East Kirkton, Bathgate

[NS 990 690]

Highlights

This Viséan lacustrine deposit in Lothian preserves the remains of a predominantly terrestrial biota, including seven kinds of amphibian, fishes and a wide range of terrestrial invertebrates and plants.

Introduction

The site is a disused limestone quarry, some 27 km west of Edinburgh (Figure 15.5), where the East Kirkton Limestone dips at about 18° NE. Although rare fossil invertebrates have been known from this locality since the late 19th century, it was during the excavations initiated by Mr S.P. Wood in 1985 that tetrapod fossils were discovered. The Limestone lies near the top of the West Lothian Oil Shale Formation. This is a highly variable succession of shale with thin cherry limestones, volcanic ash bands and rare coals and marine bands. The whole is well-stratified and indicates deposition in a dominantly freshwater lake basin with variable water depth and with continuing spasmodic ash falls. It is situated close by the West Lothian volcanic centre.

During the late 1980s a series of discoveries by S.P. Wood and others aroused great interest.

They included several fully land-going amphibians and the oldest known stem amniote which has reptile affinities (Gee, 1988; Smithson, 1989). Subsequently a systematic investigation of the site by the National Museums of Scotland team has resulted in a special volume on this locality (Rolfe *et al.,* 1994).

The East Kirkton quarry has now yielded a rich terrestrial flora and fauna, remarkably well preserved and offering a unique view of an early Carboniferous ecosystem in a volcanic setting and a tropical wet climatic regime. The preservation and taphonomy of this biota, dcscribcd by Rolfe *et al.* (1990), may be of a kind to be found elsewhere in the Midland Valley of Scotland.

Prior to the discovery of the East Kirkton amphibians, the principal tetrapod localities in the Scottish Carboniferous were in the lacustrine deposits at Cowdenbeath, Gilmerton and Loanhead (Smithson, 1985; Milner *et al.,* 1986).

Description

The section at East Kirkton has been dated as Brigantian, Upper Viséan, about 335 Ma in age. It has some 15 m of lacustrine limestones, shales, cherts and ash beds, deposited just south of the Carboniferous equator in a continental rift setting. Apart from the biota described so far, few fossils have been recorded (Rolfe *et al.,* 1994). The succession (Figure 15.6) has been extensively sampled and some 88 lithological units logged. The investigations have provided a remarkable suite of volcaniclastic lithologies and carbonate laminites (Rolfe *et al.,* 1990; Whyte, 1994). Plant fossils occur at many levels within the sequence as compressions, permineraliza-tions or as fusain charcoal.

The invertebrate fossils are largely arthropods such as harvestman 'spiders', millipedes, scorpions and large eurypterids (Rolfe, 1988; Clarkson *et al.,* 1994).

Fauna

Elasmobranchi: Hybodontoidea: Tristychiidae

Tristychius arcuatus Agassiz, 1837

Elasmobranchi: Xenacanthida

Diplodoselache woodi Dick, 1981

Acanthodii: Acanthodiformes: Acanthodidae

Acanthodes indet.

Climatiidae

gen. et sp. indet.

Actinopterygii: Actinopteri: Elonichthyidae:

Species C cf *?Elonichthys robinsoni* (scales)

Species E cf. *?Cosmoptychius* (scales)

Watsonichthys sp.

Species B Actinopterygian of no specified affinity

Species A cf. *?Rhadinichthys carinatus* (scales) Traquair, 1977

Species D *?Mesopoma* Traquair, 1890

Platysomida

Eurynotus sp.

Sarcopterygii: Rhizodontidae

Scales, gen. et sp. indet.

TETRAPODA

?Loxommatidae

gen. et sp. indet.

Temnospondyli:

Balanerpeton woodi Milner and Sequeira, 1994

Type specimen from this locality

Aistopoda

Ophiderpeton kirktonense Milner, 1994

Type specimen from this locality Anthracosauria *incertae sedis*

Eldeceeon rolfei Smithson, 1994

Silvanerpeton miripedes Clack, 1994

Type specimen from this locality

REPTILOMORPHA

Westlothiana lizziae Smithson *et al.,* 1994

Type specimen from this locality

The elasmobranchs come from units 32–37

(Paton, 1994). Spines of the xenacanth *Diplodoselache arcuatus* Agassiz, are from a fish 30–40 cm long, which may have been a versatile predator feeding upon invertebrates and small fishes. In units 26 and 36 occur small spines from small acanthodians. Units 26–38 have produced at least six actinopterygian taxa (Coates, 1994); two are probably juveniles of uncertain affinities. One is a deep-bodied species. The sarcopterygians are represented by large patches of rhizodont scales in unit 36.

The tetrapod fauna is impressive not only for the number of individuals and taxa present but also for the remarkable preservation. For example, over 30 complete or partial skeletons of the newly discovered temnospondyl amphibian *Balanerpeton woodi* have been found at East Kirkton (Milner and Sequeira, 1994). It is the commonest tetrapod in the assemblage and grew to about 50 cm in length. Superficially it is like the later genus *Dendrerpeton,* but has a more advanced structure of the skull (Figure 15.8) and (Figure 15.9). The lower jaw has fewer but larger teeth than the corresponding upper jaw. There have also been found two straight ribs from a much larger form, a probable second temnospondyl at East Kirkton. The tem-nospondyls are comprised of some 160 genera and are more numerous than all the other early non-amniote tetrapod groups combined.

In contrast, the aistopod *Ophiderpeton kirktonense* Milner, 1994 is amongst the rarest of the East Kirkton tetrapods (Figure 15.10). The holo-type is an articulated skull and anterior part of the trunk in counterpart blocks of shale from unit 82 of the section. Other material is partly disarticulated and very poorly preserved. Aistopods are a group of limbless vertebrates with very long bodies and short tails. They are clearly specialized with their snake-like form and terrestrial mode of life. They show no sign of having possessed a sensory lateral line system which is present in aquatic tetrapods. As many as 200 vertebrae may be present in the axial skeleton. The aistopod skull is highly derived with respect to the basic tetrapod pattern. There appears here to be a loss of bone so that in the extreme the skull is reduced to a set of struts articulating the lower jaw against the braincase. The maxillary dentition is of widely spaced sturdy pointed fangs. The lack of limbs and limb girdles adds to the difficulty of determining the relationship to the other tetrapods. Seven genera are known so far, allotted to three families and the group ranges from the Middle Viséan to the Permian in Eurasia (Milner, 1993b). In Britain their provenance is from the Scottish Viséan — the oldest being *Lethiscus stocki* Wellstead (1982) from the Wardie Shale — and from the Westphalian of Northumberland.

Anthracosaurids are represented by several new forms. *Silvanerpeton miripedes* is a small, gracile form, the holotype of which is an almost complete articulated specimen in black shale (Unit 82; (Figure 15.11)). A second specimen is the natural mould of the skull and anterior post-cranium. There are also some disarticulated large limb bones and vertebral elements. Clack's (1994) description of this material, amongst the earliest of the anthracosaurs, reveals it as very different from previously described early articulated anthracosaur remains, such as *Proterogyrinus* from the Upper Viséan of West Virginia. *Silvanerpeton* has the anthracosaur characters of tabular–parietal bone contact, a tabular horn and a moderate surangular crest, gastrocentrous vertebrae with poorly ossified centra and neural arches. There are over 30 pre-sacral vertebrae, a closed palate, mobile basal articulation and an intertemporal bone in the skull. This new genus differs from *Eldeceeon,* the other species of anthracosaur at East Kirkton, in the number of ribs and vertebrae, interclavicle shape, relative limb length, in having an unossified tarsus, and a pedal phalangeal count of 23 455.

The new species of *Eldeceeon rolfei* (Figure 15.12) was described by Smithson (1994) as a primitive, moderately sized anthracosaur (overall length 35 cm) represented by two specimens from Unit 76. These fossils present a combination of characters which do not fit readily into either of the two suborders of anthracosaurs, and moreover this includes the restriction of the ribs to the front half of the presacral column. Fortunately the well-ossified appendicular skeleton is preserved to show a phalangeal count of 23 454 in fore and hind extremities.

Westlothiana lizziae (Smithson and Rolfe, 1990) is the earliest known reptilomorph and Smithson *et al.* (1994) were able to describe an almost complete skeleton, as well as a second nearly complete but disarticulated skeleton and other remains. These represent a skink-like animal with a long body and small limbs (Figure 15.13). The skull is short and compact, with a very large eye and jaws armed with small teeth. The body is elongate (some 300 mm) with 36 presacral vertebrae (Carroll, 1996). The vertebrae are gastrocentrous. The limbs are relatively small, the forelimbs especially so, but well ossified. The humerus is much shorter than the femur, but each limb has a structure similar to that in the early amniotes. There are three tarsals as in primitive tetrapods, but there is a normal amniote phalangeal count. Like many primitive tetrapods, *Westlothiana* has massive dorsal as well as ventral scutes.

There are also three specimens of a very primitive tetrapod from the lower part of the East Kirkton Limestone. These animals were elongated and loxommatid-like, and possessed skulls that were up to 10 cm long, broad-snouted and alligator-like in shape. They may have been fish-eating predators.

Interpretation

The model of the East Kirkton environment proposed by Durant (1994) comprises volcanic vents surrounded by a thickly vegetated hinterland with streams carrying pyroclastic detritus to lakeside deltas and beaches. Rainfall was intermittent but sufficient to maintain a strong drainage pattern (Figure 15.14). There seems to be no direct link between the death and subsequent preservation of organic remains and the volcanic activity. Whether the burning of plants to provide the fusain was from contact with hot ejecta or lava or from ignition by lightning is not known.

Clarkson *et al.* (1994) suggest that the lake was generally cool, though occasionally temperature may have been raised by localized hot spring activity. When acidity was reduced, calcium carbonate was precipitated, covering wide areas of the lake floor and the remains lying upon it. From time to time some sediment was slumped into deeper water, triggered perhaps by local earth tremors.

During the existence of the East Kirkton lake it underwent profound faunal changes. Its early stage seems to have been as a fish-free pond full of newt- or salamander-like amphibians. Volcanic activity perhaps then put an end to the aquatic vertebrate population and only terrestrial tetrapods are found. Towards the end of the record the lake reverted to a productive body of water but with only fish representing the vertebrates.

Apart from the fishes, the bulk of the biota consists of plants, land-living invertebrates and amphibians and reptilomorphs that are amongst the oldest known. The vertebrates seem to have been largely carnivorous in habit. The elasmobranchs and palaeonscid actinopterygians were active swimmers, probably inhabiting middle depths within the lake and feeding upon inver tebrates and fry. The xenacanths, however, may have fed upon bottom-dwelling invertebrates. The acanthodians, on the other hand, were most probably plankton-feeders, with ostracods as the principle food. Amongst the palaeonscid actinopterygians, *Eurynotus* is notable in its dentition which suggests a durophagous (mollusc-browsing) habit. The sarcopterygians, known only from patches of scales, have been estimated to have been as large as 0.5 m in length, and may have been specialized lurking predators in this lake, as elsewhere (S.M. Andrews, 1985).

The tetrapods were almost all dependent ultimately upon aquatic sources of food and upon water for their mode of life generally (see (Figure 15.15) for a suggested model). The primitive lox-ommatid-like tetrapods may have been predatory upon small fishes and other tetrapods. Temnospondyl amphibians were abundant, and those at East Kirkton are the oldest known. *Balanerpeton* was a relatively terrestrial animal, like a large salamander. The aistopod may have occupied a niche comparable to that of recent snakes, living in the plant litter or even underground. Its few, large teeth suggest that it preyed on organisms almost as large as its own head — arthropods and small vertebrates in the cryptofauna. The anthracosaurs were active animals, terrestrial or aquatic, predatory on small or larval tetrapods and arthropods (Figure 15.15).

The presence of the lake, its surrounding vegetation and the warm climate were prime factors in the palaeoecology. Most of the tetrapods were essentially terrestrial in habit. For much of the time the lake waters were toxic from mineral contaminants, and may also have been cut off from other water bodies. However, for the later part of its existence somewhat less hostile conditions prevailed and the fishes entered the lake. This was accompanied by a change in the land flora, which now became lycopod-dominated, and perhaps also by a wetter climate.

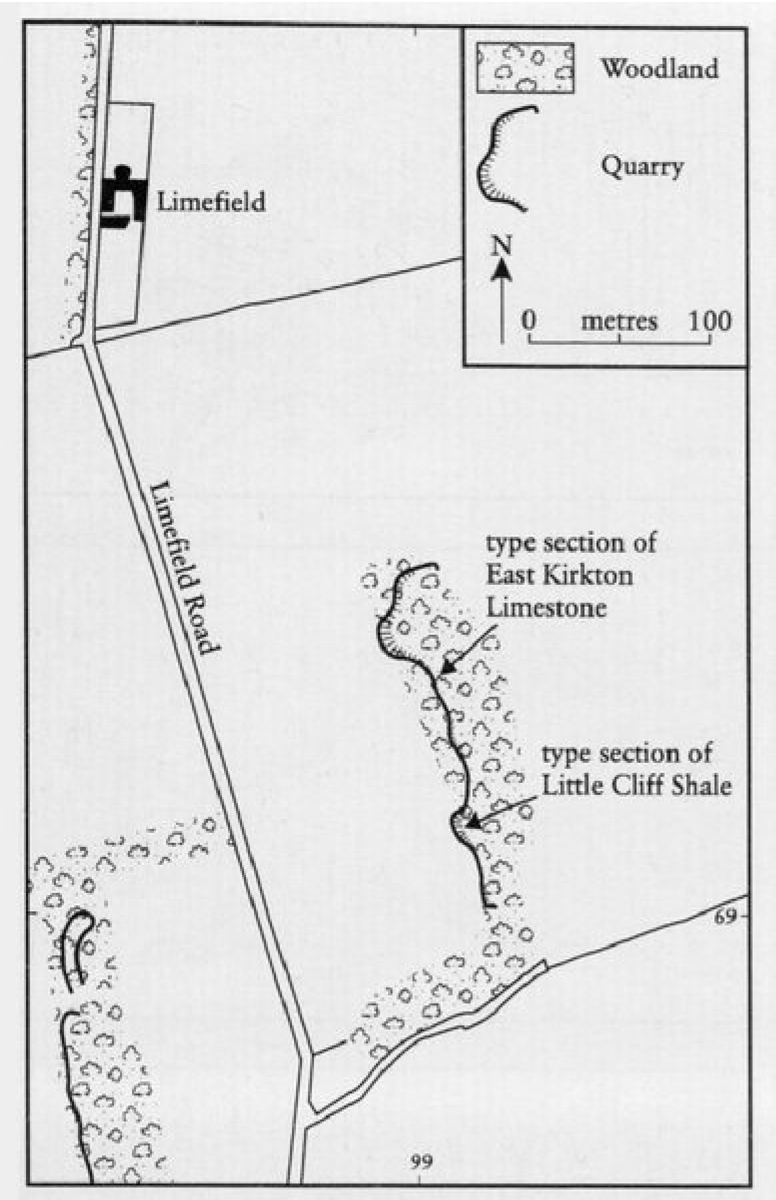
Comparison with other localities

The East Kirkton site is alone in the quality of preservation of and extent of the tetrapod fauna; the fishes in contrast are not very well preserved. There are also more detailed palaeoenvironmental data available here than there is at other localities of comparable age in Britain. Sites of some similarity in age and fauna are present in Nova Scotia (Carroll *et al.,* 1972; Holmes *et al.,* 1995) and mainland Europe (Czech Republic), though they are in general somewhat younger. *Dendrerpeton,* for example, is well known at Joggins, Nova Scotia.

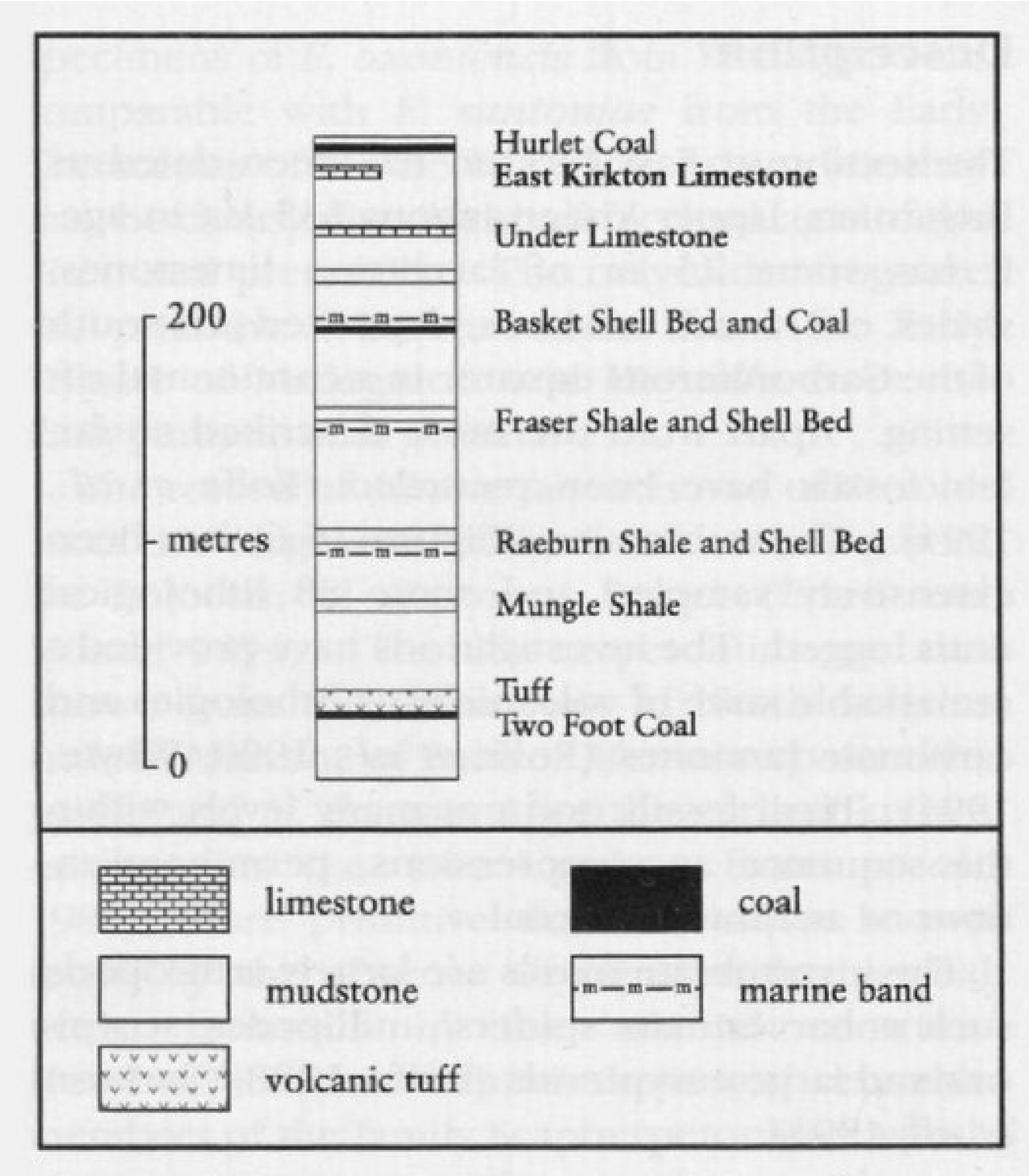
Conclusion

The conservation value of the East Kirkton site is provided by its unique and remarkable flora and fauna, exceptionally well preserved and closely studied by a team of experts in a co-ordinated team effort. It is clear that there is still much potential for further excavation and study of the remarkable tetrapods which have extended back to Viséan time the record of the reptilomorphs. Comparable early but less productive sites or sets of localities are known in the Carboniferous of mainland Europe (Milner, 1980, 1993b), eastern USA and Canada (Carroll *et al.,* 1972) and elsewhere in southern Scotland (Smithson, 1985).

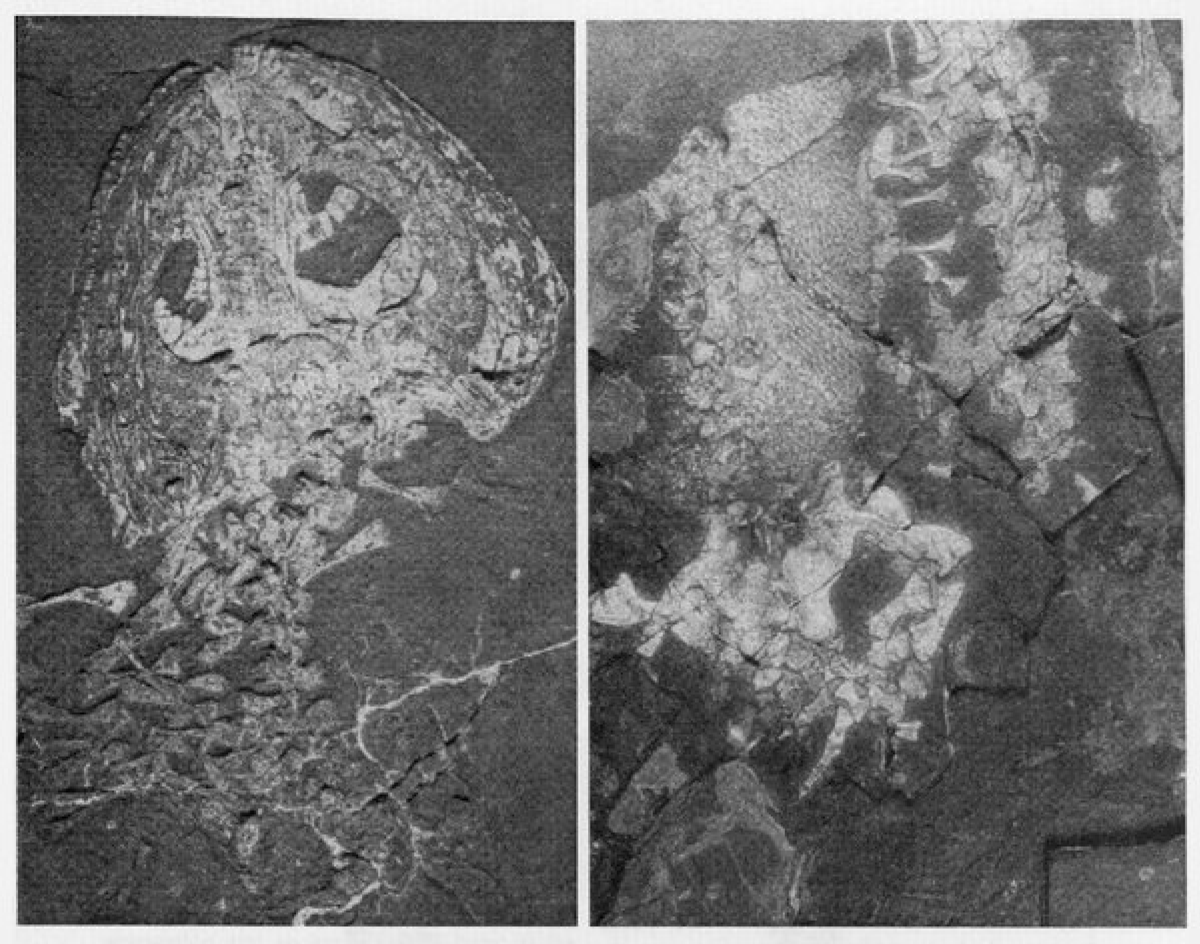
References



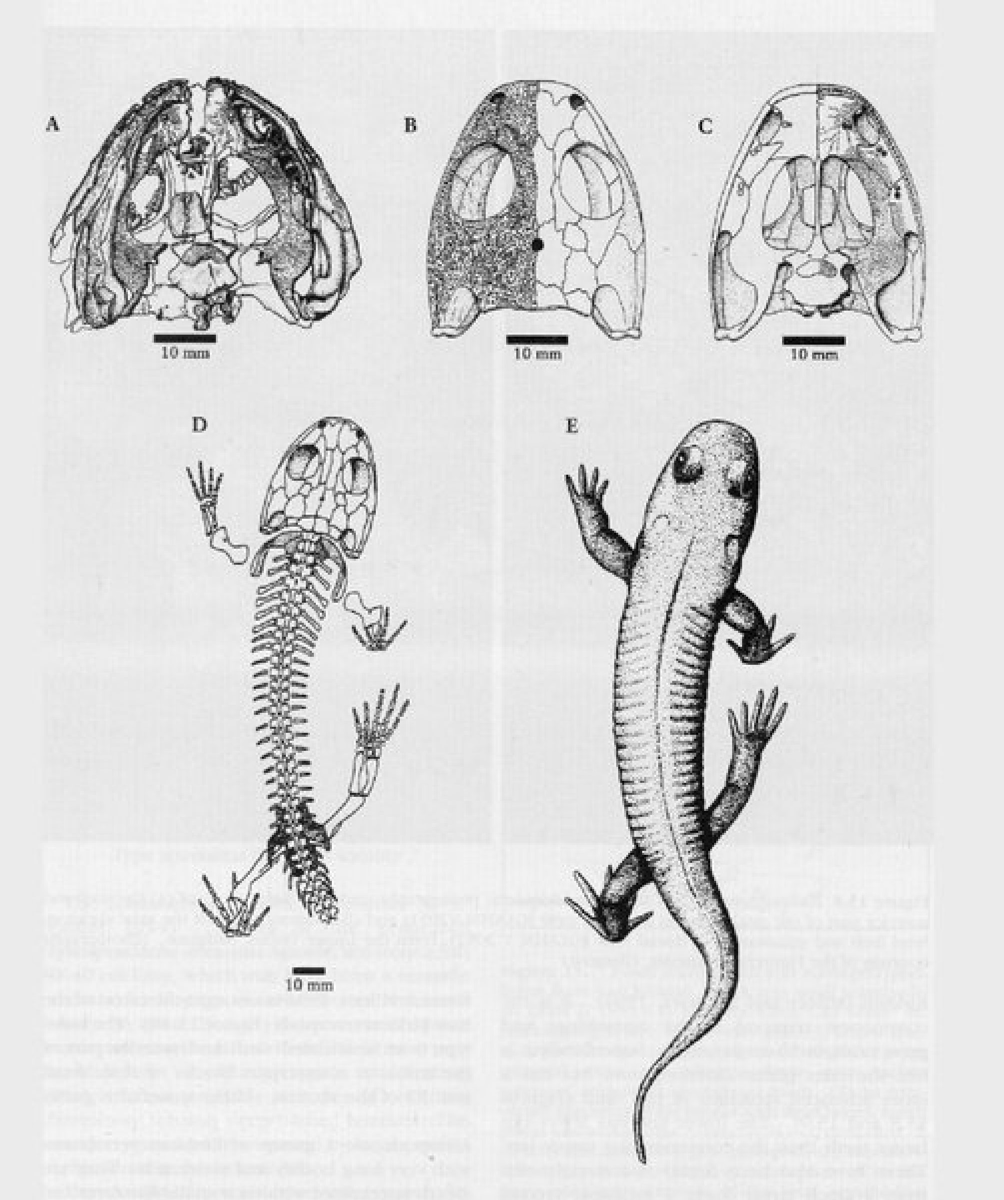
(Figure 15.5) Sketch map of the GCR Site at East Kirkton Quarry (after Rolfe et al., 1994).



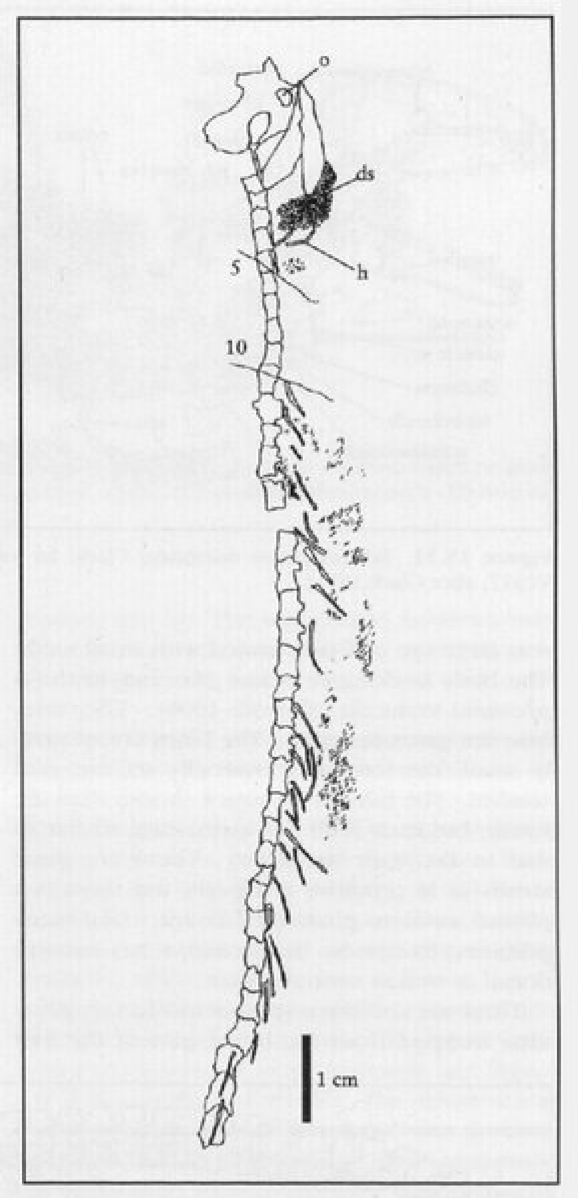
(Figure 15.6) Succession in the top 250 m of the West Lothian Oil Shale Formation (after Whyte, 1994).



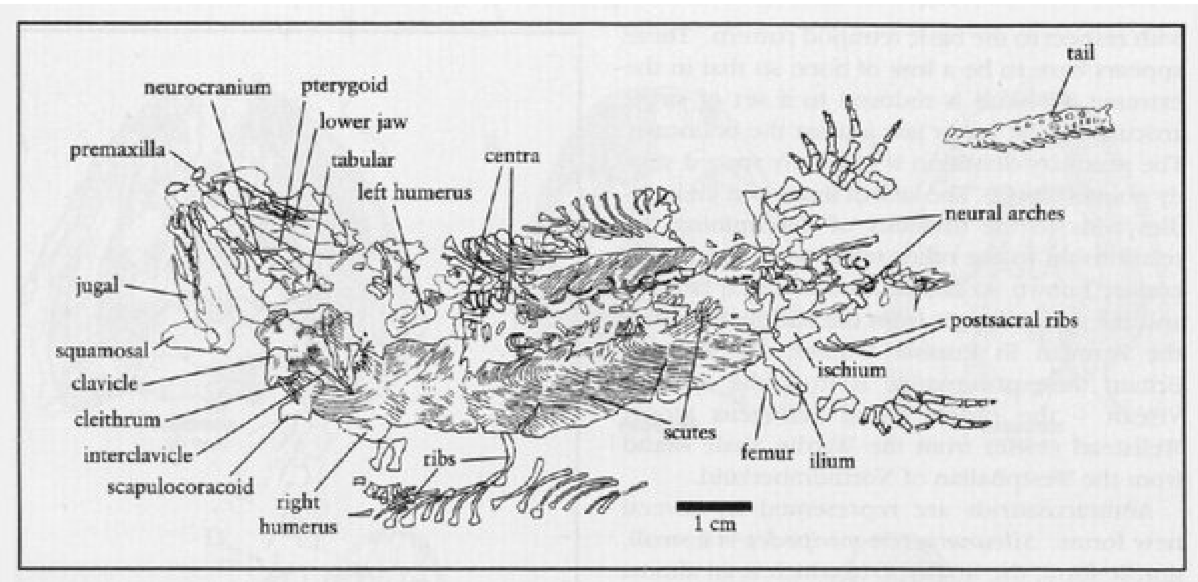
(Figure 15.8) Balanerpeton woodi Milner and Sequiera; photographs under UV light (x 1) of (A) the skull and anterior part of the axial skeleton in dorsal view (GLAHM V2051) and (B) posterior part of the axial skeleton, hind limb and squamation in dorsal view (GLAHM V 2052). From the Upper Viséan, Bathgate. (Photographs courtesy of the Hunterian Museum, Glasgow)



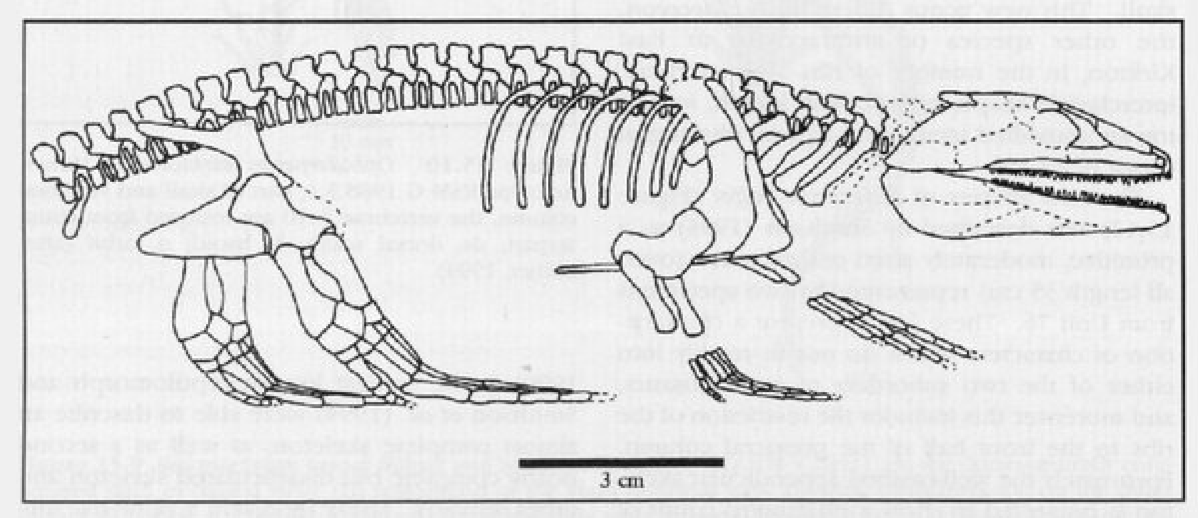
(Figure 15.9) Balanerpeton woodi Milner and Sequiera (based on GLAHM V 2051): (A) the dorso-ventrally compressed skull in palatal view; (B) restoration of the skull in dorsal view showing ornamentation on the outer surface of bones; (C) the skull restored in palatal view with marginal teeth and fangs and surface ornamentation indicated; (D) restoration of the incomplete skeleton in dorsal view; (E) the animal restored in dorsal view (after Milner and Sequiera, 1994).



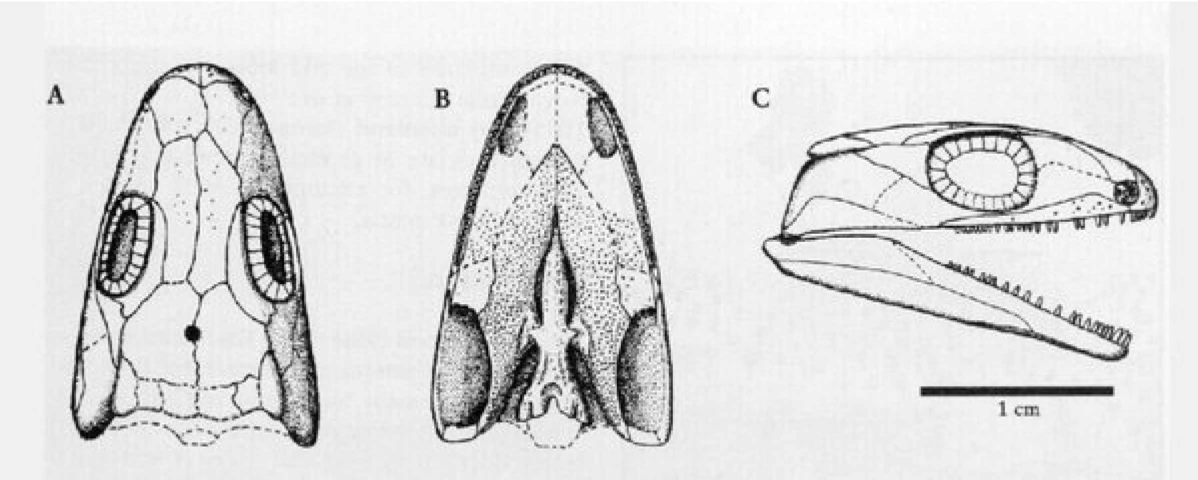
(Figure 15.10) Ophiderpeton kirktonense Milner, holotype RSM G 1988.3.1; part of skull and vertebral column, the vertebrae 5–10 are restored from counterpart; ds, dorsal scales; h, hyoid; o, orbit (after Milner, 1994).



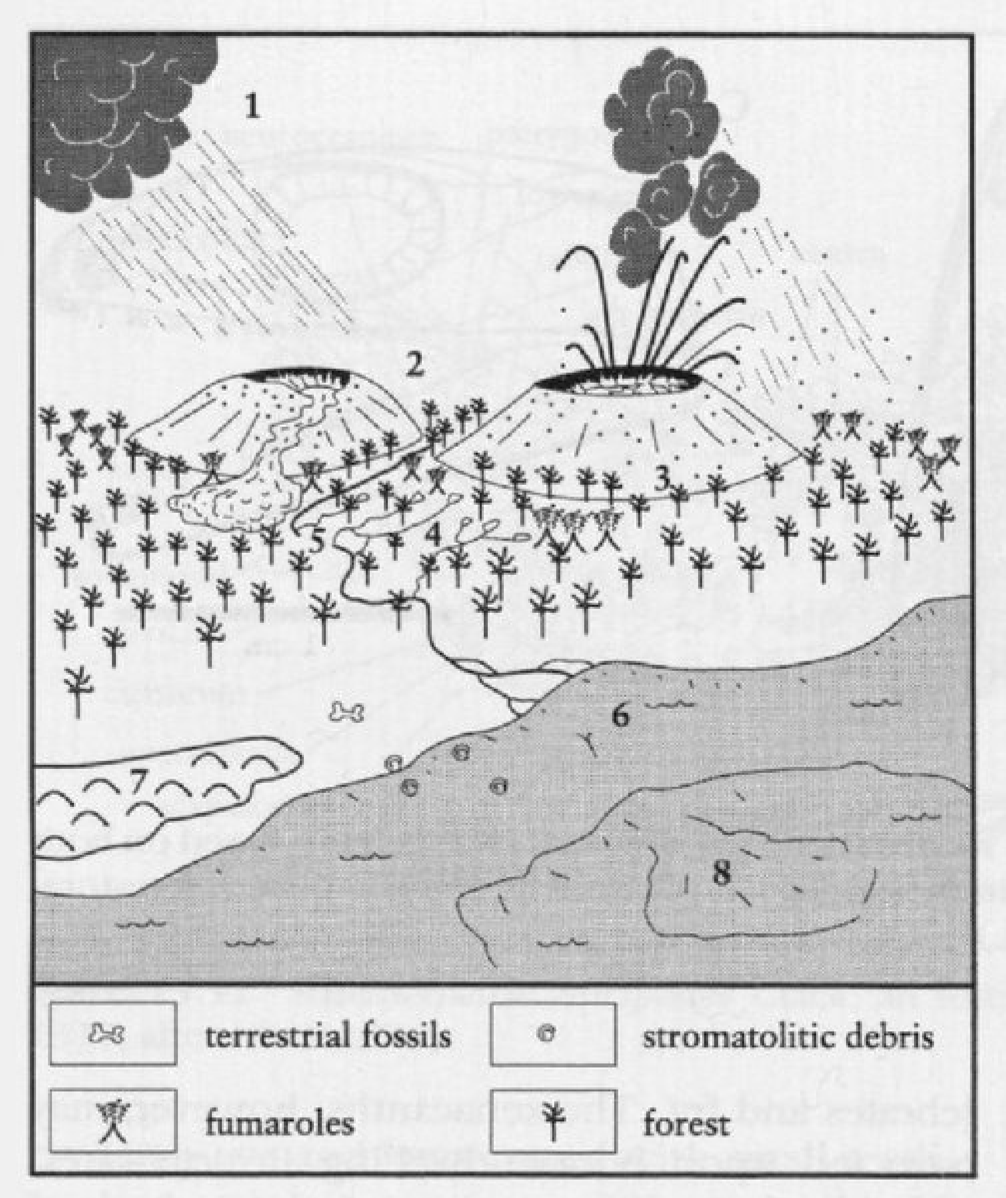
(Figure 15.11) Silvanerpeton miripedes Clack; an interpretative drawing of the skeleton (specimen UMXC V1317; after Clack, 1994).



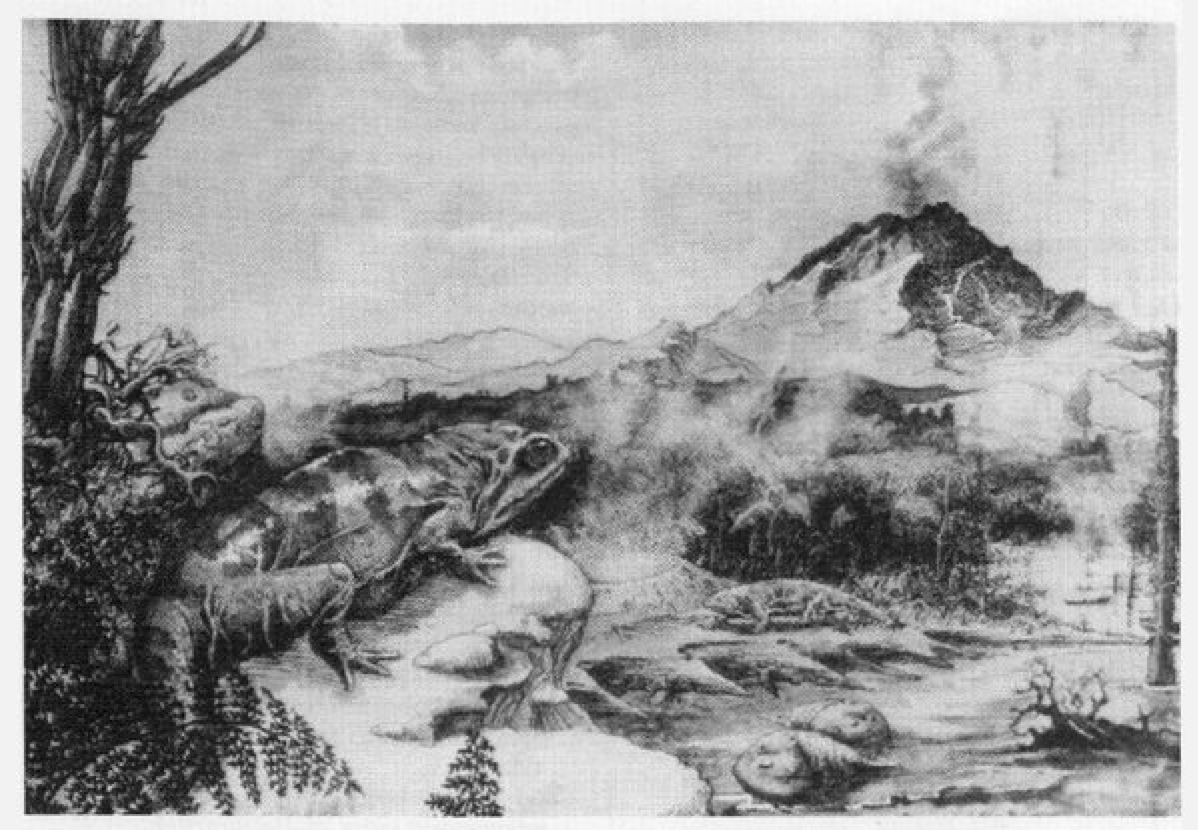
(Figure 15.12) Eldeceeon rolfei Smithson; the skull and most of the post-cranial skeleton in a provisional restoration, based mainly on the holotype (RSM G 1990.7.1) from the East Kirkton Limestone (after Smithson, 1994).



(Figure 15.13) Westlothiana lizziae Smithson and Rolfe; reconstruction of the skull and skeleton based on both known specimens. (A) Skull in dorsal aspect; (B) skull in palatal aspect; (C) skull in lateral aspect; (D) restoration of incomplete skeleton (after Smithson et al., 1994.)



(Figure 15.14) Reconstruction of the environments represented in the vicinity of the East Kirkton Lake (after Durant, 1994). 1, intermittent rainfall; 2, recently expired volcano with lava flows; 3, erupting basaltic volcano with associated heavy rainfall; 4, fumaroles and hot springs emitting mineral-rich waters; 5, intermittent stream in flood transporting volcanic detritus from flanks of volcanoes; 6, terrestrial fossils incorporated in sediment during transport; 7, exposed lake shallows or floodplain with limestone and stromatolite debris; 8, deposition of graded units in lake.



(Figure 15.15) Reconstruction of the hot springs environment that is indicated in the East Kirkton Limestone. The temnospondyl Balanerpeton is in the foreground while an Eoherpeton-like anthracosaur (Eldeceeon) is in the middle distance, next to a fumarole. The eurypterid Hibbertopterus is at the water's edge and the pteri-dosperm Sphenopteris is shown in the bottom-left corner. (From Milner et al., 1986; Courtesy of the Hunterian Museum/Modern Geology)