

How and where on Earth were and are carbonate minerals formed?

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Calcium and magnesium carbonates are formed practically exclusively by microbial decay of organic carbon compounds, by photosynthesis and by Golgi related biochemical activity of macro-organisms. Many geoscientists have thought over many years, that structureless carbonate rocks are the result of inorganic evaporation processes under high temperature in warm seas. The term "Whittings" has been used excessively. Also hot volcanic exhalations and warm springs have been repeatedly mentioned. In the early 19th Century a fervent discussion started about "Neptunism" and "Plutonism", based on the work of Lucretius and Paracelsus among others. This discussion did not come to an end. Almost unnoticed contributions to the question of biogenic carbonate production stem from Paracelsus (1493-1541), Hooke (1665) Brückmann (1721), Ludwig and Theobald (1852). Attention of modern geoscience was raised only in the 20th Century by the work of Kalkowsky (1908), Drew (1910), Nadson (1906,1928), and Bavendamm (1932). Other names to be mentioned are Degens (1976), and Krumbein (1966, 1968, 1974). Reference to the historical Odyssee is given by v. Knorre and Krumbein and Castanier (2000) in Riding and Awramik (1). Riege (1) concluded from many experiments and the literature, that the key event in bacterial calcium carbonate formation is a change in carbonate alkalinity, which can be achieved aerobically and anaerobically in biofilm environments. Prokaryotes are the most important promoters of carbonate formation. However, no specific process or biochemical pathway could be shown so far, comparable to the Golgi apparatus and other complex reactions in eukaryotes and tissue forming organisms. In a nutshell: Carbonate minerals are formed exclusively under the control of biochemical processes. Biochemical processes need life as a prerequisite. Anderson (1984) claimed further, that global tectonics only exist on earth because limestone generating life established itself under surface conditions. He continued, that Venus has no plate tectonics because no carbonate forming life exists on this planet. Some examples of why and how carbonate minerals form in a microbial biofilm or mat or planktonic environment are given during the introductory talk. Techniques of study are briefly mentioned. Reference is given also to the permanent ETH Zürich student J. Neher (see [1]). All names and processes mentioned in this abstract can be found in the following references.

- [1] Krumbein, W. E. (1966) Ph.D. Thesis, Würzburg, 130p.
[2] Krumbein, *et al.* (1994) *Biostabilization of Sediments*. BIS Oldenburg, 526p. [3] Krumbein, *et al.* (2003) *Fossil and recent biofilms* Kluwer, Dordrecht, 482p. [4] Riding, R. & Awramik, M. (2000) *Microbial Sediments*. Springer, Berlin, 331p.

Iron, sulfur and the global carbon cycle

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Calcium and magnesium carbonates are formed practically exclusively by microbial decay of organic carbon compounds, by photosynthesis and by Golgi related biochemical activity of macro-organisms. Solar energy has been transformed into useful redox differences or disequilibria within the Earth's crust since the onset of anoxygenic and oxygenic photosynthesis in the Precambrian. Inorganic oxidized carbon is transformed into reduced carbon compounds by capturing and storing solar energy. During this process many different organic compounds are formed including carbohydrates, proteins, hydrocarbons, and various other complex organic metabolic products and their diagenetic polymerisation products (melanin, humic substances, petroleum, coal, and kerogen). Many of these solar energy enriched compounds, however, are oxidized immediately or during the diagenetic transformation of sediments. The oxidation agents are oxygen, sulfate, iron and other oxidized compounds, which in turn are partly enriched with the original solar energy. On a global biogeochemical scale, however, sulphur and iron are the most important elements. Geological evidence shows that biogeochemical cycles yield stable ratios between the most oxidized forms of carbon (carbon dioxide and calcium/magnesium carbonate) and the most reduced forms (diamond, coal, methane, and hydrocarbons). Throughout Earth's history and evolution this equilibrium ratio is around 1:4, maximally 1:5. When too much carbon is stored in the crust in the form of reduced compounds or vice versa climatic and biogeomorphogenetic consequences upset the equilibrium. The biosphere reacts in a way to return to the optimal ratio. Excellent examples for this fluctuating equilibrium are the Carboniferous (too much organic carbon stored), the Permian (too little organic carbon stored) and the Tertiary with a generally equivalent production of hydrocarbons and carbonates. At present, we are seemingly in a period in which there is a global biogeochemical need to oxidize reduced carbon compounds as fast as possible in order to counteract even more dramatic global climate shifts. The highly evolved human genome seems to be the tool for this shift. Enormous amounts of reduced carbon are turned into the oxidized form as carbon dioxide, which by various biogeochemical pathways is transformed into carbonate, another oxidised form of carbon that can be stabilised and stored in the sedimentary record. Fast recycling of excessively stored solar energy may enable the survival of a global biosphere under highly stressed conditions. Humankind apparently lives in an environment of increased calcium carbonate formation. The global Microflora helps to achieve this.