East Kirkton, Lothian

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Introduction

The East Kirkton site, near Bathgate in West Lothian is a disused limestone quarry some 27 km west of Edinburgh (Figure 3.9) where Lower Carboniferous limestones have been worked as a building stone since the 19th century (Rolfe *et al.,* 1994). Some plant and invertebrate fossils were recovered from here during the latter part of the 19th century but it was not until the 1980s and the pioneering excavations of Mr S.P. Wood, a professional fossil collector, that the true fossil riches of these strata were revealed. Since then, intensive collecting by international experts has uncovered a remarkably well-preserved terrestrial fauna and flora that offers unique insights into an early Carboniferous (Upper Viséan, Brigantian) age freshwater lake ecosystem, some 328 million years old. The fossils include a primitive reptile-like tetrapod, some of the earliest-known tern-nospondyl amphibians, fishes and a variety of arthropods which are the main concern here namely eurypterids, myriapods, scorpions and the earliest-known harvestman (opilionid).

It was the discovery at East Kirkton in 1984 of the almost complete and articulated skeleton of reptile-like tetrapod *Westlothiana lizziae* (Smithson and Rolfe, 1991) by Mr S.P. Wood that prompted a detailed investigation of the strata in and around this quarry. At the time it was thought that *Westlothiana* was perhaps one of the oldest known true amniotes and this generated a great deal of interest in the fossil potential of the site. From 1987 systematic investigation of the site was carried out under the auspices of the National Museums of Scotland and the results were published in a special volume by the Royal Society of Edinburgh (Rolfe *et al* 1994).

Description

The East Kirkton Limestone lies at the top of the West Lothian Oil Shale Formation and within the quarry site there is a highly variable and well-stratified succession of shales and tuffs overlying a distinctively laminated sequence of thin cherty limestones and underlain by further shales and tuffs, altogether some 15 m of strata. The succession of carbonate laminites and volcaniclastic lithologies has been logged and extensively sampled with the identification of some 88 separate lithological units (Whyte, 1994).

The exposed 11m thick East Kirkton Limestone sequence consists, in ascending order, of calcareous tuffs (Units 88–83), an important tetrapod-bearing black shale (Unit 82), laminated cherty beds (Units 81–76), massive spherulitic limestones (Units 75–4), a series of intermediate beds (Units 73–70) then the characteristic laminated spherulitic limestones of East Kirkton (Units 69–36). Tuffs are present throughout the succession, but are especially abundant between units 76 and 72. The overlying strata are some 4 m thick of which the lower part consists of the 2m thick Little Cliff Shale (Units 36–32) and terminates with the overlying Geikie Tuff (4 m thick, Units 31–1), capped with a 2 m thick basalt lava.

Typically, the East Kirkton Limestone is a carbonate-organic laminite in which radially fibrous calcite spherules are abundant at many levels. In addition there are larger stromatolite-like accretions of laminated botryoidal radially fibrous calcite (RFC). The common inclusion of cyanophyte and chlorophyte remains within the RFC indicates a close association in the development of the RFC with microbial cyanophyte mats that spread over the sediment substrate and in some instances they may have been contemporaneous (Walkden *et al.,* 1993). The larger bortyoidal accretions often enclose elements of the micro- and meio-fauna. Stable isotopes from the calcite are similar to those of present-day freshwater precipitates and whereas precipitation may have been microbiologically mediated, the spherules and botroids are regarded as passive lake-floor cements.

The siliceous 'cherty' laminae of Units 80–79 have also been analysed in detail (McGill *et al.*, 1993) using stable isotopes. Oxygen isotopes show that the silica was deposted from meteoric water at a temperature of around 60°C. This is consistent with Geikie's claim (1861) that the silical laminae are a primary feature and result from hot-spring influence in a lake-type environment.

The tuffs are all of basaltic origin and may have been debris flows with perhaps some lahars but they have all been re-deposited. None are air-fall tuffs and so their presence does not necessarily indicate active volcanicity during deposition of the succession.

The East Kirkton Limestone is the lowest of five carbonate sequences within the Bathgate Hills Volcanic Formation and can be correlated with the Hopetoun Member of the West Lothian Oil-Shale Formation. Indeed a black shale near the base of the limestone sequence at East Kirkton has been found to be kerogenous with a high hydrocarbon-yield exceeding that of some of the Lothian Oil Shales. The succession correlates with the lower part of the Brigantian Stage at the top of the Viséan Series of the Lower Carboniferous strata.

Palaeontology

An extensive flora and fauna was recovered in the 1980s during intensive collecting by teams of experts. Most publicity has been attached to the discovery of the new terrestrial vertebrates which apart from the reptiliomorphs such as *Westlothiana* (Smithson *et al.,* 1993), *Silvanerpeton* (Clack, 1993) and *Eldeceeon* (Smithson, 1993) includes some important new specimens of some of the earliest temnospondyl amphibians known, especially *Balanerpeton* (Milner and Sequeira, 1993), which is known from more than 30 complete or nearly complete specimens. In addition, numerous acanthodian and actinopterygian fish together with some hybodont sharks have been found (Coates, 1994) and also a diversity of invertebrate and plant fossils.

Different groups of the fossil biota tend to have particular distributions within the overall sequence although plant and arthropod material does tend to occur throughout. Even so plants are most common within certain units (see Scott *et al.,* 1994, for details). The lower part of the succession (Units 88–72) is dominated by the transported remains of arborescent gymnosperms that grew in warm, fairly dry conditions. The presence of charcoal at certain levels is indicative of a prevalence of periodic forest fire, especially in the lower part of the East Kirkton Limestone (Units 88–81). Higher up Units 51–39 are dominated by pteridosperm fronds and small fern leaves that were perhaps transported further into the lake environment. The plants of the overlying Little Cliff Shale show a dramatic change to a lycopod flora adapted to rooting in permanently damp soils and may reflect the onset of wetter climate conditions.

Tetrapod and fish fossils have been found within the Little Cliff Shale (Units 38–26) and the fish predominate in the upper part reflecting a passage from terrestrial to aquatic environments Tetrapods have also been found in the East Kirkton Limestone lower in the sequence (Units 82–70), especially in the black shale Unit 82.

Ostracods have been found sporadically throughout the East Kirkton Limestone and tend to occur in monospecific swarms, for example *Carbonita* sp., which were bottom-dwelling primary consumers that fed on the lake-floor microflora. In addition, poorly preserved bivalves have been found within the Little Cliff Shale.

Of most concern here is the remarkable and diverse arthropod fauna of eurypterids, scorpions, myriapods and a single important specimen of a harvestman (opiolinid), the oldest known fossil representative of this group.

Eurypterids

Unfortunately, the horizon that, in the 19th century, provided the spectacular large three-dimensional specimens of *Hibbertopterus* (originally referred to in the Scots vernacular as 'Scouler's heids') has not yet been relocated. *Hibbertopterus scouleri* (Hibbert, 1836) was the first animal fossil to be described from East Kirkton and was the first-known British eurypterid to be found and described, although it was not initially recognized as such since eurypterids as a distinct group of extinct arthropods were only recognized in 1825 in America.

However, plenty of flattened and fragmentary eurypterid material has been found recently and from this the remains of another two genera of hibbertopteroids, *Dunsopterus* and *Cyrtoctenus,* have been identified. Nevertheless, nearly all the identifiable material from East Kirkton is attributable to *Hibbertopterus scouleri.*

Typically hibbertopteroids are short-bodied eurypterids with a large, domed prosomal shield (carapace) and with specialized food-gathering structures on the second, third and fourth pairs of prosomal appendages. New material from

East Kirkton revealed that the posterior legs and telson of *Hibbertopterus scouleri* more closely resemble those of cyrtoctenids than previously thought. This observation has prompted Jeram and Selden (1994) to postulate that *Hibbertopterus, Dunseropterus* and *Cyrtoctenus* are separate growth morphologies of a single species. A new investigation of the supposed giant spider *Megarachne,* from the uppermost Carboniferous strata of Argentina showed that this animal was also a large eurypterid related tothe hibbertopteroids (Selden *et al.,* 2005), specifically confamilial with *Woodwardopterus scabrosus* of Glencartholm (see GCR site report). When comparing *Megarachne* with *Hibberttopterus,* Selden *et al.* (2005) noted that the supposed genital plate beneath the meta-stoma in one specimen of *Hibbertopterus* figure by Waterston (1957), which resembles a similar plate seen on the ventral surface of *Megarachne,* could represent fused coxae VI. Thus the eurypterids of East Kirkton are an important component of the worldwide fauna of bizarre, giant eurpterids of Carboniferous times.

Scorpions

Articulated scorpion specimens are rare at East Kirkton, most of the scorpion fossil material consists of fragmentary cuticle. But when isolated from the matrix, the cuticle is beautifully preserved, better than any other Carboniferous material and has allowed the fauna to be described in considerable detail (Jeram, 1994). The most common scorpion at East Kirkton is *Pulmonoscorpius kirktonensis* and it is the oldest scorpion that is known to have been fully terrestrial.

The discovery of some exceptionally well preserved material here has allowed Jeram and Selden (1994) to identify the presence of true book-lungs in this genus. Book-lungs are an essential adaptation for land living and the intake of oxygen directly from air. Although most of the known specimens from East Kirkton are tiny juveniles there are rare larger individuals including a probable adult with the considerable maximum length of around 70 cm, much larger than any living scorpions, this extinct giant genus has been interpreted as a fully terrestrial top carnivore of the forest and lake-shore. With large lateral compound eyes, vision may have played a significant role in prey capture and it probably hunted by day, compared with nocturnal hunting typical of modern scorpions. The gigantism of this Carboniferous scorpion may have been due to the lack of even larger tetrapod predators and/or the more oxygen-rich Carboniferous atmosphere.

Myriapods

Fossil myriapods are uncommon at East Kirkton and what few specimens that have been recovered are not particularly well preserved but are nevertheless palaeontologically important as shown by Shear (1994. One of them, a millipede, preserves the oldest known ozopores (openings of repugnatorial glands) and spiracles, thus providing unequivocal evidence of a fully terrestrial mode of life.

The fossils were found in Unit 47 of the East Kirkton Limestone and represent at least three ecomorphotypes that were specialized for different forest microhabitats. One 'bull-dozed' its way through the litter of the forest floor, another's body has lateral knobs that enabled it to traverse through tunnels.

The fossil record of myriapods extends back at least into Silurian times and perhaps much earlier as suggested from trace-fossil evidence (Wilson and Anderson, 2004) making them some of the earliest known terrestrial arthropods. However, there is a significant gap of some 60 million years in the post-Devonian record until these East Kirkton fossils, which are the oldest known from Carboniferous times.

Opilionid

A remarkably modern-looking opilionid (harvestman) from the East Kikton Lagerstätte was reported by Wood *et al.* (1985), and formally described by Dunlop and Anderson (2005) as *Brigantibunum listoni.* Opiliones branched relatively early in their history into the modern clades; the earliest described harvestman is from the Early Devonian Rhynie Chert (see GCR site report), and this animal shows affinities to the modern Euponi clade. *Brigantibunum* was also provisionally assigned to Eupnoi by Dunlop and Anderson (2005). Thus, the East Kirkton harvestman adds evidence to the theory that the crown-group taxa of Opiliones evolved earlier than those of other arachnids, and that harvestmen are possibly fairly basal within the Arachnida (Giribet *et al.,* 2002).

Interpretation

The East Kirkton deposits have been interpreted as those of a predominantly shallow freshwater-lake basin, spasmodic ash falls and occasional marine incursions. The depositional environment was situated dose to the West Lothian volcanic centre and may have extended from West Lothian to the Glasgow district either as a single water body (sometimes referred to as 'Loch Baldernock', Whyte, 1994, p.245) in a region that lay within a humid tropical climate regime. The water body may have resulted from thedevelopment of volcanic activity impacting upon the local palaeogeography.

Whyte (1994, p. 246) pointed out that the environmental interpretation of the limestones as deposits in freshwater has been largely based on the lack of marine fossils and the presence of terrestrial fossils. However, many of the aquatic fossils belong to groups that can tolerate brackish conditions such as the ostracods, spirorbids and fishes.

The rich terrestrial flora and fauna is remarkably well preserved and offers a unique view of an early Carboniferous ecosystem in a volcanic setting with a wet tropical climate. Apart from the internationally important tetrapods and abundant fish and plant fossils, a variety of invertebrates have been recovered, largely arthropods such as harvestman 'spiders', millipedes, scorpions and large eurypterids.

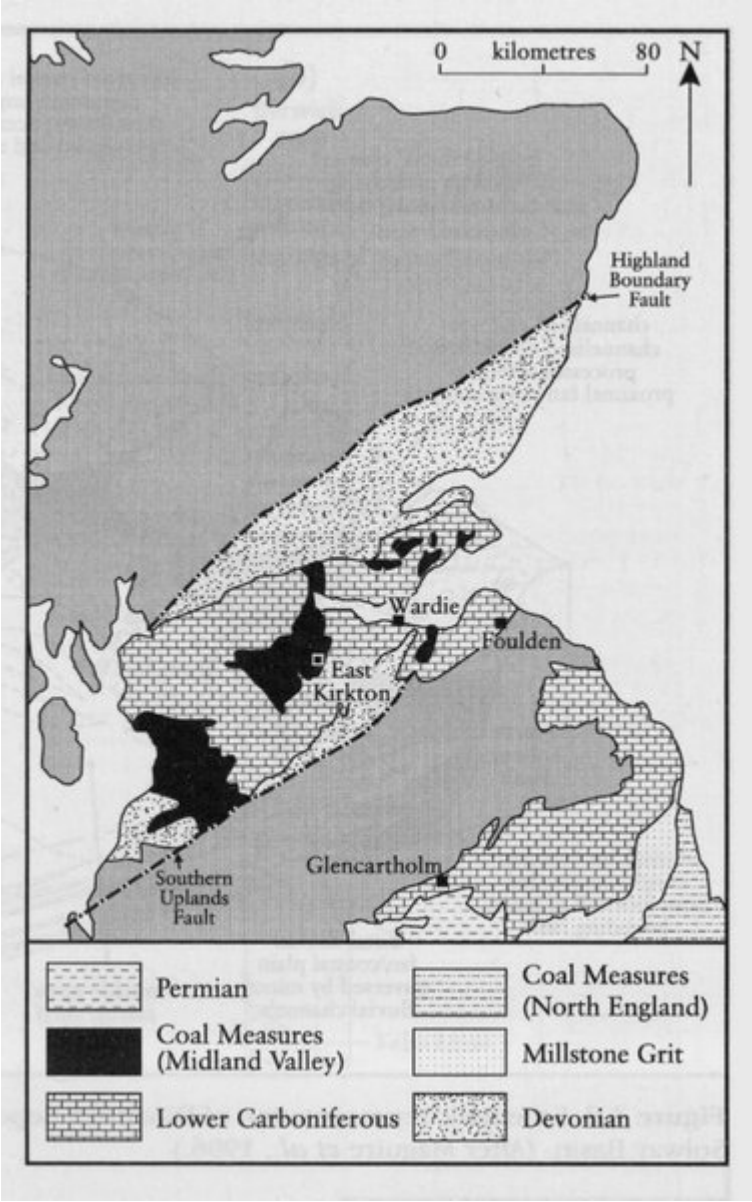
Whereas the tetrapods may have been dependent on aquatic food sources, the aistopod amphibian may have occupied a terrestrial niche comparable to that of some recent snakes, living within the plant litter or even burrowing in the soil. Its few large teeth suggest that it preyed on organisms almost as large as the gape of its own jaws. These prey would have almost certainly included arthropods and small or larval tetrapods.

A gymnosperm–pteridosperm dominated forest surrounded the water body for much of its existence and would have supported a diversity of terrestrial organisms. Some at least of these have been preserved in the lake bed sediments and some of them may have been driven into the lake environment during forest fires, especially the large scorpions and millipedes. The amphibious hibbertopterid eurypterids must have occupied the lake at those times when the lake waters supported sufficient organisms for a food chain to be established.

Conclusion

This internationally important site has a unique and diverse biota which is exceptionally well preserved and has recently been studied in considerable detail by an international team of experts. The fossil arthropods have been shown to form an integral part of evolving land communities and early terrestrial environment with their mixture of terrestrial and aquatic deposits. There is the good potential for further excavation.

References



(Figure 3.9) Geological sketch map of southern Scotland and northern England with the positions of the Scottish Carboniferous GCR arthropod sites shown. Wardie is near to the Granton Shore GCR site.