old land surface with its topography of hills was drowned by the accumulating sediment. A large river flowed through the Midland Valley towards the North Sea, depositing its load in the form of large river sand bars. From the size of these sand bars we know that the river channel was at times about ten metres deep—clearly a substantial river system well supplied with water, possibly gathered from a distant mountain source. Within the drainage catchment of the river there was sufficient rainfall to supply the river and maintain a flow.

On the other hand there is evidence of dry, semi-arid conditions. Fossil soil profiles indicate that evaporation was greater than precipitation at the site of formation of the soil. These are caliche soils, with nodules of calcium carbonate and even laminated carbonate crusts. Such soils are found today in semi-arid regions of Australia, Africa and the Indus Valley. There really is no conflict here. The water in the river was derived from a distant source and flowed through an area with a local semi-arid climate.

Thus the Upper Old Red Sandstone deposits started with deposits of rivers and alluvial fans where water was brought to an area with a semi-arid climate. For a modern example of such a situation, we need to look at the Nile, sourced in the highlands of Africa and flowing through arid desert to the Mediterranean.

As time went by in the late Devonian the climate of Scotland progressively changed, becoming more equatorial and with increased rainfall. At the same time the sea was flooding Britain from an ocean to the south and extensive shallow shelf seas were being created where there had been land before. The great sandy outwash plains of Old Red Sandstone in south Wales and Ireland were inundated by the sea, which by early Carboniferous times reached the Midland Valley of Scotland.

This was not a gradual one-way flooding, like the filling of a bath, but a pulsed process with successive periods of marine advance working their way farther and farther from the open deep ocean to the south. The sea advanced and retreated many times, responding to an external control. Many consider that long-term climatic variations, climatic cycles, were led by the regular periodicity of the orbits of the Earth, Moon and Sun system. This climate control is known as Milankovitch cyclicity with periodicities of around 20,000, 40,000, 100,000 and

410,000 years. The reason for mentioning this again is to stress that climatic variations on Earth are dramatic and geologically very rapid. The most recent Ice Age ended only about 12,000 years ago. Note that ‘most recent’ is not necessarily the same as ‘the last’.

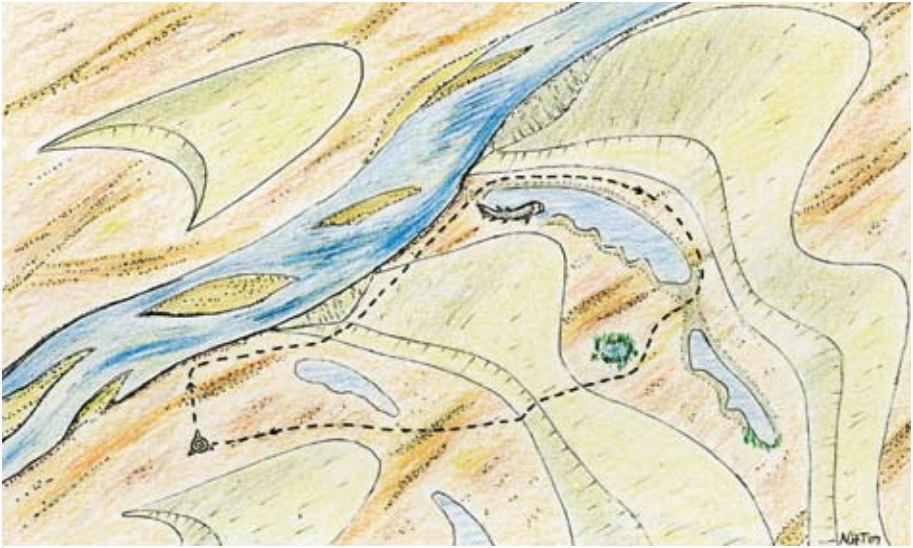
Armed with this evidence, part fact and part interpretation, I was in a position to visit the Kingdom of Fife some time in the late Devonian just prior to the incursion of the Carboniferous seas from the south.

As the Bus tracked back in time there were excellent views of times of uplift and erosion of the Scottish Midland Valley. The Bus took me back to the early Devonian, and I watched the changes in the landscape below from a height where the whole of the eastern end of the Midland Valley was in view. Surprisingly the uplift period that resulted in the unconformity between Lower and Upper Old Red Sandstone could be tied down to only a few million years of rapid tectonic activity. The uplift was followed by a long period of erosion before subsidence started and the deposition of the Upper Old Red began. Faults that were active and clearly visible ten million years before were now inactive and blanketed with sediment.

My plan had been to accurately monitor the marine transgressions and regressions that took place in the early Carboniferous and trace shoreline positions at times of maximum inundation of the land by the sea. However, while the Bus took me through the late Devonian, which was still supposed by many to be a boring time of semi-arid climate, there were great variations in the amount of greenery and water in the general scene. This looked too interesting to ignore; there seemed to be clear climatic variations prior to the time the Carboniferous seas reached Scotland. Since the Upper Old Red Sandstone was usually considered to have been deposited in a semi-arid climate, it would be good to take the Bus down for a closer look at the land when there were flowing rivers and patches of greenery. However, there were still large areas of brown sand without obvious sign of vegetation. I chose a landing site on a flat area not far from a river channel (Fig 4.4).

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Dust from the dry surface enveloped the Bus as it came to rest. As it gradually settled and drifted away on the breeze I found myself on a flat river plain with sparse low vegetation, much of which appeared to be well dried. The heat hit me as I stepped on to the surface—33°C was registering and visibility was poor due to dust and heat haze. It was the sort of scene in which a large red kangaroo would not have seemed out of place. The soil was sandy, but the surface hard and



**Fig 4.4** Route of Excursion 4 in a landscape of sand dunes, rivers and sandy outwash areas at Dura Den.

crusty; fragments of cemented sand were scattered on the surface and sheltered small drifts of sand blown by the wind. I was walking on a typical caliche type of soil, and conditions looked as arid as central Australia.

A further similarity with Australia was the sand dunes. They were crescent-shaped, generally less than ten metres high with their slip faces to the west. Thus the wind that formed them generally came from the east. The dunes merged in places to give long sinuous crest lines. The mobile dune sand was a pale yellow colour, contrasting with the more orange to redder colours of the soil surface.

I walked away from the Bus towards the river; this was clearly a major channel system and a complex of channels and sand bars stretched away into the distance. The channels individually were up to 100 metres wide, and there was a steady flow of water with a pale brown tinge. The river was flowing to the east. It was only possible to guess the depths of the channels, but judging from the sides of the exposed sand bars and the steep banks together with the steady swirl in the water, the water could well be more than two metres deep. It was certainly too dangerous to start wading, since the river bed was concealed by the murky water.

Wandering downstream I explored some of the sand bars that were attached to the main bank. It was obvious that the water level had been falling, since there were ripples on the bar surfaces and a series of terraces around the bars recording the falling water levels. Judging from the banks, the level had recently been almost a metre higher—this was a river subject to floods. There was no sign that

the weather had been wet in the area I was inspecting, so this river fluctuation must reflect variable rains much higher upstream, in mountainous areas feeding this great river.

Continuing downstream, my path was interrupted by a sand dune that had migrated to the river's edge, the slip face falling direct into the river, which swept the sand back downstream. The sand was being washed down the river, deposited on sand bars and river banks, and then blown back up the sloping alluvial plains in the form of sand dunes. It was an easy matter to climb the dune face and peer over the crest. Here was a rather different scene: several shallow stagnant pools lay between this dune and the next. The pools were shrinking, for at the margins were patches of dried and curled mud, but there was something else that grabbed my attention.

It smelt awful. The stench came on a gentle but hot breeze and caused instant retching. Rotten fish, very rotten fish. The smell was the same in the Devonian as in modern times—quite unmistakable. Along the edge of the pool hundreds, if not thousands of carcasses lay in groups, often in shallow depressions, packed closely together, rotting and drying under a hot Devonian sun. Because of the stink, the fish carcasses had to be examined from upwind, so a brisk walk to the far end of the pool was essential.

From my new vantage point breathing was more pleasant, and the cause of this mass death became apparent. The pools lay in hollows between the sand dunes, and the water had come from the recent river flood which had broken through into the low area and flooded the hollows between the dunes. The fish had maybe sought shelter in this calmer, less sediment-laden water during a recent flood, but had failed to escape back to the river channel as the water level fell. The escape route had been blocked by wind-blown sand; maybe a gale from the east had blown sand into the narrow flood channel faster than the water flow could transport it away, and as the water fell the ponds became cut off from the river channels.

The fish were then doomed, and as the floodwaters fell further the water table lowered, the ponds dried out and the fish died. They lay in various states of decay, but generally with mouths open as if in a last gasp for air, and the bony scales supported the carcasses which dried in a semi-mummified form in the sand. In some cases the body cavities had burst open, the flesh was dried and shrunk, and the sand had trickled into every cavity of the dead fish and gently enclosed delicate dried fins. Indeed, along the margins of the pool wind-blown sand was gradually covering the whole of this scene of carnage.

In remaining puddles there was still some life, as fish gasped air at the surface; these were lung fish, hoping for a miracle of another flood, but still with a trick to try. Where the sand was soft and wet some fish were thrashing about in efforts to burrow into the sediment. When fully buried they would curl up, secrete a membrane around themselves, and enter a state of aestivation, a form of suspended animation, the body functions slowing to a virtual but not complete stop. In this state they could survive for up to a year, emerging when the pool was next flooded. There was surprisingly little evidence for any scavenging of this great mass of organic material; it seemed that few animals ventured out of the wet areas in this hot climate.

Such mass mortalities of fish are a common feature of arid areas. An example from Lake Eyre in central Australia was mentioned in Excursion 3: in that case fish were swept into the lake with floodwater from a distant source, and flourished briefly before being killed, possibly by rising salinity, as the lake dried out. Another modern fish mass mortality was seen by my Aberdeen University colleague Adrian Hartley in Namibia, where a coastal lagoon was lined with dead fish drying in the sun (Fig 4.5). There was no outlet, and the fish had been trapped. Blown sand was gradually covering the carcasses, as had happened at Dura Den. The only difference was that the Namibian fish had been partly scavenged by birds. Such events might be fairly common, but the chance of preservation in the fossil



**Fig 4.5** Dead fish at the sandy margin of a coastal lagoon in Namibia. (Photograph courtesy of Adrian Hartley.)

record is very low, and such mass mortalities of fish preserved in sandstone are very rare indeed.

The surfaces of the sand dunes were bereft of signs of life; there was no evidence of burrowing animals and no tracks of arthropods or early terrestrial vertebrates. Yet there should be life, so where was it? It seemed that the shifting sands did not allow stable environments for terrestrial life to thrive and develop. Maybe seasonality or overall aridity of the climate was to blame, but there just did not seem to be a population of scavengers to clear up the mess. Later in time there would be amphibians, reptiles, birds and mammals to consume and disturb the carcasses, but here in the late Devonian they just remained, dried but entire, until covered by blowing sand.

I had seen enough and time was nearly up—the heat and aroma were incentives enough to return to the comfort of the Bus. As I trudged back, trying to avoid the soft dune sand where walking was more of an effort, I found some more permanently damp hollows in which there was some vegetation, and from the vegetation I flushed a few animals including a very cross and fast centipede. Since it had big fangs, it was a carnivore, so there had to be some prey about. All the animals were probably hiding in burrows and under stones, as happens in semi-arid areas today. There was also more dead vegetation than I had noted before, and searching and a bit of digging did reveal burrows in the surface over which the mobile dunes were migrating. I had arrived in the hot season; maybe the desert floor came alive with plants in cooler times. Maybe if I had returned after dark, with a torch, I would have found a variety of arthropods such as scorpions that emerged in cooler conditions, but for the moment I was the mad dog out in the heat of the noonday sun. I had had enough of the heat.

Once safely back on the Bus, I pondered on the likely scene when the fish of Dura Den died, and were subsequently buried and preserved. Chemical conditions in the sandstone allowed the preservation of the phosphate in their bony scales, and the sand grains of the Devonian dunes and the river had become cemented together to form sandstone during burial. Hundreds of metres of Upper Old Red Sandstone sediments accumulated during gradual subsidence of this part of Fife. A few million years later Carboniferous seas flooded the area and more sediment accumulated until the fish of Dura Den were buried two or three kilometres below the surface. It was at this depth that sand turned to sandstone.

After being buried for some 360 million years, and surviving periods of folding, faulting and uplift of the rocks, the Dura Den fish have come full circle, back to the surface, but now in an area of land where erosion is taking place. But it had to

be man, in the form of a quarry worker, who, in pursuit of building stone, split a block of sandstone and revealed the marvels of the Dura Den fish to the Victorian world of scientific curiosity and enquiry.

Sadly there are no quarries working the sandstones today, and the chance of finding another great mass-mortality bed of Devonian fish in this area is consequently remote. Others probably exist, hidden beneath grass, soil and rock. Maybe the cutting of a new road or a deep pipeline trench will one day reveal a new Dura Den.