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Interaction between Science, Technology and Architecture in Timber Construction

Clara Bertolini Cestari, Tanja Marzi,
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Éducation et culture
Culture 2000

COMPAGNIA
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HERITAGE SERIES

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ISBN : 2-84299-344-6

Les contaminants biologiques des biens culturels
Éditeur scientifique : Marie-France Roquebert
ISBN : 2-84299-322-5

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Proceedings of Culture 2000 Project: Finnish and Portuguese Actions
Editors: Clara Bertolini Cestari, José Amorim Faria, Anu Soikkeli
ISBN : 2-84299-419-1

Interaction between Science, Technology and Architecture in Timber Construction
Proceedings of culture 2000 Project : Greek, Norwegian and Italian Actions
Editors: Clara Bertolini Cestari, Tanja Marzi, Elisabeth Seip, Panos Touliatos
ISBN : 2-84299-605-4

Elsevier SAS, 23, rue Linois, 75724 Paris cedex 15
http://france.elsevier.com
Réalisation éditoriale : Nathalie Morellato
Conception graphique : Kolam
Illustration de couverture : Experimental sauna by Alvar Aalto, Muuratsalo-Finland, photo Tanja Marzi

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Imprimé Krips B.V., Meppel, Pays-Bas
Dépôt légal : décembre 2004

ISBN : 2-84299-605-4
ISSN : 1625-1199

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The 6th century timber roof of St Catherine Sinai: identification, research and proposals for its protection

Petros Koufopoulos, Marina Myriantheos-Koufopoulou,
Costas Zambas, Amerimni Galanou, Ioanna Dogani

1. A survey

It became generally known to modern research, through the publication by Forsyth and Weitzmann [1]of the American Mission of the 1960s to Sinai, that the 6th century St Catherine's Monastery Church, located in the southern part of the Sinai Peninsula in Egypt, retains almost intact its original roof (Figs. 1, 2, 3, 4, 5, Fig. 1, see colour plates page 618).

In 2000 and 2001 there had been the opportunity to carry out a thorough measured survey of the façades and the roofs of this important 6th century basilica. The survey along with the conservation studies [2] were the first step towards the creation of a comprehensive conservation scheme for the restoration of the lead sheathed roof of the church that was preserved until 1911 when it was replaced by modern corrugated galvanized iron sheets.

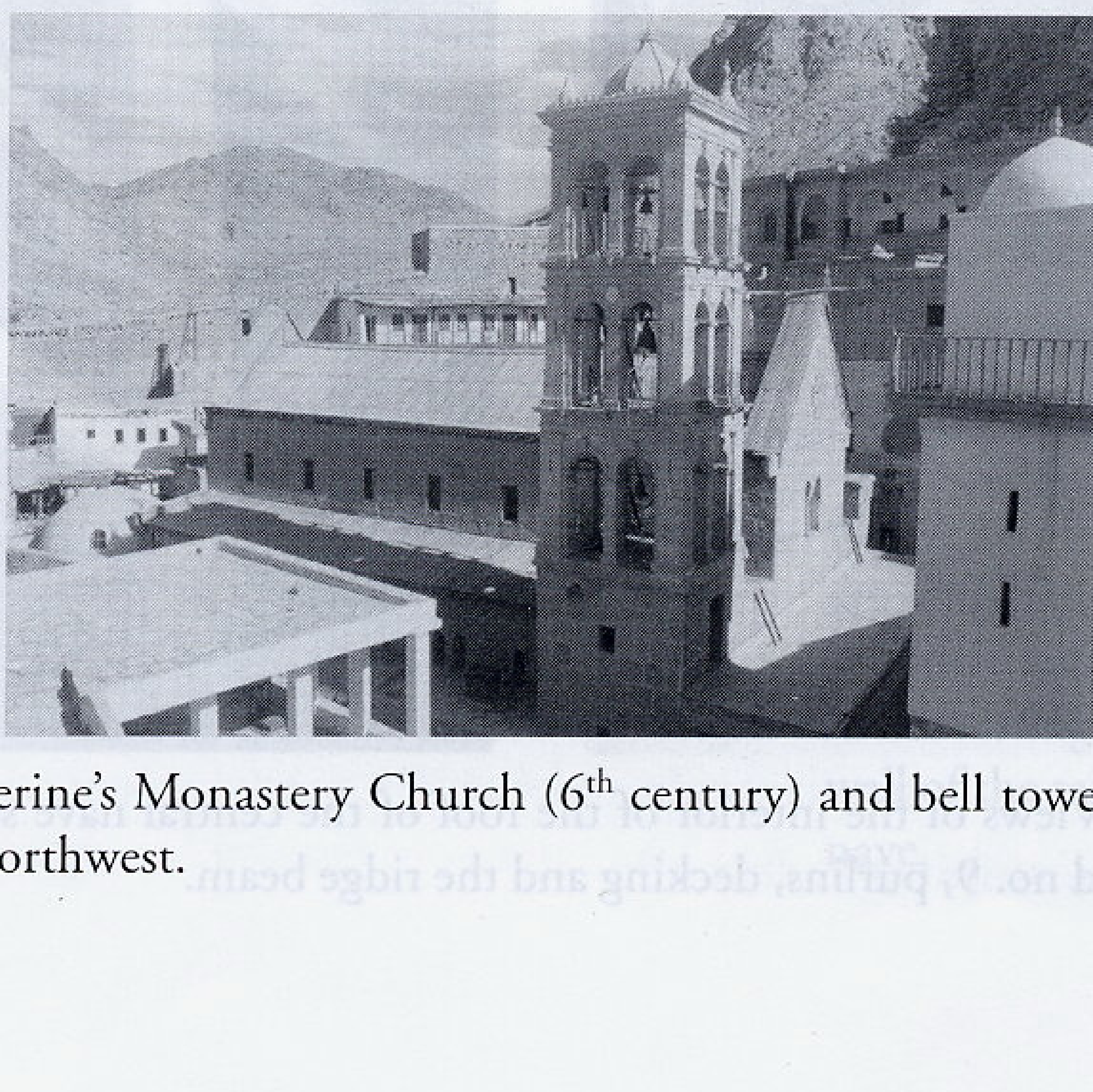


Fig. 1. St Catherine's Monastery Church (6th century) and bell tower (19th century) seen from the northwest.

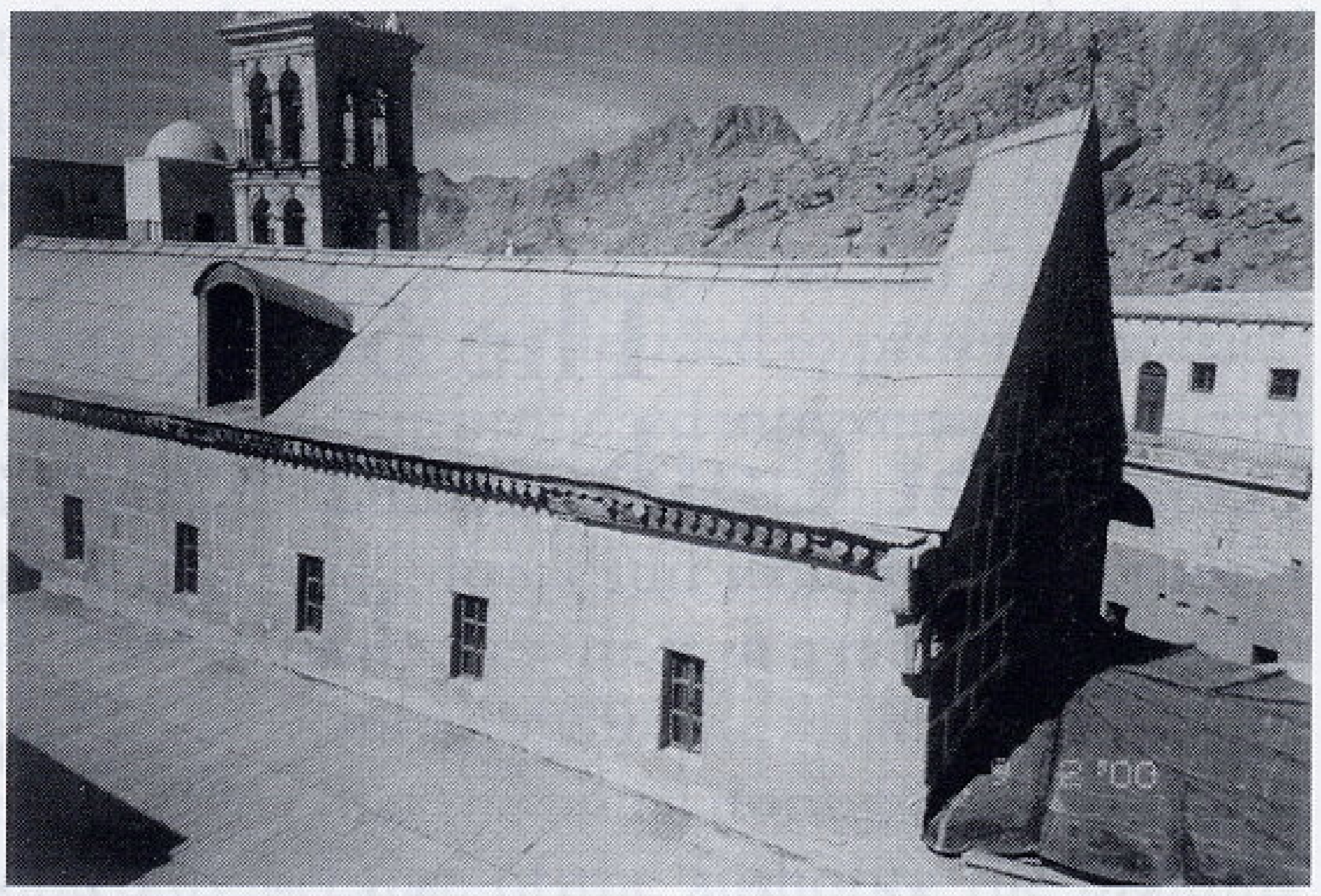


Fig. 2. General view of the church complex from the southeast. 18th century lead sheets are preserved at the apse, whereas the rest is covered with modern corrugated iron sheets (1911).

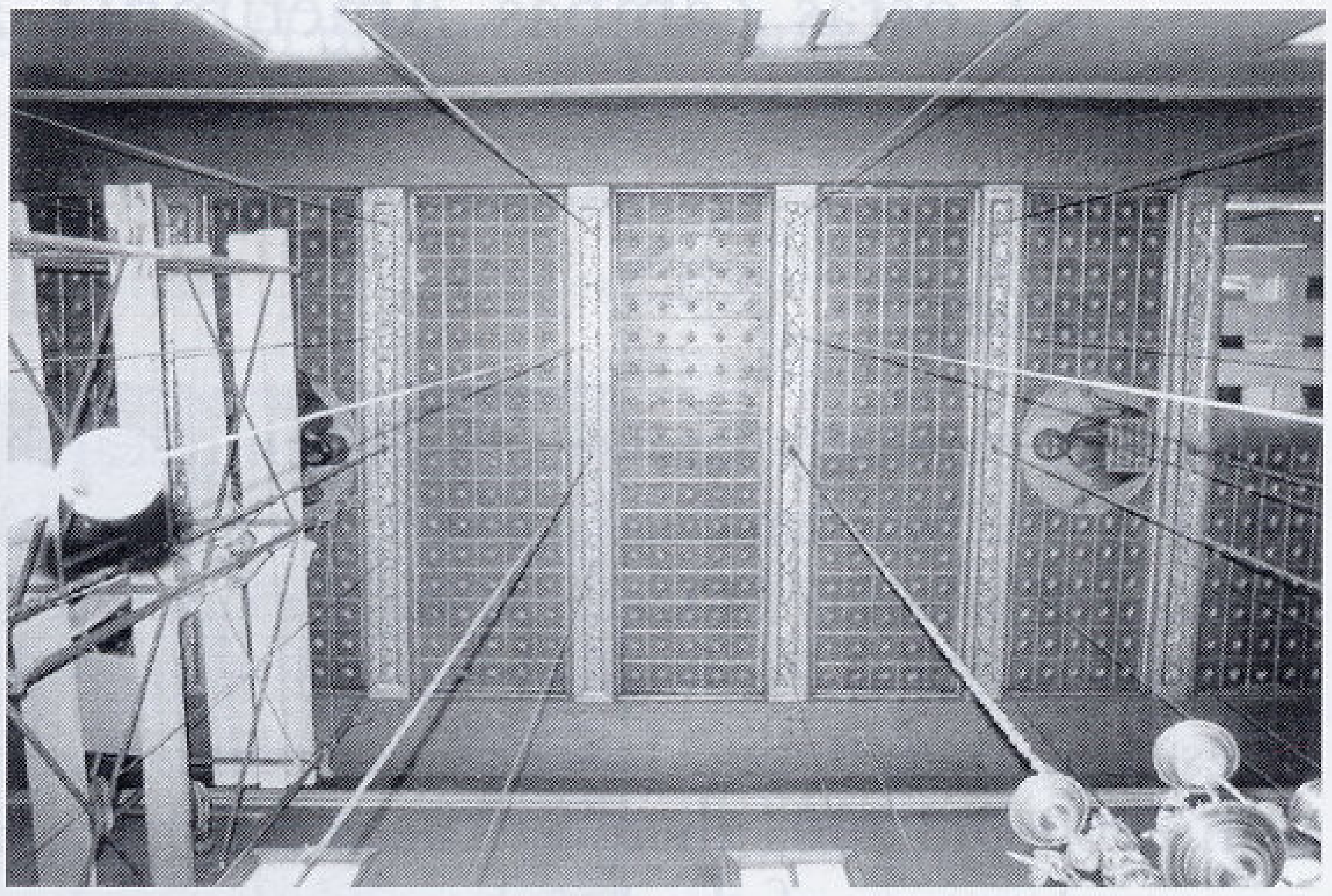
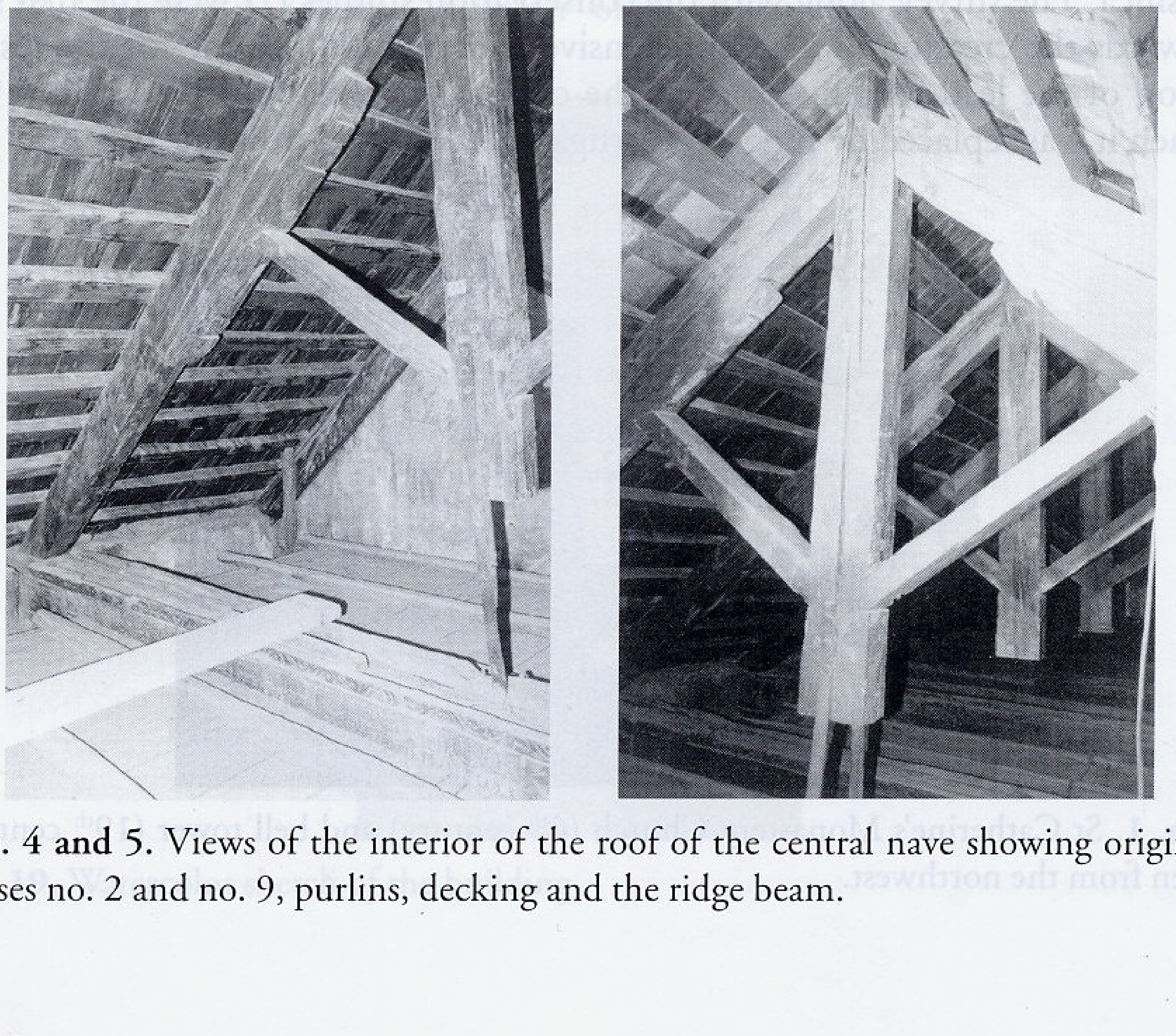


Fig. 3. Original wooden tie-beams (6th century) and posterior ceiling panels (18th century) that hide the roof trusses, as seen from the central nave of the basilica.



Figs. 4 and 5. Views of the interior of the roof of the central nave showing original trusses no. 2 and no. 9, purlins, decking and the ridge beam.

During our survey, scaffolding was used to give access to particular distant areas that the previous scholars could not approach, and to inspect aspects of great importance such as the 6th century mosaic [2b]. Especially for the interior of the roof of the raised central nave the conservators of our team were invited to map the wood species on the new detailed measured drawings, as the first identification step for the creation of a firm basis for dating (Figs. 6, 7, 8, 9, 10, Figs. 9, 10 see colour plates page 618). The research was extended to the northern aisle of the basilica that also retains its original wooden roof structure.

The remaining original roofs of the building complex of the church that used to cover the area of pastoforia and the Chapel of the Burning Bush in the east and all the side chapels were later totally reconstructed, mainly with medieval vaults. The two towers and the narthex located at the west retain the form but not the original materials of their terraces.

Modern research on the identification of the earlier building phases of the church plan was quite successfully done by Grossmann [3]. But it was the Greek architect Ch. Katsibinis [4] who gave the first reconstruction drawing for the roof of the raised central nave, its lost wooden cornice and the lead

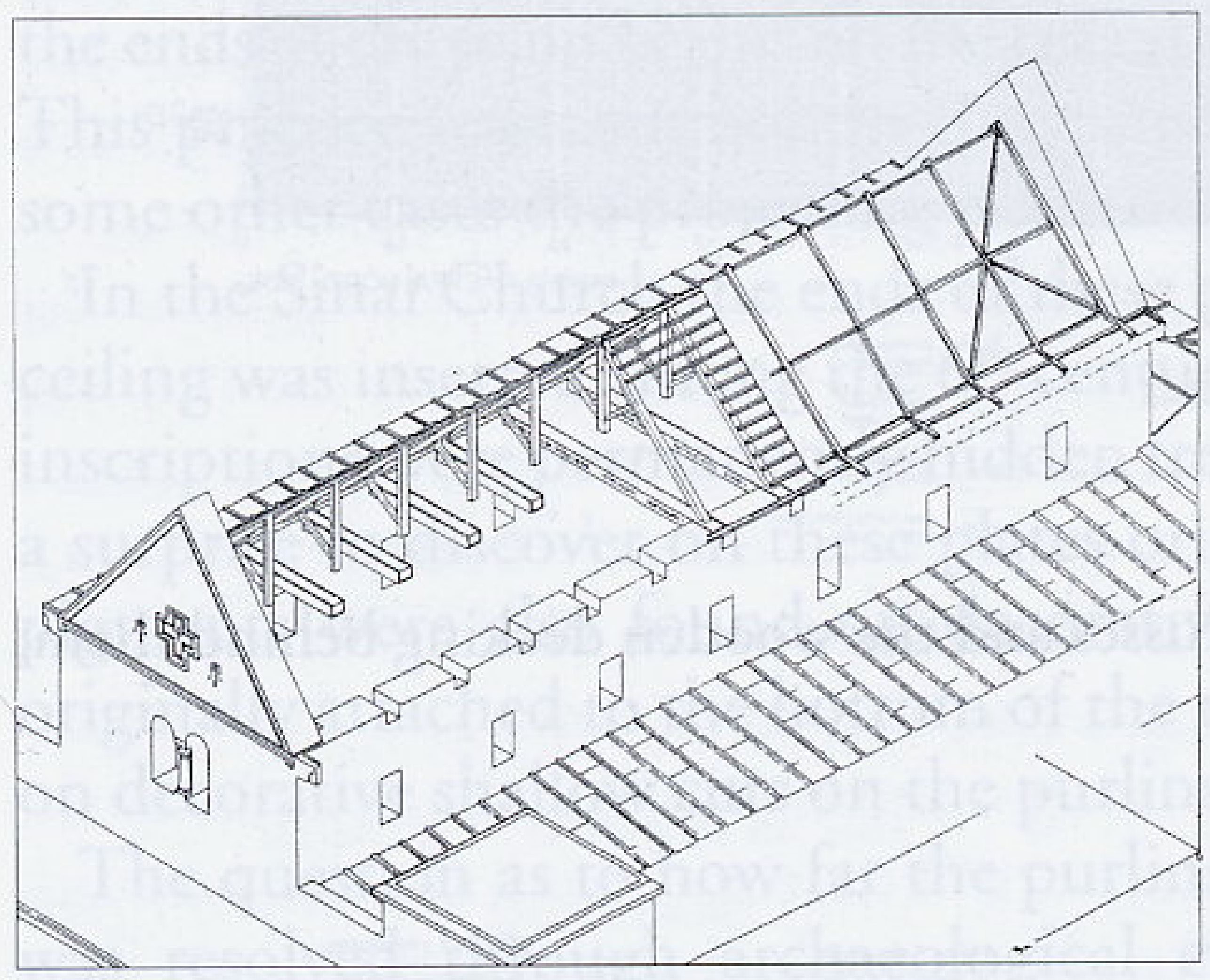


Fig. 6. Isometric drawing of the raised central nave of St Catherine's Monastery Church indicating the proposed independent stainless-steel frame that would carry lead sheets load directly to the walls.

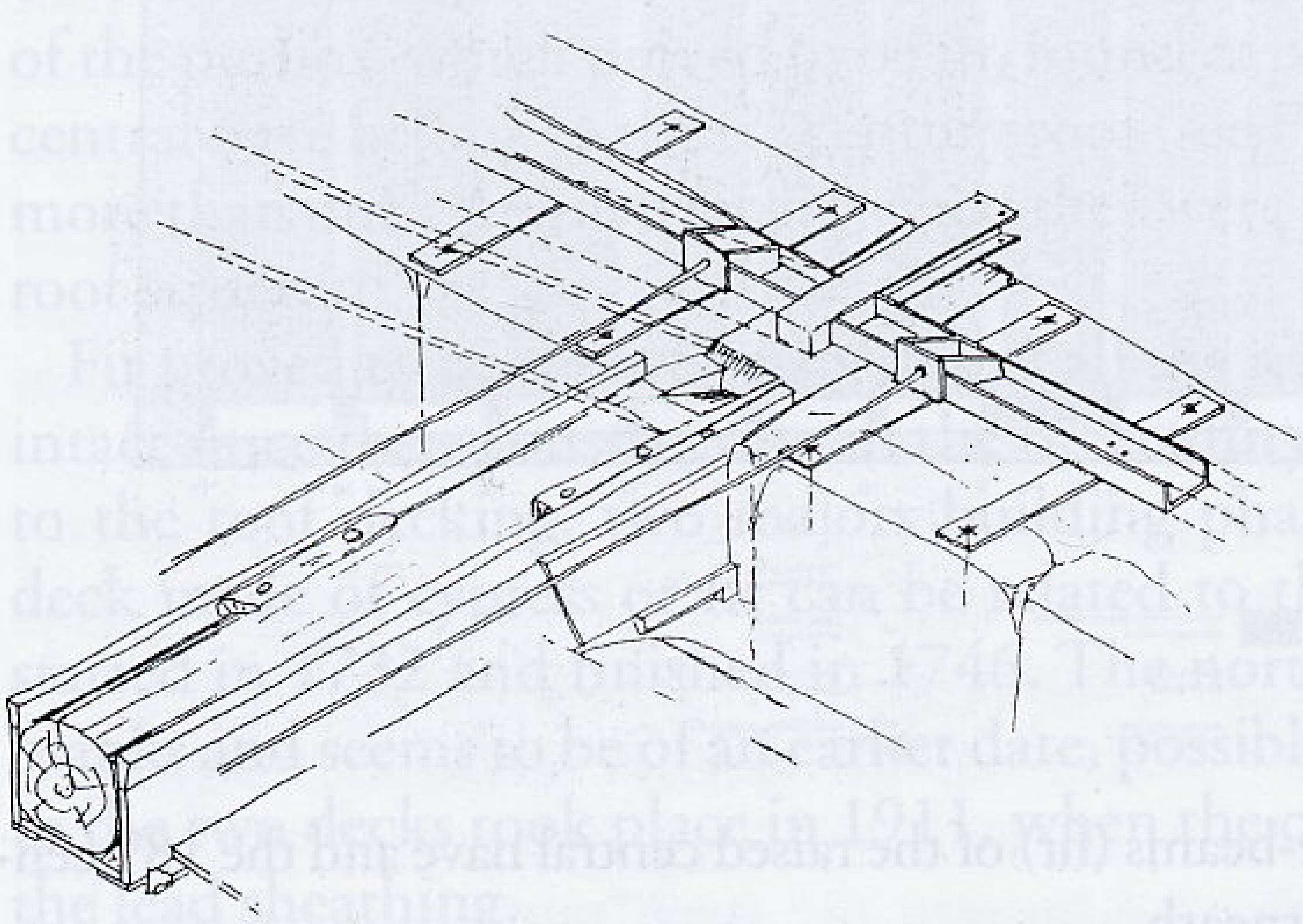


Fig. 7. Isometric sketch drawing indicating the proposed stainless-steel frame resting on the lateral wall of the raised central nave.

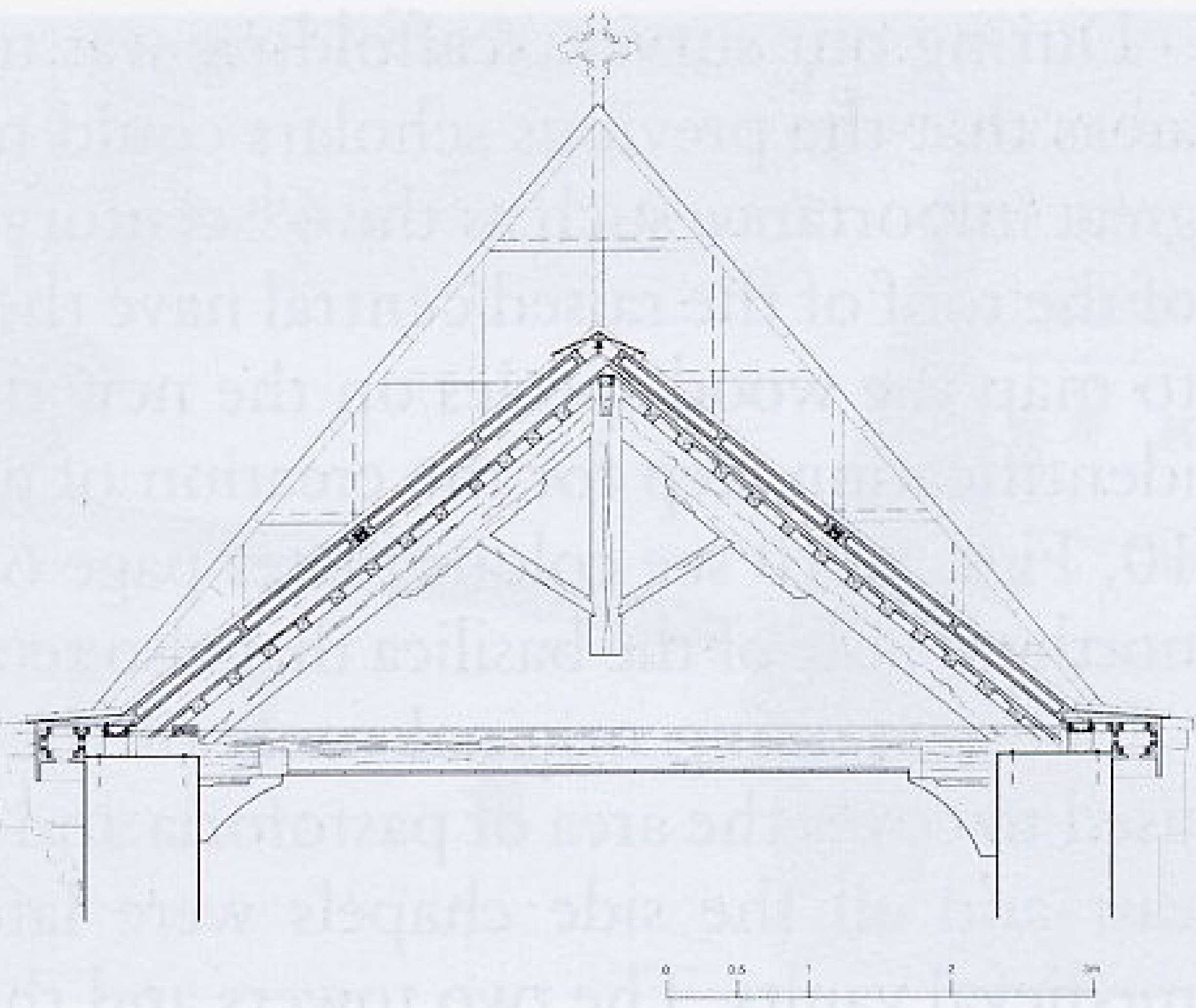


Fig. 8. Cross section of the proposed stainless-steel frame for the central roof of the Monastery's Church.

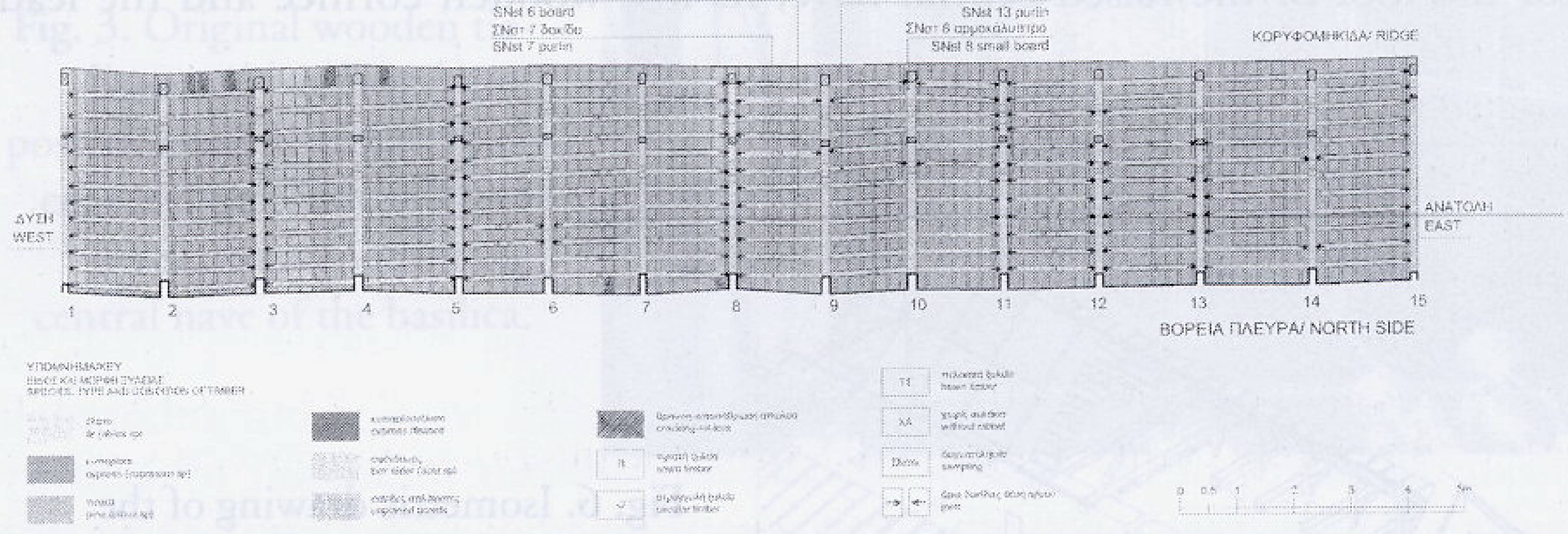


Fig. 9. Elevation of rafters of the main trusses and the wooden decking behind them.

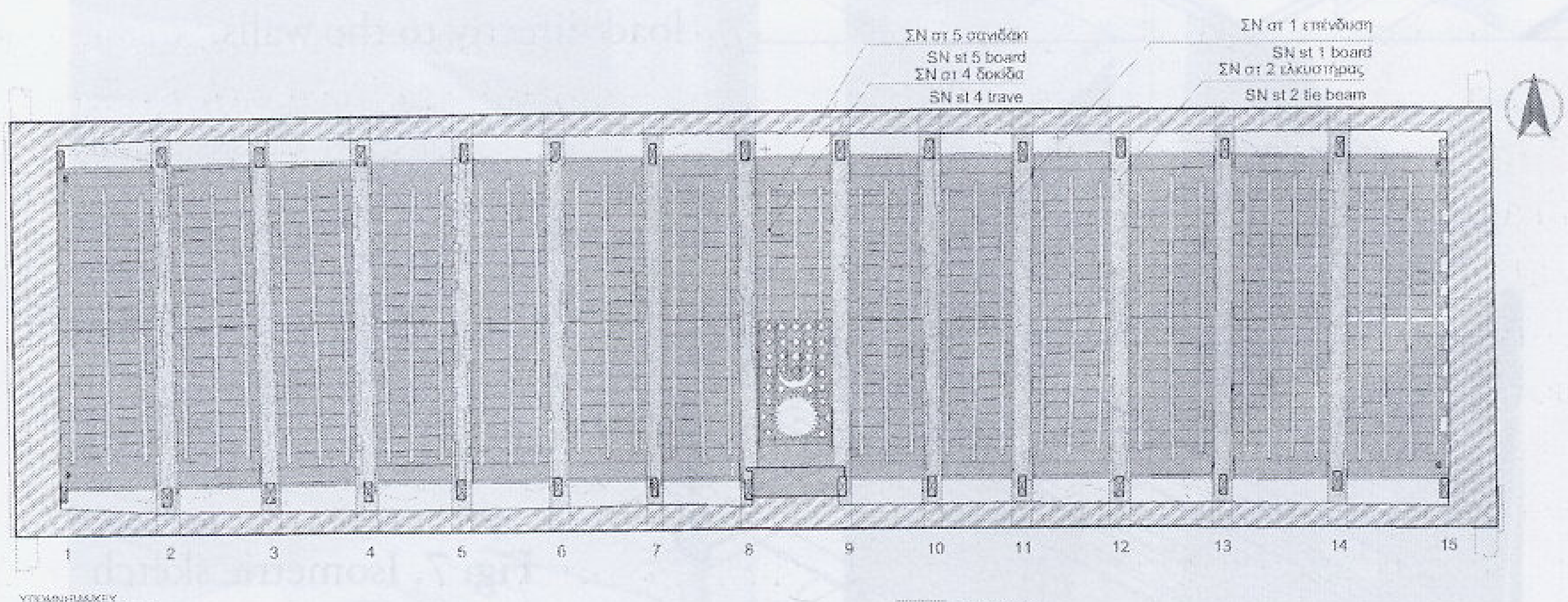


Fig. 10. Plan of the 6th century tie-beams (fir) of the raised central nave and the 18th century wooden ceiling (pine) underneath.

roof. He also supported the authenticity of the main trusses with sampling and laboratory tests.

In terms of new archaeological evidence for the roof, the architects of the team managed to record, read and date some written letters that had been previously discovered but not read by Katsibinis [5]. It is actually an inscription written on the interior face of the east pediment. We identified it as original 6th century by comparison to the lettering of the well-known 6th century chased inscriptions on three main tie-beams (nos. 2, 8, 9) of the church. One commemorates the founder of the Monastery, the Byzantine Emperor Justinian; the second inscription, the late Empress Theodora; and the third, the architect Stephen and his family from Aila. The newly read inscription has obvious similarities with that of the second truss and mentions for a second time the architect deacon Stephen. It is remarkable that the text was written before the construction of the last eastern truss, maybe because they did not mean to put this truss in this position from the very beginning. The drawing of the new inscription has been recently published [6].

More evidence to improve Katsibinis' reconstruction drawing of the lower part of the main beams that was originally visible from the nave came with the discovery of beam-bearing plates (pieces of thick planks resting underneath the ends of the main beams on the lateral walls and projecting into the nave) [7]. This practice was common in contemporary early Christian basilicas, and in some other cases the projecting elements were made of stone.

In the Sinai Church the ends of these plates were cut when the 18th century ceiling was inserted among the 6th century tie-beams. Since then all plates and inscriptions were permanently hidden from the interior of the nave. It was also a surprise to discover on these plates original red and blue pigments. Similar pigments were also found on decorative square planks with chased crosses originally attached to the bottom of the main posts. Pigments were also found on decorative shallow cuts on the purlins.

The question as to how far the purlins are authentic ancient timber or not was resolved through archaeological evidence in the south tower, where purlins bearing the same pigments were incorporated on undoubtedly 6th century lintels. With this remark it is more than certain that the larger part of the purlins, which proved to be fir, found at present on the roof of the raised central nave belong to the 6th century roof (see Fig. 9). Obviously they suffered more than one extensive repair, when they were removed and reattached to the roof structure.

Fir proved to be the wood species of all the trusses, which are also preserved intact since their construction in the 6th century (see Figs. 9 and 10). Coming to the roof decking, two majors building phases were recorded. The south deck made of cypress or fir can be related to the repair of the lead roof that started in 1732 and finished in 1746. The north deck is totally made of pine planks and seems to be of an earlier date, possibly medieval. Small-scale repairs to the two decks took place in 1911, when the corrugated iron sheets replaced the lead sheathing.

From the 18th century lead sheathing only the lead sheets on the apse bearing two cast inscriptions and the present skylight at the south side are still preserved in situ (see Fig. 2). The original (most probably wooden) cornice was destroyed everywhere around the church. We studied the reconstruction of the original 6th century form of the single-pitched roof of the northern aisle in drawings.

For the rest of the roofs of the large church complex, it was easily found that major repairs were done. For example, the roof covering of the towers of the west side was repaired in the past but retains its original form with horizontal terraces even today. Inside both towers the original intermediate timber floor is still preserved. Of special interest is the graphic reconstruction of the initial covering of pastoforia probably with horizontal terraces that were supported by a large main beam in the middle, secondary beams and deck. It seems highly possible that similar horizontal terraces were covering the side chapels along the aisles. Possibly during the Byzantine period their roofs were totally reconstructed with domes over the pastoforia. Barrel and semi-barrel vaults were also constructed at the side chapels.

Apart from the identification of what is authentic or not in the superstructure of this important monument, the aim of the architectural study is the replacement of the corrugated iron sheets with lead as it was originally and used to be till the year 1911. This would obviously improve the basilica aesthetically and provide a better waterproofing to the ancient timber below.

In the same context G. Tampone [8] had also published a proposal for the restoration of the lead roof in 1986, which seems to load directly the original timber frame of the roof with the new lead sheaths load. It was proposed to use U-shaped aluminum sections that were going to be directly bolted on the original trusses to improve their stiffness. The addition of a new deck above the existing one including thermal insulation was also proposed.

Although the calculations have shown that the roof is capable of taking the load of the lead, we have concluded that a different approach should be studied and, if appropriate, be applied. On the other hand the inspection of the apse mosaic with the conservator R. Nardi, who was invited by the Monastery in 2001, and C. Zambas, the civil engineer of the team, revealed a crack along the east wall, serious deformation of the eastern side of the apse (about 12 cm) and the detachment of the pediment walls from the side walls of the central raised nave.

We obviously need then to reinforce both the timber and the stone structure. So we are in the process of developing the design of an independent stainless-steel frame, which is presented here in principle (see Figs. 6, 7, 8). It should be placed above the existing ancient roof, which should be left intact, resting only on the long walls. A small gap for ventilation will be left between the old deck and the new one. The steel frame is meant to carry the additional loads of the new lead sheets and the insulation. At the same time, it would be designed to perform as a binding-ring beam for the walls and the pediments. Very fine tie-rods will link the two long walls and prevent the steel frame from expanding.

British firms have been consulted for the production of sand-cast hand-made lead sheets in order to have the original form and texture (about 5 mm thick). This will be a simplified version of the 18th century lead sheathing of the apse.

2. Conservation study

The scope of the conservation study focused on the roof included (a) the inspection of the structure, (b) mapping on measured drawings of materials and condition (see Figs. 9 and 10), (c) systematic sampling of characteristic timber members, and (d) collection of environmental data (temperature/humidity) as they relate to material pathology. Complementary data were collected on the dimensions and form of the timber (hewn, sawn or natural) and the hardware, in order to propose remedial treatments in accordance with internationally established principles and guidelines.

2.1. Timber

A total of 20 wood samples were taken from beams, posts, purlins and boards in order to identify the wood species used for each architectural member. The analysis was done at the National Institute for Agricultural Research by Dr. K. Paraskevopoulou. These results are in keeping with previous analyses by Ch. Katsimbinis, Professor G. Tampone, Campa and by Nili Liphschitz and Yoav Waisel of Tel Aviv University [9]. Cypress, fir and pine are not indigenous to the area; they must have been imported. Cypresses, however, may have been brought to the site by the first hermits or pilgrims to the area, as is the case with the olive tree.

2.2. Hardware

A total of six samples of nails were taken by our team and analyzed by Prof. G. Varoufakis, who specializes in archaeometallurgy. Analysis included observations on the metallographic microscope, and in carbon with sclerometry. Based on his observations, only one sample is deemed to be 6th century.

2.3. Polychromy

From the cases of polychromy that were observed two samples were taken. The first was from the cover of a truss king post, which would have been visible from below before the addition of the ceiling and which constitutes an original element. The other sample was taken from the wooden molding that supports the ceiling, added in the 18th century. The analyses included microscopic observation, Raman spectrography and Fourier Transform Infrared (FTIR) spectography.

For the first sample, it was observed that the pigments (red and yellow-ochre) were applied directly on the wooden surface. It is possible that the organic binder was gum Arabic, which comes from acacia plants. For the 18th century samples from the peripheral molding it was observed that a significantly thick preparation layer was used before the application of the pigments. This layer is constituted of gypsum and protein glue as a binder. It seems that sandarac resin was used as a varnish.

The *trusses* and their principal members are constructed in timber heartwood, as seen in the posts where the center of the log is always evident. Heartwood of conifers was known from antiquity to be more durable; it is that part of the wood which contains the extracts that are toxic to microorganisms and has lower humidity than sapwood.

All truss elements that date back to the 6^{th} century are made of fir (posts, beams, principal rafter and struts). Fir by nature is quite durable and less prone to warping than other species. It was, however, noted that select struts that were longitudinally fractured were repaired using different hardware than the authentic one, and those elements were made of cypress. Most of these elements bore saw marks.

The *purlins* are also made of fir for the most part – seven are made of cypress and do not bear rabbets. They may, however, have been recycled during the various remodeling campaigns based on their condition. This has been determined by the fact that some of the cuts made for insertions on the rafters have shifted in various directions and are now visible. Furthermore, on the northeast corner of the roof they do not match the holes made for insertions in the wall but have shifted upwards. Approximately half of them are hewn and half sawn, but this data did not constitute conclusive evidence of the dating of remodeling campaigns.

The *boards* on the north side, which are made of pine, are narrow and evenly shaped (21–23 cm wide and 0.8–1 cm thick). The joint covers on this side are also constructed of pine and they feature rabbets (6 cm wide and 0.8–1 cm thick). The construction as a whole is carefully done in an orderly manner. The boards on the south side are wider and are made of either cypress or fir (39–40 cm wide and 3 cm thick). The joint covers here are constructed of box elder and do not feature rabbets. Generally speaking, the construction is less orderly, and the joint covers have been displaced or are missing.

The following observations were made on the 18^{th} century ceiling: the *ceiling boards,* which are made of pine, seem to be of similar dimensions as the boards used on the north side of the roof. The crossbeams used to attach them are made of fir. They are of similar, slightly smaller dimensions – approximately half the thickness – of the roof beams. A bold hypothesis would be that the timber elements (boards) used in this ceiling were originally roof elements, as dimensions are very similar and so are the wood species.

2.4. Condition assessment

The overall good preservation of the roof structure is mostly due to the desert climate, which may have significant temperature fluctuations but has rather stable relative humidity (RH). Measurements both in winter and summer yielded a range of 25–30 % RH.

Structurally speaking, no members of the roof are in danger of collapse though fracturing is quite common, especially on the trusses. The only element that is quite damaged is the ridge beam, which is fractured and deformed along its entire length. Most of the damage is due to the indiscriminate use of nails for the shoring of the modern galvanized iron sheeting. Other causes of damage:

- *Fracture* must be also attributed to the desiccation of the wood, most probably due to the drying stresses early on in construction. Thermal degradation may also be responsible as prolonged exposure to high temperatures (55–60°C) causes depolymerization of hemicellulose and cellulose, which may result in loss of strength. As was previously mentioned, fracturing is also due to the hardware used in various remodeling campaigns as is evident on the ridge.
- *Biodeterioration* in the form of white rot was observed in very few cases.
- *Rotting* was observed at the ends of roof boards adjacent to areas with water infiltration, as is the case around the opening on the south side.
- *Insect attack* (woodworm) was observed in one case.
- *Deposits of dust* are evident on all horizontal members. Ironically this must be due to the satisfactory air circulation in the roof.

3. Proposal for the conservation of ancient timber roof

- Large-scale interventions are not necessitated by the condition of the timber elements. Most proposed interventions in the list below have to do with aesthetics and aim at the preservation of the status quo.
- Repair of the ridge will necessitate the temporary removal of the deck and beams of the south that are in better condition.
- Removal of haphazardly placed nails for the shoring of the galvanized corrugated iron sheathing.
- Replacement of select boards (deteriorated or unplanted).
- Realignment and replacement of missing joint covers.
- Dry cleaning of dust deposits with vacuum system and brushes.
- Design of an adequate natural ventilation system.
- Fire protection system.

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1 Forsyth G. H., K.Weitzmann, *The Monastery of St Catherine on Mt Sinai, The Church and Fortress of Justinian,* Plates (Ann Arbor, The University of Michigan) 1973.
2 The conservation study for the Church was jointly funded by the Monastery and the Getty Grant Program. We would like to express our gratitude to his Eminence Archbishop Damianos and the Holy Synaxis of the Monastery of St Catherine for their trust and cooperation. We also would like to mention the important participation in the project of the Sacristan of the Monastery fr. Daniel. The architect Cosmas Skaris who also took part in the mission coordinated most of the digitization of the measured drawings.

2b The conservators Roberto Nardi and Chiara Zizola carried out on inspection of the apse mosaic, along with Petros Konfopoulos during February 2001.

3 Grossmann P., "Architecture", Sinai, *The treasures of the Monastery of St Catherine*, Ekdotike Athenon, 1990, pp. 34-36.

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7 Op. cit. where a reconstruction drawing of the roof trusses as were seen from the interior was published.

8 Tampone G., *Il restauro delle strutture di legno*, Editore Ulrico Hoepli Milano, 1996, pp. 76-78, 369 where a cross section of the truss with the proposed intervention is published.

9 Liphschitz Nill, Waisel Yoan, "Dendroarchaeological Investigations in Israel, St Catherine's Monastery in Southern Sinai", *Israel Exploration Journal*, Volume 26, 1976, pp. 40-44, Pls. 7-8.1