Siliceous sedimentary rocks (cherts)

Introduction

Siliceous sedimentary rocks are fine-grained, dense, very hard rocks composed of the SiO_2 minerals quartz, chalcedony, and opal. Chert is the general group name used for siliceous sedimentary rocks.

Mineralogy and texture

Quartz is the primary mineral of siliceous deposits, other SiO_2 minerals in these deposits are chalcedonic quartz, amorphous silica (opal-A), and cristobalite and tridymite (opal-CT). Opal-A is primarily of biogenic origin and forms the tests of siliceous plankton and the spines of some sponges. Skeletal opal-A is metastable and converts in time to opal-CT and finally quartz.

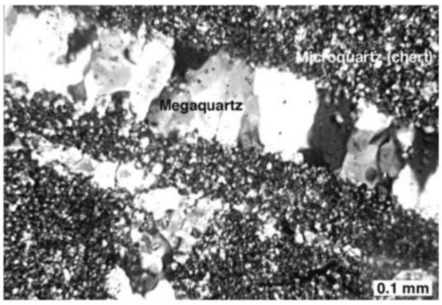

Figure 12.10 Fine-textured, nearly equigranular microquartz (chert) cut by a vein of much coarser megaquartz. Source of specimen unknown. Cross-polarized light.

Texturally, the quartz that forms cherts can be divided into three main types: (l) micro-quartz, consisting of equidimensional grains of quartz less than about 20 microns in size (Fig. 12.10), (2) megaquartz, composed of equant to elongated grains greater than 20 microns (Fig. 12.10), and (3) chalcedonic quartz, forming sheaf like bundles of radiating, thin crystals about 0.1mm long (Fig. 12.11).

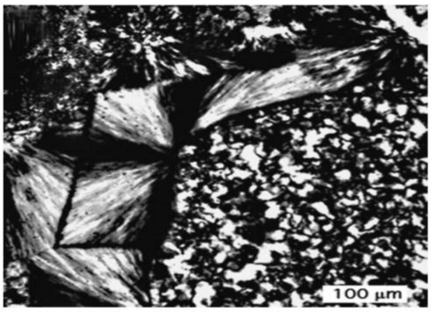

Figure 12.11 Sperulitic (radial-fibrous) chalcedony cement (lower left corner) and microquartz (lower right corner) in a chert deposit from the Gunflint Formation (Precambrian), Ontario, Canada. Cross-polarized light. (From Maliva, R.G., A.H. Knoll, and B.M. Simonson, 2005, Secular changes in the Precambrian silica cycle: Insights from chert petrology: *Geol. Soc. Am. Bull.*, **117**, Fig. 4D, p. 840, reproduced by permission.)

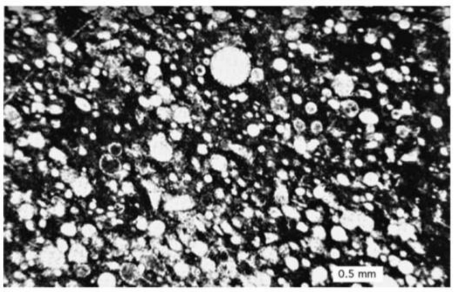

Figure 12.12. Photomicrograph showing moderately well-preserved radiolarians in chert from the Otter Point Formation (Jurassic), Oregon. Plane-polarized light. (Photograph courtesy of Robert Lent.)

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kinds of cherts

several names are applied to various varieties of chert. Flint is used for chert and particularly chert that occurs as nodules in Cretaceous chalks. Jasper is a variety of chert colored red by impurities of hematite. Novaculite is a very dense, fine-grained, even - textured chert that occurs mainly in mid-Paleozoic rocks of the Arkansas. Porcellanite is a term used for fine-grained siliceous rocks with a texture and fracture resembling that of un glazed porcelain.

Bedded and nodular chert

Cherts can be divided on the basis of morphology into bedded cherts and nodular cherts.

1 - Bedded chert

Bedded chert consists of layers of chert, ranging to several centimeters in thickness, that are commonly inter bedded with millimeter-thick partings or laminae of siliceous shale (Fig. 12.13). Bedding may be even and uniform or may show pinching and swelling. These rhythmically bedded deposits are also referred to as ribbon cherts. Many chert beds lack internal sedimentary structures; however, graded bedding, cross-bedding, ripple marks, sole markings, convolute layers, and soft-sediment folds have been reported in some cherts. The presence of these structures indicates that mechanical transport was involved in the deposition of these rocks, quite possibly transport by turbidity currents. Bedded cherts are commonly associated with ophiolitic rocks such as submarine volcanic flows or pillowed greenstones, tuffs, pelagic limestones, shales or argillites, and siliciclastic or carbonate turbidites.

Bedded cherts can be subdivided on the basis of type and abundance of siliceous organic constituents into four principal types:

A. Diatomaceous deposits include both diatomites and diatomaceous cherts. fig. 12.13

B. Radiolarian deposits consist dominantly of the remains of radiolarians, which are marine planktonic protozoans with a lattice like skeletal framework.. Radiolarian cherts are commonly associated with tuffs, mafic volcanic rocks such as pillow basalts, pelagic limestones, and turbidite sandstones that are believed to indicate a deep-water origin. On the other hand, some radiolarian cherts are associated with micritic limestones and other rocks that suggest deposition at shallower depths of perhaps 200–1000m (Iijima et al., 1979).

Figure 12.13 Thin, well-bedded cherts in the Mino Belt Group (Triassic), near Inuyama, Honshu, Japan.

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C. Siliceous spicule deposits include spicularite (spiculite), a siliceous rock composed principally of the siliceous spicules of invertebrate organisms, particularly sponges. Spicular cherts are mainly marine in origin and occur associated with glauconitic sandstones, black shales, dolomite, argillaceous limestones, and phosphorites. They are probably deposited mainly in relatively shallow water a few hundred meters deep.

D. Bedded cherts containing few or no siliceous skeletal remains have been described by many authors. Some of these cherts are probably radiolarian cherts that have undergone such severe diagenesis that no recognizable radiolarians remain. Others, For example, cherts formed by silicification (replacement) of volcanic rocks, biogenic sediments, and evaporites (Lowe, 1999).

2 - Nodular cherts

Nodular cherts are sub spheroidal masses, lenses, or irregular layers or bodies that range in size from a few centimeters to several tens of centimeters (Fig. 12.14). They commonly lack internal structures, but some nodular cherts contain silicified fossils or relict structures such as bedding. Colors of these cherts range from green to tan and black. They typically occur in shelf-type carbonate rocks. More rarely, they occur in sandstones and mudrocks, lacustrine sediments, and evaporites.. Nodular cherts originate mainly by diagenetic replacement. Diagenetic origin is clearly demonstrated by the presence of partly or wholly silicified remains of calcareous fossils or ooids, burrow fillings, algal structures, etc.

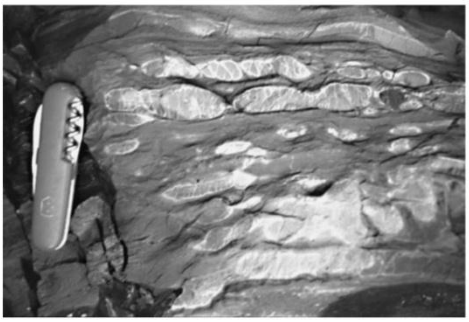

Figure 12.14 Nodular chert in limestones of the Helena Formation (Precambrian), Glacier National Park, Montana. (From Boggs, S., Jr., 2006, *Principles of Sedimentology and Stratigraphy*, 4th edn.: Prentice-Hall, Upper Saddle River, NJ, Fig. 7.11, p. 210, reproduced by permission.)

Deposition of chert

Silica solubility is affected by temperature. Solubility increases with increasing temperature; solubility at 100 oC is approximately three times that at 25 oC(Fig. 12.15). Solubility is also affected by pH. Although solubility changes very little with increase in pH up to about pH 9, it rises sharply at pH values above 9 .

Silica concentrations in seawater

Silica is transported in river water to the modern ocean as silicic acid (H_4SiO_4). In addition, silica is added to the oceans through reaction of seawater with hot volcanic rocks along midocean ridges and by low-temperature alteration of oceanic basalts and detrital silicate particles on the seafloor. Some silica may also escape from silica-enriched pore waters of pelagic sediments on the seafloor. These silica sources are summarized in Fig. 12.16.. Surface waters are particularly depleted in silica (commonly <0.01 ppm SiO2). Silica concentration increases downward in the ocean to a maximum of about 11 ppm below a depth of about 2km. The variations in silica concentration with depth reflect uptake of silica near the surface by phytoplankton and regeneration of silica at depth owing to dissolution of the silicon tests of phytoplankton.

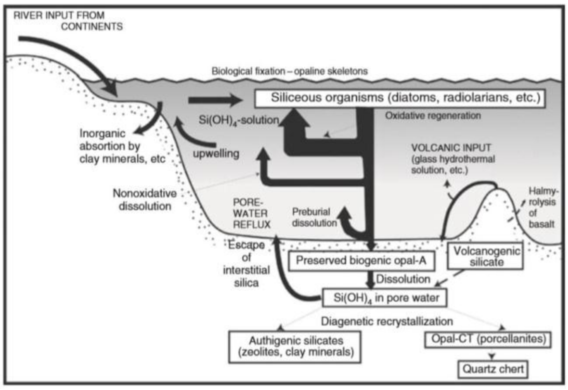

Figure 12.16 Sources of dissolved silica in seawater. {After Riech, V. and U. von Rad, 1979, Silica

Precipitation of chert from seawater

Biogenic removal of silica (biogenic cherts)

Seawater in the modern ocean, is undersaturated with respect to silica, it does not appear to crystallize readily to form quartz .Therefore, it is unlikely that chalcedony or microquartz (chert) can be precipitated by inorganic processes from highly undersaturated ocean water. Removal of silica from ocean water by silica-secreting organisms to build opaline skeletal structures appears to be the only mechanism capable of large-scale silica extraction from undersaturated seawater. Radiolarians, diatoms, and silicoflagellates are microplankton that build skeletons of opaline silica. These siliceous microplankton have apparently been abundant enough in the ocean during Phanerozoic time to extract most of the silica delivered to the oceans by rock weathering, etc.

While silica-secreting organisms are alive, their siliceous skeletons are protected by an organic coating that prevents them from dissolving in highly undersaturated seawater. After death, this coating is destroyed by biochemical decomposition and the opaline skeletons began to undergo dissolution. In areas of the ocean where siliceous organisms flourish (zones of upwelling), the rate of production of siliceous skeletons may be so high that they cannot all be dissolved as rapidly as they are produced. Under such conditions, a sufficient number of the siliceous skeletons may survive total dissolution to accumulate on the seafloor as siliceous oozes (sediments containing more than about two-thirds siliceous skeletal material). After burial by additional siliceous ooze or clayey sediment, these opaline skeletal materials continue to undergo solution; however, the dissolving silica is trapped in the pore spaces of the sediment and cannot all escape back to the open ocean. The pore waters thus become increasingly enriched in silica. Such pore waters are saturated to supersaturated with respect to silica, and cherts are thought to precipitate slowly from these concentrated interstitial solutions. Thus, the formation of cherts is in part a sedimentation process involving the depositional concentration of biogenic opaline tests and in part a diagenetic process with crystallization, and recrystallization, of the chert taking place after sediment burial.

Non biogenic cherts

The origin of bedded, ribbon cherts that contain no siliceous organic remains is poorly understood. Until recently, no similar occurrences have been reported in the open-marine environment that could help explain the presence of widespread nonfossiliferous chert deposits. It appears that concentration of silica in the (Precambrian) ocean was higher than that in the modern ocean. Higher concentrations may have been related to greater hydrothermal flux to the ocean or to high rates of chemical weathering on land (Maliva et al., 2005). These authors suggest that cherts associated with Proterozoic iron-formations formed to a large degree by primary silica precipitation in marine peritidal to subtidal environments. Presumably, silica was precipitated by chemical (inorganic) processes, although bacteria may have played some role in precipitation (Maliva et al., 1989).

On the other hand, some Precambrian cherts apparently formed by replacement of precursor sediments. like silicification (replacement) of volcaniclastic and pyroclastic deposits, terrigeneous sand- stones and shales, biogenic sediments (algal mats), and evaporites.

Replacement chert

In addition to its occurrence as bedded chert , chert can also occur in the form of small nodules, lenses, or thin, discontinuous beds. Nodular cherts are common in carbonate rocks but occur also in evaporites and siliciclastic rocks. Relict textures in these nodular cherts suggest that most are formed by diagenetic replacement. Nodular cherts formed by direct replacement of limestone by quartz (>10 microns) crystal size. Nodular cherts have also been reported to form by silica replacement of anhydrite.

Replacement cherts occur in shallow, platform carbonate rocks. Knauth (l979) suggests that the mixing zone where meteoric ground waters mix with seawater in a coastal area may be a particularly favorable geochemical environment for chert replacement of carbonates. Silica is supplied in this environment by the dissolution of sponge spicules or other forms of biogenic opal-A within the sediment pile and is then transported into the zone of mixing where replacement of $CaCO_3$ occurs. Presumably, opal-A is first transformed to opal-CT, which then replaces the carbonate and is later diagenetically altered to quartz chert.