WOOD IDENTIFICATION IN THE CAPPELLA PALATINA CEILING (12th CENTURY) IN PALERMO (SICILY, ITALY)

M. Romagnoli¹, M. Sarlatto¹, F. Terranova², E. Bizzarri¹ and S. Cesetti¹

SUMMARY

Anatomical studies were made on the structural and decorative elements of the wooden ceiling of the 12th century Cappella Palatina in Palermo, Sicily, to identify the timbers used, analyse their likely provenance, and discuss the selection criteria used by the builders. One hundred and fifty fragments were examined. *Abies* sp., *Pinus* sp., *Betula* sp., *Populus* sp. and *Fagus sylvatica* were found and all are most probably from Sicily. Some of the *Abies* fragments probably belong to *Abies nebrodensis* as they have exceptionally long tracheids, very tall rays, and abundant crystals. This species was over-logged in the past and now only 29 trees remain in the Madonie Natural Reserve in Sicily. *Abies* and *Pinus* are found in vertical and horizontal painted panels, while *Populus*, *Betula* and *Fagus* were used in smaller parts of the muqarnas (painted niches). The choice of species seems to have been related to original tree size. The large size of the *Abies* boles meant that quarter sawn panels could be used. Sicilian *Abies* was highly valued at that time for its wood quality. Special attention was paid to the problem of distinguishing partly degraded *Abies* and *Cedrus* woods. However, the scalloped torus in some samples displayed ambiguous features and these samples were therefore classified as *Abies/Cedrus*.

*Key words:* *Abies nebrodensis*, *Abies alba*, wood anatomy, Cappella Palatina, Sicily, *Betula*, *Betula aetnensis*, *Cedrus*.

INTRODUCTION

The Cappella Palatina in the city of Palermo (Sicily, Italy) is one of the most famous monuments in the world. The ceiling is a wonderful example of the arabesque style with a very complex architectural structure. It comprises several painted niches (muqarnas) and domes of different shapes and sizes (Fig. 1). The ceiling dates back to the 12th century and was built under the reign of the first Norman king of Sicily, Ruggero II, just after his coronation at Christmas in 1130 AD (Anzelmo 2003-2004).

¹) Department of Technology, Engineering, Science of the Forest and Environment, Faculty of Agriculture, University of Tuscia, Via S. Camillo del Lellis snc, 01100 Viterbo, Italy [E-mail: mroma@unitus.it].

²) Centre for Planning and Restoration - Sicily Region, Via Cristoforo Colombo 52, 90100 Palermo, Italy.
The special architectural style gives rise to some questions regarding the origin of the carpenters who undertook the work and who were possibly Muslims from Eastern Europe or North Africa. Ruggero II also appreciated the Mediterranean culture and often called upon local Palermo craftsmen to carry out his work.

Very little is known about the origin of the wood used in the construction of the ceiling. Tronzo (1997) states that cedar was used, an assumption supported by certain historical sources, even though no scientific evidence exists. *Cedrus libani* could have been imported from the Middle East as it is well known that for centuries the Lebanese extensively traded in timber with other Mediterranean countries such as Egypt (Meiggs 1982). Furthermore *Cedrus atlantica* grows in the Atlas Mountains in Morocco which is very near Sicily. In addition, historical textbooks report that *Cedrus* trees grew in the Sicilian mountains (Mattei 1908).

Many other species found in charcoal remnants of archaeological sites (Heinz et al. 1987) are widespread in the Mediterranean area and they might have been used in the building of the ceiling. For instance, the conifers *Pinus*, *Abies*, *Tetraclinis*, *Cupressus*, and *Juniperus* are present in roofs and ceilings of Mediterranean buildings, in addition to the hardwoods *Acacia*, *Castanea*, *Celtis*, and *Juglans* (Meiggs 1982; Gale & Cutler 2000).

The aim of this paper is to identify the woods used in the building of the Cappella Palatina in Palermo using microscopic analysis. This will help to understand the provenance of the timber and certain aspects of the timber trade in the Mediterranean area in the 12th century. Moreover it will enable us to differentiate wood uses according to their location in the ceiling (vertical painted panels, horizontal painted panels, bands of muqarnas and niches, bands of the cupolas), and according to physical and mechanical requirements. This is also relevant for restoration work which will be carried out under the direction of the Centre of Restoration of Palermo.

**MATERIAL AND METHODS**

The wood elements were catalogued according to their location in the ceiling. The architectural elements in the big cupolas were marked by Roman numerals, the architectural elements of the small cupolas were marked by standard numbering (cf. Fig. 1).

A total of 150 wood fragments were taken from the big and small cupolas from the frames, vertical and horizontal painted panels, and bands and panels in the niches (Table 1). The locations are indicated in Figures 2 and 3.

The fragments were extracted from the panels as carefully as possible using a cutter, chisel, and scalpel. The samples were taken from pieces that had flaked away, from areas hidden by overhangs, and from unpainted parts sticking out from the structural elements.

The sizes of the fragments ranged from 0.1 mm to about 3 mm in width, and several millimetres in length (up to 1 cm). Thin cross, radial, and tangential sections were prepared by hand. Five of the samples suspected to belong to *Abies nebrodensis*, because they had a high frequency of crystals and tall rays, were macerated to investigate their tracheid length according to the Franklin technique (Chaffey 2002) in a mixture of equal parts acetic acid and hydrogen peroxide (20–30% volume).
Figure 1. Map of the ceiling. Big cupolas are identified by roman numbers, small cupolas by Arab numbers (courtesy of the Centre for Planning and Restoration Region Sicily – Palermo).
Figure 2. The location of different elements in the ceiling (I).

Figure 3. The location of different elements in the ceiling (II).
A scanning electron microscope (SEM) was used to distinguish the presence of radial tracheids and cross-field pit types in the most problematic samples. The SEM analysis was carried out on 20 samples, that were compared with Abies and Cedrus specimens from recent collections.

RESULTS

The results of the microscopic identification of the 150 samples are summarised in Table 2.

Table 2. Results of the wood identification. The number of samples suspected to belong to Abies nebrodensis are given in parentheses.

<table>
<thead>
<tr>
<th>Softwoods</th>
<th>Number of samples</th>
<th>Type of ceiling element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abies cf. alba</td>
<td>59</td>
<td>Painted panels, frames</td>
</tr>
<tr>
<td>Abies cf. nebrodensis</td>
<td>(35)</td>
<td>Painted panels, frames</td>
</tr>
<tr>
<td>Pinus sp.</td>
<td>33</td>
<td>Painted panels, frames</td>
</tr>
<tr>
<td>Abies/Cedrus</td>
<td>10</td>
<td>Painted panels, frames</td>
</tr>
<tr>
<td>Hardwoods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Betula</td>
<td>1</td>
<td>Band of niches</td>
</tr>
<tr>
<td>Fagus cf. sylvatica</td>
<td>1</td>
<td>Band of niches</td>
</tr>
<tr>
<td>Populus sp.</td>
<td>11</td>
<td>Band of niches</td>
</tr>
</tbody>
</table>

Softwoods

Softwood species were identified in 137 samples of vertical and horizontal painted panels. The majority of them belong to either Cedrus or Abies wood types (Table 2).

Abies/Cedrus identification

There are not many microscopic wood features to help distinguish between Abies and Cedrus, and sometimes even these can take on varying degrees of importance according to the experience of the individual wood anatomist. The distinguishing features, as reported in the literature, are summarised in Table 3. It is evident that ray height in both Abies and Cedrus covers the same range (3–40 cells). Crystals also can be present in both. As the literature suggested, we paid special attention to the following in all samples:

- the number and type of cross-field pits. Cross-field pits in silver fir are taxodioid in earlywood and piceoid in latewood, whilst taxodioid, piceoid and cupressoid pits can be observed in Cedrus (Venet 1974; Schweingruber 1990) (Fig. 4–6);
- the presence of radial tracheids. They are very rare in Abies (Richter et al. 2004), whilst they are rather common in Cedrus. Radial tracheids are sometimes difficult to identify in very old cedar wood (Gale & Cutler 2000; Cartwright 2001). It is also helpful to observe the end walls of ray parenchyma cells according to the IAWA Committee indications (Richter et al. 2004);
- the scalloped torus (Fig. 7) has long been considered the most important diagnostic feature in Cedrus identification.
Table 3. Microscopic features of *Abies* sp., *Cedrus* sp. and *Abies nebrodensis* as reported in the literature.

<table>
<thead>
<tr>
<th><strong>Abies sp.</strong></th>
<th><strong>Cedrus sp.</strong></th>
<th><strong>Abies nebrodensis</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ray cells</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) toothed, horizontal walls thick, smooth to dentate, walls of the marginal cells thin</td>
<td>a) thick wall, nodular</td>
<td></td>
</tr>
<tr>
<td>f) nodular tangential walls</td>
<td></td>
<td>g) uniseriate, frequently biseriate</td>
</tr>
<tr>
<td><strong>Bordered pits in tracheids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a,d) uniseriate, rarely biseriate</td>
<td>a,h) very rarely biseriate</td>
<td></td>
</tr>
<tr>
<td>j) uniseriate</td>
<td>j,k) uniseriate and biseriate</td>
<td></td>
</tr>
<tr>
<td><strong>Tori of bordered pits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a,c,d,j) normal</td>
<td>a,b,c,d,e,j,k) scalloped</td>
<td></td>
</tr>
<tr>
<td><strong>Cross-field pits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a,d,f) 2–4 pits taxodioid in earlywood, piceoid in latewood</td>
<td>a) 1–4–6 pits, taxodioid in earlywood, cupressoid and piceoid in latewood</td>
<td>g) 1–2 up to 3 taxodioid in earlywood, piceoid in latewood</td>
</tr>
<tr>
<td>c) 2–3 taxodioid</td>
<td>b,d) 2–6 taxodioid</td>
<td></td>
</tr>
<tr>
<td>j) 1–2(–3) taxodioid and piceoid pits</td>
<td>h) 2–4 taxodioid pits in earlywood and piceoid in latewood</td>
<td></td>
</tr>
<tr>
<td><strong>Radial tracheids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a,b,f,d,j) absent</td>
<td>a,b,e,h) present with thin wall cell</td>
<td></td>
</tr>
<tr>
<td>d) few radial tracheids</td>
<td></td>
<td>g) absent</td>
</tr>
<tr>
<td>i,j,k) present</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ray height</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a,f) 15–25 (40) cells</td>
<td>a) 10–25 (3–35) cells</td>
<td>g) up to 87 cells</td>
</tr>
<tr>
<td>b) 2–20 (30) cells</td>
<td>h) (1) 3–20 (35) cells</td>
<td></td>
</tr>
<tr>
<td>g) up to 45 cells</td>
<td>i) up to 45 cells</td>
<td></td>
</tr>
<tr>
<td>j) 1–12, up to 40 cells</td>
<td>j) (1)–12–18 (32) cells</td>
<td></td>
</tr>
<tr>
<td><strong>Other microscopic features</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) traumatic resin canals, terminal parenchyma and prismatic crystal rare</td>
<td>a,e) often traumatic resin canals and prismatic crystals</td>
<td>g) crystals in tracheids, starch grains</td>
</tr>
<tr>
<td>f) crystals common</td>
<td>h,j) axial traumatic resin ducts</td>
<td></td>
</tr>
<tr>
<td>j) rays containing crystals</td>
<td>j) crystals in ray cells</td>
<td></td>
</tr>
<tr>
<td></td>
<td>k) crystals in marginal ray cells, resin ducts</td>
<td></td>
</tr>
</tbody>
</table>

References:

- Schweingruber 1990
- Giordano 1984
- Nardi Berti 1993
- Jacquiot 1955
- Cartwright 2001
- Hather 2000
- Arena 1960
- Fahn *et al.* 1986
- Venet 1974
- Esteban 2002
- Babos & Vörös 2001
Most samples studied microscopically showed taxodioid pits, and normal, non-scaled tori. However, deteriorated pits occasionally gave the impression of a scalloped torus as already stated also by Gale and Cutler (2000), Cartwright (2001), and Richter et al. (2004).

Radial traumatic resin canals were not found in the microscopic slides and this observation was confirmed by macroscopic analysis. Twenty samples were analysed by the SEM, and the presence of taxodioid pits in earlywood was again confirmed (Fig. 4),...
along with piceoid pits in the latewood (Fig. 5) in all the observed samples. SEM analysis also resolved the doubts on the tracheid pits, which showed smooth torus margins (Fig. 8), although they sometimes appear laciniate due to wood degradation (Fig. 9) and as confirmed in the light microscopic analysis. No radial tracheids were observed in the samples.

These wood anatomical features allowed us to classify 69% of the 150 samples as belonging to the genus *Abies*. In 10 of these samples the shape of the torus is not clear. It therefore would seem more prudent to classify these samples as *Abies/Cedrus* even if no radial tracheid was found by light microscopic analysis.
Figure 8. Radial surface (SEM) of an *Abies* sample from the Cappella Palatina. Smooth torus margin in tracheid pit.

Figure 9. Radial surface (SEM) of an *Abies* sample from the Cappella Palatina. Torus in tracheid pit with margin laciniate from degradation.

In order to try to assess the *Abies* species that the fragments belong to, the incidence of crystals in the rays was used as a starting point.

*Abies nebrodensis* hypothesis

Microscopic analysis does not unequivocally identify the woody fragments in Cappella Palatina as *Abies alba*. In fact, the difficulty in distinguishing among the different species of *Abies* by anatomical wood features is well known and there are no reliable diagnostic features at the species level. Crystals are present in some *Abies* species
(A. alba, A. numidica and A. pinsapo), and occasionally present in the tracheids also (A. numidica and A. nordmaniana). Other species show axial parenchyma (A. cephalonica, A. numidica and A. pinsapo). Furthermore there are differences in the number (1–5) and type of pits (piceoid in A. pinsapo, A. cephalonica, A. cilicica), in the cross-fields, and in the height of the rays (up to 40 cells in A. alba, up to 15 cells in the other species) (Esteban 2002).

Because we are in Sicily we have to consider that they may belong to Abies nebrodensis. This species is now reduced to a relic population of only 29 trees in the Natural Reserve of Madonie (Messeri 1958; Morandini et al. 1994; Aussenac 2002; Gabbrielli 2003), but was once a much more common timber tree.

The microscopic wood characteristics of the Sicilian fir, Abies nebrodensis, were described by Arena (1959, 1960) (Table 3). This is the only microscopic description of the wood of this species and it was carried out on one wood block from one tree only that grows in a private garden in Palermo.

The most relevant microscopic features described by Arena are located in the rays, which are very high (up to 87 cells). This feature is found only in Abies nebrodensis as noted by comparing Esteban’s description of the other Mediterranean species (2002). Many crystals and starch grains can be found in the rays, and the transverse walls of the parenchyma cells have many pits. Crystals in axial tracheids may even be found. However, these characteristics are not restricted to Abies nebrodensis (cf. Table 3).

A lot of crystals are present in 34 fragments of the Cappella Palatina ceiling. They are almost all in marginal parenchyma cells and up to 2–3 crystals can be counted in each cell.

The ray height in seven samples was over 40 cells, and up to 67 cells were counted in two samples. In these samples the tracheid length in earlywood ranged from 3937

Figure 10. Radial surface (SEM). Window-like pits in cross-field and dentate ray tracheid walls, identified as *Pinus* sp.
to 4900 µm (mean value 4611 µm), whilst in latewood the length ranged from 3987 to 5000 µm (mean value 4710 µm). Medium ring tracheid length was 4654 µm for ring widths ranging from 800 to 3100 µm. This mean value is higher than that found by Arena (1960) who found a tracheid length of 4030 µm in earlywood, and 4305 µm in latewood in one wood sample of Abies nebrodensis for ring widths ranging from 560 to 1860 µm.

In 35 samples (Table 2) the anatomical wood characteristics of Abies nebrodensis, as described by Arena, were observed, but the anatomical features that lead to an interpretation of Abies nebrodensis do not always appear together in the same sample.

Pinus sp.

Pinus species were found in 22% of the samples. Resin canals with thin-walled epithelial cells, 1–2 pits per window-like cross-field and dentate ray tracheids were observed in the specimens (Fig. 10). These features belong to either P. nigra or P. sylvestris.

As already known, it is not possible to distinguish between these species on the basis of their wood anatomy (Schweingruber 1990).

Hardwoods

Eleven samples of Populus sp. were found in the wooden bands of the niches and cupolas (Fig. 2 & 3, Table 2). Diffuse-porous wood, uniseriate homogeneous parenchymatic rays, simple vessel perforations, and large vessel-ray pits were observed.

Fagus sylvatica was identified in one sample due to its very large rays, diffuse-porous wood, simple perforations, occasional scalariform plates, homogeneous and heterogeneous rays, and absence of spiral thickening.

One sample of Betula species was identified by its diffuse-porous wood, 3–4 cells wide rays, scalariform perforation plates, and absence of spiral thickening.

Provenance

Microscopic analysis helped us to understand the provenance of the woods. The fact that cedars were mentioned in historical textbooks on the Cappella Palatina ceiling is not surprising. Cedrus was widely exported in the Mediterranean area, and was much preferred to the Abies species due to its aromatic quality and resistance to insect and fungal attack. Vast amounts were used in different artefacts (Meiggs 1982; Gale & Cutler 2000), however, there is some doubt about the availability of Cedrus in the centuries leading up to the medieval period.

In the Mediterranean area many different species of Abies are present (Quezel 1985; Bernetti 1995; Aussenac 2002), but Sicily is often cited for the quality of its Abies wood as it is very suitable for buildings. In his account of the great shipbuilding programme of Dionysius (400 BC), Diodorus the Sicilian says that in 750 BC Mount Etna was full of excellent firs and pines (Meiggs 1982). Some historians (Lombardi in Ventura 2001) say that Sicily was conquered by the Arabs for its valuable timber. It seems that
deforestation in Sicily began in that period and was due to intensive cutting for shipbuilding. There was even a famous shipyard in Palermo at that time. Later, Leone Diacono, a tenth century historian, wrote of Sicily as an “uneven and wooded isle”, and Edrisi describes Sicily as full of woods and water in the Norman Period (Gabrieli & Scerrato 1979; Ventura 2001).

Furthermore in the Norman period wood was considered to be a strategic commodity, and different Popes declared an embargo on selling wood to Muslim countries that needed it for their armies. The fact that this embargo existed makes it unlikely that wood was imported into Sicily from any Muslim area (Zorić 2006).

In addition to Abies, the Pinus species and especially P. nigra are very widespread in the Mediterranean basin and P. nigra subsp. laricio is still very typical in Sicily. Sicilian Pinus wood was highly valued in the past, especially for ship building (Meiggs 1982). It seems unlikely that silver fir was imported.

Populus sp. is also a hardwood that is common in Sicily and since it is not a highly valued wood, it seems unlikely that it was imported. Fagus and Betula are also found in Sicily. The Betula wood may belong to Betula aetnensis Rafin. which is an endemic species located on Mount Etna.

Selection criteria and wood properties

Abies is a light wood (specific density about 450 kg/m³ at 12% moisture content), with low shrinkage (according to Giordano 1984, volumetric shrinkage is about 10.7%), and good dimensional stability. It is suitable for painting and gluing. It is often found in painted panels in Italy (Corona 1994a; Romagnoli et al. 2003; Fioravanti & Galotta 2005), and in roofs and ceilings in Sicily (Copani et al. 2006; Romagnoli et al. 2006). Pinus wood is heavier (specific density about 550 kg/m³ at 12% moisture content) but Pinus laricio in particular has a high resin content which can interfere with paints. However, Pinus has been used for painted wood panels, especially in Spain (Marette 1961) and Portugal (Corona 1994b). It has a higher shrinkage than Abies (11.2% volumetric shrinkage), and a lower deformation index (2.3 in Abies alba and 1.8 in Pinus sylvestris).

Poplar, beech and birch have been found in the bands of the mugarnas. Poplar is the most popular, but all these species are suitable for panel painting.

Poplar merits mention because it is the most widely used species in Italy for painted panels and especially from the medieval period up to recent times. Poplar trees can get very big, but its timber can be frequently defective and contain big knots and reaction wood. In the complex architecture of the Cappella Palatina this could produce uncontrollable wood movement.

The width of the painted panels of the Cappella Palatina is about 30 cm and many of them have been cut radially (quarter sawn). In order to get these sizes, the trees must have been at least 60 cm in diameter. Poplar trees of these dimensions can be found, but they are often characterised by grain inclination and reaction wood.
CONCLUSION

According to historical texts, the Cappella Palatina ceiling in Palermo was reputed to have been constructed with Cedrus wood. However, most timber fragments identified belong to Abies sp. The distinction of Abies and Cedrus was difficult to make at times, in particular when examining the scalloped torus, and for this reason it was considered more prudent to classify 10 samples as Abies/Cedrus. The torus of the Cedrus samples sometimes does not show scalloping or scalloping is obscured in ancient wood whilst the Abies samples may appear scalloped due to decay. Anyway, other typical Cedrus features such as radial tracheids, cupressoid pits in the cross-fields, or traumatic resin canals were not observed in any of the samples examined.

Both Abies alba and Abies nebrodensis were present in the past in Sicily (Biondi & Raimondo 1980). Abies alba has managed to survive over the centuries whereas the more ecologically sensitive Abies nebrodensis has not, and its near disappearance is possibly due to overlogging in the past (Zorič 2006). Since an extensive study of the microscopic characteristics of Abies nebrodensis on living trees cannot be carried out presently, the wood specimens of the Cappella Palatina cannot definitively be determined as belonging to Abies nebrodensis. However, anatomical features described in the literature as typical for this species was found in 35 of the analysed samples from the Cappella Palatina. The diagnostic value of these features, such as the high crystal content of the rays, high number of starch grains, and great tracheid length remain to be confirmed.

The identification of the wood seems to narrow its provenance to the Mount Etna region for at least part of what was used in the ceiling. In fact Abies, Pinus, Fagus, Populus and the endemic Betula aetnensis live in this region.

The hypothesis that the wood originates from Mount Etna could be supported by historical studies (Ventura 2001) on the Palermo shipyard that report that most logs passing through the shipyard came from Mount Etna, as well as from “Cefalù, Caronia, and Nicosia”.

The study carried out on the ceiling of Cappella Palatina has highlighted the problems of diagnosing wood, and could be applied in the evaluation of artefacts in the Mediterranean area.

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IAWA Journal Supplement 3

Woods of the Eocene Nut Beds Flora, Clarno Formation, Oregon, USA

by E.A. Wheeler and S.R. Manchester

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2002. 188 pp., illus. — ISBN 90-71236-52-8
Paperback — Price: USD or EUR 45.00 (30.00 for members of IAWA)*

This book presents a comprehensive study of the middle Eocene fossil woods of the Nut Beds Flora, Clarno Formation, Oregon, USA, dated at about 44 million years old, a time of global warmth. The Nut Beds locality is one of the most diverse fossil plant assemblages of the northern hemisphere, and contains fruits, seeds, woods, and leaves.

The Nut Beds wood assemblage is the most diverse fossil wood assemblage ever described from a single locality. Full descriptions, with illustrations, of 66 genera and 76 species of fossil wood are presented. Thirty-eight genera are assigned to family, an additional seven can only be assigned to order. The affinities of the woods are primarily with extant plants of eastern/southeastern Asia, not with western North America. Some of the exquisitely preserved Nut Beds woods represent the oldest known occurrence of wood similar to that of an extant genus, e.g., Acer, Alangium, Betula, and Meliosma. New information on wood anatomical groups with extant Meliosma is presented.

The Nut Beds wood assemblage is compared to the Nut Beds fruit and seed assemblage and to other Eocene wood assemblages of the northern hemisphere. The Nut Beds woods provide a dataset useful for systematic, evolutionary, biogeographic, and paleoecologic studies, and complement the data already provided by the rich co-occurring fruit and seed assemblage.

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