STRATIGRAPHY AND RELATIVE GEOCHRONOLOGY

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Summary

Stratigraphy is the science that studies the strata, or beds, of (mainly) sedimentary rocks in order to extract from them the history of the earth's surface. By grouping the bed successions in stratigraphic units and by studying their geometrical relationships with some simple rules, it creates the fundamental temporal relative framework necessary to understand the origin of the rock units themselves. Several sub-disciplines or methodological approaches (especially biostratigraphy and paleontology) cooperate in the fundamental task of Stratigraphy, which is the correlation, that is, the recognition of the time equivalence of two different sedimentary successions. In this way a standard chronostratigraphic table, or geologic timescale, has been constructed whose divisions are continuously calibrated in terms of absolute age.

Modern Stratigraphy uses many sophisticated methods to recognize past time intervals in the rock records (stable isotopes or magnetic polarity variations) and is increasingly emphasizing the importance of non-parallel stratigraphic relationships (Sequence Stratigraphy). Moreover, the study of rhythmic or cyclic sedimentation (Cyclostratigraphy) and of rare or unique sedimentary events (Event Stratigraphy) has significantly refined our knowledge of the earth's history.

1. Introduction: Stratigraphy, Sedimentation, and Geologic Time

Stratigraphy is the science of strata, which are a common feature of many landscapes constituted mainly of sedimentary rocks. However, strata (hereafter called "beds") are also present (although strongly deformed tectonically) in metamorphic rocks, which were sedimentary in origin, and in volcanic rocks. Wedge-shaped, channeled, lenticular, and irregular stratified sediment bodies are commonly found, but beds are usually tabular or laminar volumes of rock bounded by flat and laterally continuous stratification (bedding) surfaces.

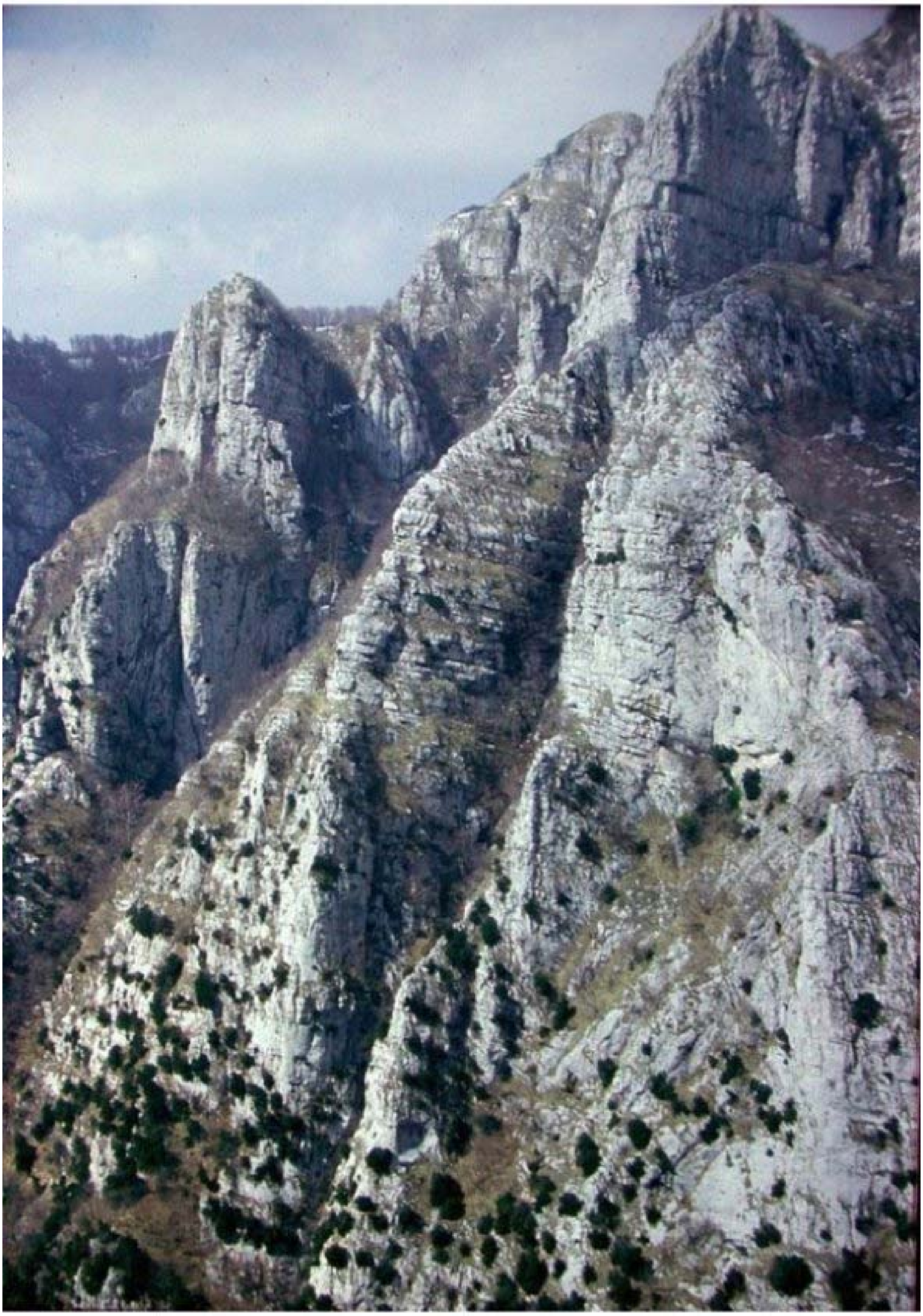

Figure 1. A mountain landscape from the Southern Apennines (Italy), showing the pervasively stratified structure of the rocks, in this case Cretaceous limestones. (Photo courtesy of A. Iannace, Naples.)

Bedded sedimentary rocks are the obvious result of erosion, transport, and deposition, especially when they are terrigenous-clastic in origin but also when they are derived from chemical precipitation, from organic matter accumulation, or from the interplay between volcanism and sedimentation (see *Sedimentation and Sedimentary Rocks*). Beds actually represent units of sedimentation, and pieces of the geological time during which a net sedimentation was locally produced in a restraint area that had been affected in the past by active geological processes.

2. The Stratigraphic Record and its Significance

Beds can appear in isolation, but more commonly they form stratigraphic successions up to several thousand meters thick, which are the sediment fill of wide ancient sedimentary basins. These are crustal depressions, mainly generated by large-scale plate tectonic processes, in which many different sedimentary environments can be present. Generally speaking, continental, marine, and transitional sedimentary systems can be distinguished and each of these may be erosional, equilibrial, or depositional (see Figure 1 of *Global Sedimentary Geology*). The dynamics of these systems produces a stratigraphic record, in which sharp to gradual change between successive sedimentary beds or groups of beds (stratigraphic units) can be observed. However, many bedding surfaces may actually represent erosion or no sedimentation (discontinuity surfaces, see *Sedimentary Geology and Paleontology*)

The stratigraphic units are characterized by their position and arrangement within the stratigraphic column and, especially, by the nature and lateral and vertical organization of their facies, that is: their lithological, petrographical, mineralogical, and/or chemical composition; their texture (grain size, shape, and relationships), and other physical properties such as remnant magnetism or many others; their fossil content; and their geometrical features, such as sedimentary and post-sedimentary structures or stratigraphic architecture, depending on the scale of observation

The nature, distribution, dynamics, and evolution along geological time of the different sedimentary systems present within basins—and of the stratigraphic-depositional units and bounding surfaces that they produce—depend on parameters such as the general shape and topography of the basin and adjoining areas, nature of and distance to the sediment source, drainage pattern, current systems, base level (usually sea-level) position and stability, and organisms living in them. These parameters are essentially controlled by climate, tectonics, and the evolution of life. So, the stratigraphic successions of sedimentary basins actually contain an ordered information (in space and time) about:

- the past distribution of sedimentary systems and environments within basins and surrounding areas, and their dynamics (Paleogeography);
- the temporal succession of climatically- and tectonically-controlled geological processes (“Paleogeodynamics”: Paleotectonics, Paleoclimatology, Paleoceanography, and so on), either acting gradually or suddenly (events) and thus producing progressive to very rapid or sharp changes in the rock record; and

- the evolution of life and of evolutionary processes in the marine and terrestrial biosphere (Paleobiology).

By applying simple rules, or Principles of Stratigraphy, to the description and interpretation of stratigraphic successions, it is possible:

- To subdivide and organize the local stratigraphic column in superimposed stratigraphic (rock) units separated from each other by bounding surfaces (Lithostratigraphy).
- To construct a relative dating scheme of successive gradual changes or sudden geological events (Event Stratigraphy) recorded for each local stratigraphic column, either by means of fossils (Biostratigraphy), remnant magnetism (Magnetostratigraphy), volcanic ash ejections (Tephrostratigraphy), paleosols (Pedostratigraphy), chemical properties of sediments (Chemostratigraphy and Isotope Stratigraphy), cyclic evolution of strata (Cyclostratigraphy), succession of depositional sequences (Sequence Stratigraphy) and of their bounding unconformities (Allostratigraphy), indicators of climatic change (Climatostratigraphy), or by a combination of several of these criteria. These procedures allow the establishment of a solid time-stratigraphic scheme (Chronostratigraphy) or relative geochronology for the studied succession.
- To propose correlations—that is, comparisons in space and time—between stratigraphic successions of different sedimentary basins.
- To interpret the dynamic and paleogeographic significance of the studied record at different scales of observation, from the individual bed (stratinomic analysis) or group of beds (facies-to-sequence analysis) to the basinal scale (basin analysis), or even to a global scale if the observed phenomena are recognized worldwide.
- To reconstruct the geological history of the earth in different areas of the world and to recognize its variation in space and time since the origin of the earth's crust up to the present day.

As a consequence, the stratigraphic record is something like a complex, fragmentary, and partially destroyed book, in the pages of which (the strata) the geological history of the earth was written. By correlating local stratigraphic successions with standardized reference sections, it has been possible to develop a geologic timescale composed of standard stratigraphic divisions (this work was mainly done during the nineteenth century).

As such, the units of Chronostratigraphy refer to physical *rock units* materialized by the stratotype and all the correlatable successions (erathems, systems, series, and stages), whereas Geochronology refers to the *time* the same units represent (eras, periods, epochs, and ages). The absolute time calibration of the chronostratigraphic/geochronologic units is based mainly on the radioactive decay of elements contained within magmatic rocks (see *Geochronology and Isotope Geology*) present in stratigraphic successions. However, it is obvious that both disciplines are different aspects of the same work: the time-correlation of rock units.

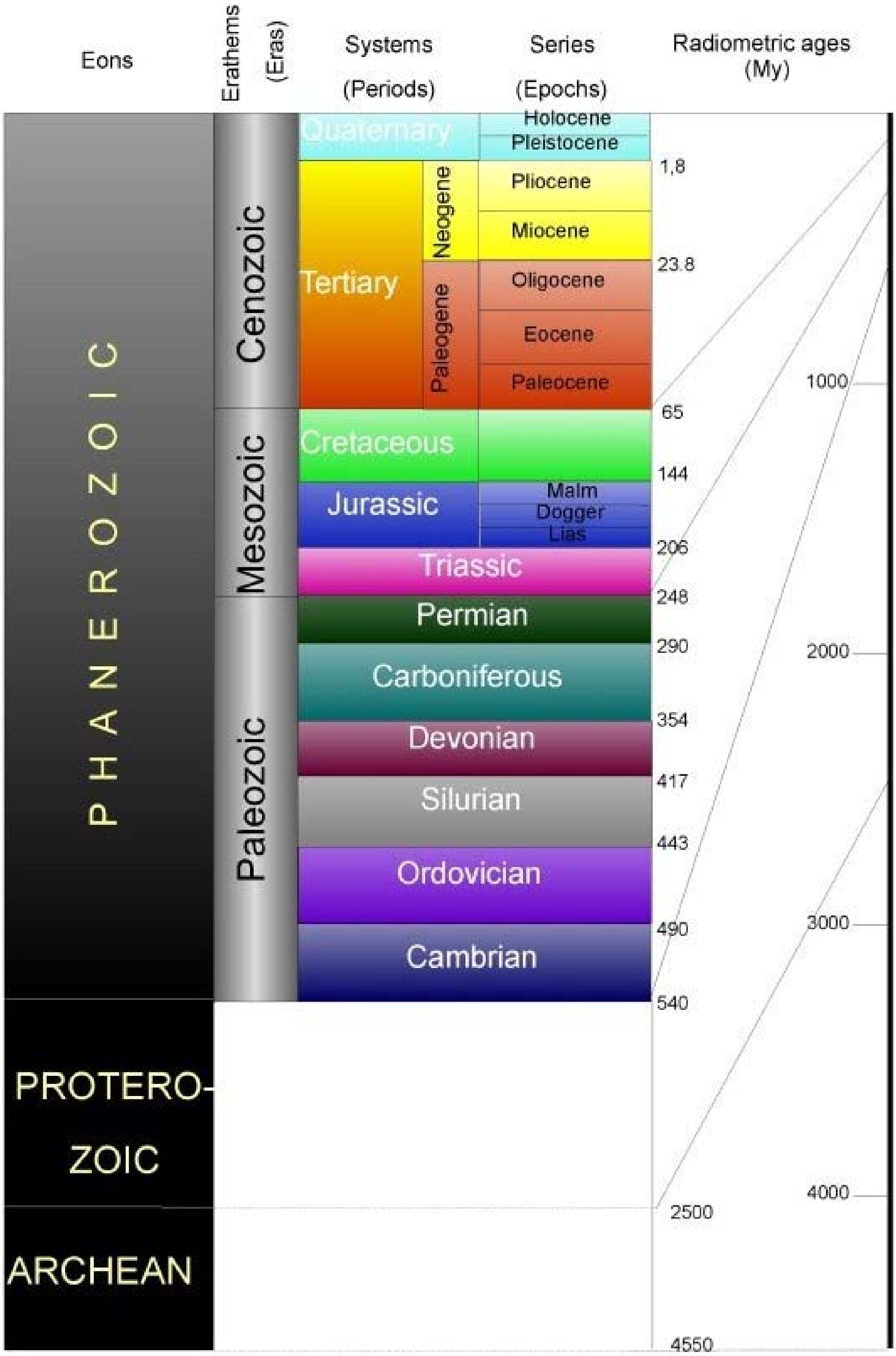

Figure 2. The geological timescale. The absolute ages are those proposed by the Geological Society of America in 1999. On the right, the proportional length of the absolute ages is shown, to show the dramatic augmentation of resolution for more recent time. Stages/ages are not indicated.

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Biographical Sketch

Agustín Martín-Algarra was born in Granada, Spain, in 1957; he graduated in Geology and then obtained his Ph.D. in the University of that city, with a thesis on the geologic and paleogeographic relations between the internal and the external zones of the Betic Cordillera. Since 1998, he has been

Professor of Stratigraphy in the Department of Stratigraphy and Paleontology of the University of Granada, where he teaches Quaternary Geology and Paleogeography.
His main research interests, attested to by over 140 contributions, include the geology of Alpine-Mediterranean belts in Southern Spain and Northern Morocco, particularly the stratigraphy, sedimentology, and basin analysis of the Betic Cordillera and of the Northern Rif, and the paleogeographic evolution of Western Mediterranean regions. More detailed sedimentological studies have focused on condensed pelagic successions and stratigraphic discontinuity surfaces, especially those associated with Jurassic-Cretaceous phosphate stromatolites.