

STANISŁAW KWIATKOWSKI

Origin of the chert laminae and silico-calcareous nodules in uppermost R \ddot{o} th cavernous limestone at Gogolin (Lower Silesia)

ABSTRACT: The Gogolin Cavernous Limestone (uppermost R \ddot{o} th; Lower Silesia) is interpreted as formed in a sabkha environment. A specific feature of this deposit is the occurrence of chert laminae and silico-calcareous nodules. These are thought to have originated due to dissolution of detrital quartz in the periods of strong evaporation at a high temperature and a high pH and, subsequently, precipitation of the silica gels during flooding by marine water resulting in a rapid fall of temperature and pH.

INTRODUCTION

The horizon of cavernous limestone occurs at the Lower/Middle Triassic boundary (uppermost R \ddot{o} th of the German-Polish Muschelkalk Basin) of the Silesia region. At the studied locality Gogolin (Lower Silesia) it is 1.6 m thick and consists mainly of dedolomites with numerous calcitic pseudomorphs after gypsum, anhydrite and halite, siliceous nodules and laminae, algal mats, fenestral fabrics, and wave ripples (BODZIOCH & KWIATKOWSKI, *in preparation*). It was formed in supralittoral ponds under sabkha conditions.

The silica in this limestone horizon occurs as: (i) thin chert beds and laminae, (ii) silico-calcareous beds and nodules in horizontal streaks, (iii) diapiric silico-calcareous nodules, (iv) silicified anhydrite nodules, and (v) silicified algal mats. In this paper a model for the formation of chert laminae and silico-calcareous nodules is proposed.

DESCRIPTION OF THE CHERT LAMINAE AND SILICO-CALCAREOUS NODULES

The siliceous intercalation (15 mm thick), in the middle of a limestone layer (see Text-fig. 1), is formed by dark gray chert almost devoid of organic pigment.

Chert consists of the microcrystalline quartz with dispersed grains of chalcedony. It contains numerous ostracodes and some small brachiopods, bivalves, and foraminifers. The carapaces of ostracodes are filled with lutecite or chalcedony spherulites and/or microcrystalline quartz with the spherulitic chalcedony overgrowths.

At the top and bottom of the chert layer, there are thin (ca 1 mm) bands of light silica. The difference between light and dark silica is not visible under microscope. The lower boundary of the chert is vague and uneven, with fragments of chert in the limestone and fragments of limestone in the chert. The upper boundary of the chert is even with only small projections of the chert into the limestone and of the limestone into the chert. Below the chert (see *A* in Text-fig. 1), the brown limestone is cavernous, colored by organic pigment, and is devoid of detrital quartz. The limestone overlying the chert layer (see *C* in Text-fig. 1) is yellow, with rich organic pigment, with detrital quartz and with no caverns.

The silico-calcareous intercalation (see Text-fig. 2) in another limestone layer, 9 cm thick, is divided in the following parts:

A — Light-brown limestone (*A* in Text-fig. 2), cavernous, rich in organic pigment, with skeletal detritus. In its lowest part, the limestone does not contain the silica bodies. Upwards, there occur some thin scarce lenses of white silica. The upper part (*A*₁ in Text-fig. 2) is divided in two segments by three thin (1 mm), wavy laminae of white silica. The bottom lamina is discontinuous, the middle lamina almost continuous, and the top lamina continuous. The segments consist of limestone with irregular silica aggregates. In the lower segment, these aggregates consist of white silica, in the upper segment they consist of dark silica with a white silica rim. The white and dark silica do not differ under microscope. Both consist of microcrystalline quartz with skeletal remains preserved in chalcedony. The boundaries of the silica aggregates are irregular and uneven.

B — Dark brown limestone (*B* in Text-fig. 2), compact, non porous, not cavernous, without silica, but with detrital quartz, dispersed oncoids of various diameter (up to 1 cm), and rich organic pigment.

C — Yellow limestone (*C* in Text-fig. 2), porous, with irregular small lenses of white silica.

Another example of silico-calcareous bed (see Text-fig. 3) is formed in a limestone bed, somewhat cavernous. The silico-calcareous band, 3–20 mm thick, is contoured by a rim of white silica, ca 0.5 mm thick.

The center of the band consists of gray silica, surrounded by white silica. Between the boundary rim and the siliceous center a yellow limestone occurs. The top surface of the band is even and for the most part horizontal. The bottom surface of the band knobs out, forming anchor-shaped protuberances. These protuberances are underlying the spherical zones of non-silicified limestone. The limestone is partly recrystallized, partly micritic, strongly brown-colored, with some aggregates of dark organic pigment. In the limestone there occur some round aggregates of chalcedony, as well as ostracode carapaces, preserved usually in chalcedony or lutecite or microcrystalline quartz with chalcedony overgrowths. The ostracode carapaces are resting with their long axes horizontal. The silica aggregates are formed by microcrystalline quartz with some chalcedony bands, limestone fragments, ostracodes and other skeletal remains, preserved in chalcedony or in calcite. The silica is much less stained with pigment than the limestone.

Silico-calcareous nodules (see Text-fig. 4) occur in the yellow limestone bed. They are irregularly flattened ellipsoids, with the top surface flat, horizontal or

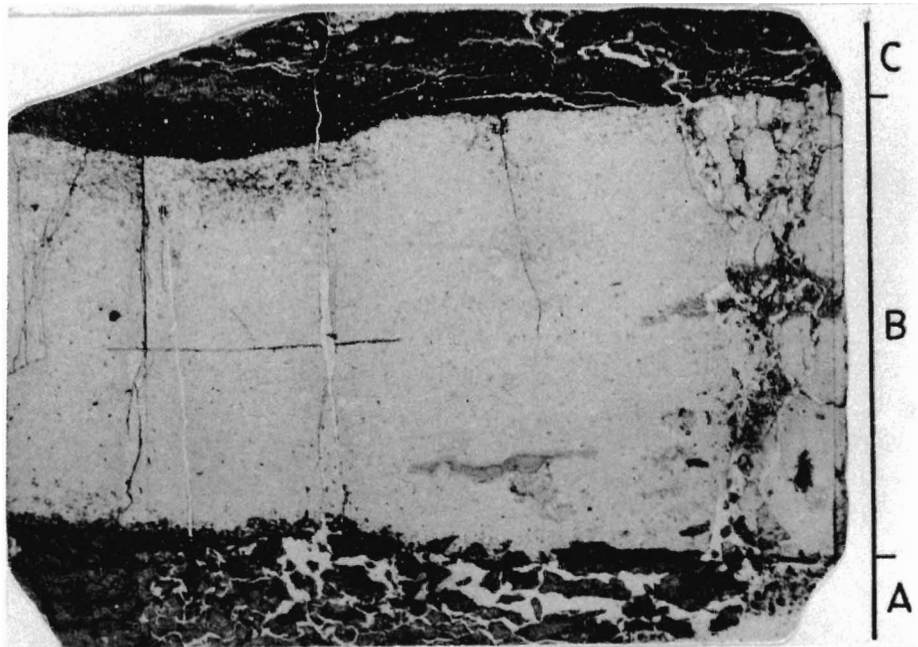


Fig. 1. Chert intercalation in a limestone bed: A and C — limestone, B — chert; thin section, $\times 4$

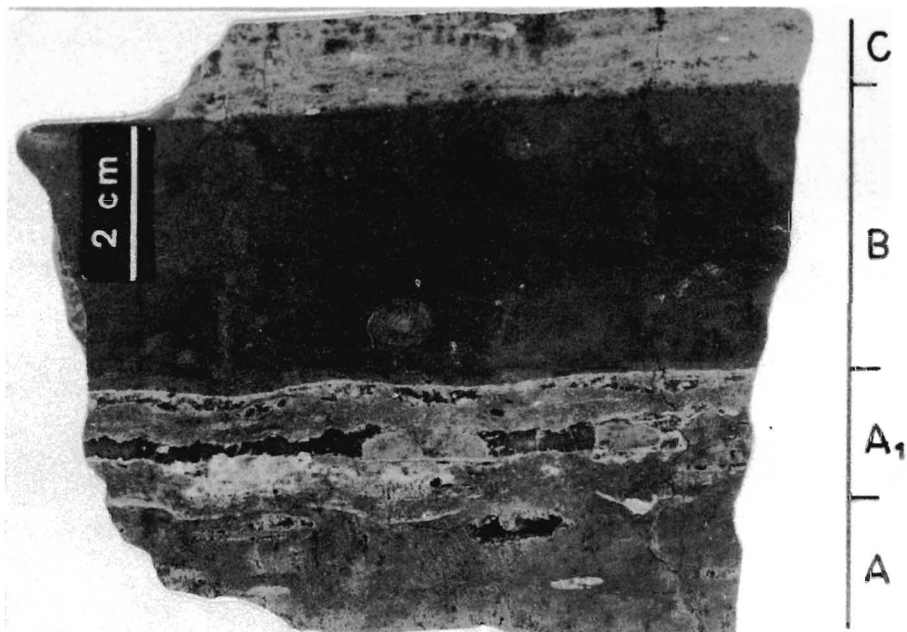


Fig. 2. Limestone with silico-calcareous intercalation

A — Limestone with caverns (black) and small siliceous lenses (white), A₁ — silico-calcareous intercalation: chert (white and black) and limestone (gray), B — limestone with dispersed oncoids (large oncolite at center), C — limestone with small silica lenses (white)

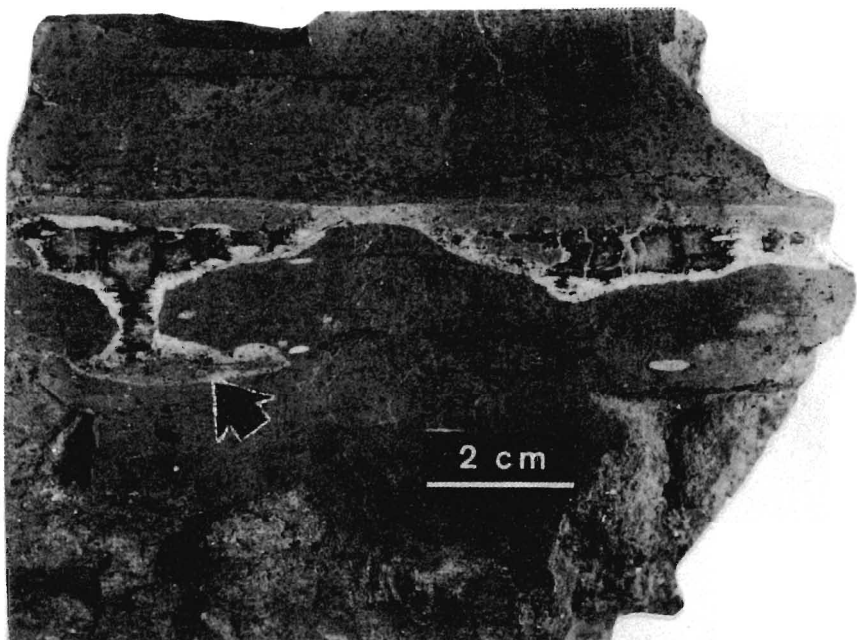


Fig. 3. Silico-calcareous band in the limestone, provided with anchor-shaped protuberances projecting from the bottom surface (*arrowed*)

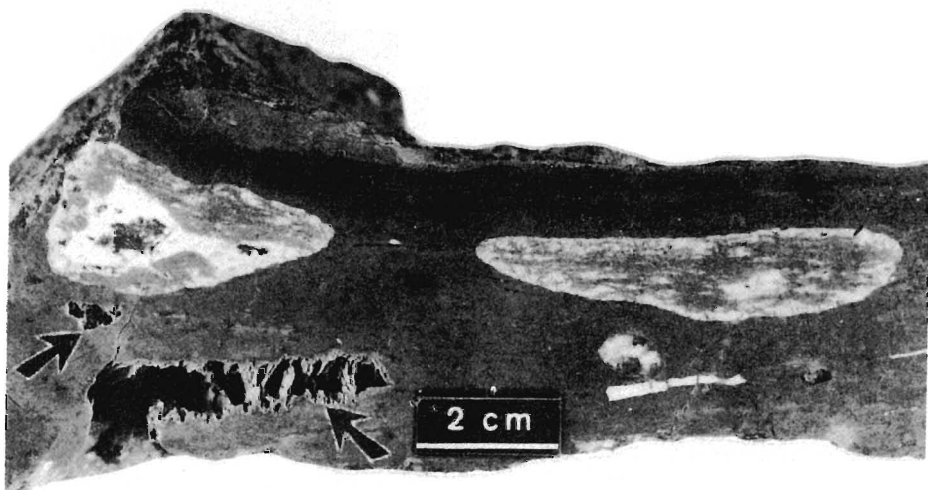


Fig. 4. Silico-calcareous nodules in the limestone: below the nodules there occur caverns (*black*) in the limestone (*arrowed*)

inclined, and the bottom surface convex, 10–23 mm thick and up to 60 mm long. They are surrounded by thin rims of white silica. Their interior consists of yellow limestone with commonly dispersed white silica aggregates. Some large aggregates contain dark silica at the center. In the limestone beneath the nodules there are caverns. The detrital quartz grains, mica flakes and shell fragments occur in limestone always above, between, and in the nodules, but they never do below the nodules. The limestone in the silico-calcareous nodules is locally recrystallized and strongly but irregularly colored by organic pigment, with shell fragments locally replaced by chalcedony. The silica occurs in horizontal bands with very irregular boundaries and with numerous patches of carbonate. It is composed of microcrystalline quartz, with detrital quartz and with poor pigment.

DISCUSSION

The physico-chemical conditions of sedimentation and early diagenesis of the Gogolin Cavernous Limestone were similar to those of recent sabkha. The temperature at the surface of the recent sabkha is very high, up to 53°C (BUTLER 1969) and it decreases rapidly downwards. In the evaporitic environment the values of pH in water at the bottom and in the upper zone of sediment are relatively high, whereas in the lower zone of sediment these values are low. In Abu Dhabi sabkha in the Trucial Coast, the pH value in lagoonal waters is 8.3, at the surface of sabkha it equals 7, at the depth of one meter it falls to 5.2 (*see* BUTLER 1969).

In the Gogolin Cavernous Limestone there alternate two types of deposit:

(I) Limestone with caverns and without detrital quartz and oncolites (*A* in Text-fig. 1; *A* and *C* in Text-fig. 2; *and* Text-fig. 4, below the nodules);

(II) Limestone without caverns and with detrital quartz, other detrital minerals, and locally oncolites (*C* in Text-fig. 1; *B* in Text-fig. 2; Text-fig. 3, the whole specimen; *and* Text-fig. 4, above and between the nodules).

The silica bodies occur in the upper part of layers of the type (I) or in the lower part of layers of the type (II).

Probably, at the time of the formation of a layer of the type (I) there was a slow deposition of calcareous mud under conditions of high salinity, temperature and pH accompanied by intense evaporation in very shallow, insulated waters. The gypsum crystals grew in these deposits. (The caverns were formed later in the rock by dissolution of gypsum and other evaporitic minerals). The quartz grains were dissolved. The silica solutions polymerized (*see* ZIJLSTRA 1987) and silica gels were agglomerated on the bottom (*see* PETERSON & VON DER BORCH 1965, COLINVAUX & GOODMAN 1971) and were partly sinking into the deposit.

Afterwards, a flooding of sea water came, and a layer of the type (II),

composed of carbonate mud, quartz sand and/or oncolites was deposited. The salinity decreased and deposit of the type (*I*), under the cover of the new deposit (*II*), passed rapidly into conditions of lower temperature and pH. The silica polymers precipitated in old and new deposit and the carbonate mud containing silica has been partly silicified. The lowering of temperature and the pH values were principal factors of the silica precipitation.

Depending on the quantity of silica available in the deposit there were formed either layers (*see* Text-fig. 1), irregular bands (*see* Text-figs 2-3) or silico-calcareous nodules (*see* Text-fig. 4). The irregular lower contact of silica bodies, different from the upper contact, indicates introduction of silica from above (*compare* DIETRICH, HOBBS & LOWRY 1963). The downward movement of silica in a deposit is also shown by diminishing silicification downwards (*see* Text-fig. 2).

As to the formation of the thin rims of white silica (*see* Text-figs 3-4) at some distance from silica aggregates, it is supposed that the silica polymers in the calcareous mud were dissolved on their peripheries and probably surrounded by a zone of true silica solution. When the temperature and pH rapidly diminished in time of flooding, the silica in true solution, less soluble, precipitated and an outer rim of the white silica was formed. Later, the silica polymers precipitated rapidly, forming irregular silica bands and agglomerates. Cloudy and diffuse shapes of silica bodies in the silico-calcareous nodules indicate that silica was precipitated as SiO_2 -gel (*compare* SALAMEH & SCHNEIDER 1980). The replacement of skeletal calcitic remains by chalcedony took place probably much later.

In one of the samples (Text-fig. 3), the shape of the silico-calcareous band suggests that it was formed by sinking of silica polymers in calcareous mud. This calcareous mud probably subjected earlier to an initial cementation, forming sphaerical calcareous zones. These zones were probably formed in bacterial microenvironments where the cementation was faster (*see* SASS & KOŁODNY 1972, RAISWELL 1976). They were surrounded by non-cemented calcareous mud. The silica polymers penetrated into this mud bypassing the cemented zones.

Over the whole rock the organic pigment is rich in the limestones and poor in the silica bodies. A part of the pigment could penetrate the rock after the silica bodies formation, but another part of pigment was primary. In one of the samples (Text-fig. 2) the dark color of the layer *B* with oncolites and the light color of layers *A* and *C* were probably original. The deposits of the layers *A* and *C* were probably in the oxidizing conditions for longer time than deposit of the layer *B* and their organic substance was more oxidized than that of *B*.

The presented model of the siliceous bodies formation may be compared with modern inorganic deposition of chert described by PETERSON & VON DER BORCH (1965). The chert precipitates in ephemeral lakes associated with Coorong Lagoon, South Australia, where two seasons are distinguished: moist winter, and dry summer, when all the lakes are completely dried. The precipitation of dolomite, magnesite, magnesian calcite, and gelatinous insoluble silica gel occurs throughout the drying season.

After PETERSON & VON DER BORCH: "The pH of lake water commonly rises to 10.2 during active photosynthesis by *Ruppia maritima* Linn., the brine, just as it approaches maximum concentration and either dries or sinks into the mud, has pH of about 8.2. Beneath the surface of the sediment there is a zone of rotting vegetation in which the pH of interstitial solutions is as low as 6.5. It is more or less at the boundary between these two pH realms that opaline silica is most obviously precipitating" and "Detrital quartz would dissolve in the solutions of high pH and reprecipitate during low stages of the lakes because of both reduction in pH as the plant life dies and as the brine concentrates and sinks into the sediment, and the final drying of the lake bed."

WHEELER & TEXTORIS (1978) described from the Triassic in North Carolina a limestone and chert of playa origin very similar to that of the Gogolin Cavernous Limestone. These rocks do not contain dolomites, and bear no evidence of volcanic ash or opaline tests. Cherts are too pure to have a soil origin (silcrete).

WHEELER & TEXTORIS think that: "Silica in the form of an opal gel was precipitated inorganically when the pH of the water fell to 7.0 or 6.5 during drying of the playa lake."

Unlike the Coorong Lagoon model, the studied deposits were mainly controlled by the marine water influx. Generally, the Coorong Lagoon model of the chert formation and the Gogolin Cavernous Limestone model are similar, but with one great difference. In the Coorong Lagoon model, silica gel precipitates in time of drying when water level in lake is lowering, and in the Gogolin Cavernous Limestone model it precipitates in time of flooding when the water level is rising.

Acknowledgements

The author would like to thank Dr. J. SZULC and A. BODZIOCH, M.Sc. for help in the field, and Dr. E. PIEKARSKA and Dr. A. ŚWIERCZEWSKA for help in the microscopic study. The photographs were taken by Dr. M. DOKTOR and Mr. P. SZEWCZYK to whom the author is in debt.

*Institute of Geological Sciences,
Polish Academy of Sciences,
ul. Senacka 3,
31-002 Kraków, Poland*

REFERENCES

- BODZIOCH, A. & KWIATKOWSKI, S. (*in preparation*) Sedimentation of the Cavernous Limestone (Uppermost Röh, Lower Silesia).
- BUTLER, G.P. 1969. Modern evaporite deposition and geochemistry of coexisting brines, the sabkha, Trucial Coast, Arabian Gulf. *J. Sedim. Petrol.*, **39** (1), 70-89. Tulsa.
- COLINVAUX, P.A. & GOODMAN, D. 1971. Recent silica gel from saline lake in Galapagos Island (Abs.). *Amer. Assoc. Petr. Geol. Bull.*, **55** (2), 333-334. Tulsa.
- DIETRICH, R.V., HOBBS, C.R. & LOWRY, W.D. 1963. Dolomitization interrupted by silicification. *J. Sedim. Petrol.*, **33** (3), 646-663. Tulsa.
- PETERSON, M.N.A. & VON DER BORCH, C.C. 1965. Chert: Modern inorganic deposition in a carbonate-precipitating locality. *Science*, **149**, 1501-1503. Washington.
- RAISWELL, R. 1976. The microbiological formation of carbonate concretions in the Upper Lias of NE England. *Chem. Geology*, **18**, 227-244. Amsterdam.

- SALAMEH, E. & SCHNEIDER, W. 1980. Silica geodes in Upper Cretaceous dolomites, Jordan. Influence of calcareous skeletal debris in early diagenetic precipitation of silica. *N. Jb. f. Geol. Paläont.*, 3, 185–192. Stuttgart.
- SASS, E. & KOLODNY, Y. 1972. Stable isotopes, chemistry and petrology of carbonate concretions (Mishah Formation, Israel). *Chem. Geology*, 10, 261–286. Amsterdam.
- WHEELER, W.H. & TEXTORIS, D.A. 1978. Triassic limestone and chert of playa origin in North Carolina. *J. Sedim. Petrol.*, 48 (3), 765–776. Tulsa.
- ZIJLSTRA, H.J.P. 1987. Early diagenetic silica precipitation in relation to redox boundaries and bacterial metabolism in late Cretaceous chalk of the Maastrichtian type locality. *Geol. en Mijnbouw*, 66, 343–355. Gravenhage.
-

S. KWIATKOWSKI

GENEZA LAMIN KRZEMIONKOWYCH I BUŁ WĘGLANOWO-KRZEMIONKOWYCH W WAPIENIU JAMISTYM GÓRNEGO RETU W GOGOLINIE

(Streszczenie)

Wapień jamisty górnego retu występujący na całym obszarze Śląska, utworzył się w warunkach typu sabkha. Jak wskazują badania profilu w Gogolinie, w wapieniu tym występują naprzemian dwa typy osadu: wapień z jamkami po rozpuszczonych ewaporatach, bez detrytycznego kwarcu, oraz wapień bez jamek, z detrytycznym kwarcem i mika, niekiedy z onkolitami. Utwory krzemionkowe występują w górnej części warstw typu pierwszego i w dolnej części warstw typu drugiego (*patrz* fig. 1-4).

Warstwy typu pierwszego odpowiadają okresom spokojnej depozycji i silnej ewaporacji, bez dopływu wody morskiej, w warunkach wysokiej temperatury i pH. W tym czasie kwarc detrytyczny rozpuszczał się, a roztwory krzemionki polimeryzowały, tworząc aglomeraty żelu.

Warstwy typu drugiego odpowiadają okresom dopływu wód morskich wraz z osadem kwarcu detrytycznego i niekiedy z onkolitami. Raptowne obniżenie temperatury i pH powodowało wytrącanie aglomeratów koloidalnej krzemionki. Otaczający aglomeraty żelu roztwór rzeczywisty krzemionki wytrącał się tworząc cienką powłokę w pewnej odległości od wytrącanego żelu krzemionkowego.

Przedstawiona interpretacja genezy utworów krzemionkowych różni się od znanej hipotezy PETERSONA i VON DER BORCHA (1965) tym, że w Coorong Lagoon w południowej Australii żele krzemionkowe wytrącają się w okresach wysychania laguny, podczas gdy w osadzie wapienia jamistego wytrącały się one w okresach wkraczania wód morskich na obszary typu sabkha.
