A brief geological history of the Mendip Hills – Dr Peter Hardy

Early times from Cambrian to the Silurian Period

In late Cambrian times, i.e. around 550 ma. southern Britain was part of a small continental terrane known as Avalonia. At the same time there were large, now more northerly continents including Laurentia (North America and Greenland, including northern Britain), Baltica and Siberia in addition to the remaining continents of Gondwana, i.e. Africa, Antarctica, Australia, India and South America. Avalonia was a relatively stable area of crust adjacent to Gondwana and in the southern hemisphere of the Earth's surface, adjacent to an ocean called Iapetus and about 60 degrees South, i.e. close to the South Pole.

Iapetus remained a large ocean through the Cambrian and into the Ordovician period but due to plate-tectonic movements the oceanic region between Laurentia and Avalonia experienced a gradual closure during the later Ordovician and Silurian, which eventually saw the fusion of North America and Greenland with Avalonia and the Baltic region and united the northern and southern parts of Britain. Meanwhile, Avalonia had separated from Gondwana by an even larger ocean, the Rheic Ocean, which had opened between it and Gondwana. This moved Britain into a sub-tropical position around 30 degrees South by Silurian times.

Caledonian rocks and their successors

The geological history of the Mendip Hills starts about 430 million years ago. Mid-Silurian volcanics of broadly similar origin to the Welsh Ordovician ones (i.e. explosive basaltic or andesitic island-arc types) are found in the Mendip Hills in and around the Stoke St. Michael quarries and are the oldest rocks to be found exposed in the Mendip Hills. The volcanic rocks and associated Silurian (Wenlockian) sediments are only visible at the surface because of an intense period of crustal compression during the closure of the Rheic Ocean from the South. This was the Variscan, Hercynian or Armorican Orogeny, which caused the uplift of the region into mountains from around 300 million years ago. This event saw the collision of southern Britain with the north-western edge of the continent of Africa. The thrust faulting and major fold structures in southern England trend approximately East to West. By the end of this episode Britain was situated North of the Equator, having crossed the tropics during the Carboniferous Period.

The periods represented since the Silurian rocks were laid down are those of the Devonian, Carboniferous, Triassic and Jurassic, with a hint of Cretaceous sediments in the East Mendips. The older of these are seen on geological maps as approximately concentric bands of rock surrounding the Silurian rocks at their centre. The later Triassic and Jurassic rocks are laid down across the top of the eroded surface of the earlier ones on an unconformity, i.e. a surface where a break in deposition and some disturbance and erosion has occurred.

This unconformable break was caused by uplift which occurred during the Variscan Orogeny, probably lasting many millions of years into the Permian. Some of the uplifted rocks were no doubt eroding away almost as fast as they were elevated, so that the depth of burial of the lowest strata was never as great as the projected height of the uplift might suggest. We can be fairly confident of this because the older rocks are relatively unaffected by their burial. No true metamorphic rocks (i.e. with new minerals formed under deep burial) have been recorded, but some crushed rocks adjacent to major faults have been found, e.g. where the Ebbor Thrust is exposed crushed limestone can be found. The Mendip Hills are now elevated to around 300 metres above sea-level, but when first uplifted they may have reached close to 2000 metres (a speculative personal estimate based on reconstructing structural features).

The culmination of the Variscan Orogeny saw an elevated ridge of low mountains stretching roughly East to West as we now see them. The detailed structure of these is a series of four separate, elongated, domed ridges (Periclines) placed '*en echelon*' i.e. slightly offset from each other, the most northerly, Black Down, being at the western end and the most southerly, Beacon Hill at the East. This sub-surface structure almost certainly persists further to the East but is now deeply buried by younger rocks and can only be observed from surface structural displacement (faults) of superficial sedimentary rocks and by borehole and remote sensing data. These hills mark the Variscan Front.

Devonian times

The first post-Silurian sedimentary rocks of the Mendip Hills were laid down from about 350 million years ago in the Devonian, when the region was South of the Equator. By the Carboniferous Period this region of Avalonia and the North American continent to which it was joined, had drifted northwards to within the tropical region. The local climate in the Devonian was one similar to today's continental deserts (such as the Sahel) but changed to something like the modern tropics by the Lower Carboniferous as the region moved further to the North. During the Devonian Period the areas to both North and South-West of our region were elevated and supplied vast amounts of freshly weathered river-borne sands, some of which were deposited over the lower-lying landscape. The rocks resulting from subsequent cementing of these sands are extremely strong and chemically inert, consequently today they form high ground which resists weathering well. They rise to their greatest height on Black Down at 325 metres and are collectively known as the 'Old Red Sandstone' the colour being due to their oxidised iron content which imparts a brownish-red colour to many beds. Exposures of this late Devonian sandstone are relatively few, but also occur on each of the higher ridges, e.g. at Pen Hill North of Wells and at North Hill near Priddy as well as at Beacon Hill in the East. In the higher levels, exposed above Burrington Coombe on the slopes below Blackdown. Reports of fish and plant remains have suggested a Lower Carboniferous age for the top of the Old Red Sandstone. Contemporary, fully marine conditions existed further South in Devon, e.g. at Torbay, and also on the North-West coast of Devon where Devonian deep-water sediments merge into Lower Carboniferous goniatite-bearing sediments. The Devonian seas even lapped on to the shores of what became the Bristol Channel and around the Quantock Hills where Devonian fossils such as corals and crinoids occur in thin limestones.

Carboniferous seas in the Mendip hills

Transgression of the sea gradually submerged much of the area, from Somerset northwards into South Wales, Ireland and to northern England. The marine inundation allowed sediments to be transported from elevated blocks of land which had resulted from crustal extension following recovery after the elevation during the Caledonian Orogeny. The major land masses in southern England were in the central Welsh and English ridge known as the Anglo-Brabant landmass and a minor elevated block in what is now Devon and Cornwall. These land areas produced pro-grading deltaic and shallow-water conditions which ranged from fully marine to entirely fresh water. The resulting sediments can now be seen in the Mendip Hills in the lowest beds of the Carboniferous sequence, known as the Avon Group. They include black shales (compressed muds) and thin limestone bands and contain a fauna of typically marine animals, especially brachiopods, but include corals and crinoids. This horizon is poorly exposed but can be seen in the West Twin Stream in the upper (southern) part of Burrington Combe.

As the marine basin became shallower due to the infilling the sediments became increasingly dominated by limestone deposition. The shallow-water sunlit sea-floor was sometimes a hospitable environment for bottom-dwelling shellfish and other organisms to colonise and the rocks today contain their fossilized remains. The commonest of these are corals, brachiopods and crinoids but bivalves and early cephalopods such as Goniatites, Orthocones and coiled Nautiloids had also evolved.

In the Mendip Hills the lowest limestone beds are known as the Black Rock Limestone which remained rather muddy but gradually became paler when the waters cleared and shallowed, as the inflow of muddy sediments was cut off. The scene could have been very similar to that of a modern shallow-water tropical lagoon, with an extensive sun-lit sea-bed punctuated by bush-like coral colonies and solitary 'horn' corals, swaying colonies of crinoids ('sea-lilies') resembling plants but actually echinoderms, and at times liberally scattered with brachiopods, some attached to firm substrates. Although some now extinct forms of fauna are represented a few might seem familiar today. Corals, bivalves and brachiopods all live on in evolved types, but trilobites were in serious decline by this time and died out entirely in the Permian. Fish remains are not often found, perhaps because of a cartilaginous skeleton which would rarely be preserved, but occasional teeth and dermal denticles (bony scales) prove their presence in other parts of Britain.

Volcanoes, again!

This apparently placid tropical environment lasted for many millions of years but, as in more northern parts of Britain, was occasionally disturbed by volcanic activity. The site of one such eruption can still be seen, on the northern shore of Sand Point, near Weston-super-Mare. Here there are basaltic lavas exposed which we know were erupted into the sea because they are in the form of 'pillow-lava'. This, as the name implies, consists of a mound of rounded and inflated balloon-like mounds of partially welded-together lava which formed in contact with water whilst the lava was still liquid, and can only form at the site of eruption. Pillow-lavas have been observed forming today in places such as Hawaii. Associated with the Sand Point lavas there are many metres of volcanic ash, sometimes separated by limestone beds. These demonstrate that eruptions were on-going over a length of time sufficient to permit further 'normal' marine conditions to develop in between eruptions. It is possible to find marine fossil corals and bivalves still embedded within the ash, presumably after being blown up by yet another explosive outburst.

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Lingula, the world's oldest living animal Genus?

One particularly revealing exposure in this volcanic episode shows a sequence of thin ash bands (averaging only a few millimetres each) in a total thickness of around 150mm. In between there are equally thin layers of sand-size particles of limestone which have been washed along by gentle currents. These deposits suggest a more or less continuous episode of volcanic activity over a period of time, in which brief pauses allowed some sand-size sediments to be washed over the latest ash layer. What makes this sequence most interesting is that it also includes the shells and 'burrows' of some tiny (5-10mm long) brachiopods known as Lingula. This animal qualifies as possibly the oldest known living Genus since its fossils first occur in the lower Palaeozoic and it is still alive today, apparently hardly changed at all. Lingula is a brachiopod of the Inarticulate group which had two shells which were not physically attached to each other, but the soft tissue kept them together. They lived in vertical burrows and fed by filtering the water for anything edible.

Naturally, the young animals were smaller than the older ones and in this rock those at the lowest layer are barely more than one millimetre across, and their burrows were of this width. As the layers accumulated the width of the burrows increased in response to the growth of the animals. Towards the top of the layer, about 150mm above the base, the burrows were around 5-6mm across. At this higher horizon a very large majority of the burrows had disappeared, the animals of earlier layers presumably having died. What is remarkable is that in this one bed of rock we can see the entire life-cycle of one generation of diminutive brachiopods. The young ones colonised the sea-bed and established their burrows but were soon buried by volcanic ash, apparently carried along by the current. They attempted to escape burial by moving upwards and those which succeeded grew a little, their burrows widened and became a little deeper. This continued through time until eventually some animals had escaped upwards multiple times, growing in the good times between eruptions or ash deposits. As the individual survivors moved upwards after each burial episode their burrows became wider but fewer as their fellows succumbed. Their shells can still be found entombed in the burrows as a record of their community's life. They demonstrate that for one episode at least, the accumulation of volcanic ash and limestone fragments combined was rapid, around 150mm compacted rock in the lifetime of one generation of brachiopods.

N.B. A comparable story has been told by the bivalves that inhabited the sands from the Coal Measures of the Upper Carboniferous in the Pennine district. In this case the rate of burial was much faster, up to a metre of sand in the lifetime of one animal. Only the luckiest of these animals managed to escape from burial by constant upwards movement. Their 'escape shafts' (not really burrows!) are clear evidence of the transitory passage upwards by bivalve shells through the continuously accumulating layers of sand. Like the Lingula brachiopods in the Lower Carboniferous limestone some of these bivalves left their shells in the shafts as evidence of their failure to keep up with sedimentation.

How did the limestones form?

One agent of sediment production is the action of animals such as brachiopods and corals secreting shells or skeletal supports. But what if there were no animals locally? Following the deposition of the Black Rock Limestone the seas remained clear and became shallower. In the absence of terrestrial mud the only material that was available for deposition was lime. This can be precipitated from warm waters inorganically when conditions become particularly saline. Lime is the first substance to become over-saturated in solution and was periodically precipitated as minute grains of a mineral called Aragonite. This calcium carbonate mineral is formed spontaneously in warmer seas where evaporation has increased the concentration of dissolved lime beyond the solubility limits. It is often assisted by the action of photosynthetic organisms which remove dissolved carbon dioxide, thus making the water less acidic. Aragonite happens to be unstable in geological time and as a consequence usually reverted to the more stable mineral Calcite. In doing so the previously soft ooze of tiny crystals set hard into a substance akin to cement and turned the soft sediment into a hard rock. In addition to this inorganic sediment marine photosynthetic organisms (cyanobacteria and/or phytoplankton) also contributed yet more hard lime by altering their immediate environment. In photosynthesis carbon dioxide is removed from solution, which reduces the acidity of the water. This lowers the solubility of the dissolved lime and causes layers of lime to accumulate around the minute bacterial cells. Layers of bacteria, each producing more lime can cause granules to form which, when agitated by wave action, roll around so exposing all surfaces to the sunlight. This results in spherical balls of lime known as 'ooliths' or 'ooids', after the ancient Greek word for an egg, which they resemble. They can make up a large proportion of some limestone layers, especially those formed in shallow sea-water. The result is known as 'oolitic limestone'. Such rocks are common in the Mendip limestones and especially well seen in the middle part of the sequence, e.g. the Burrington Oolite and Vallis Limestone. They represent shallow-water sand-banks where reasonably lively waters stirred up the sea-bed sediments.

Corals as environmental indicators

Higher in the sequence of limestones the Clifton Down Limestone is a horizon containing substantial colonies of coral called Siphonodendron (formerly Lithostrotion) which is indicative of two main features of the palaeoenvironment. The first requirement for most varieties of coral to flourish today is clear, shallow and therefore well-lit water, which benefits photosynthetic symbiotic algae inside the coral polyps, without which they fail. The other is water with reasonably constant temperature at around 26 degrees Celsius. Any significant deviation from these two conditions will affect the corals adversely and so it seems likely that the Carboniferous seas were at times within these limits.

'Algal' limestones

Not all of the limestone beds are rich in fossils, nor do they all contain ooliths. Some are fine-grained and featureless grey rocks known as calcite mudstones and indicate that the environment was poor in life. The reason for this is that the waters were so saline that almost nothing could live in them. The likelihood is that the seas were extremely shallow lagoons, cut off entirely from the open sea and under a scorching tropical sun, so they became in effect evaporation pans. The lime which was dissolved in the water would then be precipitated inorganically, or by the action of cyanobacteria or algae, and laid down as a soft mud. So-called 'algal' limestone is not a common feature of Mendip limestones although it is readily recognised for its minutely layered appearance, often in dome-like structures known as stromatolites. In Cheddar Gorge there are stromatolites, indicating that such conditions did occur.

The latest stage of the Lower Carboniferous limestone sequence is represented in the Mendip Hills by a horizon known as the Oxwich Head Limestone. This outcrops in various places, especially on the outer, i.e. stratigraphically highest, slopes of the limestones. It is the final development of Carboniferous limestone deposition and, although reported to be shelly in some exposures, includes 'Karst' features. In Burrington Coombe it can be seen at the northern end where calcilutites (lime mudstones) with several eroded bedding surfaces and limestone pebbles in hollows indicate that the limestone was being eroded sub-aerially and exposed to rain-water at times. By this late stage in the Lower Carboniferous the sedimentary basin had in effect become so shallow that little further deposition of lime was possible.

The Upper Carboniferous

The transition from Lower to Upper Carboniferous in the majority of Britain is marked by a thick unit of coarse sandstone. In the Pennines it is the Millstone Grit, in the Bristol region it is the Quartzitic Sandstone, a nearly white, fine-grained, current-bedded unit several tens of metres thick. Recorded within it are thin coal seams and palaeosols indicating a deltaic or estuarine environment. When this was laid down the sea had retreated and for much of the time only brackish or fresh water covered the region. The total area involved was enormous, covering much of Britain, western Europe and North America. The Atlantic Ocean did not exist, so Britain was simultaneously next to North America and firmly joined to Europe.

The sequence above the Quartzitic Sandstone is collectively known as the Coal Measures. The majority of the rocks are mudstones or siltstones. These are relatively weak so they are easily eroded away and rarely form surface exposures even though they outcrop. The easiest way to see some of them is to visit the few remaining coal-mine tips which are still accessible and the most convenient of these is at Writhlington Batch close to Radstock. The Radstock area is well known for its coal-mining history, which is commemorated by the head-gear from a local pit preserved now in the town centre. You can still visit the nearby waste tips and find some plant remains amongst the rocks which miners dumped many years ago. The last local mine closed in the 1970's.

The Upper Carboniferous environment was one of extensive rivers running across wide deltaic coastal plains. When the sea did encroach* it brought characteristic marine animals such as goniatite cephalopods and Lingula (shoreline brachiopods) but for most of the time the waters were fresh or brackish. In these extensive tropical swampy areas there was abundant and diverse vegetation. This was dominated by very large tree-like seed ferns, cycads, club-mosses and horsetails. Although very large, these plants were herbaceous, they were not solid wood like modern trees but had hollow or pith-filled tubular stems. Despite this flimsy structure they managed to grow many metres tall, with trunks around half a metre in diameter.

The swamp forests were periodically inundated by the sea, possibly because of sudden local subsidence caused by extensional faulting across the region*. This formed deeper water-filled areas and inevitably resulted in the death of the plants and their rapid burial by sand or mud from the rejuvenated rivers. The coal seams were formed by the slow anoxic decay of the plant material which preserved some of even the softest tissues. After each of these subsidence events the rejuvenated rivers continued to transport sediment from higher ground, rapidly infilling the newly formed basins and producing characteristic repetitive sedimentary units known as cyclothems. Many of these commenced with a sequence of fine-grained muds, occasionally containing marine animals or brackish water bivalves. As the basin became shallower the water's velocity increased and carried coarser-grained sandy sediment. The newly deposited material eventually emerged as tidal flats or river levees allowing land plants to re-colonise, and these could then form a new coal seam when their turn to be buried arose

The Permian Variscan upheaval

Following the Carboniferous period the Mendip region was involved in a global event which affected all of this area. It involved the collision of Avalonia with major continental masses including Eurasia, North America and Africa. The collision effectively crumpled the newly formed rocks of the Carboniferous and formed mountain ranges through the Appalachians and north-western Europe, and gave southern Britain a good squeeze too. Here the rocks were folded, some were sheared as thrust faults pushed over each other and so the Mendip Hills were born. All of this movement elevated the land to several thousand feet in our region, but almost as fast as it was uplifted it began to be eroded down again. The softer rocks were easily removed but the harder limestones and their foundation of tough Devonian sandstone resisted the erosive effects and remained as higher ground. The elevation marked the beginning of a new epoch in geology with a period known as the Permian. Very few rocks of this age are found in southern Britain, mainly because it was such a time of erosion, but there are some coarse pebble beds near Milverton in the extreme west of the county which are thought to be from this time and in east Devon there are Permian lavas from nearby volcanic vents. The Permian period is almost unrepresented as a rock in our region but commenced a very important change in the environment from shallow coastal plains to elevated land as the area which became Britain was deeply embedded in the newly formed supercontinent called Pangea. Another very major change also occurred however, from tropical humidity to sub-tropical arid desert environment as the region had moved northwards across the equator so experience a typically continental hot and arid climate.

The Triassic

The rocks laid down millions of years later in the Triassic period are strikingly different from those which precede them. You can often see them whenever you cross the Mendip Hills because they were extensively quarried for building purposes. Their most conspicuous use was as walling for domestic buildings and as lintels and field-gate posts, which owe their strength to the natural layering and subsequent mineralisation of the coarse pebble beds. The earliest Triassic rocks, known as the Dolomitic Conglomerate, were formed as hill-wash pebble beds on top of the eroded surface and around much of the perimeter of the hills during flash-flood events. They were subsequently strongly cemented by mineral-rich waters which circulated through the porous sediment. When quarried, large slabs could be lifted and then cut into convenient sizes. By comparison, the Carboniferous limestone is rarely so well layered, but is more massive and difficult to work into slabs, but ideal for ashlar and general rubble wall infill.

One of the most interesting features of the Triassic rocks is that they are seen in the depths of Burrington Combe and elsewhere in other gorges and deep valleys. For the Triassic sediments to have been laid down in these sites there must have been a valley or cave system available during the Triassic, so the implication is that the Mendip Hills had been uplifted and eroded to something like their present appearance during the Permian period, and have been preserved under younger cover ever since. This shows that the present landscape is at least 250 million years old!

From 250 Ma to the present

The final stage of our Mendip story is that the sea slowly began to cover the Somerset area as it extended westwards from the Zechstein Sea in the East, an area of the Tethys Ocean. At first it crept in to the low land and can be seen in the few remaining quarries south of the hills as well as on the north Somerset shore at Hinkley Point, Kilve and Watchet where fine muds and limestone bands predominate. There are abundant fossils at some horizons too, so the sea was clearly inhabited, at least from time to time. The sea-level must have risen very considerably and fairly rapidly because similar ammonites to those found at Watchet can also be seen in synchronous shallow-water limestones on the flanks of the Mendip Hills. The first ammonite seen is the marker for this period of geological time, the Jurassic. Psiloceras planorbis, a rather flattened and smooth–shelled form which is taken as the base of the Jurassic in Britain. It was followed by many other ammonite species and the Jurassic period was one of dramatic and rapid evolution of these and other marine creatures.

In addition to thinly bedded late Triassic and early Jurassic rocks representing this marine transgression mid-Jurassic oolitic limestone is present on the eastern Mendip Hills, as well as in the surrounding countryside, notably in Gloucestershire, South Somerset and Dorset. The sea gradually covered the hills but their detailed lithology demonstrates that this was shallow and that erosion happened during this period. The best accessible exposures are in Vallis Vale north of Frome where an extensive flattened surface of eroded Carboniferous rock is overlain by Inferior Oolite. The surface is penetrated by rock-boring bivalves and other organisms and overlain by oyster shells, showing that it was an extremely shallow wave-washed shoal well into the Jurassic Period. This environment is also represented by the shell-debris of the Doulting Stone which is still quarried in the eponymous village as it is highly valued for dressed stone. In the quarry at Doulting there is a depositional surface with evidence of erosion and burrowing activity, in addition to broken fossil remnants indicative of a high-energy environment during deposition.

Until recently it was though that the subsequent Cretaceous Period is unrepresented on the Mendip Hills and that it might possibly have failed to cover them. This is now known not to be the case and a local site close to Moons Hill has revealed some Cretaceous sedimentary deposits in an area which was possibly a local hollow during that time.

No younger material has been found excepting the terrestrial and shoreline deposits of the Pleistocene, mostly around the flanks of the hills at their western end. These include many examples of fissure and cave deposits with rich faunas of mammalian bones. Amongst these are the well-known Banwell Bone Cave, Picken Hole near Christon, a rock-shelter in Ebbor Gorge and the Westbury-sub-Mendip Bone cave. There is also a scree deposit dating back to the Pleistocene at Brean Down on the southern side of the landward end. These sites have produced numerous bones of many species including cave bear, hyaena, horse, woolly rhinoceros, hippopotamus and reindeer as well as many smaller vertebrates, which improbable sounding mix may reflect changing climatic conditions over a considerable time. The presence of apparently worked flint in at least one of these deposits (Westbury) also hints at the presence of Man. The last few millennia of the Pleistocene were times of marine incursion into the area surrounding the Mendip Hills, which even today is only a few metres above sea-level. These episodes deposited mainly fine-grained marine clays, but occasionally sand-banks with marine organisms are seen, especially in the ridge of slightly higher ground around Bridgwater and in the villages of Greylake and Birtle, after the latter of which the deposits are named. The outlying knolls of Nyland, Burrow Mump, Brent Knoll and even Glastonbury Tor were islands in a marsh or shallow sea until relatively recently.

Mineralisation

Following the deposition of the Palaeozoic rocks the Mendip Hills were subjected to vigorous compression from the south which produced major thrust faults and quit dramatic folding, even to the extent of overturning in the north, of the previously horizontal beds. The brittle nature of these rocks caused extensive fracturing along the fold axes and where subterranean liquids encountered alkaline conditions deposition of low-temperature minerals occurred. These commonly included lead sulphide, zinc carbonate and accessory arsenic and cadmium compounds. These were easily found at or very near the surface of the ground and so exploited from early times, i.e. at least two millennia ago, but the deposits were found to diminish at depth, showing that they were not sourced from deep down but may have originated from the now absent superficial (Mesozoic) cover. Silicification was a common occurrence throughout the mineralised areas and chert bands and totally replaced silicified beds, as at the Harptree region in the north, are widespread. This often affected the previously deposited evaporite nodules of Anhydrite and caused them to be replaced with agate and quartz nodules, known locally as Potato Stones.

- Changing sea-levels on a global scale, known as Eustatic changes, during the early Carboniferous Period can be explained by the very extensive land mass of Gondwana which covered the South Pole at this time. This was glaciated at times as is Antarctica today, and if the glaciation was intermittent as in the Pleistocene the amount of water taken up by the glaciers could well have fluctuated significantly at times.

  Later fluctuations in relative land/sea levels as seen in the Upper Carboniferous Coal Measures are more likely to have been controlled by epeirogenic (local) vertical movements associated with faulting and local subsidence during extensional settling.

We have evidence of such changes in sea-level around the shores of Somerset during the Pleistocene glaciations in the form of drowned forests and raised beaches, the most extreme variation in level might have been well over 100 metres. Such a change could easily account for the drowning of the coal-forming forests and the influx of fresh sediments to similar depths.

Peter G Hardy 2024