Glossary

This glossary provides brief explanations of the technical terms used in the introductions to the chapters and in the 'conclusions' sections of the site reports. These explanations are not rigorous scientific definitions but are intended to help the general reader. Detailed stratigraphical terms are omitted as they are given context within the tables and figures.

In addition to the terms defined below, there is a more comprehensive list of Upper Cretaceous stratigraphical terminology used in England contained in the International Stratigraphical Lexicon on the Cretaceous edited by J.M. Hancock, 1972 (*Lexique Stratigraphique International,* Volume I: Europe — Angleterre, Pays de Galles, Ecosse. Fascicule 3a XI. CRETACE). The list below includes terms either not in the Lexicon, or re-defined or introduced since the Lexicon was published.

Abundance zone (formerly 'acme zone'): a biostratigraphical unit characterized by the time range in which one or more taxa were the most abundant.

Age: a time unit, usually taken to be the smallest standard division of geological time, of shorter duration than an epoch.

Ammonite: an advanced group of cephalopods characterized by typically coiled, chambered shells that have complex sutures between the chamber walls and the outer wall of the shell.

Anglo-Brabant Massif: submerged, ancient land-mass comprising the London Platform, its northern extension beneath East Anglia and its continuation beneath the area of the present southern North Sea to join the emergent Brabant massif in Belgium. This complex structural unit exerted considerable control over Cretaceous sedimentation.

Anoxia (adj. anoxic): state of oxygen-depletion in sedimentary environments, including anoxia in pore waters within sediments, and in the bottom waters of a sea or ocean bed.

Aragonite: a magnesium-rich mineral form of calcium carbonate that is more soluble in cold water than in warm. Shells made of aragonite ('mother-of-pearl'), such as those of ammonites and nautiloids, scaphopods, many bivalves and most gastropods were not normally preserved in the relatively deep and, consequently, cooler water of the Upper Cretaceous Chalk seas, but were preserved in shallower and perhaps warmer depositional environments. For this reason, well-preserved ammonites in the Chalk are mostly found in hardgrounds and thin condensed limestone successions.

Assemblage zone: type of fossil zone (*biozone*) that is based on an assemblage of fossil species and not on the occurrence or range of a single species. The index fossil of an assemblage zone (AZ) is not necessarily restricted to that zone. Most of the traditional macrofossil biozones of the Chalk are assemblage zones. Contrast with *total range Zone* (TRZ), which is based on the total range of the zonal index fossil, and *partial range zone* (PRZ), which involves overlapping ranges of zonal index fossils. The last term is particularly used in microfossil and macrofossil biostratigraphy.

Band/Belt/Horizon: three synonyms frequently used to describe the occurrence of a fossil or a particular geological feature that is used in correlation of rock strata over a wide area. For example, the upper belt of abundant *Offaster pilula* (an irregular echinoid fossil occurring in Lower Campanian strata) spans more than one bed of chalk in England. This belt or horizon is traceable across northern Europe. Similarly, the horizon of the irregular echinoid *Hagenowia blackmorei* spans several beds of chalk. In the same way the three bands of the fossil brachiopod *Orbirhynchia mantelliana* in the Cenomanian Stage all span several beds or couplets of marl-limestone in the Chalk. The purely descriptive terms do not specify or imply a particular thickness of rock.

Basin/basinal sequence, basinal succession: basins are relative depressions or 'lows' in the Earth's crust in contrast to surrounding 'highs'. The Anglo-Brabant Massif was a 'high' during the Late Cretaceous Epoch. In contrast, areas to the south (e.g. Sussex and Hampshire) and to the north (North Sea) were relative 'lows' where thicker successions of sediment accumulated. Even within basins there may be further local 'highs'. The amount of sediment input to the basins and on the 'highs' was partly dependent on supply from land areas, the productivity of coccoliths in the oceans and seas

and on sea-level fluctuations. Where there is considerable input of sediment from land areas at times of low sea level (sea-level *lowstands),* there is generally a transition from coarse-grained sediments (sands, calcarenites) near the margin of such a depositional area to fine-grained sediments (chalks, muds) in the basin centre as the heavier, coarser detritus is progressively deposited. At times of high sea level (sea-level *highstands*) with minimal supply of land-derived sediment to the basin, there may be a basinward transition from thin, condensed limestone successions, including hardgrounds, to chalks. The fauna of such a transect changes from margin to basin, leading to various biofacies. The concept of basinal successions is particularly important in the Turonian Stage and the Lower Campanian Substage, where marl seams and volcanic clays that are preserved in the deeper environments (e.g. the Southern Province successions) are progressively lost as they are traced into the condensed Chalk Rock successions of local 'highs'.

Bathichnus paramoudrae*:* a unique trace fossil around which paramoudra flints commonly form, having a vertical shaft 20–60 mm in diameter and 5–9 m long with sub-horizontal side branches <100 mm in length (originally described by Bromley *et al.,* 1975).

Beer Stone: a local freestone from Beer quarries in south-east Devon described by De La Beche (1826) and Jukes-Browne and Hill (1903, 1904). Unlike coccolithic chalk, the Beer Stone is a calcarenite almost entirely composed of comminuted echinoderm skeletal material (mainly microcrinoid) forming a soft, gritty limestone within the Holywell Nodular Chalk Formation (near the base of the former 'Middle Chalk').

Belemnite zone: macrofossil biozone with a belemnite index species, e.g. the *Gonioteuthis quadrata* Zone. See cephalopod.

Belt: see band.

Benthic (noun: **benthos)**: Living on or near the sea bottom. Contrast with planktonic.

Bioclastic/bioclastic chalk: Chalk composed of detritus of organic origin, e.g. comminuted and/or fragmented inoceramid bivalve shell. Such chalks are typically more or less coarse-grained and gritty to the touch, e.g. the Lower and Upper Inoceramus Beds of the Ferriby Chalk Formation, the Totternhoe Stone.

Bio-event bed: a bed characterized by a fossil occurrence. The 'event' may be, for example, a fossiliferous bed within a generally unfossiliferous succession, an acme-occurrence or short-term occurrence of some particular fossil, a short-term immigration of a warm or cold-water fauna, or something distinctive such as the occurrence of inoceramid bivalve shells encrusted by serpulid worm-tubes (the *Filograna avita* event) in the Holywell Nodular Chalk Formation.

Biofacies: the sum total of a rocks' gross fossil faunal/floral characteristics that together reflect the particular environment in which the rock formed.

Biostratigraphy: type of stratigraphy involving the use of fossils (macrofossils, microfossils, nannofossils) for the establishment of zones and for the correlation of rock strata.

Biostratigraphical unit: a stratigraphical unit, or body of rock, defined or characterized by its fossil contents without regard to lithological or other physical features or relations. The basic unit is a biozone (see zone) of which there are several kinds.

Bivalve: a type of aquatic shellfish that have their bodies enclosed by two, often mirror-image, shells (valves). Modern examples in dude cockles and mussels (cf. brachiopod).

Boreal Realm: reconstruction of palaeoenvironments for the Late Cretaceous Earth split the sphere into two palaeohemispheres, a Boreal northern and an Austral southern hemisphere, separated by an equatorial Tethyan Realm. In the Boreal northern palaeohemisphere, sea-water temperatures are generally held to have been cooler than those of areas immediately to the south, but this is not universally true.

Brachiopod: a major group of shellfish superficially similar to the bivalves but distinguished by a different anatomy. The two shells (valves) are typically dissimilar.

Calcarenite: coarse, gritty limestone formed of mainly sand-sized calcareous fragments.

Calcareous nannofossils: all calcareous fossils smaller than 30 microns (μm), defined by Lohmann (1909) as including the plankton that pass through the finest plankton nets (i.e. <63 μm). This includes many organisms such as ascidian spicules, calcispheres and juvenile foraminifers, but by far the most predominant group are the haptophyte algae (golden-brown algae). Fossil calcareous haptophyte algae are the primary chalk-forming organisms (see coccoliths and nannofossils).

Calcispheres: round or oval-shaped calcareous grains about 500 μm in size, common at many levels in the Chalk, particularly Cenomanian and Turonian nodular chalks and hardgrounds (sphere-rocks), in which they are present in rock-building quantities. Thought to be the fossil cysts of calcareous dinoflagellates.

Calcite: the main mineral form consisting predominantly of calcium carbonate ($CaCO_3$). The calcite in the skeletons of the chalk-forming calcareous algae is composed of low-magnesium calcite, a very stable carbonate.

Carbonate: in geology, a synonym for limestone.

Cephalopod: a group of marine molluscs including the modem squid, cuttlefish and octopus and their extinct fossil relatives including belemnites (a form possessing a bullet-shaped internal calcium carbonate shell) and the ammonites.

Chalk: a very fine-grained limestone formed primarily by coccoliths. 'The Chalk' used as a proper noun with a capital letter, is taken to be equivalent to the Upper Cretaceous Series, reflecting the dominance of the chalk rock type in strata of Late Cretaceous age (cf. Chalk Rock).

Chalk facies: chalk is a special type of limestone formed from a rain of the calcareous skeletal material produced by marine plankton onto the seabed. These plankton are primarily coccoliths. Other types of nannofossil may be abundant at certain horizons in the Chalk and these produce different-shaped calcite crystals, affecting the properties of a chalk. Such nannofossils include cylindrical nannoconids and rhabdoliths, and prismatic Micula (see (Figure 1.9), this volume). Other chalks may contain abundant calcispheres or foraminifera, which are around 500 pm in size in comparison to the 5–10 μm size of the nannofossils. Chalk is the characteristic rock of the Upper Cretaceous succession in north-west Europe and gives its name to the Cretaceous System (Creta = Latin for chalk). Chalk facies is replaced laterally towards the margins of depositional basins by coarser-grained sediments, including calcarenites and calcite-cemented sandstones (e.g. the Wilmington Sands).

Chalk Marl: the former lowest division of the Chalk Group in southern England. 'Chalk Marl' was the name applied to the Chalk wherever it had a soft manly character. The term has been superseded in part by the name 'West Melbury Marly Chalk Formation' (Bristow et al., 1997: Rawson *et al.,* 2001). The former Chalk Marl is not co-extensive with this formation, but also includes the lower part of the succeeding Zig Zag Chalk Formation.

Chalk Rock: the Chalk Rock was defined by Whitaker (1861) and used by the [British] Geological Survey as the mapping boundary between the Middle Chalk and Upper Chalk (former divisions of the Chalk) in parts of the Chiltern Hills (Penning and Jukes-Browne, 1881; Jukes-Browne and Hill, 1903, 1904). Bromley and Gale (1982) re-defined the Chalk Rock as a formation comprising a number of hardgrounds that varied in intensity and number from west Wiltshire to Cambridgeshire. The Chalk Rock now forms a Member at or towards the base of the Lewes Nodular Chalk Formation in those areas where it can be defined, primarily in Wiltshire and Berkshire. The names for the various hardgrounds introduced by Bromley and Gale (1982) for the Chalk Rock are retained where they can be recognized.

Chalkstone: a term introduced by Bromley and Gale (1982) to describe the creamy, hard, well-cemented 'stony' parts of the Chalk Rock hardgrounds. The term can also be applied to other re-cemented chalks such as those in Northern Ireland and Yorkshire or to chalks re-cemented by Quaternary processes. The intact dry density of chalkstones is usually greater than 20 000 kg/m^3

Chert: cryptocrystalline silica (SiO_2) which may be of organic or inorganic origin, occurring as layers or nodules in sedimentary rocks (mainly limestones). Flint is a form of chert.

Chert Beds: beds of sandstone or calcareous sandstone with seams of chert characterizing the Upper Greensand of Wessex (Dorset and south-east Devon).

Chronostratigraphy: 'time layer writing', the correlation and subdivision of rock units on the basis of relative age — a hierarchy of sequential units to which the layers of sedimentary rocks are allocated, through the study and interpretation of their stratigraphy. The hierarchy of principal chronostratigraphical units is system, series and stage, which are related, respectively, to the geological time units of period, epoch and age. Rocks of the Jurassic System (a chronostratigraphical unit) were laid down in the Jurassic Period (a geological time unit).

Clay Minerals (Hydrous Aluminium Silicates): clay minerals are formed by the chemical weathering of other silicates (e.g. some feldspar minerals convert to the clay mineral kaolinite), whilst most micas are produced by the subsequent pressure recrystallization of clay minerals (see metamorphic rocks). Clay minerals are the component of an engineering soil that gives it plasticity. Clays have the properties of becoming plastic and easily moulded when wet and of becoming hard and rock-like on heating above a certain temperature. Bentonite and Fullers Earth, belong to the smectite or montmorillonite subgroup of active clays. Kaolinite is widely used for ceramics, white-wares, and refractory bricks, aggregates etc, structures. Clay minerals are significant in the Grey Chalk Subgroup and in units of chalk with significant marl seams such as the Newhaven Chalk and Flamborough Chalk formations.

Coccoliths: calcareous, planktonic, haptophyte algae.

Condensation/condensed succession: beds that are thinner in some parts of the depositional area than beds of equivalent age elsewhere, e.g. towards the margins/palaeoshoreline or over structural 'highs', are said to be 'condensed'. Simple condensation implies a smaller amount of deposition per unit time. More complex condensed successions may contain erosional hiatuses or 'non-sequences' (omission surfaces) resulting from interruptions in deposition. Longer breaks in sedimentation are commonly marked by mineralized hardgrounds. Good examples of condensed successions are provided by the Cenomanian Beer Head limestone Formation of Devon and the Turonian Chalk Rock. In both cases, there is a lateral change in the type of sediment, with basinal chalks passing laterally into hard limestones.

Conjugate joint sets: two sets of joints believed to represent complementary shear sets in which the maximum principal stress is horizontal. Such joint sets are particularly characteristic of the Holywell Nodular Chalk, New Pit Chalk, Newhaven Chalk and Flamborough Chalk formations.

Contemporaneous: a geological event that occurs at the same time as a deposit is forming. Compare with penecontemporaneous.

Cored borehole: a borehole that is drilled in such a way as to recover a cylindrical core of the rocks through which the drill penetrates. This is an extremely expensive method, but one which provides the maximum amount of information, particularly biostratigraphical (fossil) data. Other boreholes are rock-rollered or chipped so as to produce a hole in the rocks that can be used for the production of geophysical logs. From a study of the rock chippings and the form of the geophysical logs the nature of the succession drilled can be inferred.

Cretaceous: a period of geological time from 142–65 million years ago (see (Figure 1.2)).

Cretaceous Quiet Zone: term used in magnetostratigraphy to describe the long time interval in the Late Cretaceous Epoch without numerous magnetic reversals.

Crinoid: a group of echinoderms with a flowering-plant-like structure, hence the common name 'sea lily'.

Cyclostratigraphy/cyclostratigraphical couplet: type of stratigraphy based on the identification of couplets of marls and chalks/limestones that are inferred to result from orbital control of sedimentation owing to changes in the amount of sun (insolation) reaching the Earth's surface. Individual couplets and groups of couplets can be traced over enormous

distances (cf. Gale, 1995, 1996, 1998) enabling extremely high resolution in the correlation of rock strata. In the Chalk, the couplets are inferred to be precession-driven, i.e. they have a periodicity of 19–23 million years. This inferred periodicity can be checked against absolute dating based on radioactive decay of elements (e.g. Potassium/Argon (K/Ar)) in sanidine grains included in volcanic beds (bentonites).

Decollement zone/zone of decollement: term normally applied in Alpine structural geology to describe the surface along which an upper series of tectonically-folded rocks has slid over an underlying packet of less-deformed or undeformed rocks. Used in this book to describe any surface in the Chalk along which detachment of one mass from another has occurred. This includes the glacio-tectonic chalk-masses of the Norfolk coast, which are inferred to have become detached, and also includes slide planes and detached masses such as those at Downend, Portsdown and Hope Gap, Seaford Head.

Diachronous: a continuous rock body that is a different age in different places. The Glauconitic Marl is older in Sussex and Kent than it is on the Isle of Wight and younger still on the Dorset coast (see Compton Bay and White Nothe site descriptions). Hence this sedimentary deposit 'crosses time'.

Diagenesis: the changes that take place in a sediment due to physicochemical and biochemical processes at low temperature (<200°C) that convert a sediment to a sedimentary rock. These changes include early cementation on, or beneath, the seabed (formation of nodular chalks, hardgrounds and flints). They also include early consolidation (often effected by burrowing organisms) and mechanical compaction.

Diastem: small amounts of geological time not represented by sedimentation. A hardground or nodular chalk bed may represent a diastem.

Dip: rock layers are generally tilted at angles between horizontal and vertical (the angle of dip). The angle of dip is measured using an inclinometer from the horizontal downwards. Dip also has a compass direction identified as the direction of the maximum dip angle of the strata.

Disconformity: an erosional surface separating two sequences of parallel strata from one another. The erosional surface on which the Southerham Grey Pit channel has formed is a typical disconformity.

Dissolution: the dissolving of rock, particularly limestone, usually by percolating acidic groundwater. Dissolution in chalk leads to a variety of karst features including dolines, pipes, opening of joints to form fissures, and underground cavities with a range of sizes.

Echinoderm: a group of marine invertebrates, characterized by five-fold symmetry and calcareous skeleton. The group includes starfish, sea urchins, sea lilies and their fossil relatives.

Echinoid: sea urchin.

Epigenetic: structures formed after the lithification of a sediment into a rock.

Epoch: a unit of geological time, of shorter duration than a period and itself divisible into ages (e.g. the Late Cretaceous Epoch).

Era: one of the five major divisions of geological time, namely the Archean, Proterozoic, Palaeozoic, Mesozoic and Cainozoic, each of which comprises several periods.

Erosional hiatus: a gap in the stratal succession resulting from erosion of the underlying beds prior to the deposition of the overlying sediments, e.g. the erosional contact below the Totternhoe Stone. An erosional hiatus involves some degree of angular discordance between strata and is therefore more or less conspicuous, whereas a 'non-sequence' results merely from a break in sedimentation without angular discordance and may be difficult to detect.

Event horizon/stratigraphy: a band ('horizon) characterized by a wide-ranging, short-term event, which may be an occurrence of a fossil, a concentration of a particular mineral (e.g. iridium), a clay seam (either detrital or vulcanogenic), a

'spike' on a stable isotope curve, a distinctive sediment (e.g. a black shale). Many events are, by definition, either near- or absolutely isochronous and can be used to help construct a composite correlation framework for rock strata (event stratigraphy). Such frameworks are increasingly used in the case of the Chalk and coeval sediments.

Facies: the lithological and biological characteristics of a sedimentary rock that results from deposition in a particular environment.

Facies model: a general summary of a specific sedimentary environment and the biological and lithological features that result from processes of sedimentation within that environment.

Fault: a fracture in rock that has a measurable offset of the layers of rock on either side of the fault plane (surface of fracture).

Flint: (the old English word for hardstone) a siliceous rock whose composition is about 98% pure silica (i.e. SiO_2 in a variety of crystalline forms, including chalcedony, opal and quartz). The dark black flints appear to be made of a compact mass of microscopic, needle-like crystallites of quartz. By contrast, in the case of the grey flints of Northern Ireland and the Northern Province (Lincolnshire–Yorkshire), the crystals are less fibrous, stouter and much shorter (Shepherd, 1972). Others have found that flint has replaced the original chalk to such an extent that when flint is etched with acid and viewed with a scanning electron microscope the original structure of the chalk can be seen (Clayton, 1986). Details of the original pore structure of chalk are preserved. Flint is, therefore, formed during diagenesis, at an early stage of burial of the chalk.

Flood event/occurrence: a super-abundant occurrence of one or a few fossils (either macro- or microfossils) over a large geographical area and typically at one horizon, e.g. the occurrence of the inoceramid bivalve *Cladoceramus undulatoplicatus* at the base of the Santonian Stage in the Seaford Chalk Formation. Flood events are of great value for long-range interregional correlation of rock strata as they may cross from one facies to another, e.g. the *Cladoceramus* event(s) are found in chalks, sandstones, siltstones and mudstones and can be traced from North America to central and southern Europe.

Foraminifera: single-celled, calcareous, aquatic microorganisms usually less than one millimetre in diameter (a few are larger). Foraminifera from the Chalk are usually divided into benthic forms and planktonic forms (that lived in the top 50–60 m of the water column). Benthic/planktonic ratios and abundances of different species are used for both correlation and environmental interpretation. Detailed stratigraphies of foraminifera have been used to establish the geology along the route of the Channel Tunnel (e.g. Harris *et al.,* 1996a) and other tunnels in the UK.

Gastropod: a class of univalved molluscs, mostly characterized by helical shells made of aragonite.

GCR: Geological Conservation Review, in which nationally important geological and geomorphological sites were assessed and selected with a view to their long-term conservation as SSSIs.

Geophysical borehole log: method whereby a continuous trace of the physical characteristics of the rocks penetrated by a drill, e.g. radioactivity (gamma radiation), electrical resistivity, etc. can be obtained from an instrument lowered slowly down the borehole. Such traces (commonly called 'down-hole wireline logs') are of enormous value in inferring the nature of the rocks penetrated and, particularly, in long-range correlation. The identification of marl seams from low restivity 'spikes' enables the marl seam and volcanic clay framework of field sections to be confidently recognized in the subsurface succession of rock strata (cf. Mortimore and Wood, 1986; Mortimore and Pomerol, 1987).

Glacio-tectonic: refers to the detachment and deformation of rocks by contact with a mass of moving ice, e.g. the complex folded masses of Campanian and Maastrichtian Chalk on the Norfolk coast, which are inferred to have been detached from the bed of the North Sea and carried bodily southwards.

Glauconite: akin to an iron-rich clay mineral, illite, with a similar structure to that of mica. Its colour ranges from olive-green, yellowish, greyish to blackish-green. The presence of glauconite in a sediment imparts a green colour (e.g. greensands and Glauconitic Marl), and usually indicates a shallow-water, marine origin for the deposit.

Glauconitic Marl (known as 'Chloritic Marl' in the earlier literature): a glauconite-rich sandy marl also rich in chocolate-brown phosphate nodules, constituting a member at the base of the Chalk Group in southern England.

Global boundary Stratotype Section and Point (GSSP): an internationally agreed point in a rock succession at a particular locality that is taken to mark a stage or substage boundary (strictly speaking, the *base* of a stage or substage).

Greensand: term loosely applied in the Cretaceous rock succession to units of arenaceous rocks, which are green at their type localities but which elsewhere are commonly weathered brown (e.g. Aptian–Albian Lower Greensand). Where green, the coloration is generally due to the presence of the dark green mineral glauconite. The basal member of the Chalk Group in the Southern and Transitional provinces is typically developed as a glauconitic sediment, e.g. the Glauconitic Marl Member, Cambridge Greensand.

Hardground: the end member in a diagenetic series from soft nodules, through hard nodular chalks to a fully mineralized hardground. Calcitic cement pervades the rock and the convoluted erosion surface marking the top of the hardground, as well as burrow-walls penetrating into the hardground, are coated with purple-brown calcium phosphate and green glauconite. Iron-mineralization (goethite) is common. Strictly speaking, the term refers only to the surface, although it is in general use to describe both the surface and the underlying chalkstone (see Bromley, 1975b).

Hiatus: literally a 'gap', usually referring to a gap in a sedimentary succession, caused either by erosion and/or no deposition. The time 'missing' or not represented at an unconformity or other break in the stratigraphical record. Horizon: see band.

Illite: a clay mineral intermediate in structure between the mica muscovite and the clay mineral montmorillonite.

Index fossil: see zone.

Inoceramid bivalve: extinct family of Jurassic and Cretaceous marine bivalves characterized by a hinge plate with ligament pits but without teeth, and a shell composed of an external layer of prismatic crystals of calcite arranged at right angles to the shell surface and an internal layer of laminar aragonite ('mother-of-pearl'). Both layers are commonly preserved in mudstones but only the outer layer is normally preserved in chalks.

***Inoceramus atlanticus* event**: the wide-ranging common occurrence (event) of the distinctive eponymous inoceramid bivalve over a narrow interval in the higher part of the Middle Cenomanian Substage, immediately preceding the *Pycnodonte* event.

Interfluves: the ridges between fluvial valleys. In the Chalk downland, interfluves form the high ground between dry valleys.

Intraclasts: fragments of rock (clasts) contained in the same type of rock that they are derived from. Hence a fragment of chalk contained in chalk is an intraclast.

Iridium anomaly: refers to a concentration of the element iridium at a particular horizon in a sedimentary succession. Such concentrations are inferred to result from the impact of an extra-terrestrial body with the Earth, e.g. the widely-believed end-Cretaceous impact event.

Joints: fractures in rock with no measurable offsets on the layers of rock on either side of the fracture. Joints often form in sets or groups that have a statistically consistent orientation.

Jurassic: a period of geological time from 213–144 million years ago.

Karst: the following definition is from Fairbridge, 1968, *Geomorphology*: 'The term karst is derived from the German form of the Slavonic word, *krs* or *kras,* meaning rock. The word was a regional name for the area of massive limestone country north and south of the port of Rjeka in Yugoslavia, a district of many rocks, sinkholes and underground streams. The word is now more widely used to denote a type of terrain with a distinctive and unique assemblage of landforms…the result of one dominant erosion process, dissolution. The main characteristic of a karst area is the predominance of

vertical and underground drainage and the complete absence of surface streams. The Adriatic coastal areas of Yugoslavia from Istria to Kotor were the first karstlands to be described in a scientific manner by European writers (Cvijic, 1893)'. In the Chalk of England karst features include ephemeral streams (winter-bo(u)rnes) and streams that flow into cave systems (Mimms valley, Hertfordshire) as well as the features described above under dissolution. Past sea levels have largely controlled the pattern of past karstic horizons.

Late Cretaceous Epoch: the youngest epoch of the Cretaceous Period, which is followed by the Palaeogene Period. It comprises the Cenomanian, Turonian, Coniacian, Santonian Campanian and Maastrichtian ages

Litho-event bed: a body of sedimentary, extrusive igneous or metamorphic strata that is distinguished and delimited on the basis of lithological characteristics and stratigraphical position. Both the vulcanogenic and detrital marl seams in the Chalk are litho-event beds. Similarly, many of the sponge-beds, hardgrounds and marl–limestone couplets are litho-event beds.

Lithofacies: a unit of rock defined and recognized on the basis of lithological characteristics such as rock type, colour and composition.

Lithostratigraphy: a classification of sedimentary successions based on the rocks of which they are composed, and not on their included fossils. Such classifications involve a hierarchy of terms such as Supergroup, Group, Subgroup, Formation, Member, and Bed, in descending order of scale. A formation is the lowest category that can actually be mapped, although in practice it is sometimes possible to map members.

London-Anglian Platform (see **Anglo-Brabant Massif**)

Lower Chalk: formerly the lowest division of the Chalk in England. Now divided into two mapping units in southern England, the West Melbury Marly Chalk and Zig Zag Chalk formations. In the Northern Province, where the succession is thinner, only one unit, the Ferriby Chalk Formation is recognized.

Listric: listric (also 'lystrie) surfaces are the planes of thrust fractures in rocks that curve into more vertical faults.

Macrofossil: macrofossils in the Chalk range in size from shells around 2 mm to large ammonites that can be 3 m in diameter (e.g. the very large *Parapuzosia* found in the Zig Zag Chalk Formation, the Plenus Marls Member of the Holywell Nodular Chalk Formation and, commonly, in the Newhaven Chalk Formation and the Margate Chalk Member). The most important groups of macrofossils for identification of the stratigraphical level of the Chalk in field sections and in borehole cores are the inoceramid bivalves that are common throughout the Chalk; the ammonites, common in the Grey Chalk Subgroup; echinoids such as *Holaster, Sternotaxis, Micraster, Echinocorys, Conulus* and *Offaster,* common in the White Chalk Subgroup; and the belemnites, common in the higher part of the Chalk Group.

Magnetochron: a period of time defined by the remnant magnetic polarity and distinguished from adjacent magnetochrons that have different magnetic polarities.

Magnetostratigraphy: stratigraphy based on the palaeomagnetic reversals recorded in the 'fossil' remnant magnetism in rocks.

Major tectonic line: a line in the Earth's crust distinguished by the presence of a structural feature, such as a fault, fold or fold belt. Such faults or fold belts are not local features and usually extend hundreds of kilometres, as opposed to local features, which may be on a metre or kilometre scale.

Marker horizon: a conspicuous bed of rock such as a flint band or marl seam, or a level with an abundance of a particular species of fossil. Other marker horizons include palaeomagnetic reversals, volcanic ash-falls or geochemical 'spikes'.

Marl: calcareous mudstone.

Melbourn Rock: a unit of rock comprising a number of layers of hard chalkstone marking the base of the old 'Middle Chalk' in south Cambridgeshire (Melbourn), north Hertfordshire and the Chiltern Hills (Penning and Jukes-Browne, 1881). In some areas, such as Dover, the term 'Melbourn Rock' has been mistakenly applied to all the chalk with abundant shell-debris of the fossil bivalve *Mytiloides.* The Melbourn Rock of the type area underlies the main shell-rich chalks of the Holywell Nodular Chalk Formation.

Metamorphic rocks: rocks that have undergone changes in the solid state by heat and/or pressure but without melting.

Microfossils: the remains of microscopic animals and plants whose study requires the use of a microscope. The main groups of microfossils in chalk include the foraminifera, ostracods, dinoflagellates, sponge spicules, bryozoa and some radiolaria. Foraminifera in particular are used to zone the Chalk and interpret environments. Even smaller microfossils include the nannofossils.

Microfossil biostratigraphy: stratigraphy based on microfossils.

Milankovitch Cydes: named after the Serbian mathematician Milutin Milankovitch, who studied at Vienna in the 1920s under Alfred Wegner. Milankovitch Cycles refer to climatic changes brought about by shifts in the Earth's orbit around the Sun and the resultant changes in solar radiation reaching the Earth (Milankovitch, 1941). Within the Milankovitch waveband there are three primary cycles; (1) shifts in the Earth's orbit around the Sun from more circular to more elliptical over a period of 100 000–400 000 years (the *eccentricity* cycle); (2) variation in the tilt of the Earth's axis on a 41 000-year cycle (the *obliquity* cycle) and (3) the wobble or precession of the Earth's axis on a 19 000–23 000-year cycle (the *precession* cycle). Despite being called 'Milankovitch Cycles' these potential controls on the Earth's climate were first recognized by the Scottish Geologist James Croll (Croll, 1875), and applied to cyclically bedded Cretaceous sediments in the Western Interior of the USA by G.K. Gilbert (Gilbert, 1895).

Millet-seed sands: sand composed of quartz grains of millet-seed size and roundness. A term used by Bailey (1924) to describe some of the sand grains in the Scottish Upper Cretaceous deposits of the Inner Hebrides.

Montmorillonite: see clay minerals.

Mundford Grades: an engineering classification developed for the weathered and fractured state of chalk at Mundford, near Thetford, Norfolk, in the site investigation for the foundations of a large proton accelerator (Ward *et al.,* 1968). Mundford Grades have subsequently been used for the engineering classification of chalk throughout the UK. During the 1990s a new classification system has been developed, the CIRIA Grades (Lord *et al.,* 2001) and these are now used in place of Mundford Grades.

Mytiloides (Inoceramus) labiatus sensu lato*: Inoceramus labiatus,* an inoceramid bivalve, was formerly used in a very broadly defined sense as the index fossil for the assemblage zone corresponding to the Holywell Nodular Chalk Formation (i.e. topmost Upper Cenomanian and Lower Turonian substages). However, the species *M. labiatus sensu stricto* occurs in only a very small interval in the Lower Turonian part of this formation (see Turonian Stage).

Nannofossils: see calcareous nannofossils.

Nautiloid: an almost-extinct group of cephalopods with straight or coiled chambered conical shells.

Nodular chalk: hard lumpy layers of chalk about 200–300 mm thick, frequently red-orange iron-stained. Individual nodules of high-density chalk are often separated by soft, low-density, grey chalks that are late-stage burrow-fills, their high porosity preserved by the skeletal framework of interconnecting nodules. Such nodular beds and hardgrounds are defined and illustrated by Bromley (1975b), who has demonstrated the change in seabed ecology from soft sediment burrowing to hard sediment boring as the cementation progresses. Kennedy and Garrison (1975) illustrated the sequence from weak nodular beds to the development of hardgrounds.

Nodular flint: a form of *flint* comprising nodules with spines or horns and an irregular shape. Nodules range widely in size from a few millimetres thick to more than 300 mm thick and metres wide, and frequently form in bands of dispersed

nodules. These flints have been variously referred to as 'burrow-fill' or 'nodular horn-flints'.

Ocean floors: strictly those marine environments underlain by *oceanic crust* in a geotectonic (Plate Tectonic) sense. Sea floors are underlain by continental crust.

Oceanic anoxic events: periods of time when the oxygen minimum zone of the ocean floors is thought to have risen on to shelf regions leading to the formation of black shales on shelves as well as ocean basins. Three such events are recognised in the Late Cretaceous Epoch (see Jenkyns, 1980).

Oxic: oxygen-rich environments (for the purposes of this book this means oxygen-rich sea-floor environments).

Palaeogeography: reconstruction of the past geographies of the Earth in both physical and biological terms. The past distribution of oceans, seas, land, climate and ecosystems.

Palaeomagnetic reversals: a reversal of the Earth's magnetic field results in the north magnetic pole becoming the south magnetic pole. The present magnetic arrangement is termed normal (N) in contrast to the reversed situation (R). Magnetic reversals have occurred regularly throughout the Earth's history and are thought to take place over very short time intervals (days/weeks/years) and are, therefore, geologically instantaneous events providing unique marker horizons.

Paramoudra Flint: a special type of flint that forms cylindrically around the trace fossil *Bathichnus paramoudrae* (Bromley *et al.,* 1975a). Paramoudra flints are generally very large (can be more than 2 m in diameter and several metres high). The flint is usually very compact and hard. The highest uniaxial compressive strengths have been obtained from such flints (around 800–1000 MPa). Paramoudra flints occur at specific stratigraphical horizons and are a feature of Bedwell's Columnar Flint in southern England, the Warren Farm Paramoudra Flints in the Spetisbury Chalk Member of the Culver Chalk Formation and, particularly, in the 'Paramoudra Chalk' of Norfolk and Northern Ireland.

Penecontemporaneous: a geological event such as faulting, folding, uplift, channel erosion or diagenesis that occurs broadly within the rock-forming period. For example, the uplift and resultant sliding and slump folding of the Chalk at Downend Chalk Pit, Portsdown, in the Culver Chalk Formation, occurred before the highest beds of the Culver Chalk formed but after the earlier chalks had partially consolidated.

Periglacial: literally *in front of* a glacier or ice-sheet. The region of tundra conditions where the tree-line stops but where no permanent ice sheet or glacier is present. Frozen ground is common. Periglacial weathering features including patterned ground, ice-wedges, intense fracturing are a feature of the chalk in England and relate to the past cold-periods of the Quaternary Period.

Period: a major division of geological time, of shorter duration than an era and itself divisible into epochs.

Plankton: generally small organisms that drift in water bodies and have limited powers of locomotion.

Plate Tectonics: the theory that the Earth's lithosphere (Earth's crust and upper mantle) is divided up into a series of rigid 'plates' that move relative to each other (a few centimetres per year). Over geological time the continents carried by the 'plates' can 'drift apart' or 'collide' and oceans can 'grow' and 'close' as a result. Relative movement between the plates leads to earthquake and tectonic activity, which is most concentrated at boundary zones between plates.

Plenus Marls: a division of the Chalk; the basal member of the Holywell Nodular Chalk Formation and the base of the White Chalk Subgroup. Named after the occurrence of the belemnite *Praeactinocamax plenus* in the higher four of the eight beds into which the member is divided.

Rudist bivalve: type of extinct aberrant reef-building bivalve, particularly characteristic of the shallow, warm water environments of the Tethyan Realm (cf. Boreal Realm). Rudists are rare in the Upper Cretaceous rocks of the UK since these were deposited in a much higher palaeolatitude, where relatively cooler and much deeper water conditions prevailed.

Seabed: floor of a sea on which sedimentary processes are acting. Strictly a sea not underlain by oceanic crust (see ocean floors).

Sequence boundaries/stratigraphy: unconformity or disconformity bounded sequences of strata.

Sea-level curves: curves of relative sea-level change through geological time. These may be global curves or more local curves for particular basins and regions.

Sheet-flints: distinguished from tabular flints by being located on both sub-horizontal and sub-vertical fracture planes. Hence these are not strictly in place stratigraphically but may be confined broadly to a stratigraphical unit. Sheet-flints are thin (4–200 mm thick) sheets of flint, often forming two planes separated by a chalky interior. Clayton (1986) illustrated the early formation of sheet-flints and the processes that form them.

Silcrete: a silicified palaeosol ('fossil soil').

SSSI: Site of Special Scientific Interest; the designation of an area of land for statutory protection under the provisions of the Wildlife and Countryside Act 1981.

Stable isotope curves: curves derived from determination of the differing proportions of two of the stable isotopes of carbon, (^{12}C and ^{13}C) and two of the stable isotopes of oxygen (^{18}O and ^{16}O) in carbonate sediments (see Jenkyns *et al.,* 1994, Mitchell *et al.,* 1996, 1997). These determinations (referred to as $\delta^{13}C$ and $\delta^{18}O$ values respectively) may be based on analysis of the rock (so-called 'bulk-rock analysis') or of specific bioclastic components of the rock such as macrofossils and/or microfossils and nannofossils. In the most refined determinations, separate analyses are made of macrofossils, and separations of benthic foraminifera, planktonic foraminifera and coccoliths (e.g. Jeans *et al.*, 1991*).* Seawater palaeotemperatures can be calculated from $\delta^{18}O$ values. $\delta^{13}C$ curves are of great value in long-range correlation, particularly where no fossils are present. In addition they can be used to infer sudden changes in oceanographic parameters relating to transgressions. Stable isotope curves are a key element in the establishment and testing of integrated stratigraphical frameworks.

Stages: internationally agreed divisions of the geological series (see chronostratigraphy) into smaller units of time based largely on fossil assemblages. The Upper Cretaceous series is divided into six stages. During the 1980s, international working groups were organised to review the palaeontology, definition and subdivision of each Cretaceous stage (Birkelund *et al.,* 1984; Rawson *et al.,* 1996). These two publications are the primary source of information relating to stages, stage boundary definitions and stage subdivisions of the Cretaceous System. Updated details relating to the application of stage boundaries in the Upper Cretaceous rocks of the UK are given in the Appendix of this book. Two sites in England, Southerham Grey Pit, Lewes, Sussex and Seaford Head, Sussex, have been nominated as candidate global basal boundary stratotypes and points (GSSPs) for the base of the Middle Cenomanian Substage; and for the bases of the Santonian and Campanian Stages respectively.

Sternotaxis* [*Holaster*] *plana*:*** a fossil echinoid that characterizes the interval of chalk from just above the Glynde Marls to the Lewes Marl in the lower Lewes Nodular Chalk Formation. *Sternotaxis plana* was the index fossil of one of the traditional assemblage zones of the Chalk in England and France (see Owen and Smith, 1987; and British Museum (Natural History), 1962; also Turonian Stage, Appendix).

Stratigraphy: the study of the order of succession or relative position of strata (layers of rock) and the global correlation of rocks and geological events. Stratigraphy is divided broadly into lithostratigraphy, biostratigraphy, chronostratigraphy and more recently magnetostratigraphy, sequence stratigraphy, cyclostratigraphy and chemostratigraphy. Each of these topics is covered excellently by Doyle and Bennett (1998).

Stratotype: an exposure where a specific part of the stratigraphical succession is defined and acknowledged in a publication and/or by national or international agreement.

Strike: the compass direction perpendicular to the dip direction.

Subhercynian tectonic phases: highly misleading term introduced by Stifle (1924) referring to a succession of Late Cretaceous phases of deformation (uplift and rotation) of the Cretaceous rocks in the area to the north of the then uplifting Harz Mountains massif in Germany — hence the name. Must be clearly distinguished from Hercynian (i.e. later Palaeozoic) structural deformation, which takes its name from the same massif. The sub-hercynian tectonic phases were compressive orogenic (mountain building) pulses that were initiated during the later Late Cretaceous as a result of the progressive collision of elements of the North African plate with the European platform in the initial phases of the Alpine mountain building period. The subhercynian phases of uplift and deformation are the Ilsede, Wernigerode and Peine phases, to which may be added the latest Late Cretaceous Laramide phase, which was first described from North America. For further details see Mortimore *et al.* (1998); Mortimore and Pomerol (1998).

Sub-Plenus erosion surface: erosion surface beneath the Plenus Marls Member of the Holywell Nodular Chalk Formation at the base of the White Chalk Subgroup.

Subzone: a subdivision of a biozone used in biostratigraphy.

Synsedimentary: a geological event that occurs at the time of sedimentation.

System: a chronostratigraphical unit comprising all the rocks formed during a geological period, e.g. the Jurassic System comprises all the rocks of the Jurassic Period.

Tabular flints: stratigraphically consistent, continuous tabular masses of flint from 5–30 mm thick. The most significant tabular flints in the English Chalk occur in the Northern Province (Lincolnshire and Yorkshire Wolds) at the boundary between the Welton Chalk and Burnham Chalk Formations (Wood and Smith, 1978).

Taxon (pl. taxa): a classification unit of organisms based on physical similarities or surmised evolutionary relationships.

Tectonism (adj. tectonic): the processes of crustal deformation (e.g. folding and faulting) often associated with Plate Tectonics and mountain building.

Terebratulina lata*:* a diminutive fossil brachiopod (lamp-shell) that characterizes part of the Turonian (see Turonian Stage in Appendix, this volume). *T lata* is the index fossil of one of the traditional assemblage zones of the Chalk.

Thalassinoid flint/horn flint: flint reflecting the silicified sedimentary fill of a burrow of *Thalassinoides* type. Such flints are described as burrow-fill or burrow-form flints. Where there is incomplete silicification of the burrow fill, the flint takes on an irregular shape reminiscent of a horn or part of an antler.

Totternhoe Stone: a coarse, calcarenitic chalk resting on an erosion surface in the 'Lower Chalk' of the Chiltern Hills at the boundary between the West Melbury Marly Chalk and the Zig Zag Chalk formations. The Stone was originally quarried as a building freestone. The Totternhoe Stone was first described by Whitaker (1865b).

Trace fossils: many animals, some of unknown origin, lived on and in the chalk sediment forming the Late Cretaceous sea floor. These animals left behind the crawling, burrowing, boring or feeding traces of their existence, now fossilized in rock (hence *trace fossils).* The shapes and sizes of the traces, such as branching, vertical pipes, spiral or U-shaped are classified and given names including *Thalassinoides, Chondrites, Skolithos, Bathichnus, Zoophycos.* These names do not indicate the animal that created the trace. For example large (20–30 mm diameter) branching traces (*Thalassinoides),* are thought to have been produced by callianassid shrimps such as the present-day *Callianassa say* or *Callianassa major* (Bromley, 1967). In contrast, the small branching traces of *Chondrites* are of unknown origin. The trace fossils of the Chalk are illustrated by Bromley (1975a); Bromley and Ekdale (1984a,b); Ekdale and Bromley, (1984) and Bromley (1990, 1996). Burrowing activity was a prime control on diagenesis (e.g. dewatering, redox shifts) leading to the development of nodular chalks and hardgrounds and to the formation of flint. The suite of trace fossils in a chalk sample greatly influences its porosity and permeability. Variation in physical properties, such as density and porosity in a laboratory sample, are in part a reflection of the original trace fossil fabric of the chalk.

Transgression: the landward migration of shorelines. This may result from a rise in sea level, an increase in crustal subsidence or reduction in sediment input to a shelf area.

Tubular flints: characteristically slender (20–30 mm diameter) cylindrical, branching flints that can extend continuously through more than 3 m of chalk. The tube is formed by an outer annulus of flint separated from an inner flint core by a chalky layer. Frequently the inner-core is missing, forming a tube. There are several horizons of tubular flints that are stratigraphically continuous over vast distances. These include the Lewes Tubular Flints, Shoreham Tubular Flints, Old Nore Tubular Flints and Isle of Wight Tubular Flints (see Mortimore, 1986a; Mortimore and Pomerol, 1991b).

Type locality: a place or area containing the stratotype section. This can apply to both lithostratigraphy and biostratigraphy. For example, Holywell, Eastbourne, is the stratotype section for the Holywell Nodular Chalk Formation. (See also stratotype and GSSP). Also refers to the locality from which a particular fossil species was first named and described.

Unconformity: a break in the relationship between successive strata resulting from a lack of deposition during an intervening phase of tectonism and erosion; the unrepresented time interval may be substantial and there is often an angular discordance in the layers either side of the unconformity surface.

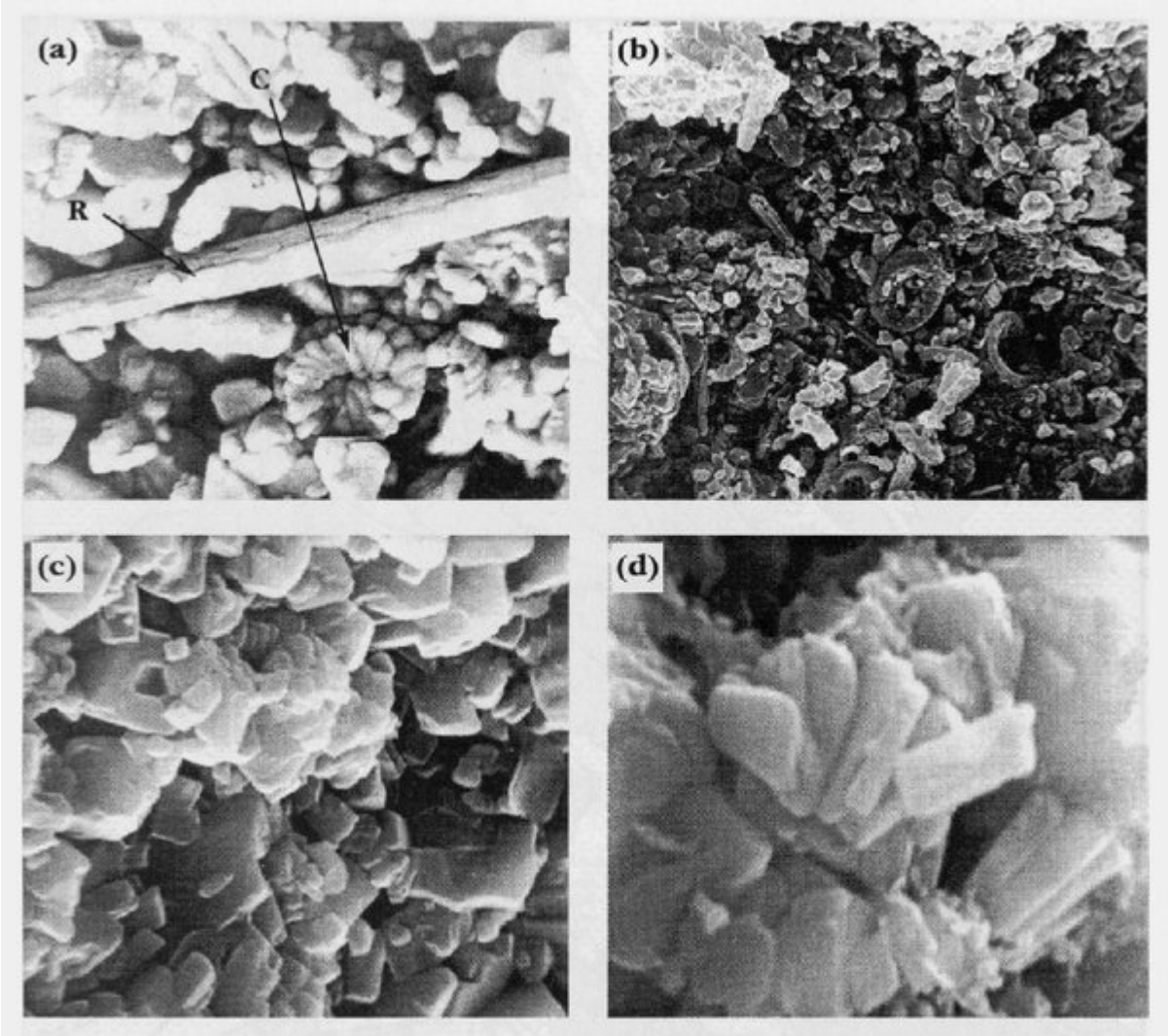
Upper Cretaceous: the upper series of the Cretaceous Period from the base of the Cenomanian Stage to the base of the Palaeocene (base of Danian Stage) spanning the time interval from 98.5–65.4 million years ago (see (Table 1.2), this volume). In ascending order, the upper Cretaceous is divided into the Cenomanian, Turonian, Coniacian, Santonian, Campanian and Maastrichtian stages (see Appendix, this volume).

Variscan structures: term referring to structural elements initiated during the Variscan Orogeny (mountain building period); commonly described as 'Hercynian' because they relate to the orientation of the Harz Mountains massif of Palaeozoic rocks in Germany. Hercynian structures must be clearly differentiated from subhercynian structures.

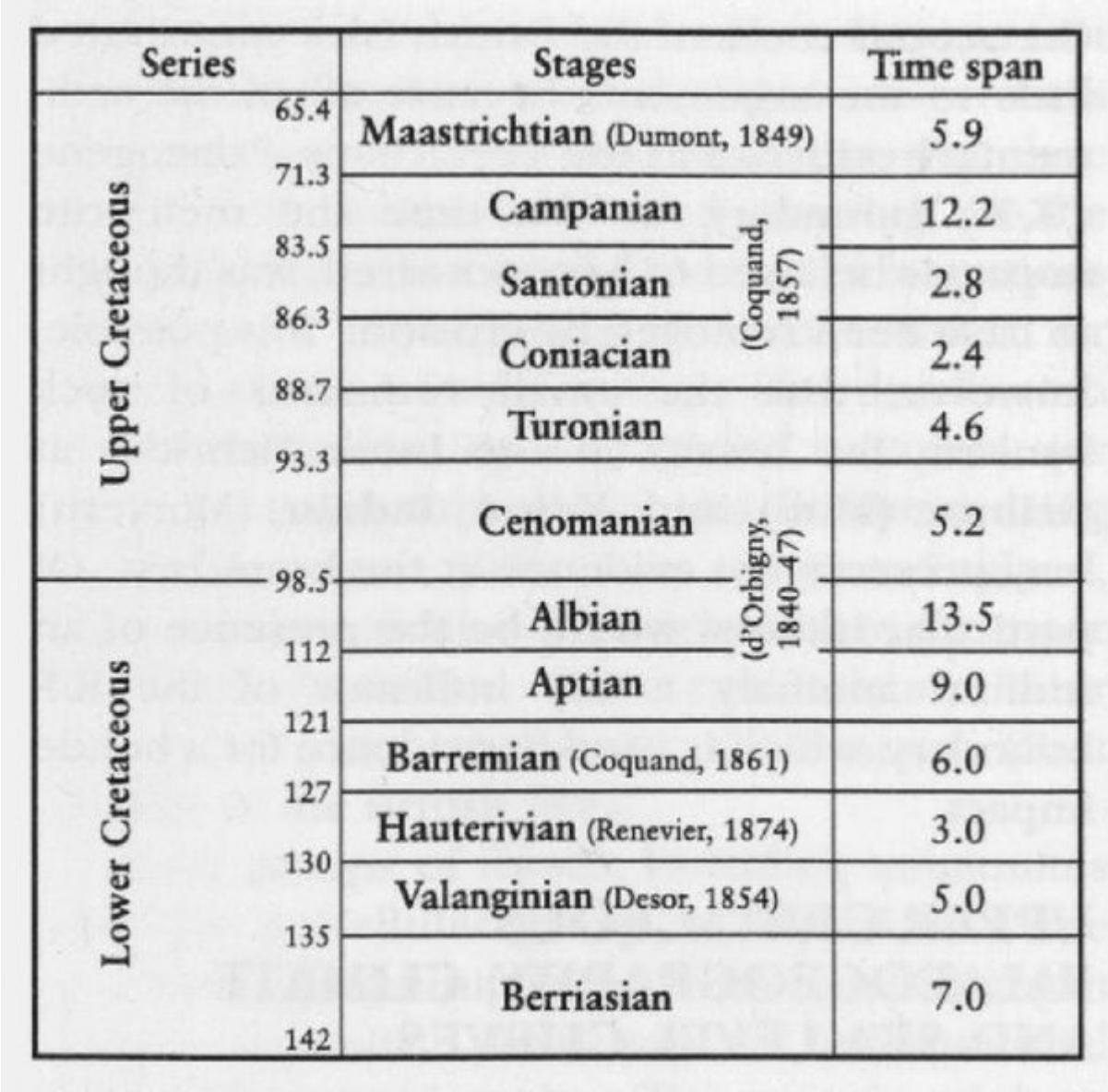
Zone: a subdivision of a Stage based on the occurrence of a defining fossil (*index fossil*) or an assemblage of fossils, for example, the occurrence of the free-swimming fossil crinoid (sea lily) *Marsupites testudinarius* in a given interval of the Chalk on the Sussex coast defines that zone in those cliffs. The same fossil may occur in another type of rock elsewhere in the world. A zone is, therefore, independent of rock type and is a biostratigraphical concept. Other zones are defined by the entry of a particular fossil taxon, which may range beyond the interval of the zone.

Zoophycos Flints: flints formed around the spiralling trace fossil *Zoophycos* (see Bromley and Ekdale, 1984a). There are several conspicuous horizons of *Zoophycos* flints in the Chalk including the Cuilfail Zoophycos, Beachy Head Zoophycos and the Tavern Flints (Mortimore, 1986a; Mortimore and Pomerol, 1991b).

References



(Figure 1.9) Some common nannoliths in chalk illustrating the variety of grain shapes constituting different chalks, as seen under the Scanning Electron Microscope (SEM). (a) Rhabdoliths (R) and coccoliths (C) in the Newhaven Chalk Formation from Paulsgrove, Portsdown (magnification X 6000). (b) A soft, low density coccolithic chalk; Newhaven Chalk Formation from Arundel (BRESD9) (magnification x 2200). (c) A high density chalk from below the Brighton Marl, Seaford Head, Sussex; the blocky crystals are Micula, Newhaven Chalk Formation (magnification x 5500). (d) Nannoconus from Strahan's Hardground, Lewes, Sussex, a very high density chalk (magnification x 13 100). (Photos: R.N. Mortimore, 1979.)



Series		Stages		Time span
Upper Cretaceous	65.4	Maastrichtian (Dumont, 1849)		5.9
	71.3	Campanian	(Coquand, 1857)	12.2
	83.5	Santonian		2.8
	86.3	Coniacian		2.4
	88.7	Turonian		4.6
	93.3	Cenomanian	(d'Orbigny, 1840–47)	5.2
Lower Cretaceous	98.5	Albian		13.5
	112	Aptian		9.0
	121	Barremian (Coquand, 1861)		6.0
	127	Hauterivian (Renevier, 1874)		3.0
	130	Valanginian (Desor, 1854)		5.0
	135	Berriasian		7.0
	142			

(Figure 1.2) Cretaceous (D'Halloy, 1822) series and stages (Birkelund et al., 1984). Age picks (Ma = million years) based on Obradovitch (1993) and Gradstein et al. (1999). (Dates obtained using $^{40}Ar/^{39}Ar$ laser fusion on 50–500 µg samples of sanidine from bentonites (volcanic ash/marls) interbedded with precisely dated fossiliferous marine sediments.)