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Micropattern of Taiwan Cypress Burl Wood Figures

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Taiwan cypress burl wood figures (BWFs) refer to the wood figures (WFs) on the burl section of *Chamaecyparis formosensis* and *Chamaecyparis obtusa* var. *formosana*. This study investigated the relationships between the micropatterns of Taiwan cypress BWFs and WF. The microscopic results of various BWF patterns indicated that the “water-ripple figure approximates a wavy figure”, “sliver-ripple figure approximates a mottled figure”, “peanut-like figure approximates a blister figure”, “phoenix tail-like figure approximates a crotch figure”, and “nail and thorn-like figure approximates a burl figure”. The water-ripple, sliver-ripple, peanut-like, and phoenix tail-like figures had the bright band pattern like a “flash light”. The nail-like figure had a dot pattern like a “nail dot”. The thorn-like figure had both the “flash light and nail dot”. The bright band, nail-like and thorn-like figures were induced three types of BWFs. The bright band was the difference between the patterns on both orientations of the tracheid, longitudinal and cross sections, where the light projected on the surface and there were different lusters due to the degree of reflection, but most compositions were longitudinal tracheid. The nail-like figures visually presented some of dark dot patterns as a lot of inclusions accumulated in each orientation of tracheid. The microscopic cellular morphology of various BWFs; therefore, are able to cover the different arrangements and patterns of the tracheid, the amount or different patterns of the inclusions, and even different patterns of wood ray arrangements.

Key words: Taiwan Cypress Burl, Burl Wood Figure (BWF), Wood Figure (WF), Micropattern

INTRODUCTION

The “tree tumor, plant tumor, virus tumor, tumorous wood, and woody tumor” are widely used in lots of science papers (Black, 1945; Littau and Black, 1952a and 1952b; White and Millington, 1954a and 1954b; White, 1958; de Torok, 1968; Eom and Chung, 1994; Gülsoy *et al.*, 2005). “Tumor” can be any size or shape and may occur on both woody, herbaceous plants and plant parts. Besides, a burl (American English) or bur or burr (UK English) is a tree growth in which the grain has grown in a deformed manner, and commonly found in the form of a rounded outgrowth on a tree trunk or branch that is filled with small knots from dormant buds (Wikipedia, 2020). The above description can understand that both refer to the same object, but burl means it yields a very peculiar and highly figured wood, prized for its beauty and rarity. The word “burl” is used in this study because it is recently popular after by furniture makers, artists, and wood sculptors in Taiwan.

Taiwan cypress refers to the Cupressaceae *Chamaecyparis* tree species of endemic species of Taiwan, *Chamaecyparis formosensis* and *Chamaecyparis obtusa* var. *formosana*, both of which have special aroma, straight wood texture, excellent

properties, and extensive use, and they are mostly developed into lumber for wood construction, furniture, and the carpentry industry. There are occasional growths of abnormal bulges on the trunks, limbs, or roots of these trees, which are known as burls, which have irregular cell arrangements and sections with special patterns (Beals and Davis, 1977), and such wood figures (WFs) are called “figure flowers” in Taiwan. As it is formed on the burl section, it is called the “burl wood figure (BWF)” in this study. The burl of the Taiwan cypress is called a “Taiwan cypress burl”, it has sinuous appearance and rough surface, and due to its special BWF pattern, it is often used as ornaments. At present, the BWF patterns are identified mostly according to experience, and because only the macroscopic pattern of the BWF is described, the cell tissue or the pattern is not probed for the research. As there are diversified BWF patterns, there are different opinions on macroscopic identification. It is difficult to determine the differences among BWF patterns, and there are even uncertainties in the appreciation of BWFs. Therefore, in addition to macroscopic identification of BWF patterns, the tissue sections are used for microscopic identification of patterns, in order that the patterns can be further understood, and the cause of BWFs can even be observed.

BWFs are WF produced of the burls of trees, where the WF is the pattern observed on the wood face, such as the patterns formed by annual ring growth layer, spring and fall woods, burls, tracheid, wood rays, parenchyma cells, color matter (inclusions), or longitudinal cell growth arrangement (Beals and Davis, 1977). The modified cell growth direction or cell orientation results in different absorbed degrees and reflected degrees of

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optical light of the surface, as well as a difference in contrast–brightness, leading to different patterns of bright bands, such as a ribbon figure slightly parallel with the longitudinal axis of the trunk; a wavy figure slightly normal to the longitudinal axis; or mottled figures of interaction; and a mounds or depression like blister figures and quilted figures; or a crotch figure formed on the tree crotch. When the tree suffers partial injury or suppression, the depression–like bird’s eye figure is formed on the surface and the burl figure is formed on the enlarged portion of limbs or dormant buds, branch knots, and burls (Beals and Davis, 1977).

Such WF patterns can form light reflected lines, blocks, or special patterns on the surface due to the variation of wood cell orientation. There are numerous factors inducing the variations of wood textures and wood figures, such as stress (such as gravitational force of sloped limbs), changeable climatic conditions, disease, or inhibited growth (Beals and Davis, 1977). When a burl is injured by environmental impact, insect or fungal deterioration, and stops growing adventitious buds that become dormant buds, the peripheral cells still grow, leading to abnormal divide, and enlarged or/and enhanced cells, which form irregular bulges or lumps in the wood texture (Black, 1945; Kelly and Black, 1949; White and Millington, 1954b; White, 1958; Beals and Davis, 1977; Eom and Chung, 1994; Dodueva *et al.*, 2007; Schweingruber, 2007), and may be used to form BWF. It can be seen that the external environment and internal cell variation influence the texture of wood, which form the WF, and similar influential factors result in peculiar appearance and complex BWF patterns, meaning there are similar formation causes of BWFs and WFs. In comparison to the identification of BWF patterns based on folk experience, the WF pattern corresponding to the Taiwan cypress BWF is more referable in morphologic observation.

The burls of some coniferous and broadleaf species have been studied, including *Picea glauca* (White and Millington, 1954a and 1954b; White, 1958; de Torok, 1968), *Picea sitchensis* (Rickey *et al.*, 1974) and *Pinus densiflora* (Eom and Chung, 1994). According to macroscopic results, burls have obvious sapwood and heartwood (Rickey *et al.*, 1974), the annual rings are regular, and it is wider than normal wood (White and Millington, 1954a and 1954b). The same section of burl can have cellular morphology in different sections, and swirled cell arrangements can be observed, such as fingerprint–like patterns, which contain a lot of resinous substances (Littau and Black, 1952a and 1952b; Eom and Chung, 1994; Crane *et al.*, 1995; Gülsoy *et al.*, 2005; Kilic *et al.*, 2012). While there are few studies about the Taiwan cypress burl, the Taiwan cypress is a conifer and the part of the aforesaid tree species and about 87–96% of its cellular elements is the tracheid. The identification of Taiwan cypress burl is similar and easy relatively.

Based on the documents and images of WF patterns, this study interviewed senior collectors of Taiwan cypress BWF patterns, and the BWF patterns on burl artwork were filmed during the interview, where the

macroscopic patterns of WFs and BWFs, as well as their relationships were investigated. The processing remainders of Taiwan cypress burl artwork production were used as Taiwan cypress burl specimens for subsequent testing, including tissue sections, cell arrangements, and the distribution of microscopic BWF patterns, and the BWF pattern was drafted from the cells or arrangement and drawn by hand, in order to observe Taiwan cypress BWF patterns in detail, which was intended to provide a reference for the identification and appreciation of Taiwan cypress BWF patterns.

MATERIALS AND METHOD

Test materials

Taiwan cypress burl processing remainders: provided by sawmill or burl artwork processing plant, the wood species were confirmed for macroscopic and then microscopic observation of burl wood figure (BWF) patterns.

Experimental methods

BWF observation

The BWF pattern was a macroscopic specimen, the matching result of the WF and the BWF was confirmed, and the tissue with special pattern was sliced as the section, and then placed under a biomicroscope (Leica, DM500, Switzerland) to observe the micropatterns of different BWFs at magnifications of 40 and 100, and the observed patterns were drawn by hand to assist the pattern identification.

Tissue section

In the burl slicing method, the specimen was taken from the observed surface with the BWF pattern, the cross–section area was about 1×1 cm, the specimen was softened in boiling water, which was boiled for 8–10 h every day for about 30–60 days, and then, it was sliced by a sliding microtome (WSL Core Microtome, Germany), where the blade cutting angle was 5–10°, the section thickness was 25–35 µm, and the section was placed in the culture dish with deionized (DI) water for future use.

Microscopic observation of specimen

The overall cell arrangement, cumulative distribution of the inclusion, and spring and fall wood arrangements of the BWF and the portion of section were observed at the magnification of 40 (×40) as local microscopic view, and micro local microscopic view was performed at magnification of 100 (×100), in order to identify the cellular morphology (e.g. tracheid, parenchyma cells, wood rays) or special structures. The observed cellular morphology was filmed.

Hand drawn patterns of BWF

The cellular morphology of various BWF patterns were drafted from the microscopic result to draw by hand, then filmed through a microscope with magnification of 100, and drawn by hand using a tablet PC and

touch pen, where the cell profile was drawn in a black line, in order to observe the cellular morphology and arrangement, and the inclusion was represented by gray.

RESULTS AND DISCUSSION

BWF observation

The WF pattern data are derived from documents (Beals and Davis, 1977; Hoadley, 2000; Corbineau and Flandin, 2013). The senior collectors were interviewed on the local (Chiayi, Taiwan) to obtain the data about Taiwan cypress BWFs, in order to divide 6 common BWF patterns according to appearance and macroscopic image. However, as the BWFs are not yet academically named, folk names are adopted in this study for description. The morphologic observations present “water-ripple figure”, “sliver-ripple figure”, “peanut-like figure”, “phoenix tail-like figure”, “nail-like figure” and “thorn-like figure”. The macroscopic and microscopic images of the BWFs were observed in this study, which were sequentially Taiwan cypress burl artworks with BWF; BWF observation specimen; general view of the specimen and section from the observation specimen; microscopic observations at the microscope magnification of 40 (local microscopic view); 100 (micro local microscopic view); and the image of the hand drawn pattern.

Features of hand drawn pattern drafted from BWF







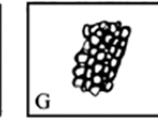




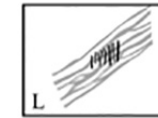
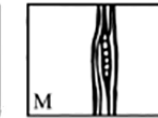
Taking a general view of the microscopic result of the Taiwan cypress BWF, it was mostly composed of the tracheid, there was dark colored inclusion accumulated in the cavity (such as cross section of tracheid), and there were wood ray tissues of different patterns. The drafted pattern was drawn by hand, the same kinds of cells (such as tracheid, wood ray) were different for different patterns and arrangements or different BWF sections, and each BWF had a similar cellular morphology, as well as a unique pattern. Table 1 shows the differences in the tracheid, inclusion, and wood ray drawn by hand, and there were 13 (A to M) morphological features

of cells denoted by letters.

The longitudinal tracheid patterns were divided into A to G, A to F was belonged to longitudinal tracheid pattern; G was cross section of tracheid pattern. The description of each tracheid pattern was as follows. A: sliver – the tracheid was parallel with the longitudinal tracheid orientation, and mostly tangential or radial sections; B: discontinuous – discontinuous tracheid, similar to A, but the cell wall was apparently segmented and discontinuous; C: turning zone – the tracheid orientation was turned, the orientation fluctuates, and a turning zone was formed at the fluctuating portion; D: intersection – the tracheid orientation turned into a triangle, its orientation had respective surrounding, a large chamber was formed by the three-way tracheid intersection, and the overall pattern was triangular; E: hook – the tracheid orientation turned into a hooked shape, the orientation bends greatly into a U or V shape, and the overall pattern was hooked; F: swirled – the tracheid orientation became swirled, the orientation surrounding seemed to have a center, and the overall pattern was like a fingerprint; G: pore – the cross section of tracheid was like porous, and normal to the cross section of longitudinal tracheid orientation, i.e. pores on cross section of tracheid.

The inclusion patterns were divided into H to K, H and I were different pattern of inclusion, and J and K were different pattern of inclusion concentration site. The description of each inclusion was as follows. H: sliver inclusion – the inclusion accumulated in the longitudinal tracheid section with sliver form, because the observable inclusion accumulation range in the longitudinal tracheid was extensive and sliver shaped; I: punctate inclusion – the inclusion accumulates in the cross section of tracheid with the punctate form, and mostly observed in the pore of G; J: sliver inclusion concentration site – the sliver inclusion concentrated on the surface in the dot pattern (nail dot), because a lot of dark colored inclusion concentrated in place, and was mostly

Table 1. Hand drawn patterns of BWF from micro local microscopic view ($\times 100$)

	longitudinal tracheid pattern						cross section of tracheid pattern
	sliver	discontinuous	turning zone	intersection	hook	swirl	pore
tracheid pattern							
inclusion pattern	sliver inclusion	punctate inclusion	sliver inclusion concentration site	punctate inclusion concentration site	wood ray pattern		
							
					crossover region	moniliform	
							

composed of longitudinal tracheid; K: punctated inclusion concentration site – the punctated inclusion concentrated on the surface in the dot pattern (nail dot), because a lot of dark colored inclusion (e.g. gravity) concentrated in place (cross section of tracheid), and was mostly composed of G.

Moreover, the wood ray patterns were divided into L: crossover region – the wood ray (e.g. dark colored line) crossed the tracheid in a brick shape form (mostly on radial section), i.e. parallel with wood ray orientation, because the wood rays were normal to the tracheid arrangement, and interlaced with each other as a brick shape; M: moniliform – the wood ray arranged such a moniliform, i.e. normal to wood ray orientation on tangential section, and presenting a shape of pore line, like a string of beads (moniliform) that was inside spindle shape of wood ray.

BWF pattern

According to the macroscopic view of the BWF specimen and the comparison between the WF and BWF, as well as the microscopic cellular morphology, the arrangement and distribution of the tissue section, and the differences among various BWF patterns were discussed below.

Water-ripple figure

The “water-ripple figure” is named in Taiwan according to its appearance, meaning it is like a ripple mark on water surface, and the BWF has straight line bright band. The wavy figure has fine cross stripes of dark-and-light alternation or contrast due to the variation of the woody texture orientation (Beals and Davis, 1977), and both are similar to each other. The bright band orientation is slightly normal to the spring and fall wood band, the bright band patterns are similar, parallel

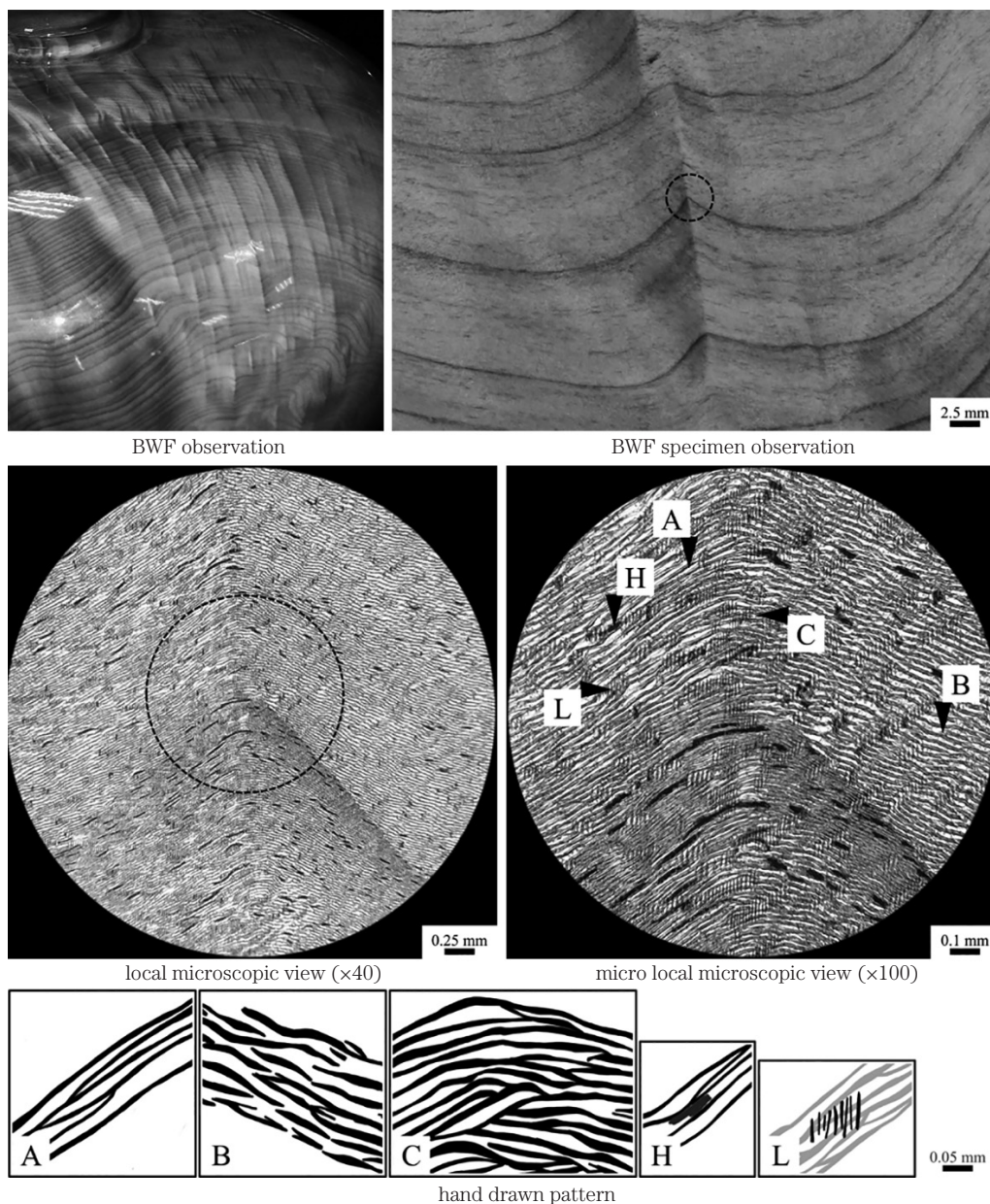


Fig. 1. Macroscopic and microscopic images of water-ripple figure of *Chamaecyparis formosensis* specimen.
Note: hand drawn pattern : see Table 1

with each other, and regular, like a crease, which is also known as a “fold flower” in Taiwan. The “flower” is a general designation of the different bright band patterns among common people, and called “flash light” to avoid being confused with the “figure flower” (another name of the BWF in Taiwan). The macroscopic and microscopic images of the water-ripple figure specimen are shown in Fig. 1.

The dark colored fall wood band of the overall specimen was fluctuating, the overall orientation of the woody texture could be identified as a wavy arrangement, and several straight line bright bands slightly normal to the woody texture orientation were formed on the surface, i.e. bright band pattern of the water-ripple figure, where it was observed that the fluctuation of the fall wood band forms an inverted V-shaped peak pattern, and the bright band connected various peaks with contrasting luster. According to the general view of the BWF specimen observation and the section with local microscopic view ($\times 40$), the fall wood band showed a turning pattern due to its woody texture fluctuation, like a peak. According to the micro local microscopic view, the tracheid had three patterns, which were A, B, and C (with hand drawing, Table 1). Moreover, A: sliver and the wood ray were crossed on the longitudinal tracheid orientation forming H (sliver inclusion); B: discontinuous and some of wood ray forming L (crossover region, like a brick shape).

Sliver-ripple figure

The “sliver-ripple figure” of the burl appearance is like a curly filament. It is named “sliver-ripple” or “Q filament” in Taiwan, when the bright band is a curve in close view, the overall pattern is like an electric wave. The mottled figure is a broken line or dotted line due to the interaction of the longitudinal and transverse bright bands on the surface of wood. The general view of the artworks with BWF showed that the bright band of sliver-ripple figure was curvilinear, and two curvilinear bright bands had different curvatures, which intersected each other and surrounding lusterless surface to form a long and narrow block (Fig. 2). The general view of the BWF observation specimen showed that the two curvilinear bright bands intersect each other, keeping a face between two bright bands, and it was lusterless, as compared with the bright band. The local microscopic view showed the lusterless face between two bright bands, where the hexagonal cells correspond to the left and right bright bands. The micro local microscopic view showed two tracheid arrangements, which were A: sliver and G: pore, the accumulated inclusion were H: sliver inclusion and I: punctate inclusion, and the wood ray pattern presented L: crossover region (Table 1). In addition, A and G were different sections, meaning the same section of the sliver-ripple figure had two different tracheid patterns. It is similar to the cellular morphology of *Pinus densiflora* burl (Eom and Chung, 1994). According to the general view of the Fig. 2 corresponding to A and G, G was lusterless on the cross section of surface, and A was in proximity to the two bright bands,

meaning the bright band was related to A.

The sliver-ripple figure was curvilinear, and the two adjacent bright bands (flash light) intersected each other surrounding the lusterless face to form several block patterns. The overall pattern was like an electric wave, and similar to the mottled figure. According to the microscopic view, the sliver-ripple figure had the longitudinal (A) and cross (G) sections of the tracheid pattern on the same surface of the BWF. The longitudinal tracheid was divided into A: sliver and B: discontinuous. The morphological differences had different reflected degrees for light. In terms of the proportion of different pattern of the tracheid, when B or G were more than A, as the reflection range of A was relatively narrow, the light reflection was relatively apparent, and when light projected on the surface, the bright band was formed on the tracheid band composed of the A arrangement. Moreover, according to the features of the hand drawn pattern drafted from sliver-ripple figure, besides A, B and G, the inclusion patterns were sliver inclusion (H) and punctate inclusion (I), and there was a brick shape with crossover region (L) cellular morphology, where the bright band was induced by the differences among A, B, and G.

Peanut-like figure

The “peanut-like figure” is named according to its irregular circular bulges, like spheres or beads. It is also known as a “bead burl” in Taiwan, where the BWF on its section is a “peanut-like figure”, and the pattern is similar to the blister figure. The local microscopic view showed that the BWF was like annual rings, and the spring and fall wood bands had several concentric circle, which was called a “mushroom swirled shape”, i.e. mushroom surface in Japanese (MOKUME), meaning tangential section. The face of the blister figure has mounds or slight depressions like rough circular blocks. In addition, the curve interlaced bright bands fan out from the center position of the concentric circles. This kind of direction was slightly normal to the concentric circle-like spring and fall wood bands (Fig. 3). It was also known as an “axis flower” in Taiwan.

The surface of the specimen had several circular blocks formed of spring and fall wood bands, i.e. mushroom swirled shape. The BWF observation specimen showed that the spring and fall wood bands were arranged outwards from the center (axis) of the circular blocks, like growing annual rings, and the bright band seems to fan out from the center, and the orientation was slightly normal to the spring and fall woods with directional. The local microscopic view showed the center position of the concentric circle shape, the micro local microscopic view had an annular dark colored band, and the cell orientation slightly inclines to the lower right. According to the partial enlargement, A with nonuniform caliber could be observed, H accumulated in the pores on cross section of tracheid, and M: crossover region could be observed, as shown in Table 1.

According to micro local microscopic comparison, the inclusion was distributed in some places, and the pattern was dark colored ribbon-like, meaning the macroscopic fall wood band was surrounded by the accumulated inclusion (H: silver inclusion).

The peanut-like figure was characterized by the mushroom swirled shape with a concentric circle, which was similar to the blister figure, as the face had dark colored lines and was arranged outwards in the form of concentric circles to form several irregular dark colored circles. According to the macroscopic and microscopic images, the peanut-like figure surface was mostly composed of longitudinal tracheid (A: sliver), which were densely arranged, and the calibers were nonuniform.

The H: sliver inclusion accumulated in A, and presented concentric circle-like dark colored lines, meaning the concentric circle pattern in the mushroom swirled shape of the peanut-like figure was not induced by the variation of spring and fall woods. According to the observations of the hand drawn pattern from the peanut-like figure, there were A, H, and M. A: sliver; therefore, was the main cellular morphology of this BWF, but the concentric circle pattern of surface was induced by H: sliver inclusion, and some of them were M: moniliform in this BWF.

Phoenix tail-like figure

The “phoenix tail-like figure” is named in Taiwan

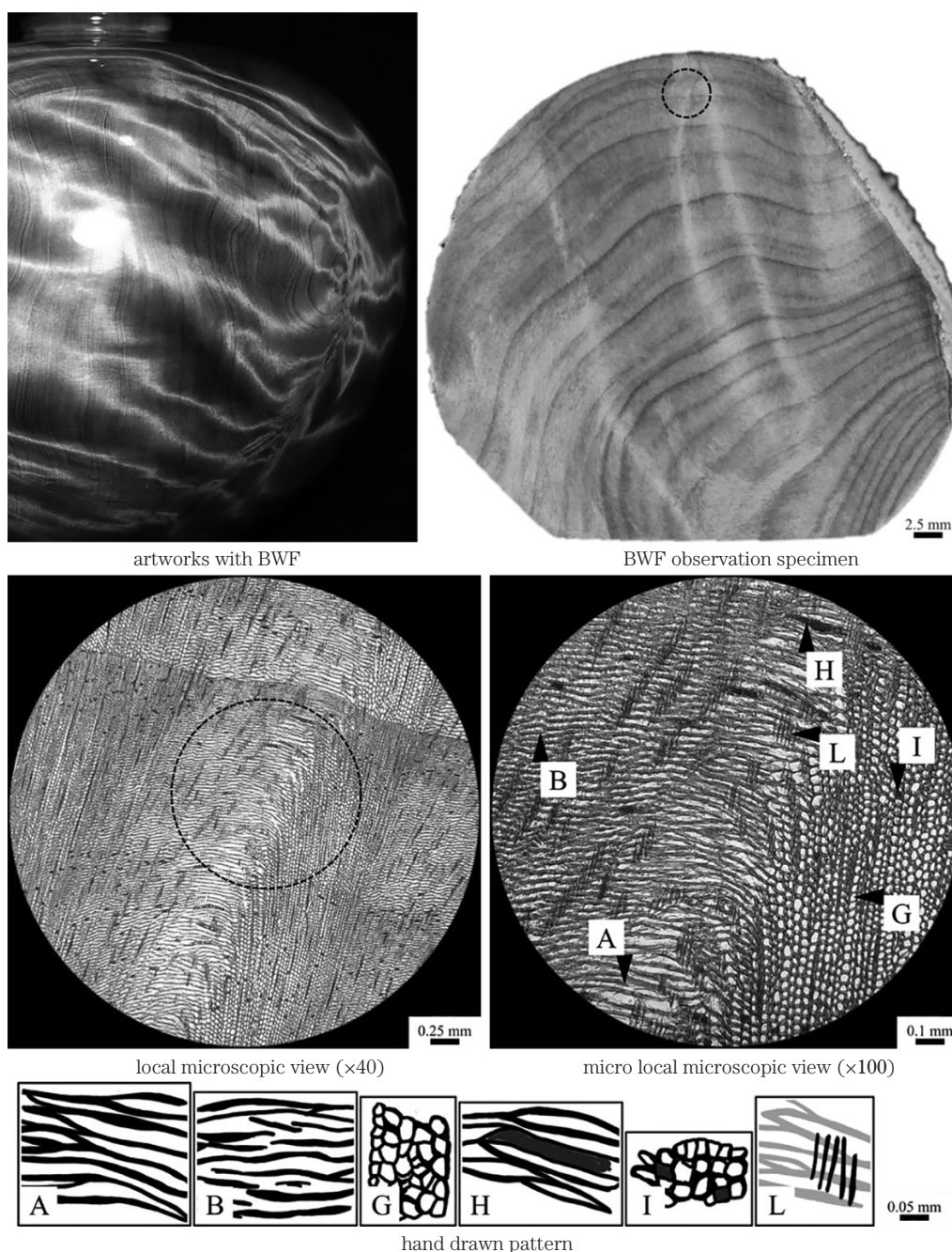


Fig. 2. Macroscopic and microscopic images of the sliver-ripple figure of *Chamaecyparis formosensis* specimen.

Note: hand drawn pattern : see Table 1

according to the burl appearance, which has mound bulges, like the eye-like spots on a peacock feather. This BWF has multiple patterns, similar to a crotch figure. The crotch figure is formed at the tree crotch, the cell arrangement is disordered, the pattern is like a feather, or the curved woody texture is like a swirl. The phoenix tail-like figure with swirled and penniform BWFs were different sections from artworks with BWF (Fig. 4). When the swirled shape was regarded as a plane, on the section normal to it, the bright band spreaded to both sides to form a strip-shaped penniform pattern, and the bright band expanded outwards in clockwise and counter clockwise rotations, the overall pattern was swirled and cyclonic, the inner side had a

small turning radius, and swirls liked a flame or feather, while the outer side had a large turning radius. The spread to both sides was not obvious, and it was curvilinear.

The overall visual effect was like a spread and overlapped state. It is called an “overlapped flower” in Taiwan. The penniform bright band seemed to be composed of several small feathers due to the overlapped flower effect. According to the BWF observation specimen, the lusterless face was inserted between bright bands, forming a dark colored boundary leading to the visual gradient effect, and the cellular morphology on both sides was close to the location of the bright band

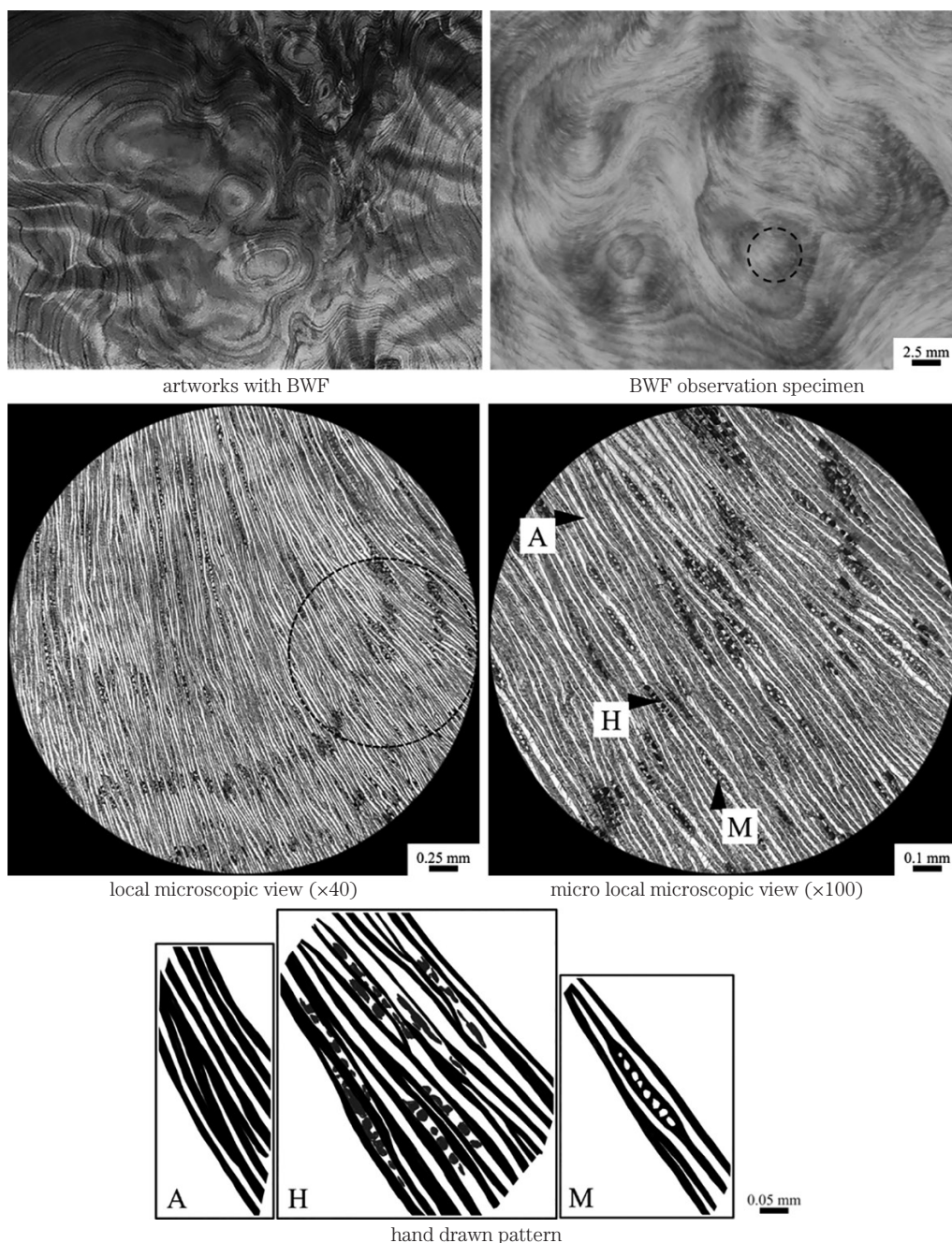


Fig. 3. Macroscopic and microscopic images of the peanut-like figure of *Chamaecyparis obtusa* var. *formosana* specimen.

Note: hand drawn pattern : see Table 1

(A). The local microscopic view ($\times 40$) was apparently a penniform pattern. The micro local microscopic patterns were A, B, G, H, I and L. Moreover, H was accumulated in both A and B with some of the punctate inclusion (I). The crossover region (L) was also observed in A and B.

The phoenix tail-like figure was similar to the crotch figure, and this BWF was diversified, and generally spreads out like a feather. The tracheid of the phoenix tail-like figure had the tracheid of longitudinal and cross sections, and such patterns had different light reflected degrees. The A was able to form a bright band, the B and G were lusterless on the surface, and A had larger

proportion, such the bright band. Moreover, the bright band of the phoenix tail-like figure had a special pattern, called an “overlapped flower” in Taiwan, meaning the bright band is divided by one or several narrow lusterless faces, like the outer edge of a feather, and the corresponding cellular morphology was such pattern of B. The hand drawn pattern drafted from A, B, and G, and there were H and I with L as well. The BWF of the surface was mainly induced by the differences among A, B and G.

Taking a general view of the aforesaid water-ripple, sliver-ripple, peanut-like, and phoenix tail-like figures, in terms of features, the water-ripple figure had the pat-

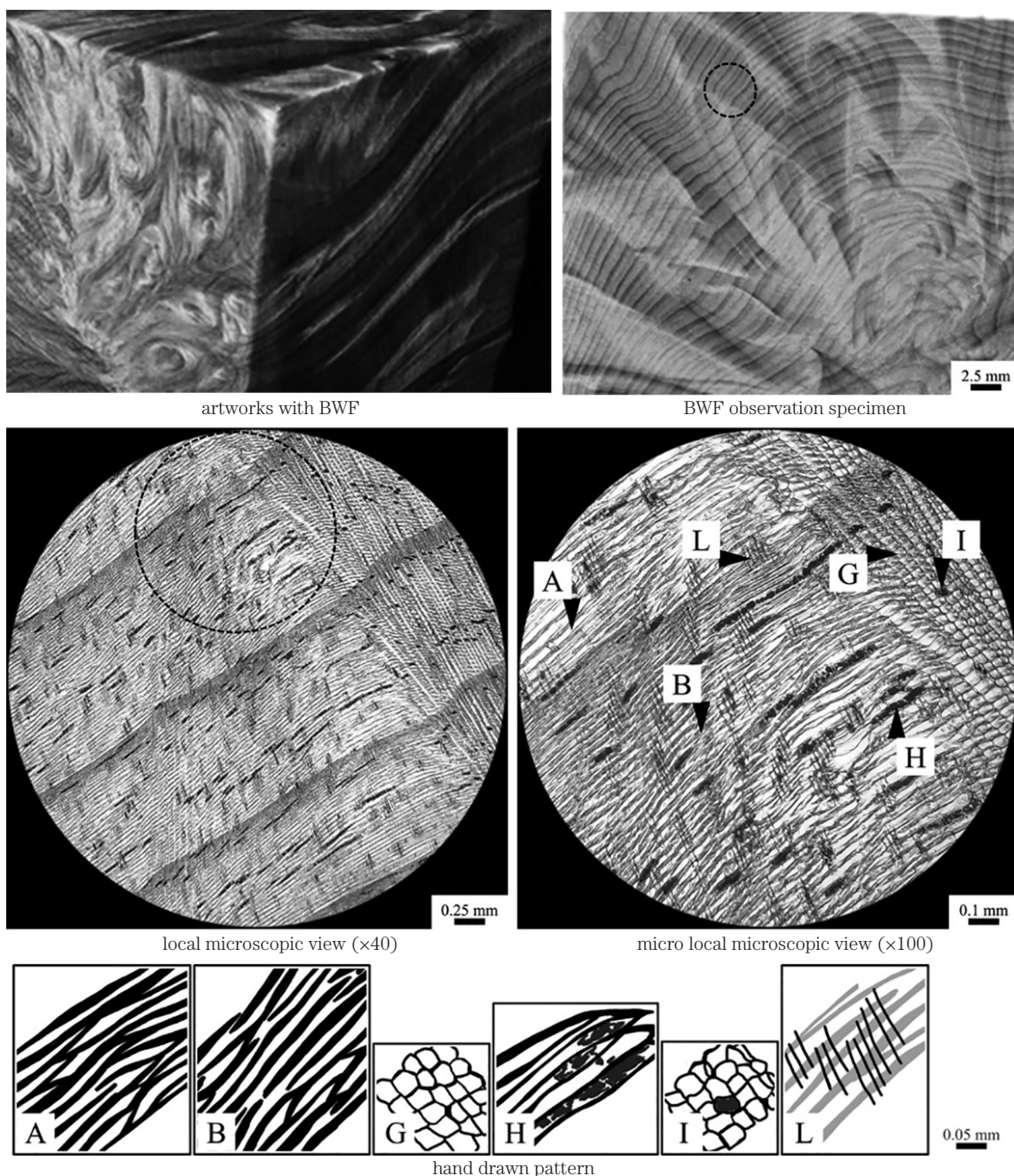


Fig. 4. Macroscopic and microscopic images of the phoenix tail-like figure of *Chamaecyparis formosensis* specimen.

Note: hand drawn pattern : see Table 1

terns of A, B, C, H, and L; the sliver-ripple figure had A, B, G, H, I, and L; the peanut-like figure had A, H, and M; the phoenix tail-like figure had A, B, G, H, I, and L. The four figures had different patterns, which could be the basis of BFW identification, and they had a common point, i.e. the bright band. From the macroscopic and microscopic images, the four figures are suggested that they can be classified as the same type, and called “bright band BWF type”.

Nail-liked figure

The “nail-like figure” is named “nail burl” as the burl surface has nail pores and shothole-like patterns, or

many raised punctated objects. Its BWF is also called a “nail-like figure” in Taiwan, which is similar to a burl figure. The burl figure is the wood figure formed on the section of tree bulges, or dormant buds and burls. The nail-like figure section has branch knot-like dark colored dots, called “nail dots”, which is the foremost feature of the nail-like figure. The BWF observation specimen showed the different quantities, sizes, or distribution densities of the nail dots, and the distribution was irregular (Fig. 5).

According to the view of the nail-like figure specimen, a high content of the inclusion was accumulated in

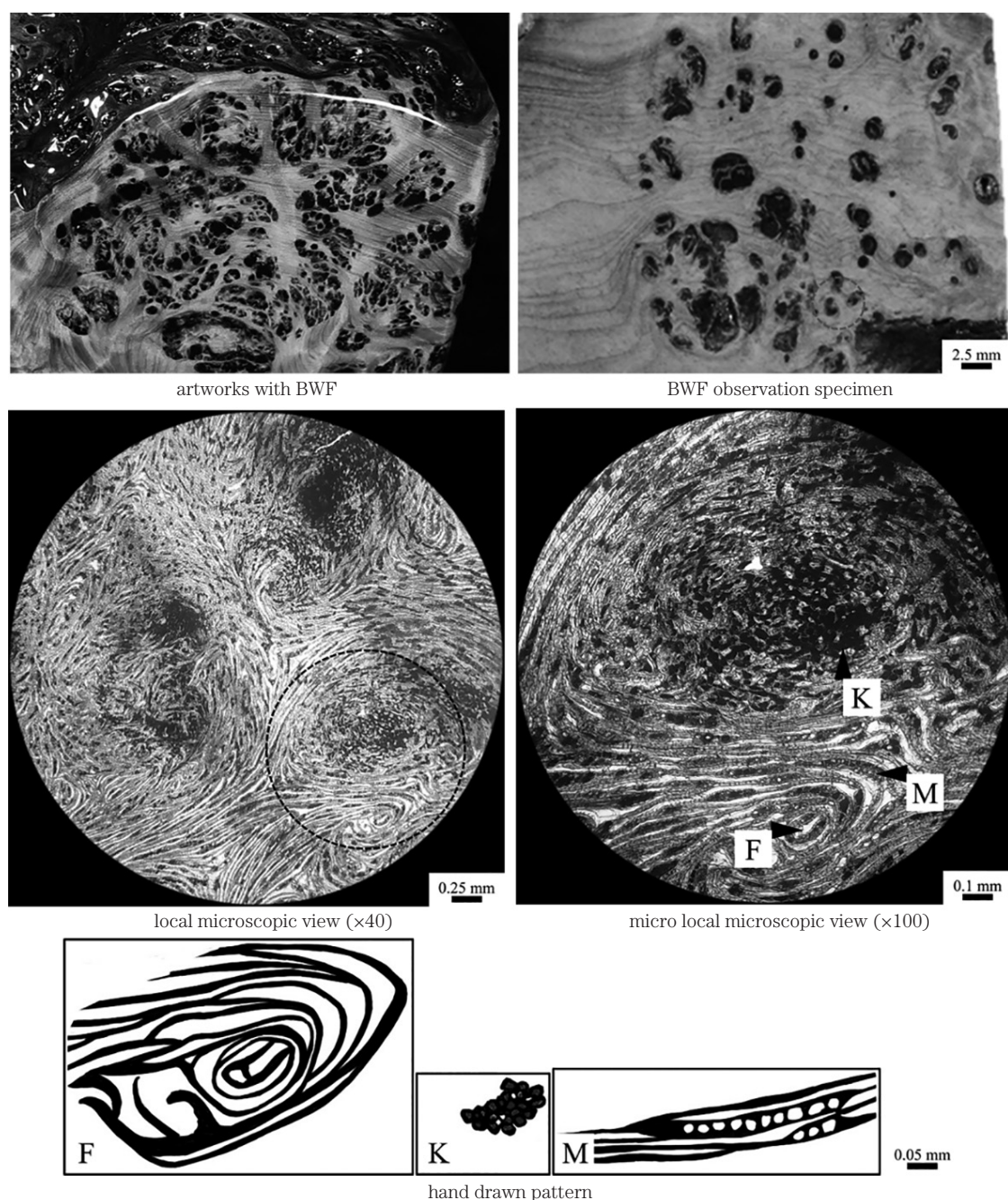


Fig. 5. Macroscopic and microscopic images of the nail-liked figure of *Chamaecyparis obtusa* var. *formosana* specimen.

Note: hand drawn pattern : see Table 1

the tracheid, concentrated in some places, and several dark colored dot shapes (nail dots) were presented visually. The main hand drawn patterns were F, K and M in Fig. 5. In terms of the inclusion pattern, the J: silver inclusion concentration site and K: punctate inclusion concentration site (Table 1) occurred in the inclusion concentration site, meaning the inclusion concentration site could be composed of G. The peripheral longitudinal tracheids surrounded the J and K as the center to form multiple tracheid patterns, e.g. intersection (D), hook (E), or swirl (F) patterns, and the concentration site was the “nail dot” pattern. According to the feature of the hand drawn pattern drafted from the BWF, the nail-like figure had D, E, and F, the inclusion patterns of J and K (such like nail dot in the image of BWF observa-

tion specimen), as well as the M. Therefore, this figure is suggested that it can be as a unique type, and called “nail-like BWF type”.

Thorn-like figure

The thorn-like figure is called “thorn-like burl” due to its mound bulges, and the bulges have punctated convex thorns, its section has the dot pattern (nail dot) of the nail-like figure, and the curvilinear or penniform bright band (flash light) spreads outwards from the nail dot, and identified as the integration of the bright band and the nail dot, which is a similar pattern that also occurs in the burl figure, meaning the nail and thorn-like figures are not yet academically separated. Moreover, the nail dots are mostly clustered and concentrated in a

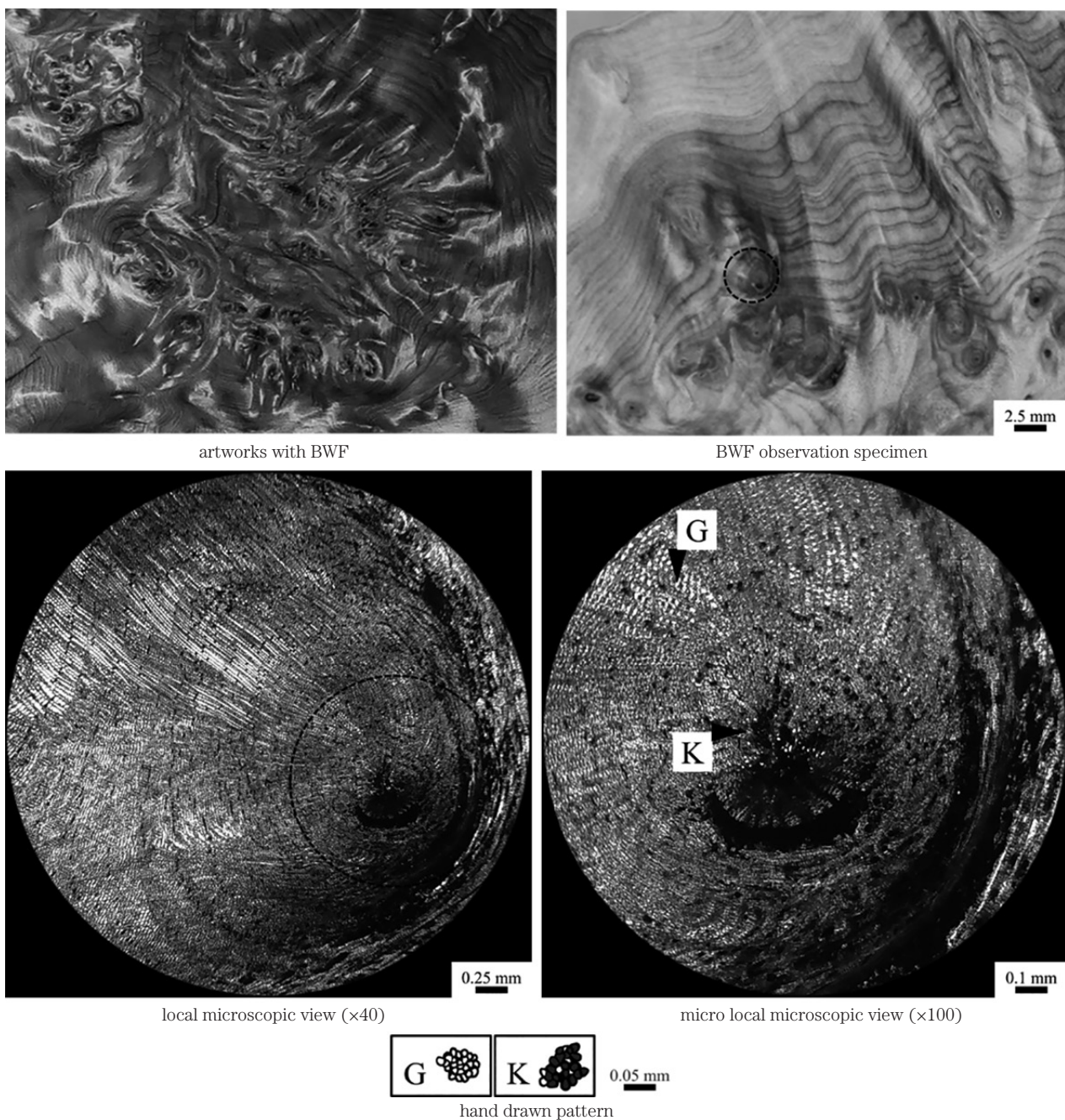


Fig. 6. Macroscopic and microscopic images of the thorn-like figure of *Chamaecyparis obtusa* var. *formosana* specimen.
Note: hand drawn pattern : see Table 1

range, the bright band fans out from the center of the clustering range or the nail dot, and the bright band pattern of some thorn-like figures is similar to the phoenix tail-like figure. It is; therefore, named the “phoenix tail-like thorn-like figure” among common people in Taiwan. The theory of bud dots of Schweingruber (2007) and the estimation of the nail dots, i.e. bud dots of the nail-like figure. The nail dots of the thorn-like figure may be induced by a crosscut sprout (bud dot).

The thorn-like figure had bright band (flash light) and nail dot patterns (Fig. 6). The nail dot was resulted from the K: punctate inclusion concentration site and G: pore. The microscopic view also showed a cross section of tracheid with punctate inclusion (I); the bright band was such A in the microscopic view, which was different from the peripheral I, and there was difference in the light reflection, meaning that A had the better reflected degree. The tracheid of the thorn-like figure seemed to be arranged outwards from the nail dot (main patterns was G and K in Fig. 6), in the form of concentric circles like annual rings, and the wood ray orientation extended from the nail dot. The overall pattern was like the cross section of a tree, meaning the nail dot of thorn-like figure might be at the burl sprout. According to the observations of the hand drawn pattern drafted from this BWF, the feature of the thorn-like figure include A, G, I, K and L: crossover region (brick shape) was found. The bright band was induced by the difference between A and G, and the nail dot was the pattern of K.

The nail and thorn-like BWFs had nail dots, and the thorn-like figure had the morphological characteristics of the bright band. The two BWFs had different tracheid patterns. The tracheid pattern of the nail-like figure was composed of longitudinal tracheid, including intersection (D), hook (E), and swirl (F), meaning the three patterns were induced by the modified longitudinal tracheid orientation. This pattern seemed to be diversified, but the tracheid arrangement was irregular. On the contrary, the tracheid pattern of the thorn-like figure was composed of A and G, where the tracheid band composed of the a arrangement was in the bright band of the BWF surface; G was like a lusterless surface, and the tracheid pattern and feature were slightly similar to the sliver-ripple and phoenix tail-like figures. From the above results, this figure is suggested that it can be as another unique type, and called “thorn-like BWF type”.

Taking a general view of the longitudinal tracheid in Table 1, from the patterns of A to F, only A and C of turning zone could form bright bands, while the other patterns were lusterless on the surfaces of BWF. Wherein, A was sliver, and in comparison to other longitudinal tracheid (B to F), there was slight variation in the orientation or pattern, e.g. segmented (B: discontinuous) or greatly curved (E or F). It was a relatively simple pattern of a longitudinal tracheid, and a tracheid was in parallel arrangement. Beals and Davis (1977) indicate that the cell sidewall (longitudinal tracheid) has better reflected degree of light, while the other patterns are difficult to have the same direction of reflection during

light projection, thus, like the reflection in water only occurs in an undisturbed water surface, it cannot be seen when the water is disturbed, meaning the bright band are composed of a “simple” tracheid pattern. However, the Taiwan cypress wood does not have bright band patterns, meaning the bright band still needs some relatively “complex” tracheid patterns to generate the luster difference in the light projected on the surface of wood, in order to highlight the the bright band. In other words, the bright band is from “simple” A, but its diversified and beautiful BWF patterns are from other “complex” and lusterless tracheid patterns. Therefore, the concept can prove that the nail-like figure has no bright band because this pattern is with inclusion, and there is no complete reflection surface (A pattern) for light reflection.

CONCLUSION

Taiwan cypress BWF patterns were able to be divided into bright band, nail-like, and thorn-like BWF types, as well as in Taiwan the folk name of the BWFs were included, water-ripple, sliver-ripple, peanut-like, phoenix tail-like, nail-like, and thorn-like figures. According to the hand drawn patterns drafted from the BWF, such cells were approximately divided into tracheid, inclusion, and wood ray patterns, and the feature were induced, the tracheid patterns include sliver (A), discontinuous (B), turning zone (C), intersection (D), hook (E), and swirl (F), as well as the pore (G) on the tracheid of cross section; the inclusion patterns included sliver (H) and punctate (I), and sliver inclusion concentration site (J) and punctate inclusion concentration site (K); the wood ray patterns included the crossover region (brick shape) of the radial section (L) and the moniliform of the tangential section (M). The longitudinal tracheid was on both sides of the bright band of the water-ripple figure, which were sliver and discontinuous. The sliver-ripple, phoenix tail-like and thorn-like figures had both cross section of and longitudinal tracheids on the same surface of BFW, and the three bright bands were composed of sliver-like longitudinal tracheid. The bright band was induced by the different reflected degrees of the tracheid pattern, meaning when light was projected on the surface. There were different luster contrasts visually, and the different orientations result in different bright band patterns. The concentric circle pattern of the peanut-like figure was resulted from the inclusion accumulated in some cross section of tracheid, the nail dots of the nail and thorn-like figures were induced by the concentration of a lot of inclusion and as the inclusion color was relatively deep, and dark colored concentric circles or a dot pattern was presented visually. Therefore, this study suggests that the Taiwan cypress BWF patterns are mainly related to the textural variation of the cellular morphology, the arrangement and inclusion of pores on cross section of tracheid, as well as to the amount of inclusion.

AUTHOR CONTRIBUTION

Wei-Chih HUANG performed the experiments and analyzed the data. Ming-Chun JANE assisted the experiments and participated in the design of the study. Noboru FUJIMOTO supervised the works. Han Chien LIN designed this study and wrote the paper. The authors assisted in editing of the manuscript and approved the final version.

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