Geological history of Yorkshire

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The solid geology of Yorkshire is dominated by rocks of the Carboniferous to Cretaceous systems (Figure 1). The hills and dales of the Pennines in the west, together with the industrial cities of the centre and south, are underlain by Carboniferous rocks. These continue at depth where a narrow belt of Permian scarps and broader Triassic vales stretch south from Teeside and bisect the county. To the east, the deeply dissected tableland of the North York Moors is formed of Jurassic rocks and the rolling wolds to the south lie on the Cretaceous. The effects of the last glaciation are widely apparent in the moulding of landforms, and a veneer of glacial and periglacial sediments obscures much of the solid geology, particularly in the lowlands. Much older rocks, forming the foundation of the county at depth, are exposed at the surface only locally in the far west, where they extend the geological record back to the early Ordovician (Figure 2). The rocks of the county contain a wide range of economic resources, from lead and zinc to iron and coal, which have been exploited from at least Roman times to the present day. The scars of their extraction are widespread in the countryside and their importance to Yorkshire's historical development is evident in the industrial base of the major centres of population.

At the beginning of this geological history, the area of the British Isles existed as the pieces of a giant jigsaw moving slowly towards their final assembly. In the early–mid Ordovician, the area that is now Yorkshire occupied the northern margin of the micro-continent of Eastern Avalonia, which lay in high southern latitudes (Figure 3)a. During the Ordovician and early Silurian, Eastern Avalonia drifted northwards towards the mid-latitude continent of Baltica, consisting of the landmass from Scandinavia to the Urals, and the large equatorial continent of Laurentia, comprising present-day North America, Greenland, Scotland and northeast Ireland, as the intervening Iapetus Ocean and Tornquist's Sea gradually narrowed by the subduction of ocean crust.

The Ordovician to Silurian sedimentary sequence, now exposed in the inliers along the Craven Fault Belt near Settle (Excursion 1), has similarities with that of the Lake District. Turbiditic sandstones, with interbedded siltstone, conglomerate and mudstone (see clastic rocks) of probable Early Ordovician age are possibly several kilometres in total thickness. They were tightly folded, uplifted and eroded in the Middle Ordovician interval when a subaerial volcanic island arc was active on the northern margin of Eastern Avalonia, parts of which are preserved in the Lake District. Subsequent crustal extension produced a foreland basin, resulting in the return of marine conditions with a transgression in the Late Ordovician, when shallow water, mixed clastic–carbonate rocks 450 m thick, which are locally richly fossiliferous, were deposited. In the Silurian, 35 m of graptolitic mudstones and siltstones were laid down in the Llandovery as the seas deepened. The infilling of the foreland basin, the remnant seaway between Laurentia and Avalonia, occurred in the Wenlock and Ludlow, with a 1600 m thick succession of mainly turbiditic sandstones and siltstones.

The collision between Eastern Avalonia, Laurentia and Baltica culminated in the compression and deformation of the Lower Palaeozoic rocks of Northern England in early Devonian times. The Acadian Orogeny, the terminal phase of the Caledonian Orogenic cycle, formed a continental area of fold mountains and rugged uplands striking northeast–southwest across most of the area that is now the British Isles. Granite magmas were generated at depth during the orogeny and injected as plutons into the deformed sedimentary pile. No granites crop out at the surface in Yorkshire, but the Wensleydale Granite and a probable granite under Market Weighton have been detected at depth by geophysical survey. The Wensleydale Granite has been proved by a borehole and dated at 400 ± 10 Ma.

The Devonian was a period during which erosional processes removed much of the upland relief and provided great quantities of coarse sediments to intermontane basins and to flood plains on the continental margin to the south. However, in the Yorkshire area, no deposits from this period have been proved, and the truncated remnants of the folded Lower Palaeozoic rocks are directly overlain by sediments deposited during the Dinantian (early Carboniferous) marine transgression. This strongly angular unconformity can be seen at outcrop in the Craven Inliers and to the west and north of the county, suggesting that a similar relationship occurs throughout the county at depth.

Post-Caledonian crustal extension broke up the eroded roots of the Caledonian mountains into a series of relatively buoyant blocks and subsiding half-graben basins that still influence the topography of northern England today. The Askrigg Block, underlain at depth by the Wensleydale Granite, is defined on its southern margin by the east–southeast trending Craven Fault Belt (Excursion 2), south of which is the Craven Basin (Figure 3)b. The western and northern margins of the block are defined by the Dent Fault and the Stainmore Trough (lying between the Askrigg and Alston Blocks), close and parallel to, but mostly just outside the present county boundary. The transgressing early Carboniferous seas first flooded the basins, and locally at the block margins basal conglomerates and reddish sandstones accumulated. As the seas deepened and cleared, shales and limestones of early Dinantian age were deposited in both the Stainmore Trough and Craven Basin.

Carboniferous sedimentation was dominated by cycles of transgression and regression on several scales. The six stages of the Dinantian (early Mississippian) are based on mesothem cycles with calcareous shales and richly fossiliferous, sometimes bituminous limestones characteristic of the transgressive phase, and oolitic limestones, algal limestones. dolomites and in places sandstones, pebble beds and disconformities marking the regressive phase in shallow waters. In the Craven Basin, where the Dinanthian sequence is some 3 km thick, early sediments are bioclastic limestones and calcareous shales but, episodic earth movements from mid-Dinantian into Namurian times resulted in northeast–southwest folding and increased subsidence in which goniatite-bearing, deep-water shales predominated. In the transition zone between the Craven Basin and the Askrigg Block, and around Clitheroe, marginal reef limestones were developed between basin and block in mid and late Dinantian times (Excursion 2). In the Stainmore Trough, subsidence and sedimentation more nearly kept pace and neither significant deep water fades, nor reef facies, were developed. The Askrigg Block, on which the Dinantian is less than 500 m thick, was not completely inundated by the sea until late Dinantian times (Excursions 2, 5, 6). Minor sedimentary cycles become increasingly apparent within the topmost mesothem, with many repetitions of marine limestone succeeded by shale, sandstone and in places seatearth and coal. These are Yoredale cycles, a term derived from the old name for Wensleydale, where they are classically developed. The limestone component dominates at lower levels and towards the southern part of the Askrigg Block where open marine conditions prevailed. The elastic sediments increased in proportion in younger cycles and to the north, reflecting the increasing influence of southward prograding deltas. The Dinantian limestones are commonly rich in corals, brachiopods and foraminifera, all of which help to date and correlate the sequences.

The Yoredale facies extends up into the Namurian, but from south to north across the county is replaced at progressively younger horizons by the thick and often coarse-grained fluviatile and deltaic sandstones of the Millstone Grit (Excursions 5, 6, 7, 8, 9, 10). By early Namurian times, the clearly defined basin and block topography had largely disappeared, although subsidence rates remained highest, and sedimentary sequences therefore thickest, in the basinal areas. In the Craven Basin, the succession reaches 2.5 km in thickness, in contrast to a mere 370 m on the Askrigg Block and 500 m at Stainmore. These sediments were deposited from river systems flowing predominantly southwestwards into the area. As the deltas advanced, turbidites locally formed on basinal slopes in front of them, over which the deltaic and fluviatile sediments prograded, often building up to sea level to form forested flood plains and swamps. Episodic transgressions of the sea across the delta top resulted in the deposition of thin marine bands with goniatites, vital for dating and correlation.

By Westphalian times, although the cyclicity was undiminished, the marine incursions were fewer and shorter in duration though still widespread. The sandstones were finer grained and thinner and periods of soil formation and swamp vegetation more frequent and prolonged, resulting in thicker coal seams. These Coal Measures (Excursions 8, 9, to) are now exposed in the Leeds–Sheffield industrial belt of south–central Yorkshire where the sequence is 1500 m thick, and are present in the subsurface to the east. Yorkshire was now part of a broad subsiding area called the Pennine Basin, which in turn was part of a vast belt of tropical Coal Measures sedimentation extending from eastern U.S.A. to Poland. To the south of this was a rising landmass, developing as a result of the Variscan Orogeny. Towards the end of the Westphalian, sediments from this landmass caused the infill of the Pennine Basin with cyclic continental red-beds, followed by a period of rather gentle folding, extensive faulting and uplift, particularly in the former basinal areas. For 30 m.yrs., during the late Carboniferous and early Permian, the resulting upland landscape was deeply weathered and peneplaned in a largely hot, dry climate.

The Carboniferous rocks, principally the Dinantian and Namurian of the Pennines, are host to economic deposits in the form of numerous mineral veins (Excursion 4). The principal metalliferous minerals are galena and sphalerite, with some chalcopyrite, pyrite and bornite, and scattered occurrences of several other minor components. These occur as localized masses or are dispersed in veins in which the main constituent is usually baryte, occasionally witherite and locally fluorite. Mineralization probably occurred in the latest Carboniferous as a result of the circulation of low-temperature hypersaline brines, possibly expelled from the thick sedimentary sequences of the basinal areas (so called Mississippi Valley-type mineralization), through joint fracture systems imposed by Variscan earth movements. Vein fractures are widest and cleanest in sandstones and limestones, and locally the latter have been replaced by ores. The Romans certainly mined lead and pre-Roman exploitation has been suggested. The peak of mining activity was in the late 18th and first half of the 1 gth century, whilst most recently, limited mining activity has concentrated on the former gangue minerals baryte and fluorite.

Renewed subsidence in Permian times placed Yorkshire near the western margin of a broad basin extending across northern Europe into Poland, situated in the hot, dry belt about 12–13° north of the equator. Basal and marginal piedmont breccia wedges and sheets are associated with patchy continental dune sands of presumed late Cisuralian age (Figure 3)c (Excursion 14), resting with gentle unconformity on the Carboniferous (Figure 1), (Figure 2). At the beginning of the Guaclalupian, the basin, then well below sea level, was flooded, extensively reworking the sands and introducing a period of marine and hypersaline conditions in a fluctuating epicontinental sea. Four major cycles of limestones, later altered to dolomites, and succeeding evaporites, including gypsum (now anhydrite), halite and potash salts, were developed. These cycles resulted from periodic recharge of the basin by normal marine waters, from which limestones, 'many oolitic and locally fossiliferous, were formed around the margins. Only the limestones and dolomites are prominent at outcrop in a narrow north–south belt bisecting the county, the evaporites being reduced to thin, silty dissolution residues (Excursions 13, 14). In the first cycle, fossiliferous bryozoan and stromatolitic patch reefs formed, but in the third cycle the limestones contain only a few plant and invertebrate species. Limestones of the second and fourth cycles do not crop out in Yorkshire but are present in thicker sequences in the subsurface to the east, where potash is mined at Boulby near the coast west-northwest of Whitby. Towards the end of the Permian, continental, water-lain red sandstones, siltstones and mudstones gradually filled the basin from the west.

These continental clastic deposits are unfossiliferous and span the Permo-Triassic boundary, which is consequently difficult to define. In addition, the soft sandstones, marls and evaporites of the Triassic, deposited along the western margin of an epicontinental North Sea Basin are rarely seen at outcrop, forming low ground largely mantled by glacial deposits in the Vales of Mowbray and York. The early Triassic (Sherwood Sandstone) consists of fluvial sandstones, with some flood-plain mudstones and siltstones and, in the south of the county, pebble beds deposited by north-flowing river systems. These are overlain with gentle unconformity by a thin concentrate deposit and then by dolomitic and silty mudstones (often red) and evaporites (principally halite) of the Mercia Mudstone, the result of waters from the Tethys Ocean flooding into the North Sea Basin, forming a shallow hypersaline marine environment. Macrofossils are rare but plant spores allow dating and correlation of the lower part of the sequence. Renewed transgression at the end of the Triassic produced thin, shaly mudstones with a bivalve fauna, bone beds and argillaceous limestones overlain by soft lagoonal mudstones. The total thickness of Triassic deposits increases from about 400 m at outcrop to some 700 m in the subsurface beneath east Yorkshire.

The late Triassic transgression was the first phase of a major rise in sea level, establishing widespread open marine conditions at the beginning of the Jurassic. In the Yorkshire area, a Cleveland Basin is recognized, bounded to the south by the Market Weighton Block on the northern edge of the East Midlands Shelf (gg-figure name="ygs_yorkrck_fig_03_00">(Figure 3)d. Some beds show depositional thinning over the block. However, thinning of Jurassic and early Cretaceous rocks across the Market Weighton area is partly the result of periods of post-depositional erosion, with only the lower part of the Lias being traced continuously across the structure beneath the unconformity at the base of the Chalk (Figure 1) (Excursion 15). Some important facies changes occur not over the block but to the north of it.

The Lias Group is a sequence of richly fossiliferous mudstones, calcareous in part, with subsidiary shallow marine sandstones and ironstones of about 420 m maximum thickness in the Cleveland Basin (Excursions 11, 16, 17, 18). Concretions are abundant. A cyclic repetition of thin limestones and shales is very evident in the lower part of the succession. In contrast to the two preceding systems, abundant ammonites allow a very precise dating and correlation of the sequence. Other fossils include a wide range of bivalves, brachiopods, belemnites, less common echinoderms, marine reptiles and wood. The ironstones, alum shales and jet were of economic importance historically.

Uplift and gentle folding terminated this marine sequence and the Middle Jurassic consists of about 250 m of fluviatile and deltaic sandstones, siltstones, shales and minor coals with marine intercalations, resting unconformably on various levels of the Lower Jurassic (Excursions 11, 17, 18, 19). These deposits were laid down by south-flowing river systems originating immediately to the north. South of Yorkshire, they pass transitionally into the fully marine sequence of central and southern England (Figure 3)d. Fossils are often common in the marine interbeds and the marshy delta-top environment supported a rich flora which is locally well preserved. A transgression returned fully marine conditions to the area late in the Middle Jurassic. The first sediments deposited were a variety of sandstones, shales and limestones up to 50 m thick, many highly fossiliferous, principally with bivalves and ammonites.

Minor episodes of gentle warping and erosion broke up the Upper Jurassic succession on the Yorkshire coast (Excursions 19, 20), whilst inland and to the south of the county the widely uniform muds of the Oxford Clay became established. This facies only extended to the coast in upper Oxford Clay times where it is 45 m thick. There, it is succeeded by a highly variable 100 m thick complex of limestones, including coral patch-reefs, and fine-grained calcareous sandstones. These too show lateral facies changes north of the Market Weighton area to marine muds typical of much of the eastern Midlands.

Renewed transgression extended marine clay facies back across the Yorkshire area with the deposition of the Kimmeridge Clay, the most laterally persistent and uniform of all late Jurassic sediments and the principal source rock for North Sea oil. Unfortunately, the unit is poorly exposed in Yorkshire although in boreholes it may reach about 270 m in thickness. The latest Jurassic and very earliest Cretaceous strata are not represented in Yorkshire because renewed earth movements resulted in the uplift of an extensive landmass extending from central England into western Europe.

Transgression early in the Cretaceous returned marine conditions to Yorkshire with the deposition of a richly fossiliferous sequence of soft shales and clay some 100 m thick (Excursion 20). The principal fossils are ammonites and belemnites and almost the whole of the lower Cretaceous is represented by this uniform sequence, making it the best and most complete example of this period in the U.K.

Towards the end of early Cretaceous time, the supply of mud ceased and the sea deepened and cleared. This began the period of maximum transgression in the Mesozoic ((Figure 3)e, with uniform marine conditions across the whole of western Europe (Excursions 15, 20, 21). Calcareous oozes formed, composed almost wholly of the minute platelets of coccoliths (unicellular algae) which abounded in surface waters. Initially, iron oxides stained the oozes and up to 30 m of red chalk is recorded in southeast Yorkshire, with varied faunas of sponges, bivalves, brachiopods, echinoids, and crinoids. In the late Cretaceous, the red chalk is succeeded by the familiar white chalk which reaches a maximum thickness locally of 500 m. The rock is more marly and harder, due to calcite cementation, than in southern England and flints are present between about 4.0 m and 210 m above the base. The fauna is similar to that of the red chalk, although ammonites are also sporadically found. Distinctive laterally continuous marl and flint layers have proved excellent marker beds for local correlation between sections. The highest parts of the chalk do not crop out in Yorkshire, although they are present in part under the glacial deposits of Holderness.

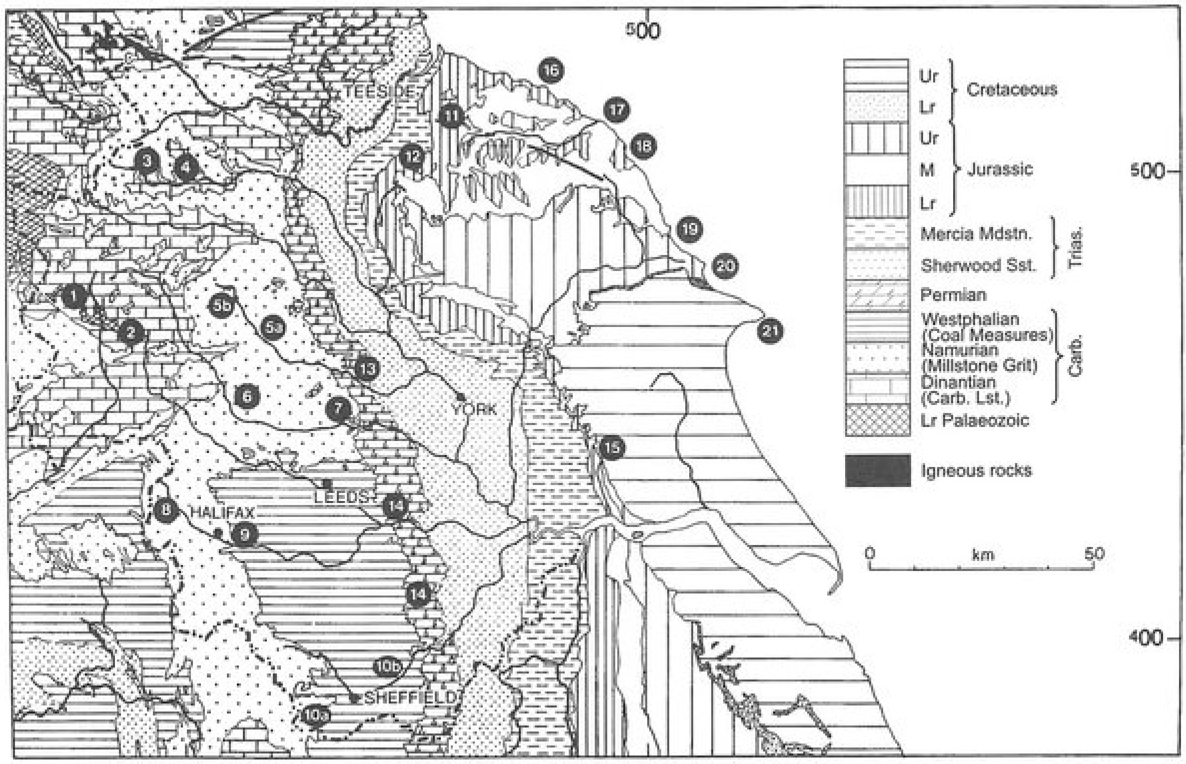
A major retreat of the sea, together with uplift at the end of the Cretaceous, means that Tertiary sediments may never have been deposited in Yorkshire, although thick sequences are known offshore beneath the North Sea. These earth movements lifted the northwest part of the British Isles and were largely responsible for the prevailing shallow southeasterly tilt of the Mesozoic rocks in eastern and southern Britain. The only undoubted Tertiary rock in the county is the Cleveland Dyke (Figure 1), a thoeliitic basalt intrusion up to 25 m wide and a distant representative of the Tertiary igneous complex of Mull. It has been worked almost to exhaustion, mainly for roadstone in a series of quarries from Great Ayton across the Cleveland Hills (Excursion 11).

The most recent geological activity, that of the Quaternary, has had a profound influence on the physiography, superficial deposits and soils of the county (Excursions 3, 11, 12, 20, and briefly elsewhere). The whole area was probably covered by ice sheets on many occasions, but the bulk of the evidence relates to the last glacial stage, the Devensian. Glacial and glaciofluvial sediments of this age cover northwest Yorkshire and the lowlands of the Vale of York, Teeside and

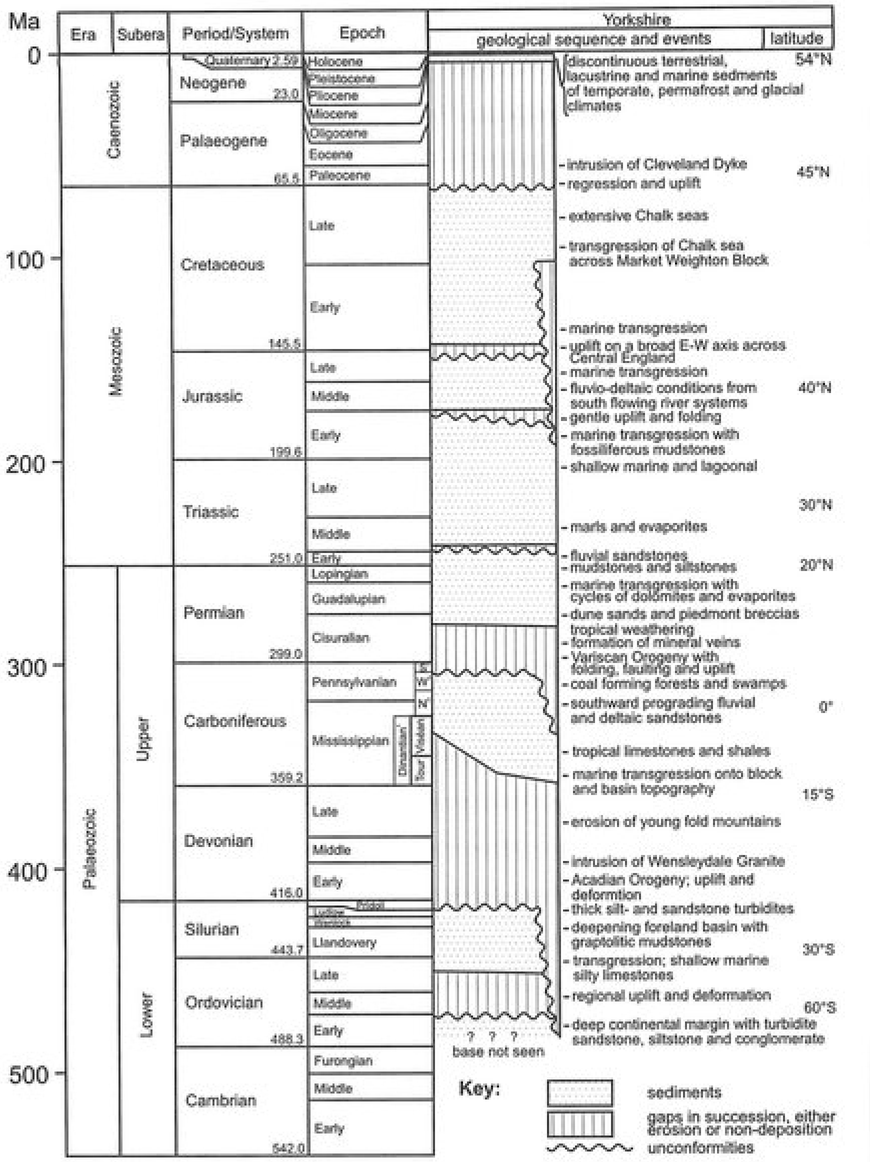
Holderness (Figure 3)f. Elsewhere, periglacial processes redistributed existing superficial sediments as sheets of gelifluctate and thin sheets of loess across hillside slopes and plateaux, often now mixed in the present topsoil. In the Pennine dales and Cleveland Hills, the effects of glacial meltwater are preserved in the form of channels and outwash deposits. The lowlands of the Vales of Mowbray, York and Pickering, and in Holderness, contain complex associations of till, sand and gravel, and laminated lake clays. Erratics in these deposits are derived from the Lake District, the Cheviot Hills, Scotland and, in the eastern part of the county, Scandinavia. Locally, interglacial deposits with mammal remains survive in caves, and interglacial shorelines indicate the positions of former high sea levels, similar to that of the present day.

It is only some 17 000 ^{14}C yrs (see dating) since the Devensian ice sheet began its retreat from Yorkshire, and the last ice in the northwest Pennine fells disappeared only about 10 500 ^{14}C yrs ago. With post-glacial sea level rise, the county has gradually assumed the familiar form of the present day. This rise is still continuing, albeit very slowly, and coastal erosion in areas such as Holderness, for example, is causing the shoreline to retreat on average by about 1.5 m per year. However we are long past the climatic optimum of the present interglacial and in the distant future (in human terms) the glaciers could return to Yorkshire.

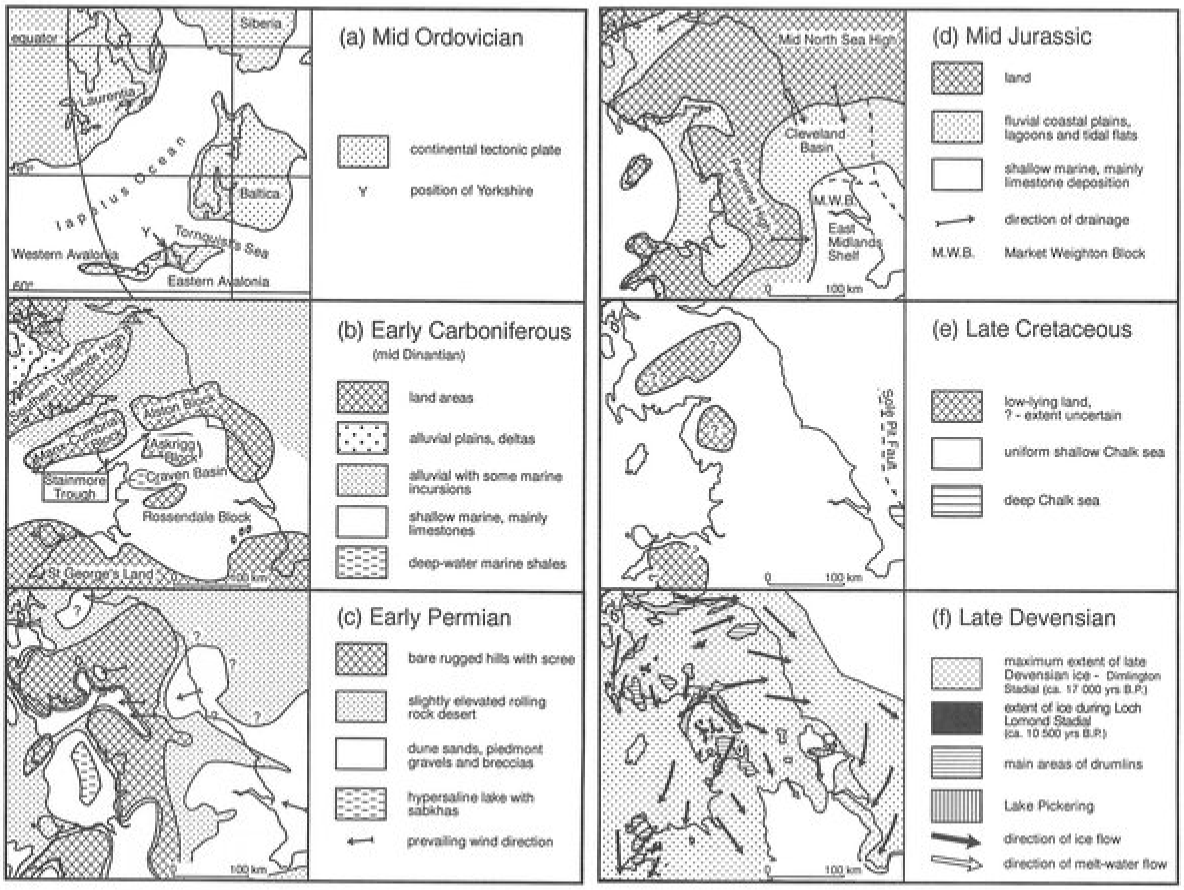
Bibliography



(Figure 1) Pre-Quaternary geological map of Yorkshire and adjoining areas showing the location of excursions.



(Figure 2) Geological column and sequence of events in Yorkshire. 'The terms Dinantian, Namurian (N), Westphalian (W) and Stephanian (S) no longer have formal status but are retained here for convenience.



(Figure 3) Palaeogeographic maps indicating: (a) the distribution of continental plates in the mid Ordovician (based on Scotese & McKerrow 1990) and (b-f) the distribution of land and major sedimentary environments at various times in Yorkshire and surrounding areas (based on Cope, et al. 1992 and other sources).