

Chapter 7

Stratigraphy

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7.1 Introduction and Concepts

Stratigraphy is the study of the succession and time-related architecture of rock strata. Stratification is not limited to sedimentary rocks, but is also found in igneous rocks, particularly volcanic rocks, and in certain plutonic rocks. All bedded rocks can be treated stratigraphically, i.e. to establish age relations between beds. However, the term “stratigraphy” is used primarily in the context of sedimentary research.

Stratigraphy involves the study, subdivision and documentation of sedimentary successions, and on this basis to interpret the geological history they represent. In order to reconstruct an environment or special events in the geological past, regionally or even globally, it is necessary to correlate sedimentary horizons from different areas. It is important to establish which sedimentary units were deposited at the same time or by the same or similar sedimentological or biological processes, even if they are not quite contemporary. Correlation is generally a question of what is possible to achieve with the available amount and quality of data.

We usually have no possibility of determining definitely which beds were deposited at the same time, but attempt to use all the information available in the rocks. This information falls into five main categories: (1) Rock composition and structures resulting from sedimentological processes. (2) Fossil content, which is a result of biological, environmental and

ecological evolution throughout geological history. (3) Content of radioactive fission products in minerals or rocks which may be used for age dating. (4) Magnetic properties of rock strata. (5) Geochemical features of sediments. These correlation methods are so different that it has been found useful to work with three forms of stratigraphy which can be used in parallel:

1. *Lithostratigraphy*: Classification of sedimentary rock types on the basis of their composition, appearance and sedimentary structures.
2. *Biostratigraphy*: Classification of sedimentary rocks according to their fossil content.
3. *Chronostratigraphy*: Classification of rocks on the basis of geological time.

Geochronology is the actual subdivision of geological time.

The first two are thus based on rock relationships which can be described, and are often collectively referred to as rock stratigraphy.

Despite radiometric dating, geological time is not absolute. Even this dating method gives different ages, depending on which half-life is used for calculating radioactive decay, and is encumbered with many other uncertainty factors. Chronostratigraphy is therefore a theoretical and abstract concept which describes a time scale we cannot measure exactly. Rock stratigraphy, on the other hand, takes the rocks themselves as its starting point and is based on boundaries which are identified as potentially suitable for correlation across greater or lesser areas. For rules for stratigraphic nomenclature, see stratigraphy.org. The different types of stratigraphic units are listed below in hierarchic arrangement. See also Stratigraphy.com.

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Lithostratigraphic	Biostratigraphic	Chronostratigraphic	Geochronological
Supergroup	Assemblage zone	Eonothem	Eon
Group	Range zone	Erathem	Era
Subgroup	Acme zone	System	Period
Formation	Interval zone	Series	Epoch
Member	Biozone	Stage	Age
Bed		Chronozone	Chron

7.2 Lithostratigraphy

The *formation* is the fundamental lithostratigraphic unit defined in a bedded succession. An important property of a formation is that it should be easily recognised in the field or a borehole due to its composition (lithology). The formation is thus a mappable unit, which can be visualised on an ordinary geological map (e.g. 1:50,000) or recognised in the description of a bedded succession. There is in principle no limit to the thickness of a formation, but it usually varies from a few tens to several hundred metres. A 50–300 m thick sandstone, over- and underlain by quite different rocks such as shale or limestone, would constitute a natural formation. However, a formation will seldom be homogeneous, and for more detailed mapping it will be useful to divide the formation into smaller units. Parts of a sandstone formation containing shale or conglomerate beds, for example, can be defined as *members* of the formation.

The smallest unit in the lithostratigraphic classification is a *bed* which is assumed to have been deposited by a single depositional process without a break in sedimentation, and is distinguishable from the beds above and below. When sections are logged, beds are often recorded as “units”. Beds which are <1 cm thick are called *laminae*, but this is a purely size-descriptive term. Most beds/units contain, or may even be entirely comprised of, laminae. Only when a lamina lies isolated between significantly different sediments will it be named, e.g. if it is a thin tephra (ash bed) or bentonite in a shale succession.

For some purposes it is expedient to group several formations together into a larger unit called a *group*. A group normally consists of three to six formations and can be divided into two or more *subgroups*. The largest lithostratigraphic unit is a *supergroup*, which consists of two or more groups. This unit is used when a common name is needed to encompass a thick sedimentary package.

In sedimentary basins which are partly or entirely buried in the subsurface, for example the North Sea basin, formations and groups are defined on the basis of records from wells, such as well logs. In offshore areas where it is difficult to find enough geographical names to give the stratigraphic units, other names are then also used, including historical names, names of animals etc.

7.2.1 Lithostratigraphic Terminology

As research into sedimentary successions expanded, it required a standardised lithostratigraphic nomenclature that could be applied anywhere. Therefore, a set of international rules was established for naming lithostratigraphic units. This is summarised below:

1. A stratigraphic unit should preferably be defined with reference to a type section (stratotype) present in a good exposure, or in a well where the unit is adequately represented.
2. Each stratigraphic unit ought to be named after a geographical site, located preferably near the type section if exposed on land. Offshore stratigraphic units may be named after marine features (e.g. fishing banks), although in the North Sea basin other names have also been used.
3. The same name ought not to be used for more than one stratigraphic unit. The unit which is first defined has priority.
4. Stratigraphic names may consist of a name, i.e. from a locality, and a stratigraphic unit, e.g. Kimmeridge Formation or Kimmeridge Clay. In the US many stratigraphic names are well established even if they do not strictly follow the international rules for stratigraphic nomenclature.

7.3 Biostratigraphy

Biostratigraphy is based on the fossils in sedimentary rocks. Its tasks are to group strata into units based on fossil content, and apply these to correlate sedimentary successions. Biostratigraphy has made it possible to correlate sedimentary rocks on a global basis, and forms the foundation for global stratigraphic classification of sedimentary successions in combination with radiometric and other age dating methods. The biostratigraphic application of fossils is based on the fact that during the course of geological time, biological evolution took place whereby some species died out and new ones appeared. Any particular species will therefore be represented only in sediments deposited within a limited time span, and can be used to recognise this time span or part of it.

7.3.1 Nature of the Fossil Record

7.3.1.1 Fields of Application

Industrial application of biostratigraphy is mainly based on microfossils, owing to the fact that these

microscopic remains commonly occur in large amounts, and can be extracted easily both from drill cuttings, sidewall cores and conventional cores. The rapid evolution of many microfossil groups makes them valuable tools in subsurface stratigraphic work (Fig. 7.1). In addition to the general tasks of age determination and correlation, their applications include: unconformity identification, characterisation and correlation of seismic (depositional) sequences, fingerprinting of formations, reservoir zonation and palaeoenvironmental modelling. These applications are crucial in petroleum exploration, contributing significantly to assessments of reservoir distribution, source rock evaluation, trap evaluation, estimation of reserves, field development studies and impacts on drilling problems. The fast evaluation potential of microfossil samples is also an important factor in any subsurface work.

7.3.1.2 Distribution of Microfossils

Practically all rocks of sedimentary origin contain microfossils, although their abundance, diversity and state of preservation are highly variable. These features are strongly influenced by the age, depositional

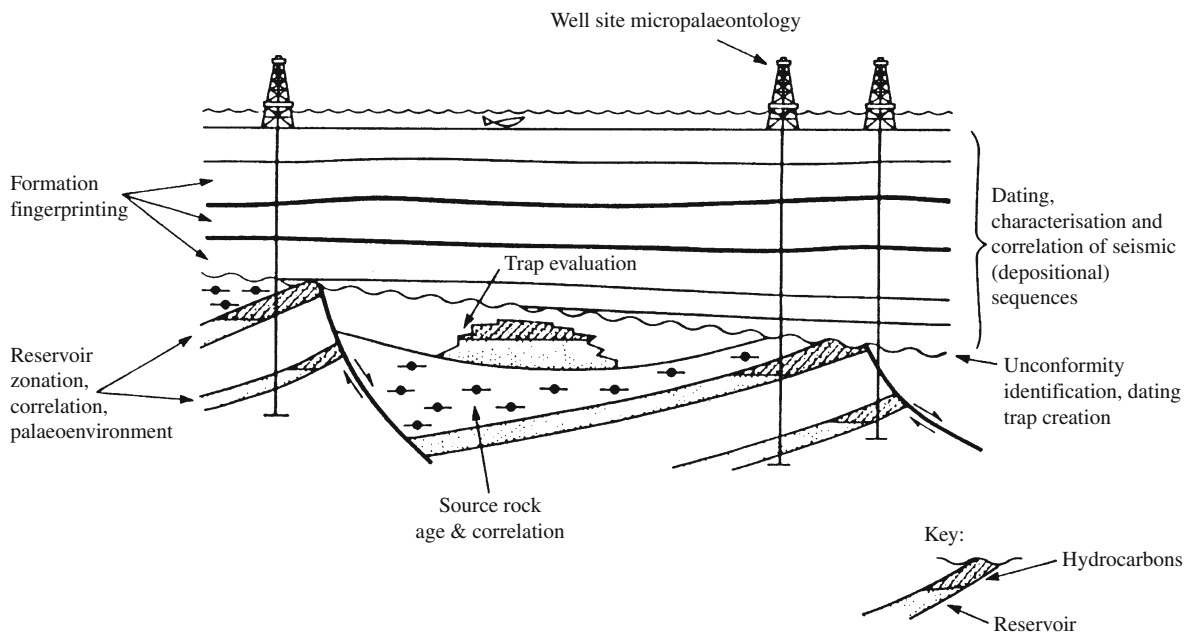


Fig. 7.1 Application fields of micropalaeontological methods in petroleum exploration and appraisal activities (from Copestake 1993)

Microfossils \ Rocks	Spores, pollen	Dinoflagellates	Acritarchs	Foraminifera	Conodonts	Ostracods	Prasinophyceans	Calcionellids	Chitinozoans	Botryococceans	Coccolithophores	Radiolarians	Silicoflagellates	Diatoms
Clays and shales	●	●	●	●	⊗	●	⊗	⊗	●	⊗	●	●	⊗	⊗
Limestones and marls	⊗	⊗	⊗	●	●	●	⊗	●	⊗		●	⊗	⊗	
Flints and cherts	⊗	⊗	⊗	⊗	⊗	⊗					⊗	●	⊗	⊗
Coal, lignite, peat	●	⊗	⊗				○			⊗				
Sands and sandstones	⊗	⊗	⊗	⊗	⊗	○	○		⊗					
Dolomites, ankerites	⊗	⊗	⊗	⊗	⊗	○	○	○						
Evaporites: gypsum, halite	⊗	○	○											
Metamorphic rocks: slates, phyllites, marbles	○	○	○	○	○									

● Abundant
 ⊗ Common
 ⊗ Rare
 ○ Sporadic

Fig. 7.2 Distribution trends and importance of major microfossil groups in different types of rocks

environment, composition and diagenetic history of the sediments. Marine mudstones, marls and limestones usually have a particularly rich microfossil content of high diversity (Fig. 7.2). Well sorted sandstones have a generally low microfossil content, as most microfossils are both lighter and smaller than the average sand grains. Dolomites are also poor in microfossils because most of the fossil organisms with primary calcite have been dissolved during dolomitisation, or because the beds represent an evaporite environment. Coals and related organic sediments are rich in terrestrial microfossils (spores and pollen). Evaporites are characterised by small quantities of microfossils, mainly of terrestrial origin.

Microfossils occur in Precambrian rocks but rapid development of many central groups started in the Cambrian (Fig. 7.3). Every part of the stratigraphic column from Cambrian to recent time contains one or several microfossil groups which are potentially useful for biostratigraphical or palaeoecological purposes. According to skeletal composition, microfossils can be arranged into five groups, which comprise several taxonomic divisions:

(1) Calcareous microfossils: calcitic and aragonitic foraminifera, single-celled heterotrophs; ostracods, microscopic crustaceans; calpionellids,

uncertain origin; carophytes, algal reproductive organs; calcareous nannoplankton, single-celled algae.

- (2) Arenaceous microfossils: agglutinated foraminifera, single-celled heterotrophs.
- (3) Siliceous microfossils: radiolarians, single-celled heterotrophs; diatoms, single-celled algae; silicoflagellates, single-celled algae; ebridians, single-celled heterotrophs.
- (4) Phosphatic microfossils: conodonts, primitive vertebrates.
- (5) Organic-walled microfossils: acritarchs, uncertain origin; prasinophytes, cysts of green algae; chitinozoa, uncertain origin; chlorophytes, freshwater algae, algal colonies; dinoflagellates, single-celled algae.

7.3.2 Factors Controlling Stratigraphic Application

There are several factors influencing the applicability of microfossils to stratigraphic purposes. The most important ones having a positive effect on the application potential are: (1) Presence of hard parts with high probability of preservation. (2) High evolution rate of taxa. (3) Extensive regional distribution, or