Energy and Earth Science
Vol. 7, No. 1, 2024
www.scholink.org/ojs/index.php/ees
ISSN 2578-1359 (Print) ISSN 2578-1367 (Online)

Original Paper

Textbook Error Theory about Aragonite Structure

Chen Guiqing[1] & Chen Junhao[1]

[1] Guangzhou Jinan University 510630, Guangzhou, China

Received: November 25, 2023 Accepted: December 7, 2023 Online Published: March 25, 2024

doi:10.22158/ees.v7n1p10 URL: http://dx.doi.org/10.22158/ees.v7n1p10

Abstract

Science constantly discovers new theories and concepts, overturning erroneous theories and concepts. Textbooks never correct, fallacies are left to future generations. There are two erroneous theories about the structure of aragonite in textbooks: (1) The authoritative Chinese textbook "Outline of Shellfish Studies" by Zhang Xi and Qi Zhongyan believes that shells can be divided into three different crystal structures, with the middle layer being a prismatic layer that occupies the majority of the shell and is composed of calcite (cubic crystal system, hexagonal crystal cells). The shellfish academic community in China quotes many Japanese literature, and these theories may have been copied from Japan. (2) The geological crystallography book records that the structural physical properties of aragonite are unstable and will eventually transform into calcite. We use X-ray derivatives found that after a long geological time, aragonite not only did not become calcite, but also the grain is growing large: monocrystalline, calcite is still decreasing, calcite is changing to aragonite.

Keywords

marine biology, X-ray diffraction, Shell, Prismatic pearls, Aragonite structure, Calcite structure, Geology and crystallography

1. Introduction

Recently, we consulted renowned shellfish scientist Xie Yukan from the South China Sea Institute of Oceanography, Chinese Academy of Sciences to discuss this issue. It is understood that his graduate students still believe that the prismatic layer of the shell is composed of calcite through microscopic verification. Do shellfish scientists still not know that crystal structure can only be determined by X-ray diffraction, or by observing morphology under a microscope? The German physicist Roentgen discovered X-rays on November 8, 1895! In 1959, Shinjiro Kobayashi and Tetsuko Watanabe from Japan proposed that prismatic pearls have a calcite structure. Many domestic and foreign papers have not raised objections to this, which is wrong. Japanese shellfish scientists are also unfamiliar with crystallography.

What changes will occur when shells are buried in the ground for thousands of years? The geological crystallography book records that the physical properties of aragonite structure are unstable and will eventually transform into calcite, which has become common knowledge. Wrong, it's the transformation of calcite into aragonite structure.

Aragonite gemstones are composed of minerals such as aragonite, calcite, iron oxide, and opal, and belong to secondary minerals with aragonite as the main component. Only Xizang, Penghu in Taiwan Province and Sicily in Italy produce aragonite gemstones in the world. In theory, there should not be any aragonite gemstones in the world, because after billions of years, all the aragonite structures it contains have already transformed into calcite structures. However, in reality, they still exist, indicating that this theory is incorrect.

2. Materials and Methods

2.1 Modern Shells

The following shells are provided by Xie Yukan, Sanya Director of the South China Sea Institute of Oceanology, CAS.

Pinctada martensi, Pinctada maxima, Hyriopsis cumingii, Cristaria plicata, Pteria (Magnavicula) penguin, Pinctada margaritifera, Pinctada nigra, Pinctada chemnitzi, Anodonta woodiana, Lamprotula mansuyi, Mactra antiquate, Arca (Anadara) granosa, Meretrix meretrix, Perna viridis, Tridacna (Chamestrachea) squamosa, (Meretrix meretrix), Nautilus pompilius, Trochous nilotticus, Turbo chrysostomus, Erosaria caputserentis, Trachycadium flavum, Macoma truncate, Corbicula fluminca，Haliotis diversicolor, Nerita albicilla, Mytilus edulis, Spondylus nicobaricus, Chama dunker and Abra profundorum.

The pearl and shell is ground into powder with agate mortar and passed through a 360-mesh screen. Using the D/max-1-A type X-ray diffractometer, using the Cu target K_α ray diffraction, under the conditions of 40kV and 50mA, within 30min from 2θ range 20^0-80^0, the instrument uses the Plot plotter, automatically prints 2θ, the absolute intensity I and the corresponding crystal face group spacing d. Refer the above results to the international universal phase analysis (JCPDS) card to determine the crystal structure of the sample.

d=0.1974nm, and the bottom crossbar of the spectral line has an aragonite structure. d=0.3030nm, and the dashed line at the bottom of the spectral line shows a calcite structure. d=0.3019, the calcite III structure with ripple at the bottom of the spectral line, and the silica structure with rod, point, and rod at the bottom of the spectral line with d=0.3336.

2.2 Ancient Shells

In the 1980s, Huang Baoyu, a researcher at the Nanjing Institute of Paleontology, provided four kinds of ancient seashells, such as splitodonta, splitodonta radiata, Euhylidia Dui and Liunia, which were collected from 102 points in Ding Village, Xiangfen, Shanxi Province, and were all hundreds to thousands of years old.

Borrowed four ancient shells from Dr. Tan Yehui and Dr. Chen Zhiyun of the South China Sea Institute of Oceanography in Guangzhou: the Clams marmosa, the smooth blue clams, the river clams and the great clams. The first three species were collected from the late Quaternary loose sedimentary rock center of Yuanzhou Production Team 1 well, Shunde, Guangdong Province. In the early 1970s. The fourth kind was extracted from Longan village water conservancy project in Shunde, Guangdong Province. Years 500 to 1,000 years.

Grind as above into powder and pass through 360 mesh screen. It was diffracted by Empyrean X-ray diffractometer.

3. Experimental Results

3.1 Pearl Layer Structure of Shells

Only the pearl layer of the *Ostrea rivularis* shell has a calcite structure. The white inner layer of the *Pinna atropururea* shell is also a aragonite structure, and the black luminescent part around it is a calcite structure, which is also considered a pearl layer.

The pearl layer of the other shells is entirely composed of aragonite structure. Explain that the above theory is correct.

3.2 Prismatic Layer Structure of Shells

At present, only the prismatic layer of the *Pinna atropura* shell is found to be a ca1cite structure, while the loose part of the Ostrea rivularis shell is a calcite ca1cite-III structure. The prism layers of the other shells are all aragonite structures. This indicates that the above theory is incorrect.

Some shells are too thin to be layered, so they have to undergo full shell X-ray diffraction. The majority of the entire shell of *Spondylus nicobaricus*, *Haliotis diversicolor*, *Nerita albicilla*, *Mytilus edulis*, *Chama dunker*, and *Abra profundorum* are also aragonite structures.

3.3 The Periostracum Layer Structure of Shells

Contains a large amount of amorphous organic matter. Some shells also contain aragonite structures. Some shells also contain calcite structure ca1cite. The “Outline of Shellfish Science” states that it is incorrect for the stratum corneum of shells to be composed solely of “conchiolin”.

3.4 Prismatic Pearls Are All of Aragonite Structure, Without Calcite Structure

3.5 Schistodesmus Sp. Prismatic Layer

Wilderness number ADY201, 1983/9/9. All spectral lines are aragonite structure, no impurity spectral lines.

3.6 Schistodesmus Lampreyanus (Baird & Adams) Prismatic Layer

Wilderness number ADY201, 1986/12/16. All spectral lines are aragonite structure, no impurity spectral lines.

3.7 Unio Douglasiae Griffith et Pidgeon

Wilderness number ADY201,1986/12/16.

3.7.1 *Unio Douglasiae* Pearl Layer

The only weak spectral line of calcite appears, with a relative aragonite content of 0.15% in calcite. All other spectral lines are aragonite structured.

3.7.2 *Unio Douglasiae* Periostracum Layer

All spectral lines are aragonite structure.

3.8 Lamprotula Hazinic (Heude) Shell

Wilderness number ADY193, 1986/12/16.

3.8.1 *Lamprotula Hazinic* Pearl Layer

All spectral lines are aragonite structure, no impurity spectral lines.

3.8.2 *Lamprotula Hazinic* Prismatic Layer

The only weak spectral line of calcite is d_{104}=0.3034nm. The relative content of calcite is 0.23%. All other spectral lines are of aragonite structure.

3.8.3 *Lamprotula Hazinic* Periostracum Layer

The only weak spectral line of calcite is d_{104}=0.3024nm. The relative aragonite content is 0.17%. All other pectral lines are aragonite.

3.8.4 Pearl Cores Made from Modern *Lamprotula Hazinic* Shells

All spectral lines are aragonite structure.

3.9 Trapezidae, Trapezium Liratum (Reeve, 1843) Periostracum Layer

The results are shown in Table 1, the same below. Two strong silica spectral lines appeared with d=0.3370nm and I/I_0=70.2%; d=0.1824nm, I/I_0=56.00%, which is the silica that ancient shells have adhered to in soil for many years, because modern shells have never seen these spectral lines; All other spectral lines are of aragonite structure.

3.10 Corbulidae, Potamacorbula Laevis (Hinas) Periostracum Layer

All spectral lines comply with card 041-1475, All pectral lines are aragonite structure, no impurity spectral lines.

3.11 Corbiculidae, Corbicula Fluminea (Müller)

3.11.1 *Corbicula Fluminea* Prismatic Layer

All spectral lines are aragonite structure, no impurity spectral lines.

3.11.2 *Corbicula Fluminea* Periostracum Layer

The majority of the spectral lines below the second strongest in the table are aragonite structures.

Two weak calcite spectral lines appeared: d_{104}=0.3033nm, I/I_0=8.71%, and d_{113}=0.2282nm, I/I_0=7.26%.

The strongest spectral line of aragonite is d=2697nm, and I/I_0=67.1%. The strongest spectral line of calcite is d=0.3033nm, and I/I_0=8.71%. The relative aragonite content of calcite is 1.2%.

The strongest spectral line d=0.3336nm is the strongest spectral line of silica SiO_2, and the spectral line d=0.4249nm is the second strongest spectral line d_{100}=0.4255nm of silica SiO_2.

There is also a spectrum line d=0.3205 nm and I/I_0=18.38%, which is unknown.

The stratum corneum of river clams contains a high amount of silica, which has been stuck in the soil for many years, because modern shells have never seen these spectral lines. If it is removed, it still has a relatively complete aragonite structure, and the aragonite spectral lines of ancient river clam shells are the same as those of modern river clam shells, without any changes.

3.11.3 Modern *Corbicula Fluminea* Prismatic Layer

The only weak impurity mass spectrum line appeared, d=0.3632nm, I/I0=3.21%, and All other spectral lines are of aragonite structure.

3.12 Corbiculidae, Corbicula Maxima Prismatic Layer

Excavated from the Longyan Village Water Conservancy Project in Shunde, Guangdong. Collection time: February 1961.

3.12.1 *Corbicula* Pearl Layer

The X-ray diffraction pattern is very special, with the absolute intensity of the strongest spectral line d=0.2875nm reaching I=4290.7 (the maximum intensity of the spectral line in a typical shell is about 700). The spectral lines are very strong, narrow, and few, all of which are thick aragonite grains with a strong “single crystal tendency” and no impurities. Unlike geological crystallography, where the structure of aragonite is unstable, it will eventually become calcite. Instead, it develops towards a higher degree of crystallization, indicating that the structure of aragonite is stable.

According to the Scherrer formula of X-ray diffraction theory of crystals, the strengthening, narrowing, and decreasing of spectral lines are caused by the growth and thickening of grains in this diffraction direction (preferential orientation growth), which we refer to as the “single crystal tendency”.

The growth process of the shell pearl layer is the process of aragonite crystal growth, constantly in an unbalanced state. Due to vacancies or impurities filling the lattice, the lattice distortion changes the crystal plane group spacing d, causing the spectral lines to widen and continuously generating new internal stresses. After the death of shellfish, crystal growth stops and no new internal stress is generated. The stress inside the shell gradually releases, vacancies are gradually filled or impurities are gradually eliminated to the grain boundary to eliminate internal stress. At this time, internal stress is also concentrated at the grain boundary, so this area is prone to weathering. The grains of aragonite continue to grow, therefore; Make the spectral lines stronger, narrower, and fewer!

Due to the large size of the clam shell, it is less affected by the surrounding soil, which better reflects this process.

3.12.2 *Corbicula* Prismatic Layer

It X-ray diffraction pattern of the prismatic layer of the clam shell is similar to that of the pearl layer, with strong, narrow, and few spectral lines. All spectral lines are thick aragonite grains with a “single crystal tendency”, and there are no impurity spectral lines.

The prism layer is between the nacre and the stratum corneum, and the internal stress release is slower, so the spectral lines are slightly more than the nacre.

3.13.3 *Corbicula* Periostracum Layer

All spectral lines are aragonite structure, no impurity spectral lines.

According to the X-ray diffraction diagram of the corneum of large corbicula shell on the right of FIG.1, the absolute intensity of the strongest spectral line d=0.1980nm I=481.16. Due to the large amount of amorphous organic matter in the corneum, the monocrystallization is affected, which greatly reduces the absolute intensity and slightly increases the spectral line. Once again proved the ancient shell monocrystalline trend!

Table 1. X-Ray Diffraction Data Various Shells

Pinctada martensi pearl layer		*Pinctada martensi* prismatic layer		*Pinctada martensi* periostracum		*Pinctada maxima* pearl layer		*Pinctada maxima* prismatic layer		*Pinctada maxima* periostracum		*Perna viridis* pearl layer	
d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)
0.3387	100	0.3394	79.2	0.3020	100	0.3397	100	0.3391	55.8	0.3031	100	0.3390	69.88
0.3264	48.8	0.3270	44.3	0.2483	12.6	0.3272	47.3	0.3266	30.3	0.2488	12.1	0.3268	37.01
0.3018	5.76	0.3026	13.5	0.2274	13.8	0.2702	65.7	0.2697	100	0.2279	14.5	0.2697	100
0.2695	77.4	0.2699	100	0.2084	13.7	0.2483	39.2	0.2481	32.8	0.2089	11.8	0.2481	38.47
0.2368	51.6	0.2371	47.2	0.1904	13.8	0.2373	46.4	0.2369	43.8	0.1909	15.4	0.2369	44.8
0.1972	46.3	0.1975	38,9	0.1867	13,7	0.1976	51.7	0.1973	27.3	0.1871	12.9	0.1973	34.58

Table 2. Continued Table 1

Perna viridis prismatic layer		*Perna viridis* periostracum		*Pinna atropurpurea* pearl layer		*Pinna atropurpurea* prismatic layer		*Pinna atropurpure* periostracum		*Hyriopsis cuming* Full shell		*Cristaria plicata* Inner middle layer	
d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)
0.3392	100	0.3401	100	0.3402	58.81	0.3854	12.33	0.3028	100	0.3401	61.1	0.3400	65.4
0.3269	58.06	0.3276	66.98	0.2876	39.16	0.3034	100	0.2486	13.78	0.3277	34. 1	0.2874	39.6
0.2699	70.44	0.2705	55.07	0.2706	100	0.2282	17.01	0.2277	14.59	0.2704	100	0.2703	100
0.2370	52.06	0.2486	43.17	0.2487	41.81	0.2091	14.37	0.2087	13.67	0.2374	36,3	0.2484	38.6
0.1975	50.07	0.1978	60.89	0.2375	36.58	0.1910	19.1	0.1908	21.35	0,1977	37.2	0.2373	40.3
0.1877	36.22	0.1880	42.76	0.1978	37.13	0.1873	16.45	0.1870	16.51	0.1743	35,2	0,1977	40,6

Table 3. Continued Table 2

Cristaria plicata periostracum		*Ostrea rivularis* inner layer		*Ostrea rivularis* Loose part		*Ostrea rivularis* Lower shell surface		*Ostrea rivularis* Upper shell surface		Prismatic pearl powder		Prismatic pearl inner surface layer	
d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)	d (nm)	I/I_0 (%)
0.3421	100	0.3032	100	0.3831	8.9	0.3032	100	0.3031	100	0.3402	95.03	0.2755	20.33
0.3295	54.3	0.2491	5.5	0.3019	100	0.2491	11.2	0.2490	10.3	0.3278	50.40	0.2716	100
0.2716	83.3	0.2281	10.1	0.2274	14.8	0.2281	16.8	0.2280	15	0.2708	100.00	0.2499	19.89
0.2495	43.1	0.2091	6.9	0.2085	11.4	0.2091	12.3	0.2090	13	0.2486	35.94	0.2383	19.36
0..2383	42.8	0.1909	24.4	0.1904	17.7	0.1909	20.0	0.1909	20.7	0.2378	40.89	0.1822	16.97
0.1983	77.7	0.1873	14.3	0.1868	17.4	0.1872	17.6	0.1872	17.4	0.2335	22.42	0.1751	41.15

Table 4. Shell X-ray Diffraction Data

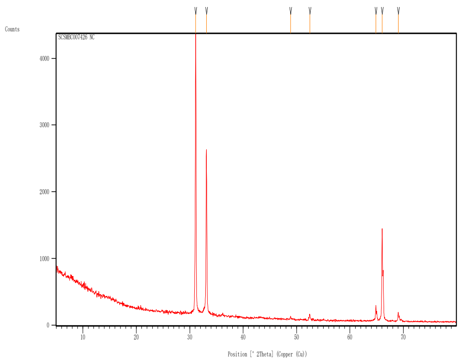
Schistodesmus sp. prismatic layer		*Schistodesmus lampreyanus* prismatic layer		*Unio douglasiae* pearl layer		*Unio douglasiae* Periostracum layer		*Lamprotula* sp. pearl layer		*Lamprotula* sp. prismatic layer		*Lamprotula* sp. Periostracum layer		Modern *Lamprotula* sp.Pearl nuclei	
d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%
0.3400	91.4	0.3398	73.2	0.3399	66.6	0.3397	100	0.3399	58.9	0.3401	100	0.3397	100	0.3395	53.9
0.3275	48.4	0.3274	43.6	0.3275	35	0.3274	51.6	0.3274	31.3	0.3277	51	0.3274	51	0.3273	31.9
0.2702	100	0.2702	100	0.3038	1.64	0.2700	63.2	0.2702	100	0.3034	2.6	0.3024	1.9	0.2700	100
0.2484	52.9	0.2484	42.9	0.2702	100	0.2483	38.3	0.2484	37.3	0.2703	61	0.2482	31.4	0.2483	32.9
0.2373	55.4	0.2373	46.9	0.2484	40.4	0.2371	37.6	0.2373	40.3	0.2373	39.8	0.2338	35	0.2371	31.6
0.1977	52.9	0.1976	39.5	0.2373	41.2	0.1976	61	0.1976	29.4	0.1977	64.8	0.1976	76.3	0.1976	31.9

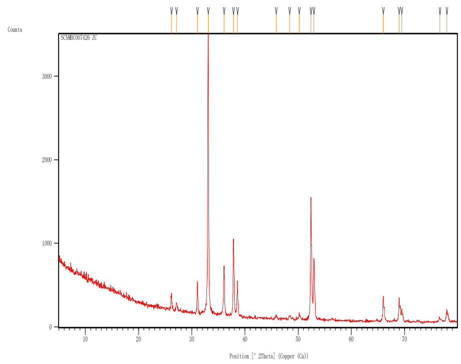
Table 5. Continue Table 4

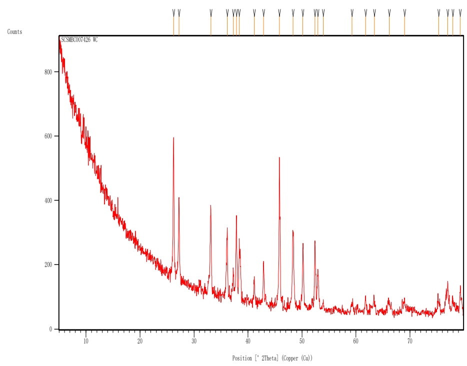
***Trapezium liratum* periostracum layer**		***Potamacorbula laevis* periostracum layer**		***Corbicula fluminea* prismatic layer**		***Corbicula fluminea* periostracum layer**		Modern ***Corbicula fluminea* prismatic layer**		***Corbicula maxima* pearl layer**		***Corbicula maxima* prismatic layer**		***Corbicula maxima* periostracum layer**	
d nm	I/I_0%	dnm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%	d nm	I/I_0%
0.3418	100.00	0.2885	23.50	0.3404	31.86	0.4249	17.42	0.3632	3.21	0.2875	100.0	0.2879	10.97	0.3399	90.81
0.3370	70.20	0.2725	76.00	0.3282	15.23	0.3336	100.0	0.3409	100.0	0.2706	58.06	0.2709	100.00	0.3279	54.75
0.2121	13.89	0.2705	100.00	0.2706	100.0	0.3033	8.71	0.3285	50.6	0.1744	2.09	0.2492	16.96	0.2703	54.46
0.1989	78.70	0.2488	49.58	0.2491	31.42	0.2697	67.10	0.2709	94	0.1438	5.77	0.2378	27.43	0.2377	56.42
0.1890	59.93	0.2375	54.28	0.2377	51.42	0.2485	30.65	0.2377	53.6	0.1415	32.81	0.2334	13.13	0.1980	100.0
0.1824	56.00	0.2332	25.17	0.2332	22.73	0.2282	7.26	0.1980	52.4	0.1361	3.21	0.1747	42.95	0.1883	50.92

Table 6. Relative Aragonite Content of Calcite in Ancient and Modern Shells

The content of calcite relative aragonite in ancient shells is less than 2%, which is negligible					
Schistodesmus sp. Shell prismatic layer	0%	*Lamprotula hazinic* Shell prismatic layer	0.23%	*Corbicula fluminea* shell periostracum layer	0.78%
Schistodesmus lampreyanus shell prismatic layer	0%	*Lamprotula hazinic* Shell prismatic layer	0.17%	*Corbicula maxima* shell pearl layer	0%
Unio douglasiae shell pearl layer	0.15%	*Trapezium liratum* shell periostracum layer	0%	*Corbicula maxima* shell mprismatic layer	0%
Unio douglasiae shell periostracum layer	0%	*Potamacor bula laevis* shell periostracum layer	0%	*Corbicula maxima* shell periostracum layer	0%
Lamprotula hazinic shell pearl layer	0%	*Corbicula fluminea* shell prismatic layer	0%		
Calcite relative aragonite content in modern shells					
Pinctada martensi shell periostracum layer	100% calcite	*Pinctada chemnitzi* shelll periostracum layer	100% calcite	*Haliotis diversicolor* shell	8.3%
Pinctada maxima shell periostracum layer	100% calcite	*Ostrea rivularis* Gould shell Most of the majority	100% calcite	*Nerita albicilla* shell	14%
Pteria (Magnavicula) *Penguin* shell periostracum layer	100% calcite	*Pinna atropurpurea Sowerby* Shell prismatic layer	100% calcite	*Mytilus edulis* shell	22%
Pinctada margaritifera shell periostracum layer	100% calcite	*Pinna atropurpurea Sowerby* shell periostracum layer	100%c alcite	*Chama dunker* shell	15%
Pinctada nigra Shell periostracum layer	100% calcite	*Spondylus nicobaricus* shell	8.5%	*Abra profundorum* shell	19%







Corbicula maxima X-ray diffraction pattern: **Figure 1. Pearl Layer. Figure 2. Prismatic Layer. Figure 3. Periostracum Layer**

3. Research Conclusion

3.1

The "Outline of Conchology" believes that it is correct that the nacreous layer of the shell is aragonite structure, but the peral layer of the oyster shell and the black shiny nacreous layer of the purple cracker are calcite structure.

3.2

The "Outline of Conchology" believes that it is wrong that the prismatic layer of shell is calcite structure. At present, only the prismatic layer of oyster shell and purple cracked jade is calcite structure, and the prismatic layer of other shells is aragonite structure.

3.3

The "Outline of Conchology" believes: That the Stratum corneum of a shell is composed of only conchiolin. This theory is flawed. Most of them have calcite structure, and a few have aragonite structure!

3.4

Shinjiro Kobayashi, a Japanese scholar, proposed in 1959 that prismatic pearls have a calcite structure in his "Pearl Research". Why does prismatic pearls lack luster? Because its nacreous thickness is a=0.384 millimeters, the normal nacreous thickness is b=0.613 millimeters (thicker nacreous layers can reach 0.92 millimeters or more), with many fewer layers, resulting in a lack of birefringence effect, resulting in a lack of pearl luster and oil luster. It also causes the pearl nucleus to have strong reflection light, and after interference, it appears earthy yellow. This is the reason why prismatic pearls lack pearl luster.

3.5

From the X-ray spectra of the *Corbiculidae, Corbicula maxima* pearl layer, prism layer, and keratin layer of the clam shell buried in the ground for thousands of years, it can be seen that the structure of aragonite is developing towards a higher degree of crystallization-"single crystal", indicating that the aragonite grains are getting larger and more stable over time.

3.6

Modern shells contain some calcite, but ancient shells have almost no calcite. After a long period of time, calcite has turned into aragonite in shells!

The records in geological crystallography books and textbooks are incorrect.

3.7

Other ancient shells besides the *Corbicula maxima* shells also have changes in decreasing, narrowing, and strengthening spectral lines over time. However, shells that are too thin and not completely layered are easily affected by the stratum corneum. It is better to use thicker shells for detection!

3.8 The Rest of the Ancient Shells Are Small and Not Easily Stratified

3.9

X-ray diffraction from the prismatic layers of ancient shells once again confirms that the prismatic layers of shells are all aragonite structures.

Funding

90 year old commemorative works III

Fund project "Artificial growth of aragonite crystals and artificial development of pearls"

Chen Guiqing, Chen Junhao 1985 (Approval No. 85084).

Fund project "Research on the Structure and Imaging Mechanism of Artificial Pearl Cores and Artistic Image Pearls"

Chen Guiqing, Chen Junhao 1989 (Approval number 890xx).

References

Chen, G. Q., & Chen, J. H. (2017). New Conclusion on the Crystal Structure of Pearls and Shells. *Journal of Applied Oceanography*, *36*(4).

Chen, G. Q., Chen, J. H., & Chen, P. (1986). A study on the natural pearls and shells of Pinctada martensii. *Marine Medicine*, *1986*(3), 4-7.

Chen, G. Q., Chen, J. H., & Zhang, X. J. (1985). X-ray diffraction study on the shell of Jinjiang oyster. *Marine Medicine*, *1985*(3), 4-6.

Chen, J. H., & Chen, G. Q. (2018). *Crystal Structure and Application Exploration of Pearls and Shellfish*. Jinan University Press.

Chen, J. H., & Chen, G. Q. (2019). The Ancient Shells Were Sdudied by X-ray Diffraction and Electron probes. *Journal of Water Resources and Ocean Science*, *8*(6), 86. https://doi.org/10.11648/j.wros.20190806.11

Kaiichi, M. (1965). *Zhenzhu Chronicle, Beilongguan*.

Kobayashi, S., & Watanabe, T. (1961). *Research on pearls 169-176*. Technical Hall.

Rock and Mineral Research Office, Department of Geology, Nanjing University. (1978). *Crystallography and Mineralogy*. Beijing: Geological Publishing House.

Zhang, X., & Qi, Z. Y. (1961). *Outline of Conchology*. Science Press.

Zhao, S. R. (Ed.). *Crystallography and Mineralogy* (p. 412). Geological Publishing House. Curriculum textbooks for higher education in the 21st century.