Feature

‘A hard rain’s a-gonna fall’: torrential rain, flash floods and desert lakes in the Late Triassic Arden Sandstone of Central England

The Arden Sandstone Formation of central and western England is a thin but conspicuous arenaceous unit within the Late Triassic Mercia Mudstone Group. Sedimentological and palaeontological data point to lacustrine depositional conditions, in contrast to the red desert mudstones above and below which were deposited as continental dryland desert floodplains. The Arden Sandstone records deposits of the lake margins and may be the high stand lateral equivalent of the halite and gypsum deposits which formed in the lake centre. The Carnian age of the Arden Sandstone potentially links it to the Carnian Pluvial Episode, marking the coalescence, spread and freshening of the formerly saline desert lakes, and deposition of sandy, fluvial and lacustrine deposits, during the wetter climate that prevailed for at least a million years.

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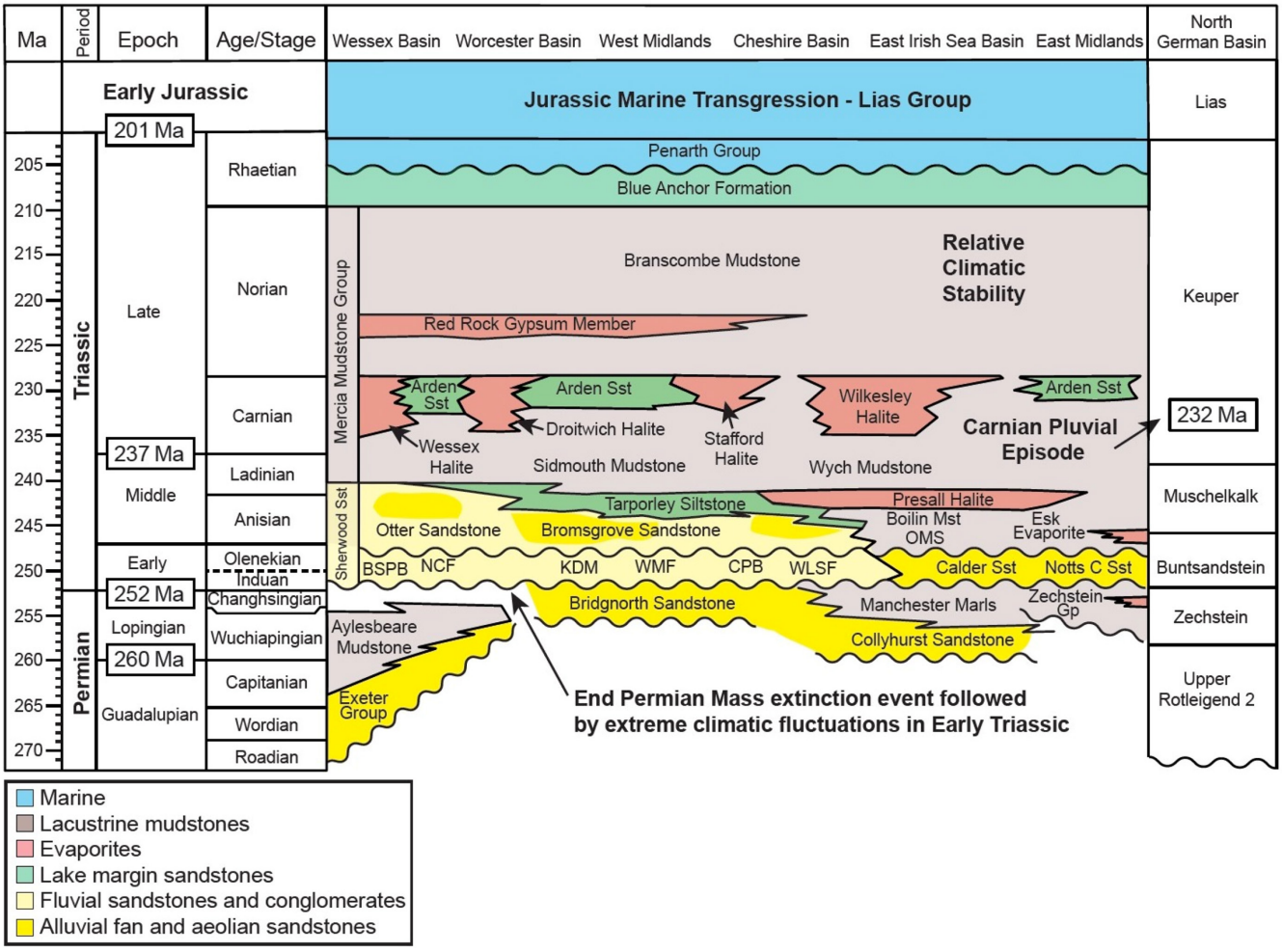
The Arden Sandstone Formation is a distinctive, buff to pale green-coloured sandstone and mudstone deposited about 230 Ma during the Late Triassic Carnian Stage, and seen at outcrop and in boreholes in central and western England, north of the Mendip Hills. Stratigraphically, the formation is used to divide the essentially continental Late Triassic Mercia Mudstone Group into a lower unit of dominantly red desert mudstones, the Sidmouth Mudstone Formation, from an upper unit of rather similar mudstones, the Branscombe Mudstone Formation (Fig. 1). The Arden Sandstone Formation has previously been assigned to the upper part of the Carnian Stage but continental sequences such as this are difficult to precisely date, and it may well be instead the lateral equivalent of the mid-Carnian Dunscombe Mudstone Formation seen further south in the Wessex Basin, which includes comparable arenaceous and lake margin lithofacies.

The type-area of the Arden Sandstone Formation is within the Knowle Basin of the central English county of Warwickshire, with its type-section in old cuttings on the Grand Union Canal at Shrewley, not far northwest of the county town of Warwick. Sections at Shrewley were first described by the Reverend Peter Bellinger Brodie (1815–1897), vicar of nearby Rowington from 1853 to 1897, recipient of the Geological Society of London Murchison Medal for 1887, and long-term honorary curator of the Warwickshire Natural History and Archaeological Society’s museum in Warwick. In Warwickshire the Arden Sandstone Formation has been extensively quarried for use as a building stone, including in the construction of the fine St Peter’s Church in Wootton Wawen, St Mary’s in Lapworth and St Laurence in Rowington (as well as many other local churches) and the National Trust’s medieval manor house at Baddesley Clinton. The fine grained, quartz-rich nature of the sandstones, variously cemented with diagenetic dolomite, make it a remarkably resilient building stone. More broadly, the Arden Sandstone outcrop gives rise to characteristic elements of the classic Warwickshire Arden landscape; an historic, hilly area of former wooded pasture and heath, now characterized by pockets of ancient woodland and brick and timber villages; William Shakespeare’s ‘Forest of Arden’.

The Shrewley canal cuttings are now represented by a Site of Special Scientific Interest, owned by the



Canal and River Trust, protected by Natural England and monitored by the Warwickshire Geological Conservation Group. A number of other exposures occur nearby, including reference sections at Rowington, also on the Grand Union Canal, a road cutting on the Arden Sandstone escarpment at Blackford Hill, south-east of Henley-in-Arden, in a glacial outwash valley at Mows Hill Dingle, on the south side of the watershed dividing the Trent-Severn river basins, and a road cutting at Inkberrow, just over the Warwickshire-Worcestershire border, west of the town of Alcester (Fig. 2). The outcrop exposures are supplemented with borehole records, some of which included core. This thin but striking sandstone-dominated sequence can be traced from these sites in the Knowle Basin further south into the Worcester Basin, and eastwards into the Hinckley Basin and then onto the North Sea Shelf.

Arden Sandstone characteristics

A typical Arden Sandstone succession, as seen in the Knowle Basin, is around 10-m thick and comprises thinly bedded, sharp-based, fine grained, dominantly grey-green, symmetrically rippled sandstones which are overlain by thicker sets of planar and trough cross-bedded sandstones. There is, however, much variation in the Arden Sandstone sequences and their thicknesses (Fig. 3). Around Inkberrow, for example, a 5 m sandstone-dominated exposure includes preserved standing waves, climbing current ripples and upper flow regime plane beds (Fig. 4).

The nearby Spernal borehole section, by contrast, contains relatively few sandstone beds, which are all thinly bedded and dominated by symmetrical ripples, and is similar in overall sequence to the Henley-in-Arden section, with a distinct upper sandstone unit. The interbedded green coloured mudstones are very silty and rippled and contain abundant desiccation cracks. Many of the ripples are symmetrical. Outcrops at Shrewley, Rowington and Mows Hill are similar to the Spernal borehole sequence in their lower part, but all have an upper thicker bedded sandstone unit. At Rowington this includes sandstone sets up to 0.7 m in thickness with planar and trough cross-bedding (Fig. 4). Palaeocurrent directions obtained from Inkberrow, Henley-in-Arden and Rowington all indicate

Fig. 1. Stratigraphy of the Triassic sequence in England, showing the occurrence of the Arden Sandstone Formation and relationship to the underlying Sherwood Sandstone Group and overlying marine Jurassic. Adapted from Newell (2017).

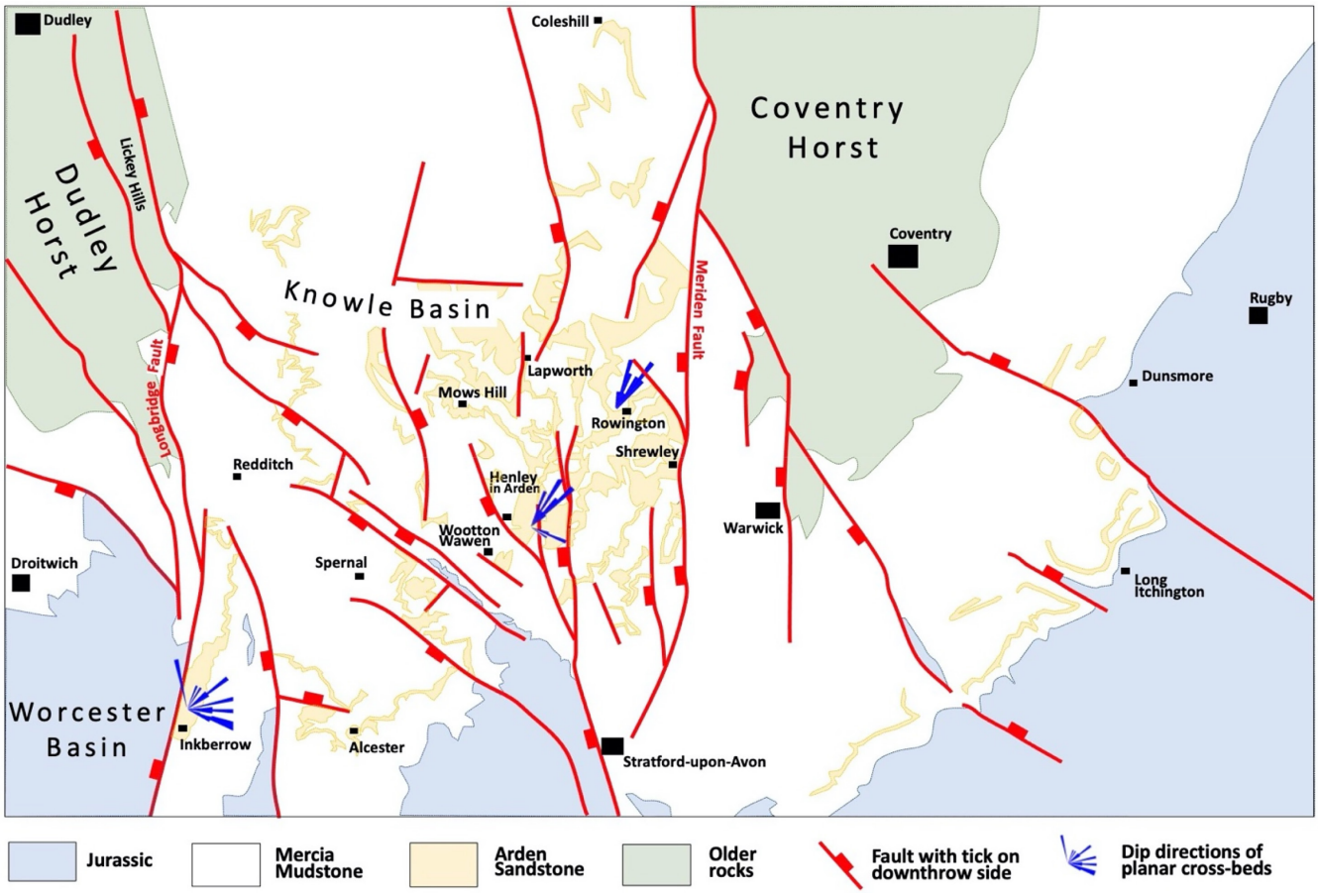


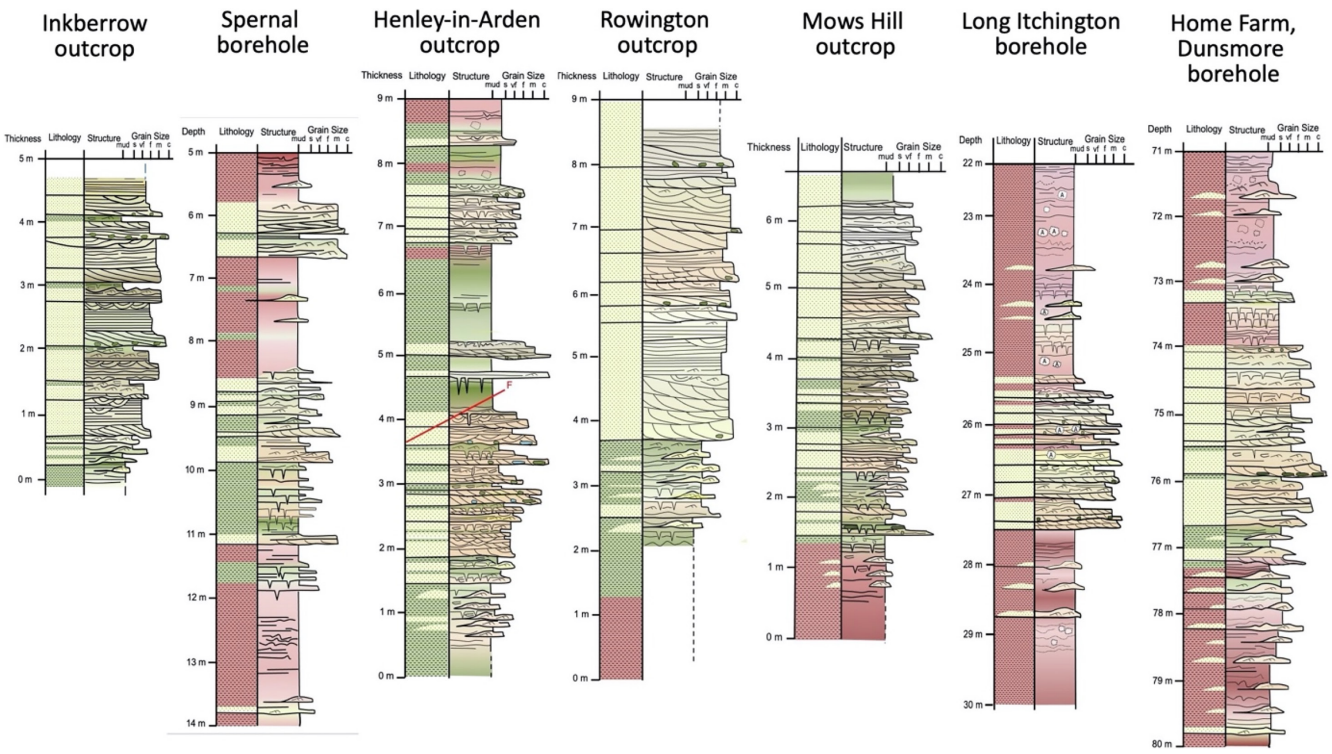
Fig. 2. Outcrop map of the Arden Sandstone based on the British Geological Survey online geology viewer showing the main locations in the Midlands and dip directions of cross-bedding foresets in the fluvial sandstones of the Arden Sandstone.

flow to the north and north-east (Fig. 2). Evaporite traces in the outcrops are confined to rare, isolated casts after small halite crystals, preserved in the lower thinly bedded sequence at Shrewley (Fig. 4), although gypsum and anhydrite nodules and veins are common in the borehole records. These sediments are in striking contrast to the more monotonous, brick-red mudstones, above and below.

The Late Triassic climate

The Late Triassic climate of Britain in the landlocked eastern interior of the super-continent Pangaea between 15 and 20 degrees north, was one of circum-equatorial heat and extreme aridity, giving rise to widespread red beds across present day eastern North America and NW Europe (Fig. 5). Following the devastating volcanically-induced End-Permian Mass Extinction at 252 Ma, life on land slowly recovered among the Mid-Triassic floodplains and rivers of central and south-west England, only to be stressed again, as the Mercia Mudstone desert encroached. The red coloured, pedogenically altered and locally evaporitic Mercia mudstones above and below the Arden Sandstone represent the deposits of extensive, flat-lying, desert alluvial plains, comparable to those of the modern Ranns of Kutch in western India. Some of the mudstones may have been wind-blown, comparable to the adhesion ripples of partially wet, wide and flat alluvial plains. Arid dolomitic soils developed on these alluvial plains, and ephemeral lakes formed in the adjacent basin centres. Anhydrite nodules were precipitated in the soils, and when the lakes dried out, evaporitic halite beds were precipitated. Life was sparse in these harsh environments, as evidenced by the overall scarcity of fossils.

But what does the Arden Sandstone interlude signify? Studies of Carnian deposits worldwide have identified this as a time of global climatic and attendant evolutionary change; a significant perturbation of the rather inhospitable Late Triassic climatic scene. The recognition of dramatically increased rainfall and hydrological recycling midway through the Carnian (around 233 Ma) gave rise to the term 'Carnian Pluvial Episode', initially coined as the 'Carnian Pluvial Event' in the late 1980s, by a group of British researchers, Alastair Ruffell, Mike Simms and Paul Wignall. The Arden Sandstone displays many features indicative of this climatic regime. The plane-bedded, high-energy sandstones of the Inkberrow



road cut record the deposits of a flash flood river, whilst the nearby, sandstone-poor Spernal borehole sequence represents a lake margin into which the Inkberrow river flowed. The sandstone exposure at the Inkberrow section is some 250 m in length, orthogonal to the depositional flow, providing a minimum width of the flash flood river channel.

Triassic Lake Arden

Some idea of the extent and geography of this Arden Sandstone Formation lake ('Lake Arden') can be gained from sections further afield, as reflected in the visionary palaeogeographical maps published by Professor Leonard Wills from the 1940s until the mid-1970s, and subsequent workers, influenced by Wills' work (Fig. 6). Regionally, sandstone-poor lake margin sequences like that of Spernal, can be traced north-eastwards along the Arden Sandstone outcrop from Newnham-on-Severn, south of Gloucester across the Worcester Basin, into the Knowle Basin as far north as Coleshill, east of Birmingham and as far east as Long Itchington, towards Rugby, a lateral distance of more than 100 km. Desiccation cracks in mudstones, mud flake clasts, symmetrical ripples, possible wrinkle structures (likely evidence of microbially-bound sediment) and micro-faulting also typify these lithofacies. The desiccation cracks and mud flake clasts represent repeated wetting and drying episodes along sediment-starved lake margins. Lacustrine lithofacies comprising finely interlaminated fine-grained rippled sandstones and silty mudstones are present in the Spernal borehole and also in boreholes in the Tewkesbury area of Gloucestershire, south-east of this shoreline. In the basin centre, in the area around Droitwich, Worcestershire, halite and gypsum bearing mudstones occur at or slightly below the stratigraphic level of the Arden Sandstone Formation and likely represent the central, perennial parts of the Lake Arden.

A mixture of lake margin and fluvial beds in the Inkberrow, Henley and Shrewley areas delimit another shoreline into which fluvial sediment was introduced. The interplay between lake margin and fluvial facies was controlled by the ephemeral supply of sandy sediment, as well as the fluctuations in lake level brought about by climatic change. Sedimentation along the lake margin was therefore discontinuous, interrupting extended periods during which older shoreline deposits were reworked by lake wave action. The fine-grained nature of the lake margin sediment and small thickness of the beds suggest that the lake margin waves were small. 'Lake Arden' was, however, large, covering an area of some 3000 km^2 (Fig. 5), but the rivers flowing into it were evidently localized. Cross-bedded sandstones at the top of the Arden Sandstone sequence, as at Henley, Shrewley and Rowington, represent small deltas building out into the lake at the peak of its development and extent. The lake margins were winnowed by small waves to create the parallel-crested symmetrical ripples that characterize the thin-bedded sand-

Fig. 3. Representative sedimentological logs of the Arden Sandstone, showing lithologies, grain size profiles and sedimentary structures. Colours represent field and core appearance. Log locations indicated on Fig. 2.

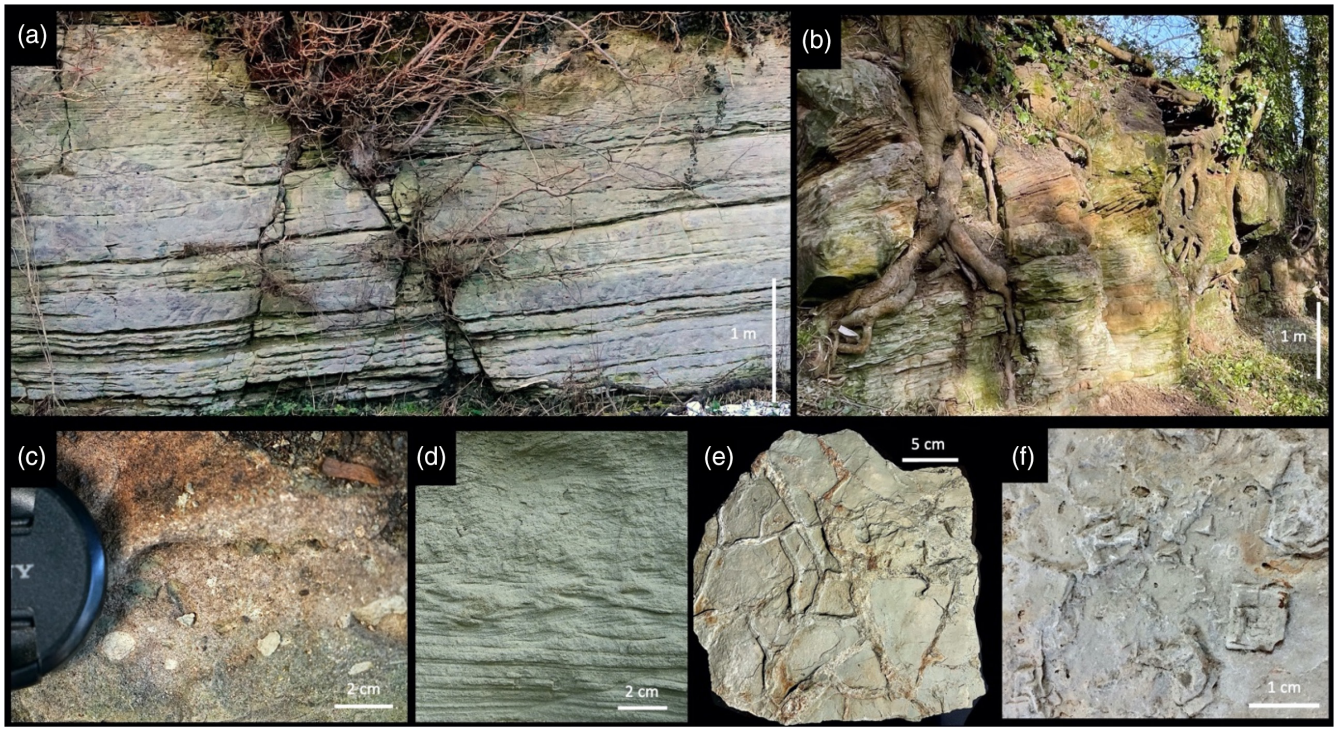


Fig. 4. Representative sedimentological characteristics of the Arden Sandstone at outcrop. **a**. Sand-dominated sequence at Inkberrow, showing the presence of upper flow regime plane beds deposited from a flash flood. **b**. Large scale cross-bedding above wave-rippled sandstones, Rowington. **c**. Dolomite pebble and mudstone intraclast conglomerate lag sandstone, Henley-in-Arden. **d**. Waning current transition from plane bed through climbing ripples to current ripples, Inkberrow. **e**. Desiccation cracks developed on top of a mudstone lamina, Long Itchington. **f**. Cubic hopper crystal pseudomorphs after halite, Shrewley.

stones, whilst desiccation cracks and scattered halite casts record drying of the lake margin as the lake levels repeatedly rose then fell.

Over the last decade, the Carnian Pluvial Episode has been recognized worldwide in both terrestrial and marine successions, on the basis of sedimentological, geochemical and palaeontological criteria. Several humid episodes are indicated, and are associated with significant negative carbon isotope excursions, accompanied by atmospheric warming. In this context, the Arden Sandstone Formation could well record the coalescence, spread, and freshening of the formerly saline desert lakes, and deposition of sandy, lake margin deposits, under the generally wetter climate that prevailed for a million years or more. The ephemeral rivers that locally fed the lake as 'flash floods' are exemplified by the sequences exposed at Rowington and Inkberrow, which record the deposits of small lake deltas and fluvial input points, respectively.

Life in Lake Arden

Uniquely and importantly for the continental Late Triassic of England, the Arden Sandstone Formation is relatively fossiliferous (Fig. 7). The former quarries at Shrewley furnished the very first reptile footprints known from the Triassic of Great Britain. These are tracks now attributed to the pentadactyl ichnogenus *Rhynchosauroides*, preserved on the surface of a rippled sandstone slab that was described and illustrated by Roderick Murchison and Hugh Strickland, in 1840. The reptiles that produced these types of tracks were evidently quite small, and probably included lizard-like lepidosaurian taxa, and perhaps also rhynchosaurs, well known from their skeletal remains in slightly older Triassic units in the region and from Carnian rocks in Scotland. Also, with reference to the Warwickshire exposures, the Reverend Brodie documented and described many interesting discoveries in the local quarries and cuttings in the latter half of the nineteenth century. These included locally abundant conchostracans ('clam shrimps', now attributed to the genus *Euestheria*, originally thought to be bivalve molluscs), further examples of *Rhynchosauroides* tracks, the skull bones of large, extinct temnospondyl amphibians, fin spines and teeth of small to medium-sized sharks, small bony fish, as well as a poorly-preserved assemblage of bivalve molluscs at Shrewley.

The shark fin spines are up to 15 cm long and suggest a full body size of up to 1.5 m. Brodie also discovered a sandstone block preserving a cast of a *Chirotherium* footprint (the famous 'hand beast') in a ploughed field on the Arden Sandstone outcrop near Preston Bagot, which is close to the present-day Blackford Hill exposure at Henley-in-Arden. In his later years, Brodie's son Douglas had evidently taken an interest in the local quarries and found further fish remains and reptile tracks. Many of these discoveries, including the Murchison—Strickland *Rhynchosauroides* slab and a good number of the Reverend Brodie's specimens, are housed today in the collections of the Warwickshire Museum.

Plant macrofossils from the Arden Sandstone comprise conifers (including possible cones of *Voltzia*), horsetails and ferns. Palynomorphs confirm a Car-

nian age, and are associated with *Plaesiodictyon mosellanum*, a freshwater green alga, that has a widespread occurrence in the Upper Triassic, a result of aerial, wind-blown distribution independent of fluvial activity and animal vectors. Spores and pollen recovered from green mudstones of the Arden Sandstone Formation in the English Midlands indicate a flora on the lake margins which included bryophytes (mosses and liverworts), horsetails, ferns, cycads and conifers. So-called 'fucoids', noted at Rowington, are now recognized as small *Planolites*-like worm burrows and can still be seen at that location, and elsewhere.

The remaining Arden Sandstone sites in Warwickshire additionally still reveal abundant crustacean burrows, common *Euestheria* clam shrimp fossils, plant remains and common but tiny, abraded fragments of reptile bone.

These fossils provide unique insight into the prevailing Carnian ecosystem. Until recently, many palaeontologists and geologists interpreted the Arden Sandstone Formation in terms of a marginal-marine bay or estuarine environment, given the presence of evaporite minerals in the Mercia Mudstone above and below, and the presence of inferred brackish-marine fossils, notably the shark remains, and bivalve moulds found at Shrewley. Leonard Wills, however, as early as the late 1940s, invoked a freshwater environment, unconvinced that the poorly preserved bivalve moulds discovered many decades earlier by Brodie were of 'marine aspect'. Detailed sedimentological investigations are now confirming the fluvial and lacustrine nature of the depositional environment, supported by the growing evidence for intense pluvial run-off, at least periodically, associated with the Carnian Pluvial Episode. Some of the Shrewley bivalves resemble freshwater unionoid pond-mussel species described from contemporaneous deposits in the New Oxford Group of Pennsylvania. Similarly, the bony fish have close counterparts in Carnian freshwater lake sediments within the North American Newark Supergroup. Equally, the shark fin spines and teeth discovered by Brodie could well have been species that tolerated fresh water or salinity fluctuations. Amphibian remains are also a good indicator of low salinities. The clam shrimps, known today from ephemeral freshwater ponds and lakes, likely fed on algal mats in the temporary lake-margin ponds. The bony fish and sharks thriving in the lake waters were probably preyed on by the large amphibians. The *Rhynchosauroides* tracks point to abundant small reptiles in the lake margin settings, with a variety of food sources. The drifted plant remains indicate lush vegetation on interfluves, or better drained areas bordering the lakes. Evidently the Late Triassic landscape bloomed, at least periodically, as the Carnian rain invigorated the desert streams and freshened the salt lakes. Overall, the palaeontological data indicate that freshwater conditions prevailed within the lake, at least at times. When the lake tended towards hypersalinity, the lack of marine fossils favours evaporation as the cause of salinity, rather than marine incursion.

The Carnian world: the broader picture

The cause of the Carnian variation in the Triassic climate remains elusive. The discovery of a prominent negative $\delta^{13}C$ isotope compositional excursion in plant material present in Carnian sediments at the base of the Carnian Pluvial Episode is widely speculated to be the result of a huge injection of CO_2 into the late Triassic atmosphere–ocean system. Many geologists consider the contemporary extensive volcanic eruptions on North America's west coast (the so-called Wrangellia Large Igneous Province or 'LIP') as the driver for this Late Triassic climate perturbation. The growth of an oceanic plateau, partly preserved as >3-km thick basalt flows in Alaska's Wrangell Mountains, would have resulted in huge amounts of volcanic gases such as CO_2 and SO_2 being released into the Carnian atmosphere. Oceanic volcanism was also contemporary in NeoTethys from Turkey, through Cyprus to Oman (Fig. 5). It is also possible that the onset of Atlantic Ocean Rifting was associated with volcanic activity in the Central Atlantic Magmatic Province, earlier than has been so far recognized. In the geological record, LIP volcanism is often correlated to episodes of major climate change and extinctions. The release of these 'greenhouse' gases into the atmosphere could have resulted in global warming and consequent acceleration of the hydrological cycle, thus strongly enhancing the continental weathering. Moreover, if rapid enough, a sudden rise of CO_2 levels could have acidified seawaters with the consequent rise of the carbonate compensation depth and a demise of carbonate platforms in the western Tethys, leading to increased rainfall, dramatic global warming, turning the deserts of central Pangaea into much wetter and humid environments. Other researchers believe the development of a mountain range consequential of the Cimmerian orogeny on the southern side of Laurasia (Fig. 5) deflected the summer monsoon, resulting in strong rainfall and humid conditions in the Tethys realm. A third, more speculative hypothesis ascribed the Carnian period as a time of 'peak mega-monsoon', when the aerial extent of land in the tropical humid climate belt reached its maximum. As Pangaea continued to drift northwards, after a brief wet mid-Carnian interval, the climate returned to arid conditions in the late Carnian, evidenced by the deposition of red mudstones and evaporites in NW Europe.

Conspicuous large terrestrial tetrapods found over much of the world during the Carnian included dicynodonts (synapsid 'mammal-like reptiles'), rhynchosaurs, and crocodile-like archosaurs. Among the last

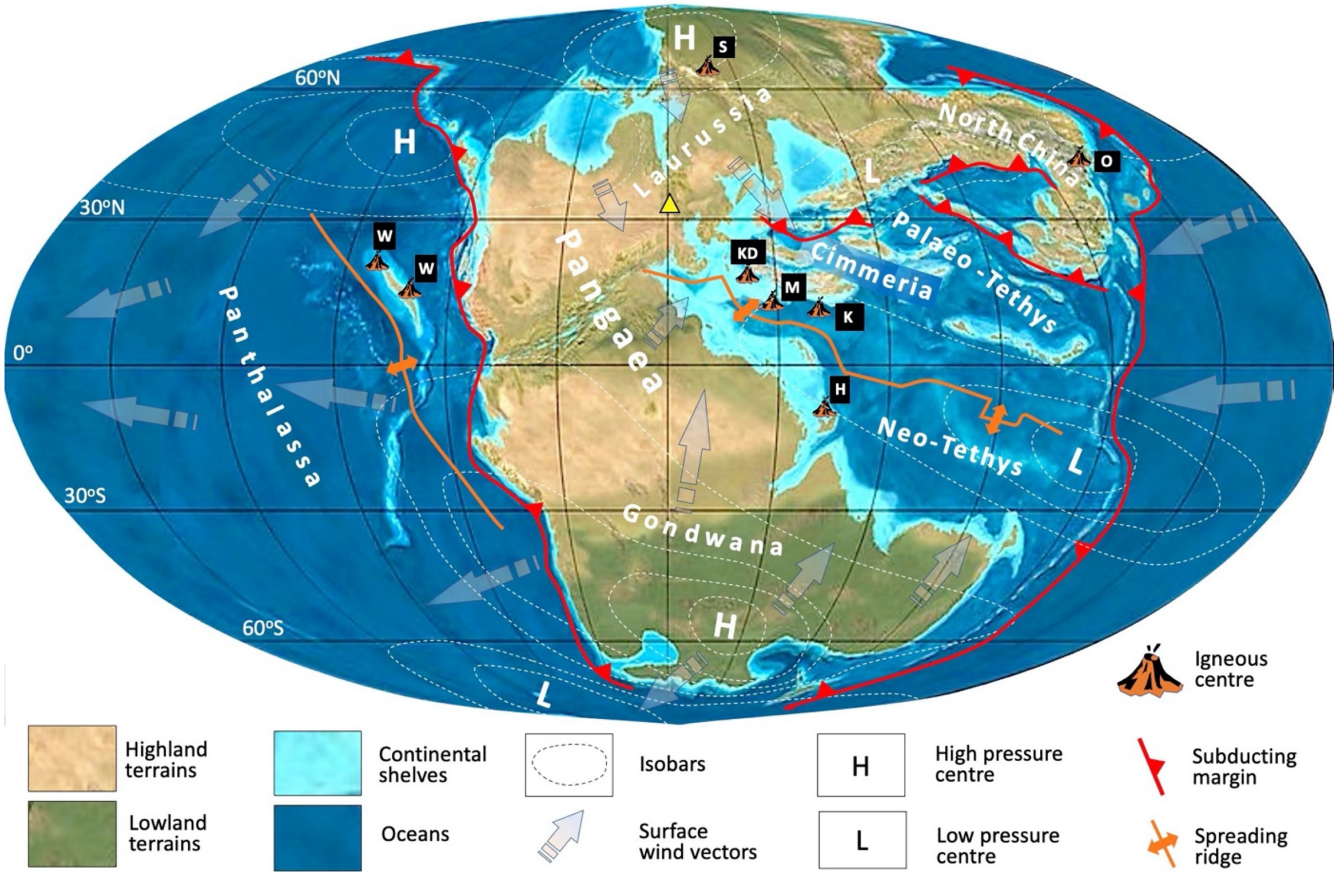


Fig. 5. The Carnian world, based on the PALEOMAP project, http://www.scotese.com, showing the distribution of continents and ocean basins for the Late Triassic, active subduction and spreading margins, and summer atmospheric circulation. Active igneous centres in the Late Triassic: W Wrangellia LIP, S Siberian, KD Kara Dere (Turkey), M Mamonia Complex (Cyprus), K Kocali (Turkey), H Hawasina Basin (Oman) and O Ordos Basin (China). Yellow triangle indicates the approximate position of central England.

of these, the single *Chirotherium* print from the Arden Sandstone is thus fascinating, indicating the presence of 'rauisuchians', top predators several metres in length, and related to the precursors of crocodiles. Immediately following the Carnian Pluvial Episode, midway through the Carnian, early dinosaurs became more frequent elements of faunas in several parts of the world. They remained generally rare, however, limited to a few small bipedal groups, and are so far unrecorded from the UK. During the ensuing Norian Stage, dinosaurs continued to diversify and increase in size, and by the beginning of the Jurassic, following the End-Triassic Extinction, they dominated the terrestrial scene and continued to do so until the end of the Cretaceous. Rhynchosaurs briefly flourished over much of the world during the drier conditions following the Carnian Pluvial Episode, but abruptly disappeared for unknown reasons at, or shortly after, the end of the Carnian. Dicynodonts, also not yet recorded from the UK, lingered on until the close of the Triassic, perhaps being ultimately outcompeted by herbivorous dinosaurs.

Palaeontologists believe that the rapid diversification of the dinosaurs, and the origin or radiation of other tetrapods including turtles, crocodiles and mammals, was triggered by Late Triassic environmental changes such as the Carnian Pluvial Episode, which also led to major changes in the world's flora.

The Arden Sandstone Formation provides a window into Carnian continental and aquatic environments, reflecting the climatic and sedimentological conditions that allowed preservation of an interesting assemblage of body fossils and ichnofossils. Clearly, the wetter conditions did not last, and the Arden Lake reverted to a mosaic of saline desert lakes and dusty, dry mud flats, under the hot, arid, Norian climate. Mercia Mudstone conditions prevailed once again, until sea-level rise associated with the rifting of Pangaea towards the end of the Triassic, accompanied by another episode of significant climate perturbation (leading to the End-Triassic Extinction), brought in the marine conditions and diverse sea life that dominated the UK Jurassic. Fossils are scarce in the latest Triassic desert sediments of the southern UK, though trackways of theropod and sauropodomorph dinosaurs among basin margin deposits in South Wales confirm the post-Carnian dinosaur radiation.

The unknowns

Many questions remain. The extent of the Arden Sandstone lake is not known in detail. Was it really a

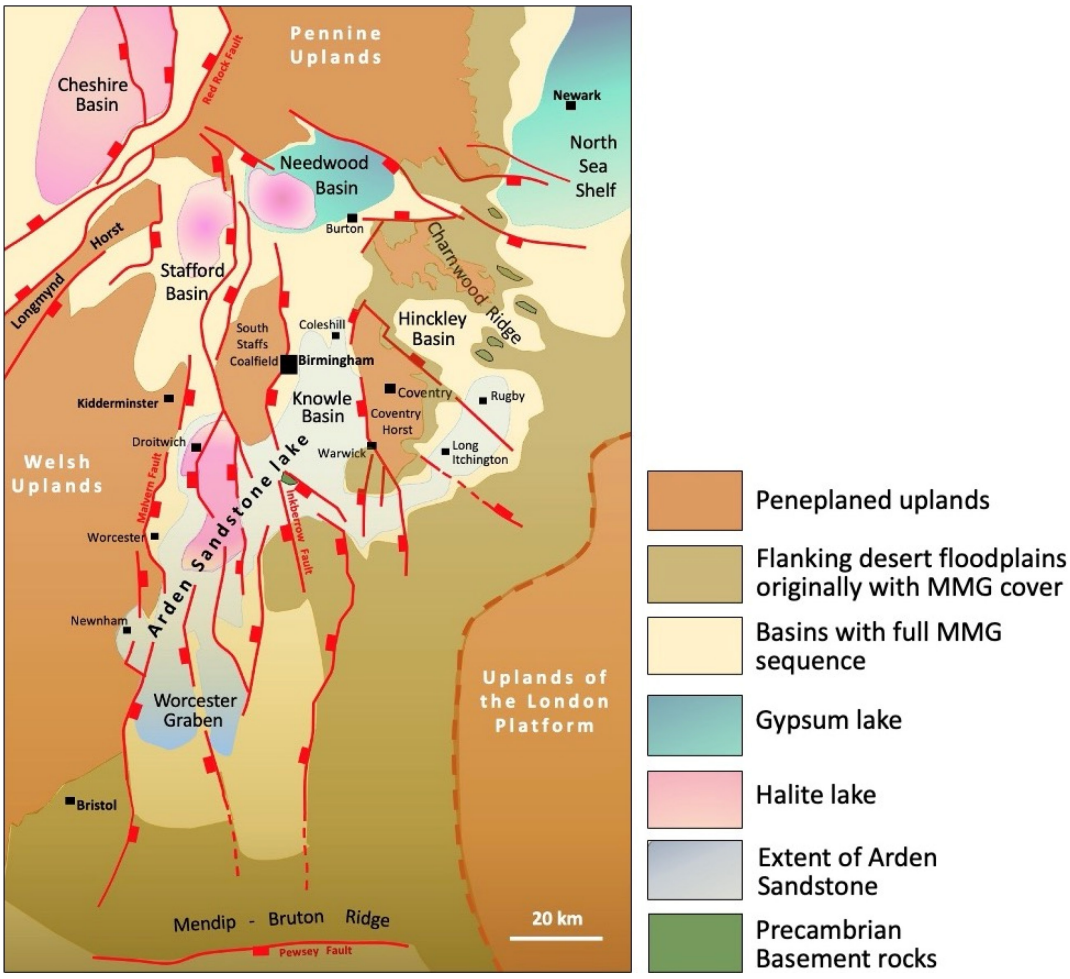


Fig. 6. Palaeogeography of the Arden Sandstone lake in the Carnian, based on the map produced by Leonard Wills in 1970, with additions and updates from new outcrops and boreholes. The Arden Sandstone extends across much of the Knowle Basin in the English Midlands whilst the Droitwich Halite lake is restricted to a localised graben area. During deposition of the Arden Sandstone lake the South Staffordshire Coalfield Horst, Coventry Horst and Charnwood Ridge were low relief, subaerially exposed hinterlands. The extension of the Arden Sandstone lake further south in the Worcester Graben is very poorly constrained. Wills considered that the flanking desert flood plains were originally part of the Mercia Mudstone depositional basin but had a much reduced thickness compared with the basin centres. The extent of the Mendip-Bruton Ridge and its lateral continuity is poorly defined but it is likely to have formed a topographic barrier with Late Triassic basins to the south.

single 'Lake Arden', or did it comprise multiple lakes? Was it separate from the lakes which developed in the Wessex Basin to the south, or the Cheshire Basin to the north? How did our freshwater lake, evidenced by the Arden Sandstone, relate to the halite deposits of a similar age in the central Worcester Graben? In the Wessex Basin, small lake deltas are known to have developed in the Dunscombe Mudstone Formation at the maximum lake extent and are lateral facies equivalents of the Dorset Halite Member. The Arden Sandstone Formation in the English Midlands could, therefore, be the lake margin equivalent of the Droitwich Halite deposits.

We know little about the provenance of the sands and the feeder river catchment areas for the Arden Sandstone, let alone the river courses. Were the central England Carnian lakes initiated by marine incursions, or flash floods? When and where did the abundant plant and animal life originate? Why do the sediments associated with the Arden Sandstone remain green coloured rather than the red of the rest of the Mercia Mudstone Group?

Of particular importance, the age and duration of Arden Sandstone Formation deposition need to be established with more clarity to confirm that it is indeed the time equivalent of the Dunscombe Mudstone Formation, and hence the Carnian Pluvial Episode. The possibility remains, as some palynological evidence currently hints, that it was a manifestation of a slightly later, and more minor, humid episode such as has been recently documented in South America. Recent advances in magnetostratigraphy and astrochronology have provided a high resolution timescale for the Late Triassic which may be a means of better constraining the age of the Arden Sandstone Formation, and the cause of the Mercia Mudstone Group cyclicity first recognized by Leonard Wills. Ongoing investigations of these fascinating rocks, relying largely on protected and conserved sections, temporary exposures, borehole cores and museum collections, will surely shed further light on this vanished Late Triassic world.

Acknowledgements

We would extend our sincere thanks to the Warwickshire Geological Conservation Group for their ongoing work in identifying and conserving their local Arden Sandstone Formation sites. The Canal and River Trust and Warwick-

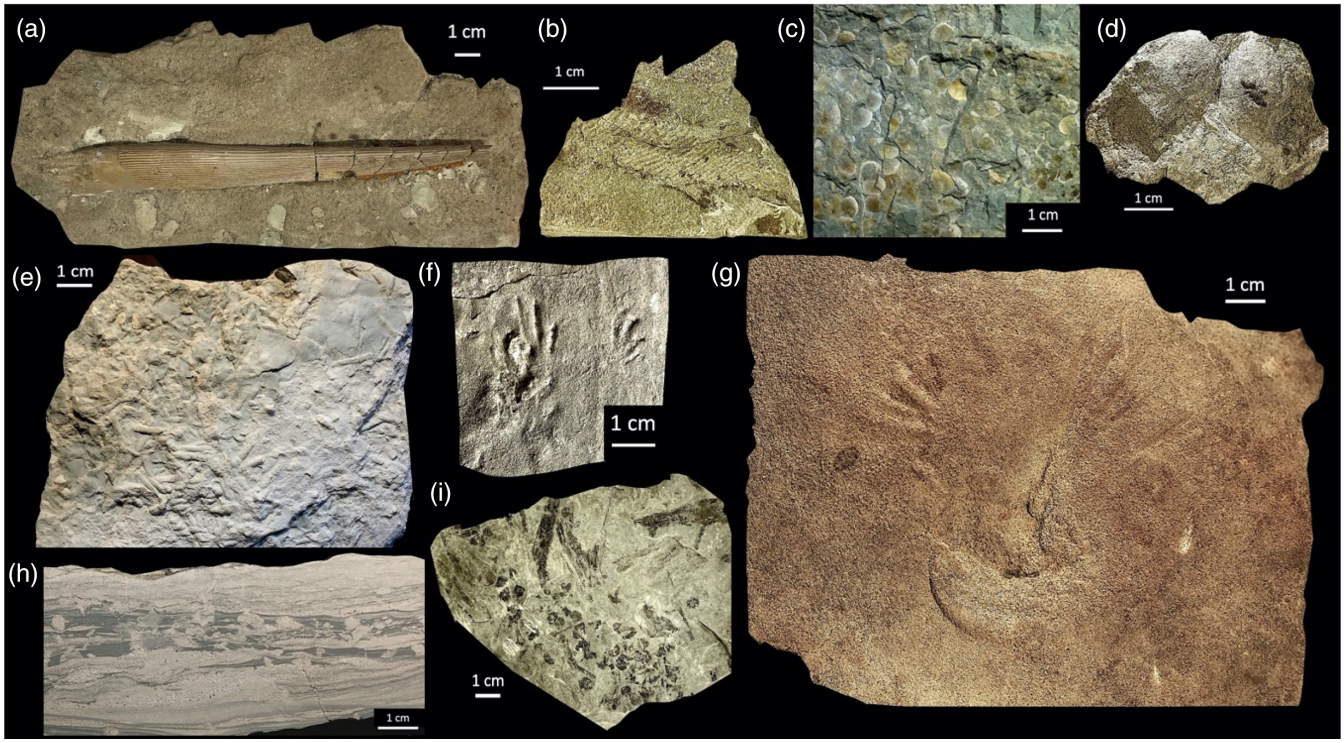


Fig. 7. Selected fossils and ichnofossils from the Arden Sandstone Formation of Warwickshire. **a**. 14 cm-long shark dorsal fin spine, *Acrodus keuperinus*, Shrewley, Warwickshire (Warwickshire Museum collection, donated by P. Brodie, 1892. Collection no. G124). **b**. Part of a small fossil fish, *Palaeoniscus superstes*, Shrewley, Warwickshire (Warwickshire Museum collection, donated by P. Brodie, 1892. Collection no. G138). **c**. Concentration of conchostracans, *Euestheria*, Henley-in-Arden logged section, Warwickshire. **d**. Indeterminate articulated bivalve, Shrewley, Warwickshire (Warwickshire Museum collection, donated by P. Brodie, 1892. Collection no. G6170). **e**. Intense *Planolites montanus* horizontal burrowing, Henley-in-Arden logged section. **f**. Small *Rhynchosauroides* reptile footprints, Shrewley, Warwickshire (Warwickshire Museum Collection, donated by P. Brodie, 1892. Collection no. G9437). **g**. Reptile footprints, *Rhynchosauroides*, and associated impression from Shrewley, Warwickshire attributed by Reverend Peter Brodie to the posterior of a small '*Labyrinthodon*', whilst sitting down in damp sediment. We now know that *Rhynchosauroides* is attributable to the activity of small terrestrial reptiles, though this trace remains enigmatic. (Warwickshire Museum collection, donated by P. Brodie, 1892. Collection no. G9435). **h**. Vertical slice cut through fine-grained sandstone-mudstone interbeds with well-developed *Planolites montanus* burrows, Henley-in-Arden outcrop. **i**. Drifted plant debris, Shrewley, Warwickshire (Warwickshire Museum collection, donated by P. Brodie, 1892. Collection no. G11797).

shire County Highways kindly allowed members of the group to work on the Shrewley and Rowington Grand Union canal sections, and Blackford Hill section, respectively. HS2 and Balfour Beatty Vinci generously provided access to the Long Itchington cutting and associated cores. The British Geological Survey is acknowledged for providing access to borehole cores. Warwickshire Museum's collections continue to provide an outstanding repository of local geological specimens and data.

Suggestions for further reading

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