A PETROGRAPHICAL STUDY OF THE CHINESE AGALMATOLITES

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With one Plate.

I. Introduction.

The most popular Chinese agalmatolites are Shoushanshih (壽山石), Changhuashih (昌化石), Chingtienshih (青田石) and Kwanglüshih (廣綠石). They are named after the names of places, as the name Shoushanshih is from Shou Shan Hsiang, Ming Hou Hsien, Fukien (福建閩侯壽山鄉); Changhuashih from Kang Shan, Chang Hua Hsien, Chekiang (浙江昌化康山); Chingtienshih from Ching Tien Hsien, Chekiang (浙江青田縣) and Kwanglüshih from Kwangtung (廣東). These agalmatolites have been mined for many years ago and are highly valued by most scholars. The chief uses are for carving seals, images, pagodas, etc. At present the pure and beautiful colour stones are seldom found and most of them are impure and fractured.

In December, 1927, Prof. Lacroix was in China and took a trip to Jehol (熱河), he found pagodite in Weit'chang, Chih Fêng Hsien, Jehol (熱河赤峰圍場). The use is the same as Shoushanshih, Changhuashih, etc. Recently Mr. K. Y. King (金君開英) sent me some specimens of agalmatote from Ling Hsi of the same province, Jehol (熱河赤峰林西). The writer call it Linghsishih, as it is the usual way of naming a stone after the name of place.

The carving of these agalmatolites, as told by the jewllers, is hard to manipulate with the Changhuashih. Because it contains crystals of quartz with a diameter of 2 mm. The quartz crystals are called by jewllers "sand nails". The rest of the agalmatolites do not contain quartz crystals and carving is thus facilitated.

The scientific study of the Chinese agalmatolites has not been done very much, although descriptions of colours, uses, etc. have been beautifully written in Chinese books. Before this writing Mr. C. Liang, Dr. H. T. Chang and Prof. F. Slavik of Czechoslovak Republic studied the Shoushanshih, Ming Hou Hsien.

Fukien, and Prof. Lacroix examined the pagodite in Weit'chang, Jehol*. The writer studies some more agalmatolites which are also known to the Chinese scholars, and compares the results which have been obtained by the authors just mentioned.

II. SHOUSHANSHIH 寿山石

Shoushanshih was examined in the field by Mr. Liang in the year about 1915. The following paragraphs about the history, geology, classification and production are abstracted from Mr. Liang's "Mineral Resources of Fukien" (福建矿務誌略).

History:—Shoushanshih was mined in the time of Wu Tai (五代). In Sung dynasty (宋朝) it was gradually known to the people. The mining was continued to Yuan dynasty (元朝), although it was stoped in the middle of Sung. In the time of Ming (明朝) officers were appointed to charge the mining operations. From that time to Ching dynasty (清朝) the mining business was more prosperous and the value of the stone was gradually high. At present the mining is still in progress, and the method of mining is rather rudimentary.

Geology:—The principal rocks of Shoushanshih region are granite, intruded by quartz porphyry. Shoushanshih is found in these rocks in the form of veins. In some places it is weathered into broken pieces and is removed from the original place to the river beds. In other places it is covered by a diorite mass. When Shoushanshih is found in the dark green slate, it usually contains many impurities. The thickness of the vein is from several inches to two feet.

Classification:—The Shoushanshih has many Chinese names, such as Tung Shih (凍石), Wax-stone (蠟石), pagoda stone (塔石), etc. The English name may be called agalmatolite. It is classified into fifty different kinds, and each kind has a different name. The classification is chiefly made by colours.

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* Lacroix, composition des roches éruptives, Bull. Geol. Soc. of China, Vol. VII, No. 1, p. 22.

Productions and uses:— The annual production and uses of Shoushanshih are given in the following table.

Kinds	Annual production and prices.	Uses	Country, exported to.
Fine material	3000 catties. Each 100 catties Cost $50-100 (Mex)	For seals. bottles, ornamental articles, etc.	Japan
Rough material	10000 catties. Each 100 catties cost $1.50 (Mex)	For building purposes.	
Rock material	60000 catties. Each 100 catties cost $1.20 (Mex).	For raw material in soap making, idols, etc.	Japan

Macroscopic study:—It is massive. H = 2—3. S. G. = 2,58. Feel smooth and greasy, Colour white, green, yellow, gray, orange. etc. Streak usually white; of colored varieties lighter than the colour. Translucent to substranslucent. The impure variety contains phenocrysts of other minerals with the appearance of rock.

Microscopic study:—The microscopic descriptions before this writing were made by Dr. H. T. Chang, and Prof. F. Slavik. The summary of Dr. Chang's description is as follows:

"The sky blue and grass green agalmatolites are probably made of pyrophyllite. The pea green agalmatolite may be mixed with small quantity of pinite. The agalmatolite from Tu Ling Kêng (杜林坑) and Chiu Cha Shan (九茶山) contains chiefly pyrophyllite which crystallizes in the neddle like form with small extinction angle and high birefringence. Besides, there are some other substances which are not easy to identify as their optical properties are unclear. The agalmatolites from Shou Shan Hsiang (壽山鄉) and Kao Shan (高山) do not seem to contain pyrophyllite, but they probably contains pinite and isotropic substance".

Prof. F. Slavik studied the agalmalolite from Tu Ling Kêng and his description is contained in a letter to Dr. W. H. Wong, Director of the Survey, Peping, and it reads as follows:

"It contains quartz phenocrysts in the known prophyritic form ($10\bar{1}1$) ($01\bar{1}1$) without or almost without the prism ($10\bar{1}0$), rounded, as the quartz crystals in rhyolites and porphyries are by magmatic corrosion. These crystals are irregularly disseminated in a compact mass, which appears in microscope to consists of two substances. The one is isotropic, with refractive index n = 1, 561, the other crystalline, in minute scales with negative characters of birefringence, refractive index about 1,565 or a little higher. The crystalline mineral is concentracted in small aggregates the form of which sometimes seems to indicate the nature as pseudomorphs after feldspar phenocrysts whilst in most cases the outlines of these aggregates are quite irregular, meanwhile they fill short microscopical veinlets.

Concerning the mineralogical determination of both substances, it is not possible to give these distinct names identifying them with known minerals. The Boricky' test with hydrofluoric acid gave only very few crystals of natrium and potassium silicofluoride, to that both minerals are to be regarded as silicates of alumina; the mean refractive index of the crystalline mineral is nearer to that of kaolinite (β = 1,565, γ = 1,588 to 1,600 after Larsen) than that of pyrophyllite, (talc) or muscovite (1,588 to 1,600). The refractive index of the isotropic mineral 1,561 agrees with that of halloysite (1,555 Larsen).

In one part of the sample, I observed small colourless crystals which have been proved to be diaspore. They are flattened parallel to (010), the polar edges of (212) meet with the vertical axis at the angle of circa 56° obs., 57° 12 ½' calc. The vertical direction is optically positive. α parallel to the vertical axis, = 1,71 (measured with the immersion method, Michel-Lévy and Lacroix determined on crystals of diaspore (α = 1,702)".

The writer also examined some slides of Shoushanshih, and in one slide from Chiu Cha Shan he found the mineral diaspore crystallizing in the acicular form.

Chemical composition:—Shoushanshih was chemically analysed by the Technology of Fukien (福建工業學校) and it gives the following percentage.

SiO_2	42.709
Al_2O_3	49.947
Fe_2O_3	1.209
FeO	———
MgO	1.109
CaO	2.209

Alkalies	1.425
Loss on ign.	1.200
	99.808

The chemical composition of Shoushanshih is some what like kaolinite but the percentage for alumina is too high and that for water is too low. Dr. Chang regards the shoushanshih as a mixture of several minerals, and its chemical composition will not resemble any of single mineral alone.

III. CHANGHUASHIH 昌化石

Changhuashih has another two names, (1) called Chihsuehshih (雞血石) and (2) Yüshih (玉石). The geology was examined by Mr. T. O. Chu in the year 1924. The following paragraph about the geological condition is translated from Mr. Chu's report on the geology of Chekiang.

Geology:—Changhuashih is found in Kang Shan (康山), Chang Hua Hsien, Chekiang. Kang Shan is about 1200 Meters above sea level. It is a granite hill, and on the northern slope there is lower paleozoic limestone. In the vicinity of Changhuashih there is no limestone but a kind of porphyry in which the lenticular masses of Changhua agalmalotite are found. The size is from several inches to more than one foot with red veins of cinnabar.

Macroscopic study:—The specimen now exhibited in the museum of the Survey, Peping, are very like the rock rhyolite. It has phenocrysts and ground mass. H = 2 — 3, and in some parts it is much harder as the specimens contains crystals of quartz.

S. G. = 2.62. Colour greyish white, Streak same as colour. Feel smooth and greasy. Translucent to subtranslucent. Quartz crystals with a diameter of 2 mm are disseminated in the greyish white ground mass. Feldspar phenocrysts are also found. The most striking substance is the cinnabar which forms small irregular patches with scarlet colour. The Chinese term "Chihsuehshih" which means hen's blood stone is thus used.

Microscopic study:—Big crystals of quartz have the same appearance as those found in rhyolite. The corners are mostly rounded and the surface is much fractured. The feldspar is extremely weathered, and the optical properties are entirely lost. The ground mass is microfelsitic and composes of quartz and feldspar. The cinnabar forming irregular masses are unevenly distributed. The colourless mineral is determined to be kaolinite. It shows distinct cleavage and resembles somewhat muscovite, but the birefringence is much lower. The sign of elongation is positive. Under crossed nicols it

is biaxial negative, although the interference figure is very indistinct. Magascopically it is subtransparent. H=2—3.

Chemical composition:—The chemical composition of Changhuashih is given in the following:

SiO_2	68.410
Al_2O_3	18.900
Fe_2O_3, FeO	0.320
MgO	0.440
CaO	1.175
Na_2O	3.385
K_2O	0.470
Loss on ign.	7.752
	100.852

The chemical composition of Changhuashih approaches very nearly to rhyolite. The percentage of volatile matter (Loss on ignition) is 7.752 which contains not only water but also mercury and sulphur. The total iron gives only 0.320 percent to indicate that Chenghuashih contains very few mafites which under microscope is practically nothing. From the facts of chemical composition and microscopic study the Changhuashih can be called a weathered rhyolite.

IV. CHINGTIENSHIH 青田石

Chingtienshih has the same uses as Shoushanshih and Changhuashih. Formerly it was highly valued by most scholars. Now in the market the pure and beautiful colour stone can not be frequently obtained and the prise is much lowered.

Macroscopic study: - It is massive. H=2.3 S. G.=2.78-2.79. Feel greasy. Colour yellowish green, brown, yellow with red spots, orange yellow, etc. Streak lighter than the colour. Translucent to substranslucent. Index of refraction measured by immersion method is about 1.580.

Microscopic study:—Under microscope Chingtienshih has two kinds of structure, the one is uniform compact and the other porphyritic.

The uniform compact Chingtienshih contains very few inclusions of other minerals. Under crossed nicols it shows high birefringence with scale like appearance which resembles pyrophylite.

The porphyritic Chingtienshih shows outlines of phenocrysts and ground mass. The phenocrysts, having the crystalline form of feldspar, are

deeply altered in the same magnititude as that of ground mass. A long slender crystal with distinct longitudinal cleavage looks like mica, and one other mineral having the form of amphibole is also found. Both of them have lost their optical properties entirely. Iron solution in the dark coloured variety is usually found in the interspaces between the phenocrysts and ground mass. Iron spots in some specimens are distributed through the whole mass.

Chemicnl composition:—The chemical analysis of Chingtienshih is made on the yellowish green specimen which is a compact uniform mass without many phenocrysts. The result obtained is given below:

SiO_2	62.570
Al_2O_3	32.020
Fe_2O	———
FeO	———
MgO	0.467
CaO	1.304
Na_2O	0.879
K_2O	0.439
Loss on ign	3.060
	———
	100.739

The above chemical composition is similar to pyrophyllite which given 66.7% for SiO_2, 28.3% for Al_2O_3, and 5.0% for water. The other properties such as hardness, specific gravity, and refractive index, all of which are already stated in previous paragraphs, are also alike with that mineral. In mineralogy text the pyrophyllite gives H=1-2, S.G.=2.8, refractive index=1.58. These figures are also not much deviated from the Chingtienshih.

V. KWANGLÜSHIH 廣綠石

Macroscopic study:—It is massive. H=2-3. S. G.=2.84. Colour dark green. Streak light green. Feel greasy. Shinning specks on fractured surface. Small fragments when examined with magnifying lens show some fine scales, dissemenated in the whole mass.

Microscopic study:—Under microscope it is an uniform mass without phenocrysts of other minerals. Refractive index is about 1.575. Birefringence is high. The whole mass is scaly. Small fragments show distinct cleavage. Extinction angle is small abont 7°. The colour is light green, somewhat like chlorite. Pleochroism is from light green to yellowish green.

Chemical composition:—The chemical composition of Kwanglüshih is given below:

SiO_2	48.589
Al_2O_3	40.140
Fe_2O_3	———
FeO	———
MgO	0.532
CaO	1.189
Na_2O	4.810
K_2O	2.970
Loss on ignition	1.830
	100.060

The Kwanglüshih as shown by the chemical composition is an aluminium silicate with soda. When compared with pyrophyllite it is too high in Al_2O_3 and low in SiO_2 although the physical properties such as hardness, specific gravity and optical properties are some-thing like. The mineral pinite in mineralogy text includes some varities of Chinese agalmatolite. But pinite is a silicate of aluminium and potassium corresponding more or less to muscovite and contains about 10.00% of K_2O. This chemical composition of Kwanglüshih is quite near to that of paragonite which gives SiO_2 = 48.00, Al_2O_3 = 38.29, Fe_2O_3 = 0.91, MgO = 0.36, Na_2O = 6.70, K_2O = 1.89, Loss on ignition = 2.51 = 98.66*. But the other properties do not agree with it. Kwanglüshih may be a mineral between the micas and chlorites. At presnet there is no appropriate English name, and the Chinese name Kwanglüshih is still used.

Kwanglüshih may be a new mineral but without certainty, as the specimen at hand is limited. In the near future the writer is going to Kwangtung and hence he may have the chance to examine the Kwanglüshih more plentifully.

VI. LINGHSISHIH 林西石

Linghsishih is not commonly known to most people. There is no Chinese name for it. The writer as the usual way call it Linghsishih after the village of Ling Hsi. The specimen studied are sent by Mr. K.Y. King, for which he should express his thanks.

Macroscopic study:—It is massive. H = 2 +., S. G. = 2.5. Colour white. Streak same. Translucent to subtranslucent. On the broken surface there are some small shinning specks. The pink coloured mineral looks like feldspar.

* Dana, System of mineralogy, p. 628.

Microscopic study:— It is microfelsitic and contains essentially one substance which optically negative with distinct cleavage. The birefringenc is nearly the same as quartz. This mineral is determined to be kaolinite. It occurs in two distinct forms, (1) in veins forming crystals with a diameter of .008 mm. and (2) not in veins forming small particles. Besides, there are granules of epidote. Kaolinite is also found in the pagodite of Wei-tchang by Prof. Lacroix.

Chemical composition:— The chemical composition of Linghsishih and that of the pagodite of Weitchang which is analysed by Prof. Lacroix are given below:

	Linghsishih	Pagodite, Weitchang
SiO_2	44.089	44.18
Al_2O_3	38.854	39.40
Fe_2O_3	0.391	0.41
FeO		0.15
MgO	0.564	——
CaO	1.830	0.82
Na_2O	0.558	0.09
TiO_2	——	0.59
P_2O_5	——	——
H_2O↑	13.502	14.21
H_2O		0.19
MnO	——	tr.
	100.353	100.42

The chemical compositions of Linghsishih and Weitchiang pagodite are similar to each other. Both of them approach the chemical composition of kaolinite which gives SiO_2 = 46.50, Al_2O_3 = 39.50, H_2O = 14.00, = 100.00.

VII. Conclusion.

The Chinese agalmatolites so far as I have studied can be differentiated into two kinds, (1) is the pure with microfelsitic structure and (2) is the impure with porphyritic structure.

The pure agalmatolites contains essentially kaolinite and, in some cases, pyrophyllite. The porphyritic agalmatolites sometimes has the same mineralogical constituents as that of the pure one, and in addition it contains crystals of quartz and some other altered minerals.

The origin of the agalmatolite is differently explained by different authors. Dr. Chang explains the origin of the Shoushanshih in the following ideas: The Shoushanshih is generated from the quartz porphyry. But the processes of formation of agalmatolite are not due to alteration of the porphyry but due to a second fusion, as this is evidenced by the clear boundaries of the agalmatolite veins. At the time of intrusion of the quartz porphyry, the temperature and pressure were certainly very high to fuse a part of the pre-existing rocks. The fused part was injected into the fissures and fractures of the porphyry to form the agalmatolite veins.

Mr. 吉木文平 studied the agalmatolite in Kong Shan; Japan (日本光山), and he regarded it as a result of replacement by the hydrothermal action of volcano.†

Prof. Lacroix puts the formation of agalmatolite under the heading of the alteration of rhyolite.

The specimens studied by the writer do show the alteration phenomena As in the porphyritic agalmatolites of Tu Ling Keng, Fukien and Chang Hua Hsien, Chekiang, the phenocrysts of the feldspar are extremely weathered and ost all the properties, except the crystalline form. The other mafites, although in small quantity, have been subjected to the same degree of alteration.

The chief alteration agency will be the circulating waters which eliminate the soluble constituents—alkalies and retain the refractory element—aluminium. Those agalmatolites have the form of veins may be formed later than the surrounding porphyries, but both of them have been subjected to the same alteration agency.

† Jour. Geol. Soc. Tokyo, Vol. 33. pp. 273-296.

Explanation of Plate I.

Fig. 1. Shoushanshih.—Crystalline mineral is concentrated in small aggregates, the form of which seems to indicate the nature as pseudomorphs after feldspar phenocryst. (Photo by Prof. F. Slavik)

Fig. 2. Shoushanshih. (Photo by Prof. F. Slavik)

Fig. 3. Changhuashih showing phenocryst of quantz (Q) Kaolinite vein (R) and Cinnabar (C) + Nicols. × 63

Fig. 4. Chingtienshih showing phenocrysts and ground Mass. The phenocrysts compose of scally like substances which are determined to be pyrophyllite. ×63

Fig. 5. Kwanglūshih under crossed nicols. ×63

Fig. 6. Linghsishih composes of Kaolinite. + nicols. ×63.