

SYMMETRY IN EDUCATION

**SYMMETRIC PATTERNS AND
ETHNOMATHEMATICS IN THE SOUTH PACIFIC:
INSPIRING RESEARCH AND HELPING EDUCATION**

Dénes Nagy

Institute of Applied Physics, University of Tsukuba
Tsukuba Science City, 305 Japan
and
Department of Mathematics and Computing Science
University of the South Pacific, P.O. Box 1168, Suva, Fiji

Even a brief look at the decorative arts of the South Pacific island countries makes clear that it is an exciting treasury of symmetric patterns. This fact was also noticed by some mathematicians and anthropologists. Grünbaum and Shephard (1987) in their comprehensive mathematical monograph *Tilings and Patterns* refer to the art of this region and cite the survey by Guiart (1963) entitled *The Arts of the South Pacific*. Another interesting example can be found in the book *Symmetries of Culture: Theory and Practice of Plane Pattern Analysis* by Washburn and Crowe (1988), where the first author is an anthropologist with some mathematical interest, while the second author, symmetrically, a mathematician with some anthropological interest. The jacket of this book is illustrated with a tapa (bark cloth) from Fiji, while the inside of front cover is decorated by another tapa from Samoa. Both of these are discussed briefly in the book (pp. 177 and 258-259).

**1 A POSSIBLE FIJIAN INFLUENCE ON THE MATHEMATICAL
CLASSIFICATION OF BLACK-AND-WHITE SYMMETRIC
PATTERNS BY WOODS**

More recently there is even an interesting speculation by Crowe about a possible Fijian influence on the very front line of symmetry studies in the Western world (cf., Crowe and Nagy, 1991, pp. 80-83; 1992, pp. 132-135 and 139). Before discussing it, we summarize some of the background topics. It is well-known for people interested in the mathematical classification of periodic patterns that there are exactly 7 types of frieze patterns (frieze or strip groups) and 17 types of wallpaper patterns (wallpaper or plane groups). We may also color them periodically, let us say with black and white, as in the case of the chessboard (check

pattern) where the colors of the identical units alternate. Obviously such a coloring leads to a richer set of types. Indeed, there are exactly 17 and 46 types of black-and-white (two-colored) frieze and wallpaper patterns, respectively. (To avoid confusion note that crystallographers usually also include in their lists the degenerate cases, specifically the one-colored patterns, where the second color is not used, and the gray ones, where each unit is colored by both black and white; thus they refer to $17 + 7 + 7 = 31$ frieze patterns and $46 + 17 + 17 = 80$ wallpaper patterns.) The exhaustive lists of all the mathematically possible types of black-and-white (two-colored) frieze and wallpaper patterns were discovered independently

- by a group of German and Swiss crystallographers in 1929 indirectly: Hermann, Weber, Alexander and Herrmann in their subsequent papers in the major crystallographic journal, *Zeitschrift für Kristallographie*, spoke about two-sided patterns, although Weber illustrated the case of wallpapers by one-sided patterns using black and white triangles on a blank background where the colors refer to the two sides,

- by a British textile specialist, Woods (1935-36), explicitly: he dealt with two-colored patterns and illustrated all of the types with black-and-white tilings (mosaics).

While the German-Swiss works are widely known in the literature of mathematical crystallography and of symmetry analysis of decorative arts, there are very few references to the papers by Woods published in a textile journal of small circulation (the few references known to us are due, in chronological order, to Shubnikov, Donnay, Washburn, Grünbaum, Jablan, Opechowski). Crowe deserves great credit for the more recent popularization of Woods's work: he published an article about his life and work and reprinted his black-and-white tilings (Crowe, 1986; cf., Washburn and Crowe, 1988, front and back cover, pp. 5, 9, 63-64, 70-75). Crowe is right when he emphasizes that the papers by Woods, unlike the work of the German-Swiss crystallographers, anticipated the approach based on tilings, which dominated the later works by the Russian crystallographic school (Shubnikov, Belov, and others) and also gained an importance in geometry (Delaunay, Fejes Tóth, Heesch, Grünbaum and Shephard). Note that the importance of the study of tilings in the context of crystallographic symmetries was pioneered by Fedorov's monograph published in German in 1900 and the Russian school continued this tradition. Indeed, while they generalized the classical crystallographic symmetries as black-and-white and multi-colored symmetries, they frequently represented the 2-dimensional cases by colored tilings. May we add that Woods's term "counterchange symmetry" is very similar to Shubnikov's "antisymmetry", i.e., the combination of a geometric symmetry operation with color interchange: the white units are transformed into black ones of identical shape and vice versa (later we will return to the physical importance of this concept). Thus, Woods's terminology is an important step in the direction of later developments. There is no doubt that the approach by Woods has a great importance and, considering the fact that some great pioneers were aware of it, his papers could have some impacts.

Now we should turn to the possible 'Fijian connection'. When Crowe, together with this author, made a field trip in 1990 to Somosomo village, Taveuni island, Cakaudrove (Thakaundrove) province in Fiji, where the so-called Cakaudrove-style

tapa is produced with black-and-white geometric patterns, he noticed a great similarity between the Fijian patterns and Woods illustrations (Fig. 1).

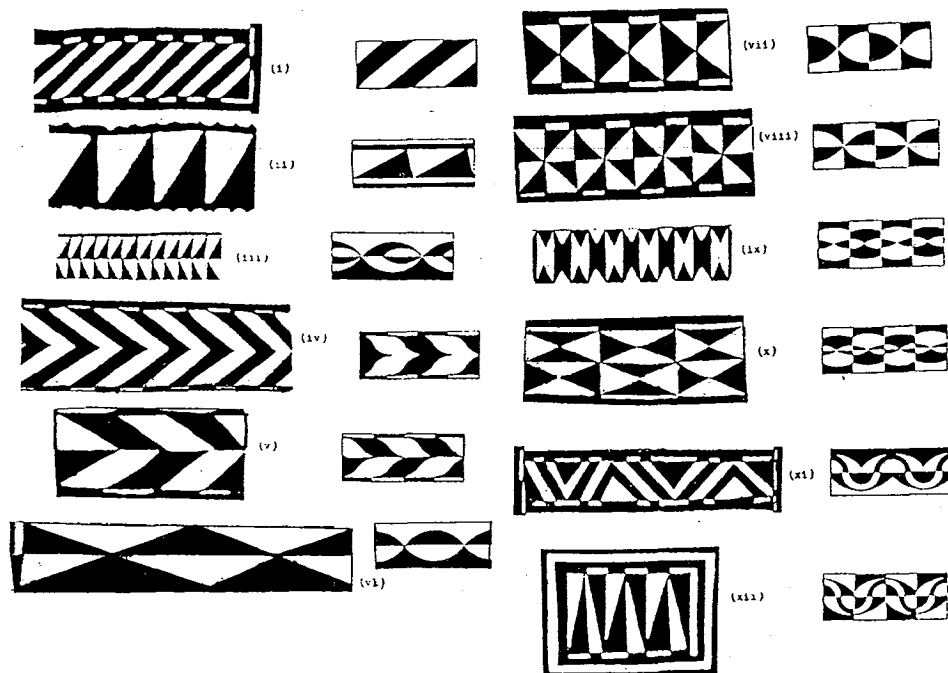


Figure 1: Fijian Cakaudrove-style frieze patterns (left) compared with Wood's tilings (right). Note that here we have 12 pairs: those types that are identified in tapas, partly in modern works, partly in historic collections (e.g., item [v] is in the Pitt Rivers Museum in Oxford). The exhaustive list has 17 types; all of them are presented by Woods (1935, pp. T207-T208), cf., Washburn and Crowe (1988, p. 71). Interestingly there are almost no changes in style if we compare 19th century works kept in foreign museums and contemporary works made by Fine Nailevu (b. 1923) of Somosomo village in the presence of Crowe and this author in 1990 (see here items [iii], [vii], [viii], and [ix]). This invariance of patterns is amazing and present an interesting insight for contemporary researchers into old traditions of the South Pacific. Note that Somosomo village is probably the only settlement in the world located on the international dateline. It is also the traditional residence of the current paramount chief of Fiji, Ratu Sir Penaia Ganilau, and his house is decorated by Fine Nailevu's works. (After Crowe and Nagy, 1991, pp. 80-81; 1992, pp. 132-133).

Incidentally, the most exciting similarity is not the shape of the repeated units (basic motifs), but the composition of the border lines at some of the friezes: a white unit is closed by a thin black segment and vice versa. This method is used frequently in Cakaudrove-style, while Woods – without an actual mathematical need – introduced the same method in some cases of his tilings (cf., Fig. 1, [iv] and [v]; also see two further examples in his exhaustive list). There are also some similarities between typical Cakaudrove-style wallpaper patterns and Woods's tilings; these are based, however, not on the border lines, but on the repeated units (Crowe and Nagy, 1992, pp. 135 and 139). Considering the fact that Woods studied mathematics at Oxford and the Pitt Rivers Museum in the same city has a Cakaudrove-style tapa with the described border-composition (Fig. 1, item [v]), it is

highly possible that Woods had seen it. Moreover the tapa from Fiji could give him an inspiration for his works on classifying black-and-white patterns.

May we add here some further support to this speculation. Tapa is a very interesting form of textile and many comprehensive books on this subject refer to it. Textile fabric is usually defined as cloth made by combining fibers, which could be natural, i.e., of plants, animals, and rarely minerals (as in case of the asbestos), and synthetic. The typical method of producing textiles is weaving (the original Latin word *textilis* means "woven"). There are, however, other ways of interlacing fibers, such as knitting, lacing, netting, and braiding. Last but not least, there are noninterlaced textiles, including very old ones produced by ancient civilizations, which are made of fibrous layers by mechanical pressure, adhesive bonding, or some other ways. While in the earlier mentioned cases the fibers are well oriented, here we see a more or less random order. In case of felt, animal fibers, usually wool, are united by pressure (the term comes from the Latin *filtrum*, filter; also see *pellere*, to beat, to push, cf., the Greek *pelas*, near). Is there any noninterlaced textile where plant fibers are united? The answer is: yes, the tapa. This internationally used term for the South Pacific bark cloth came from the Tahitian language, where it was probably coined by the simple imitation of beating fibrous strips of barks by a wooden beater as "tap-tap-tap" (this form of coining a word is called in linguistics onomatopoeia). The Fijian word for tapa is *masi*, while the frequently used expression *masi kesa* means "tapa [which is] decorated". The source of fibrous strips is usually the inner white layer of the bark of the paper mulberry tree (*Broussonetia papyrifera*, which is used for papermaking in China and Japan). These fibers are not suitable for weaving, but it is easy to unite fibrous strips by beating and thus to make large fabrics. This simple form of making textiles, however, did not spread widely in the world, partly because the obtained cloth is not very strong, partly because the paper mulberry tree and other suitable plants, in large quantity and with strong fibers, are native only in a limited area. An interesting example is the case of the New Zealand Maoris who lost this craft after moving from various tropical islands to their present location with colder climate. In the same time, some of their Polynesian relatives who remained in tropical islands still produce tapas. Note that people often confuse the South Pacific tapa with the Chinese and Japanese handmade paper. Although both of them are made of the bark of the paper mulberry tree, the processes are very different. Papermaking is based on soaking the bark in water, then the obtained pulp is dried and pressed, while the tapa is a textile fabric made of fibrous strips of the bark by beating them together physically, without using a watery treatment. We summarized these basic ideas just to explain why the South Pacific tapa is so important for textile specialists when classifying fabrics according to the method of combining fibers. Woods (1904-1984), who spent most of his career working at the Department of Textile Industries of the University of Leeds and who published many articles in the *Journal of the Textile Institute*, obviously should have had some knowledge about tapa. He could even have seen related publications where Fijian tapas, kept in various Western museums, feature. It is hard to believe that he did not study the black-and-white geometric pattern of the Fijian tapa kept in the Pitt Rivers Museum located very close to his *alma mater* in Oxford. Moreover this could be the link between his early interest in mathematics and the later one in textiles, which connection is also emphasized in the general title of his four-part series of article "The geometrical basis of pattern design" (Woods, 1935-36).

2 DECORATIVE ARTS AND ETHNOMATHEMATICS

How could the South Pacific people develop such a rich set of patterns that excite mathematicians? How could they inspire – if the earlier speculation is correct – new discoveries in mathematics? As a preliminary approach to these questions, may we refer here to the fact that there are two kinds of mathematics:

- an intuitive one developed in the framework of arts and crafts and some other activities of everyday life,
- a scholarly one taught by professional teachers and developed in academic circles.

Obviously the first one is older and also a source of inspiration for the second one. In the beginnings these two were not separated at all. In the ancient Greek culture the tendency for separation was started in about the 6th century, B.C., and it was more or less completed in the time of Euclid in the 4th century B.C. with the birth of an abstract mathematics based on a deductive system. The craftsman's mathematics, however, never disappeared, although it was rarely documented in books (the information was passed from generation to generation during common work), and scholarly mathematics more or less ignored it. More recently, however, the need of applied mathematics, i.e., the mathematical treatment of various practical problems, created new interest in this old tradition. Educators of mathematics made another step by emphasizing the importance of *ethnomathematics*, a term coined by the Brazilian mathematician D'Ambrosio. Indeed, this is a very useful term to refer to the previously mentioned craftsman's mathematics and other mathematics-related activities of everyday life.

We suggest considering the achievements related to South Pacific patterns in the context of ethnomathematics or, more generally, ethnoscience because we also deal here with intuitive crystallographic ideas. The methods of composition in decorative arts obviously need ethnomathematical skills. Usually a basic motif is repeated by using geometrical transformations. In case of painted decorations, the artist often uses a stencil representing the basic motif or some other unit (e.g., the unit cell, i.e., a smallest unit that is suitable to build the entire structure by translations). The artist moves this stencil into newer and newer positions and creates a dense arrangement of equal copies of the motif, which activity usually leads to a periodic order. This process is very similar to crystallization when atoms (ions, or molecules) move in a solution and start an accumulation according to the densest packing. The periodic coloring of patterns is analogous to the tendency in some crystal-structures for the geometrically equivalent units to have different physical properties, e.g., positive versus negative magnetism, which can be represented by black-and-white coloring of the symmetric patterns. The earlier mentioned chessboard (or a check pattern) is a good example for such a black-and-white or two-colored symmetry, which is also called magnetic symmetry. This is the reason that the works by Woods have a great importance in both fields: crystallography and decorative arts. The similar result obtained by the German-Swiss group of crystallographers and by the textile specialist Woods is an exciting symbol of the fact that symmetry groups, including the black-and-white ones, can be approached from both directions: crystallography and decorative arts. In both fields the 'deep structure' of patterns (we adapt here Chomsky's term from linguistics) can be described by symmetry groups. The similar patterns presented by South Pacific artists and Western scientists demonstrate the fact that related results

can be achieved in both ways: ethnomathematics and scholarly mathematics. Although the typical application of ethnomathematical ideas is to help in mathematics education, there are some special cases when the ethnomathematical achievements may inspire research results. The possible Fijian influence on Woods could be such a case. This type of inspiration is very rare, but not unparalleled: the German mathematician Heesch remarked that one of his discoveries was inspired by Islamic patterns, while the Dutch crystallographer MacGillavry discovered the incompleteness of a table of colored symmetries by the fact that she could not identify the symmetry groups of two periodic drawings by the artist Escher. Finally, we should note another similarity between crystallography and decorative arts: there is no perfect symmetry, just a general tendency for symmetry which is interrupted with various imperfectnesses. These may add new and in some cases useful properties to crystal-structures (e.g., semiconductors) and may make the patterns more beautiful (some experimental-psychological studies demonstrate that perfect symmetry is boring and people would prefer small violations of symmetry). Later we will return to this problem.

Let us discuss some general questions in connection with decorative arts. With some simplification it can be claimed that there are two major tendencies in decorative arts:

- the figurative tendency, where the artists try to give a true representation of objects, and they have a strong desire that these objects can be easily recognized,
- the non-figurative tendency, where there is no dominant connection with actual objects of our environment.

We should add immediately that these two tendencies are not strongly separated. Obviously, all figurative representations have some tendency toward geometrical abstraction, while the non-figurative shapes frequently have some associations with actual objects. As an interesting example, we may refer here to the beginnings of Escher's periodic drawings. The Dutch graphic artist first made a careful study of Islam ornaments, specifically Moorish patterns in Spain, and then he tried to substitute for the abstract shapes natural objects such as birds, fishes, frogs, lizards, etc. It is possible that he rediscovered images of animals that could also have inspired the old masters of Moorish patterns when they choose one or another shape. Note that in Southern America both types of patterns were produced in ancient times: 'Escher-like' periodic patterns with animals and abstract geometric ones.

Decorative arts have a special position in culture. This is the only form of the plastic arts (aside from architecture) that is widely practiced everywhere. The above statement is not true for painting and sculpture which have less importance in some cultures. Of course the border between decorative arts and the other two is a bit fuzzy: there are objects that can be considered in both ways. The lack of or limited use of painting and sculpture may have various reasons. In the case of Islam it is frequently although a bit mistakenly emphasized that the figurative representation is totally forbidden, and thus there is no painting and sculpture at all. In the *Koran* there are no direct statements about such a prohibition, just references against idolatry (cf., the *Old Testament's* similar statements). True, the *Hadith*, the collection of traditional sayings of the Prophet, includes quotations that are interpreted as the prohibition of figurative representation. On the other hand, there is a less known, but rich iconographical tradition in Islam (see, e.g., Sir

Thomas Arnold's classical monograph *Painting in Islam: A Study of the Place of Pictorial Art in Muslim Culture*, Oxford: Clarendon Press, 1928). A modern researcher of the subject also concludes that there is practically no period of Islamic culture when figurative representation was suppressed, with the singular exception of the religious sphere – mosques and mausoleums – where idolatry was feared (E. J. Grube, *The World of Islam*, London: Hamlyn, 1966, see pp. 11-12 and dozens of figurative paintings and some sculptures). This also means that the decorative arts still have a special position in Islamic culture as the only form of plastic arts used in religious buildings. The similar tendency in the case of many palaces, where geometric decorations feature, could be an influence of the religious architecture since most of them include small mosques or mausoleums. The Moorish palace in Spain, the Alhambra (14th c.), is frequently mentioned in connection with its rich geometric decorations. However, we cannot say that the figurative representation is totally absent in the Alhambra: there is a fountain at the center of one of its large courts that is supported by 12 stone sculptures of lions (this part of the palace is named the Lion Court).

In some other cultures the limitation of painting and sculpture is connected with other factors. For example, nomadic people would have difficulties in carrying big paintings or heavy sculptures, while fragile miniatures would not survive long periods. In other places the typical materials and tools necessary for painting and sculpture are not easily available. In all of these cultures the decorative arts have a special emphasis: exactly this form of art attracts the majority of artistic creativity of the people. This concentration of creativity, which is less distributed among other forms of plastic arts, could lead to an unusual richness of decorative arts. Although they still may use figurative elements in decorative arts, the lack of stronger traditions in painting and sculpture, as well as of the special skills in making figurative representations (at least among a group of artists-craftsmen), may lead to the preference of abstract geometric motifs. It should be noted, however, that these are not definitely abstract geometric motifs on purpose: the artists frequently associate their motifs with objects of nature and the artificial environment. We discussed such a possibility in case of Moorish motifs adapted by Escher, and now we give here more explicit examples from the South Pacific. A frequently observable swastika-like motif with four black triangles around the center of a white square (see it in Fig. 1, [viii], left-side frieze) would be considered by most people as an abstract geometric shape. It has, however, a widely known name in Tonga referring to a figurative origin: "two birds". The same motif in the Cakaudrove-style of Fiji is called "South wind". (Note that this motif is also frequently used in Africa.) In Cakaudrove all geometric motifs have names and some of them are associated with objects of nature such as *bati-ni-i'a*, teeth of the fish; *bati-ni-vasua*, edge of the *Tridacna* clam [shellfish]; *dogo-lo'i*, bent mangrove; *drau-ni-niu-musu*, leaf of coconut which is broken, *savu-musu*, waterfall which is broken. Other names are associated with artificial objects (e.g., comb, rope, railing of the bridge), while the names of a smaller group refer to functions during the composition (e.g., closing the waterfall pattern); see the full set of the currently used motifs and their names in the paper by Crowe and Nagy (1992, pp. 143-144). However, these names are not widely known any more: many of the Fijians would consider the corresponding motifs as geometric ones. We may observe here a transition from an originally figurative tendency to a non-figurative one: for the artist it is still figurative representation in some sense, while the public consider it

as non-figurative. A similar tendency can be observed in another field, in the case of some complicated Chinese and Japanese characters, where the original ideas represented graphically are not clear even for the well-educated native speakers. These were figurative characters in ancient times, but, during various modifications (simplifications, combinations, etc.), they partly lost this meaning. Although the people know the actual meanings of these characters, they cannot fully explain their graphical origins. The difficulties are also connected with the fact that about 80-90 per cents of the currently taught and widely used 1,800-2,000 characters (the total number is more than 50,000) are not simply pictographic, but phonetic-ideographic or even just phonetic, i.e., only a part of the character has some association directly or indirectly with the actual meaning, while the remaining part, or even the entire unit, refers to another character – and another ‘graphical story’ – with similar pronunciation (cf., the funny English label “4 sale”, which cannot be understood without discussing the word “four” and the similarity of its pronunciation to the preposition “for”). This is the reason that many of the sophisticated characters, which were fully figurative for their creators in early ages, became, at least partly, geometric sets of strokes for modern people. Note that this author believes that the effective teaching of such characters, especially for adult foreigners, should be based on the historic etymology and not on the memorization of geometric systems of strokes. Unfortunately large numbers of textbooks do not follow this rule.

In the case of figurative decorative arts the basic motif is carefully elaborated and thus it has an emphasis. The properties of this motif may strongly limit the arrangement of its repeated copies. For example, if this motif is symmetric, most of the entire pattern follows this symmetry. Often the natural position of the represented object(s) of the basic motif also influences the pattern. For example, if horses are repeated on a wallpaper, it would be strange to have some of them upside-down, although this is not a definite rule (see some drawings by Escher ruled by geometry, not by nature). In the case of non-figurative decorative arts there is less emphasis on the basic motif; its shape is not determined by concrete objects, and the artists have more freedom in arrangement. This is the main reason that the non-figurative decorative arts are rich in symmetries. The Islamic ornamental art is frequently surveyed from the point of view of geometry and symmetry (Abas, Belov, Bourgoin, Bulatov, Critchlow, El-Said and Parman, Gómez at al., Grünbaum at al., Hankin, Lalvani, Makovicky, Müller, Norman, Otto, and others). There are also some similar works about African art (Crowe, Gerdes, Zaslavsky) and Native American art (Campbell, Jernigan, Washburn, Witherspoon, Zaslavsky). Now we would like to add to this list the decorative arts of the South Pacific. Note that in the cases of the Australian aborigines and the New Zealand Maoris there are some important symmetry-related studies (Crowe, Lucich, as well as Donnay, Doyle, Hanson, Knight, respectively).

3 SYMMETRY-RELATED RESEARCH AND A UNIVERSITY COURSE AT THE UNIVERSITY OF THE SOUTH PACIFIC

When this author moved to the University of the South Pacific in 1989 for a long period, one of his main motivations was an interest in symmetric patterns and, more generally, in the ethnomathematics of the region. On one hand, we were glad

to see that all the covers of the mathematics textbooks published by the University of the South Pacific are decorated by Escher's drawings; on the other hand, we were sorry to see that the exciting geometrical patterns of the South Pacific were not used for similar purposes. The most striking examples of symmetric patterns can be seen in case of the tapas, but there are some other fields of arts and crafts, including mat-weaving, string-lashing, tattooing, wood-carving, that present interesting symmetries. (Note that *tattoo* is again an international word that was adapted from Polynesia, cf., Tahitian, Tongan, Samoan *tatau*.) We initiated an ethnomathematical research project at the university. We also understood, however, that this is not only mathematical work, but also anthropological. Many of the fields considered are not yet investigated from the point of view of patterns, the motifs and their names are not yet cataloged, and, surprisingly to us, the university has no department of anthropology or ethnography. In addition to this, some of the traditional crafts are dying out, consequently we are in the last moments to record them. We also realized that there is an international interest in connection with such projects. The joint field trips with Crowe (Department of Mathematics, University of Wisconsin at Madison, U.S.A.) in 1990 led to some new discoveries and also to the joint papers that were already referred to in connection with Woods (Crowe and Nagy, 1991; 1992).

We also developed for third year mathematics students a special topic course: *Symmetries, Patterns, and Polyhedra*. This course was given in the second semester of 1990 (note that the academic year in Fiji, similar to many countries in the Southern Hemisphere, runs from February to December). The required texts included some chapters of Coxeter's already classical book *Introduction to Geometry* (Reprint of the 2nd ed., New York: Wiley, 1989) and of Grünbaum and Shephard's *Tilings and Patterns: An Introduction* (New York: Freeman, 1989). The latter one is the abbreviated teaching edition of their monograph of 1987. More than 20 students enrolled in this class, and this author was glad to see that the ethnomathematical context and some intuitive geometric ideas could give a new inspiration to them. Indeed, in the field of pattern mathematics – this term was coined by Zaslav, an American chemist who authored many fine works on symmetry in Native American design – the people of the South Pacific have a special tradition. This statement is also true in case of the Indian community of the region. The traditional Indian design is very rich in abstract geometric shapes. *Mandalas*, *yantras*, and *chakras* are geometrical diagrams representing various forces and energies of the cosmos in a very abstract form and are also used as meditative tools (see about this topic the article "Symmetry in Hindu philosophy" by Trivedi in this quarterly, Vol. 1, No. 4, pp. 369-386, 1990). Note that the Indian community of the South Pacific kept the oral traditions, rather than the philosophical ones. Thus, most of the Indian students never have heard about the philosophical background of these diagrams, but they know some of the related geometric symbols from their arts and crafts. The average result of this course was better than in the case of the most third year courses in mathematics. We also dealt with research problems and the interest of the students was very encouraging. One of them, Surya Prakash, solved an open problem by discovering a new type of tiling. We hope to continue sometime this form of teaching using ethnomathematical ideas.

Last but not least, we should return to the question of non-perfect symmetries. The artists and craftsmen of the South Pacific do not use sophisticated tools: their

symmetric patterns are far from being perfect structures. For example, we observed that during the decoration of rectangular tapas they do not estimate carefully the space to be filled, which often leads to some extra place at corners that is too small to introduce a full copy of the basic motif. The artists, instead of trying to eliminate these imperfectnesses in the pattern by preliminary measurements, developed rather a special skill of filling such blank places with appropriate elements of the motifs. There are many other fields of arts and crafts where a similar tendency of dissymmetry, i.e., the lack of perfect symmetry, can be observed. In some cases this tendency has a purpose: to create a higher level of balance by ignoring the perfect symmetry. This is a problem that needs more investigation. Here we just mention one field that gained some attention among anthropologists, but has not yet been investigated from the point of view of symmetry. The people of the South Pacific had a special skill in navigation. They were able to migrate to very distant islands. The common canoe in the South Pacific – which surprised the crew of Captain Cook during their voyage – has an outrigger on one side to help the stabilization of the main hull; it is a 'dissymmetric catamaran'. Or, if you wish, this is an intuitive discovery of Pierre Curie's dissymmetry principle...

REFERENCES

- Crowe, D. W. (1986) The mosaic patterns of H. J. Woods, *Computers and Mathematics with Applications*, B12, Nos. 1-2, 407-411; Parallel edition, In: Hargittai, I. ed., *Symmetry: Unifying Human Understanding*, New York: Pergamon Press, 1986, 407-411.
- Crowe, D. W. and Nagy, D. (1991) Cakaudrove patterns, [Lecture given by Crowe], In: *Intuitive Geometry: Colloquia Mathematica Societatis János Bolyai, No. 63*. Amsterdam: Elsevier, 77-83.
- Crowe, D. W. and Nagy, D. (1992) Cakaudrove-style masi kesa of Fiji, *Ars Textrina*, 18, 119-155.
- Grünbaum, B. and Shephard, G. C. (1987) *Tilings and Pattern*, New York: Freeman, xii + 700 pp.; Abbreviated teaching edition, *Tilings and Patterns: An Introduction*, *ibid.*, 1989.
- Guiart, J. (1963) *The Arts of the South Pacific*, New York: Golden Press.
- Washburn, D. K. and Crowe, D. W. (1988) *Symmetries of Culture: Theory and Practice of Plane Pattern Analysis*, Seattle, Wash.: University of Washington Press, x + 299 pp.; Paperback ed., *ibid.*, 1991. [The jacket of the original edition of this book is decorated by a Fijian tapa, while the design on the front and back covers present the 46 two-colored wallpaper patterns by Woods (1936, pp. T312-T316); in case of the paperback version just the Fijian tapa is available on the cover, see Woods's patterns on pp. 74-75.]
- Woods, H. J. (1935-36) The geometrical basis of pattern design: Part 1, Point and line symmetry in simple figures and borders; Part 2, Nets and sateens; Part 3, Geometrical symmetry in plane patterns; Part 4, Counterchange symmetry in plane patterns, *Journal of the Textile Institute: Transactions*, 26, T197-210, T293-308, T341-357, and 27, T305-T320.