14th Congress of the International Society of Photogrammetry
Hamburg 1980
Commission V
Workilg group V-1

PHOTOGRAMMETRIC SURVEY OF THE DOME OF THE ORTHODOX BAPTISTERY OF RAVENNA

Presented paper:

P. Canella*, G. Lombardini**, G. Vianelli*
* Regione Emilia Romagna
** Istituto di Topografia, Geodesia e Geofisica Mineraria Università degli Studi di Bologna.

Abstract:The purpose of this study on one hand is to locate, through orthophotographic plotting,the successive operations of restoration carried out on the mosaic decorations of the structures of the dome vault;on the other hand is to quantify,through zenithal orthophotographic plotting added to the analitycal one,the deformations induced in the vault by the subsidence to which Ravenna territory is subject.

Introduction: Graphical representation of a monument or building is necessairly accomplished using orthographic projections onto appropriately chosen planes in space of the surfaces which make-up the object to be drawn. It is evident that the choice of these planes is particularly important in order that the resulting representation of the building or monument will be the best possible. A good drawing must accurateli show not only the formal appearance of the structure but also the quality of the building materials as well as the construction characteristics used in building it. As known, current procedures employed for making a survey of a building by the traditional direct method involve the use of the meter, plumb line, level, square, etc. and are based on the assumption that the various lines and surfaces which delineate the structure are geometrically well defined lines and surfaces which have taken well defined positions in space. It is most improbable that a drawing made fron this type of survey will show absences of parallelism, asymmetries and possible irregularities in the structure, factors which are especially important for the conservation of a building or monument. In contrast, these problems in obtaining an accurate representation of a building or monument are easily resolved using the photogrammetric method. The camera registers every little detail and nuance on film with precision and objectivity, thus the work of art being surveyed can be studied and explored in the smallest detail in order to have a correct basis for comparison or more important to have available all the information necessary to determine the best methods of conservation.

GENERAL CONSIDERATIONS

The Orthodox Baptistery in Ravenna, also known as the "Neoniano" derived from Bishop Neone who commissioned its construction, dates from the V century and thus preceeds the true Byzantine period even though the Byzantine influence is clearly visable. The Baptistery is a structure formed by an octagonal base of around 4.5 m per side. Four of the sides are occupied, for a third of their remaining heoght, by covered niches protruding the outer part of the base. Three chapels and the present baptisimal font are located in these niches. The original baptisimal font is located at the center of the building and consists of an octagonal sculptered marble basin whose height is about 1.1 m and whose external dimensions are about 1.5 m on each side. One of the sides forms an elevated pulpit. From the time of its construction until today, the Baptistery, just as all the other buildings and mounuments of the same period in Ravenna, has sunk nearly 3 meters into the ground because of the phenomenon of subsidence in Ravenna and the surrounding area. Thus, the present height of nearly 12 m, measured from the ground to the eaves of the Baptistery, represents only about 4/5 of its total height. The present floor is the third floor constructed during the period of subsidence of the building and it is already about 50 cm below ground level. The present study was made possible by the cooperation of the Istituto Di Topografia, Geodesia e Geofisica Mineraria of the Facoltà di Ingegneria, Università di Bologna and the Regione Emilia-Romagna. The objective of this study was twofold: 1) to determine and quantify the deformations of the dome for the purpose of measuring the extent of subsidence relative to the various structures which make-up the building and 2) to make it possible for those studying the mosaics to recogonize the successive restorations of the dome's mosaic decorations using the stereoscopic pictures obtained with our photogrammetric methods in addition to 8 color orthophotoprints.

PHOTOGRAMMETRIC PROCEDURES USED IN TAKING THE PHOTOGRAPHS FOR THE ZENITAL SURVEY OF THE DOME

Initially, in order to obtain the data relative to the subsidence and thus the deformation of the structure, two series of stereoscopic zenital photographs were taken: the first series was made using a Veroplast monocamera, film size 13x18 cm, Matr.N. 00209 made by the Officine Galileo in Florence and owned by the Istituto di Topografia, Geodesia e Geofisica Mineraria. The second series was made using a Wild P 31 monocamera, film size 4x5 inches, Matr.n. 55015 made by the Officine Wild in Heerbrug and loaned to us by the Wild company in Milan. However, these photographs proved to be insufficient and did not completely cover the dome. Better results were obtained using only the Galileo camera to make 4 scans (perpendicular to each other) comprised of 3 photographs each. The pictures for these scans were taken with the camera mounted on a dolly; the center of the objective was maintained at about 30 cm from the floor in order to insure that the area covered was as large as possible. Care was taken not to decrease excessively the basic ratio, expressed in percent, between the maximum and average from the objective of the camera to the surface being photographed since a too low ratio was not compatible with the instrument being used to make the orthographic projections for the stereo plotting. The following ratio resulted : $\frac{4666}{9821} = 47\%$.

Even though this percentage is high, the large overlapping assured that the stereoscopic character of the photographs was not lost at the time of oreparing the models. For the Veroplast camera, the sensitive materials used were black and white glass plates (REPLICA 23 AGFA-GEVAERT , film size 13x18 cm, 16 ASA) as well as flat film (KODAK-VERICOLOR, negative and KODAK-EKTACROME, positive, for artificial light and 80 ASA) applied onto glass plates using bioadhesive paper (HEATSEAL FILM). For the Wild camera, we used flat film (KODAK-VERICOLOR for artificial light, film size 4x5 inches) mounted in appropriate frames.

The definitive zenital photographs, taken in 4 scans comprised of 3 photographs each, covered the area of a square whose sides were an average of 6.64 m long consisted of a total of 8 stereograms. The positions used for taking the pictures resulted in a basic ratio which varied from $\frac{3.32}{11.09} = 30\%$ to $\frac{3.32}{6.42} = 50\%$ giving an overlapping which varied from 70% to 50%.

In order to have uniform and constant illumination the pictures were taken at night with artificial light from four 1000 W iodime lamps having a color temperature of 3500°K. A diaphragm ratio of 1:12 was used; exposure time was 15 sec for the black and white film and 9 sec for both the positive and negative color film. The caracteristics of these scans are given in fig. 1 e 2.

PHOTOGRAMMETRIC PROCEDURES USED IN TAKING THE PHOTOGRAPHS FOR THE SURVEY OF THE SEGMENTS OF THE DOME

For this survey, the dome was divided into 8 segments, each one overlapping its weight bearing arch. The Wild camera was used to photograph each segment separately. Two photographs were takers of each segment from positions at each and of a line H.20 m long and diametrically opposed to the segment Fig.3 . The camera was positioned about 1.90 m from the floor with its optical axis inclined at 45° to the horizontal (Fig.4). As can be seen from Figure 9, this inclination was sufficient to cover the entire surface of each segment from the central keystone to the capital of the weight bearing arch.

DETERMINATION OF THE POINTS OF REFERENCE

Points of reference for each individual stereogram were taken in order to draw the optical models in the desired positions on the floor of the Baptistery which formed a regular octagon along with the center of this octagon; these points were marked with small brass cones inserted directly in the pavement. The survey of all these distances was made, a total of 24 measurements forming an optimum network having 9 elements more than the minimum 15 required (Table 1). The results reported in Table 8 were obtained from the calculations and compensations of the network using the usual method of indirect observations. The computer program for the calculations supplied not only the compensated coordinates of the vertices (Table 2-3) which were then translated to avoid negative values but also their average quadratic error and if desired the elements for determining the ellipses of error (Fig. 5). As expected; because of the small distances involved, method of marking the reference points and the use of a previously calibrated steel cord, the maximum errors in measurement were of the order of ± 2 mm. A precise geometric leveling of the vertices of the octagon (points 2-3-4-5-6-7-8-9) was done from the central position (point 1) (Table 4-5-6). The level used was a ZEISS Ni1 belonging to the Istituto di Topografia,Geodesia e Geofisica Mineraria. Using the external vertices of these trilateral sections, 8 base lines more or less parallel to the individual segments of the dome were located. Teodolites (DK M 2 A with a periscopic eyapiace made by the KERN company) ware positioned at each end of the base line and the method of frontal intersections was used to determine the reference points on each individual segement necessary for the stereo plotting. Characteristic points already present on the dome were chosen as the reference points. The axes on which the spacial reference points, calculated in this way, were located were then rotated 45° around the x-axis in order to obtain the projection of the reference points for each segment onto a plane parallel to a cord connecting the vertex and the base of the segment.

STEREOPLOTTING PROCEDURES USING THE ORTHOGRAPHIC PROJECTOR

The stereoplotting operation using an orthographic projector was done with the collaboration of the Compagnia Generale Riprese Aeree of Parma who allowed us to use their excellent stereoplotter, a PLANIMAT Zeiss Matr.n.119222 and their orthographic projector, a GIGAS GZI - Zeiss Matr.n.121229. This particular equipment was chosen because during the stereoplotting it was necessary to explore the optical model at a very large scale. The PLANIMAT stereoplotter seemed particularly suitable in order to assure the best approximations obtainable for the numerical determinations to be made directly on the photographs printed on glass. The relative orientation of the photographs was done using a cimbination optical-mechanical procedure taking into consideration seven points of the photograph, six of which were in order to draw the optical models in the desired positions on the floor of the Baptistery which formed a regular octagon along with the center of this octagon; these points were marked with small brass cones inserted directly in the pavement. The survey of all these distances was made, a total of 24 measurements forming an optimum network having 9 elements more than the minimum 15 required (Table 1). The results reported in Table 8 were obtained from the calculations and compensations of the network using the usual method of indirect observations. The computer program for the calculations supplied not only the compensated coordinates of the vertices (Table 2-3) which were then translated to avoid negative values but also their average quadratic error and if desired the elements for determining the ellipses of error (Fig. 5). As expected; because of the small distances involved, method of marking the reference points and the use of a previously calibrated steel cord, the maximum errors in measurement were of the order of ± 2 mm. A precise geometric leveling of the vertices of the octagon (points 2-3-4-5-6-7-8-9) was done from the central position (point 1) (Table 4-5-6). The level used was a ZEISS Ni1 belonging to the Istituto di Topografia, Geodesia e Geofisica Mineraria. Using the external vertices of these trilateral sections, 8 base lines more or less parallel to the individual segments of the dome were located. Teodolites (DK M 2 A with a periscopic eyapiace made by the KERN company) ware positioned at each end of the base line and the method of frontal intersections was used to determine the reference points on each individual segement necessary for the stereo plotting. Characteristic points already present on the dome were chosen as the reference points. The axes on which the spacial reference points, calculated in this way, were located were then rotated 45° around the x-axis in order to obtain the projection of the reference points for each segment onto a plane parallel to a cord connecting the vertex and the base of the segment.

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The average lenght for the position of the projecting element of the GIGAS GZ 1 Zeiss orthographic projector is 475 mm, ranging from a minimum of 320 mm to a maximum of 630 mm for a total distance of 310 mm. Thus, the maximum ratio between the differences in distance between the objective and surface photographed and the average distance of projection was equal to $\frac{310}{475} =$ $= 65.26\%$; however, the orthographic projector could only tolerate a focal legth between 147 and 159 mm. Once it was determined that the orthographic projector was suitable for use in the stereoplotting operation, it was then necessary to determine the ratio of the optimum scale which would be suitable for the characteristics of both the instruments. For this reason, the photographs, obtained with the WILD P 31 camera whose focal length was 99.42 mm for the pictures taken of the individual segments, were enlarged 1.5 times using a SEG VI enlarger belonging to the Compagnia Generale Riprese Aeree. This enlargement brought the focal length to 149.13 mm, compatible with the characteristics of the orthographic projector; the average scale of the photographs, originally between 1:81.13 and 1:99.82 were thus brought to values between 1:54.09 and 1:66.55. In this way it was possible to obtain models with the Planimat on a scale of 1:40 which the orthographic projector then plotted at an enlargement of two times giving a scale of 1:20. The zenithal photographs, obtained with the Galileo camera at a focal length of 151.93 mm and having a scale between 1:49 and 1:80, were enlarged 1.62 times giving a focal length of 230.93 mm and a ratio of scales between 1:30.25 and 1:49.38. With these enlargements, it was possible to obtain optical models with the Planimat having a scale of 1:20 which the orthographic projector then plotted at the same scale. However, the original photographs used for these procedures had an enlargement ratio equal to 4 x in order to maintain a focal length compatible with the plotting instrument, i.e. between 147 and 159 mm.

STEREOPLOTTING PROCEDURE USING THE NUMERICAL METHOD

Numerical stereoplotting of the dome surface was done using the 12 zenithal pictures taken with the Veroplast camera in black and white and printed on glass plates and the stereoplotter Planimat Zeiss equipped with Ecomat belonging to the Compagnia Generale Riprese Aeree. These photographs were used to make 8 optical models (scale 1:30) completely covering the whole surface of the dome. A series of profiles along the y-axis of the stereograms were made from these 8 models; the real distance between these profiles was about 24 cm. The data points of these sections were fed into a computer using an Ecomat recorder and a Facit 4070 tape punch, always using actual distances of about 24 cm. In this way for each model, we obtained a network formed by more or less square sections 24 cm on a side with known spacial coordinates of the verticies. These coordinates were rotated and translated in order to refer them to the same set of axes and thus a single network made up of squares 24 cm on a side was obtained which covered the entire projection of the dome. Using a table plotter, Calcomp Mod. 7800, we obtained a section on which the height of each point was indicated which, in turn, allowed a relatively accurate location of the central point of the dome. Similarly, using the Calcomp mod. 7800, drawings were made of a series of sections on the dome distinguished by meridian planes. Using the coordinates of the points in these sections, the best fitting equation representing the curvature of each section was determined. Averaging these results, an extrapolation was made to determine the best approximation of the equation for the generating curve of the dome.

CONCLUSIONS

The deformations of the dome of the Orthodox Baptistery of Ravenna which is perhaps done to the phenomenon of subsidence which has been continuing for some time in Ravenna and the surrounding area were located and quantified using the results of the photogrammetric survey reported here. A study of this type has much more significance than just the pure and simple reporting of a series of measurements, which even when obtained with very sophisticated techniques conclude in the simple survey operation and in a dry presentation of numerical values. However, this photogrammetric survey made using steroplotting with orthographic projections allows the combined study of the measurements along with an accurate reproduction of the Baptistery in color; thus both a qualitative and a quantitative evaluation of the deformations can be made.

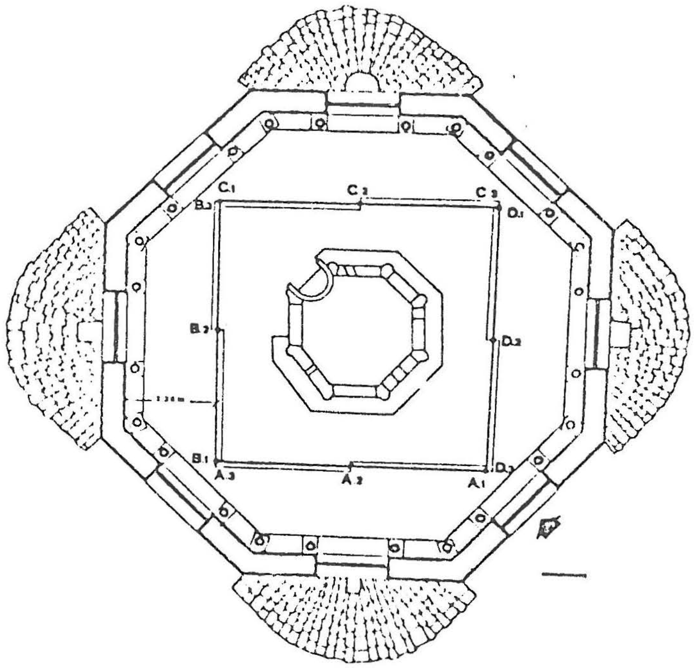


Fig.1 - Project of the zenithal final shootings executed with the Galileo Veroplast camera.

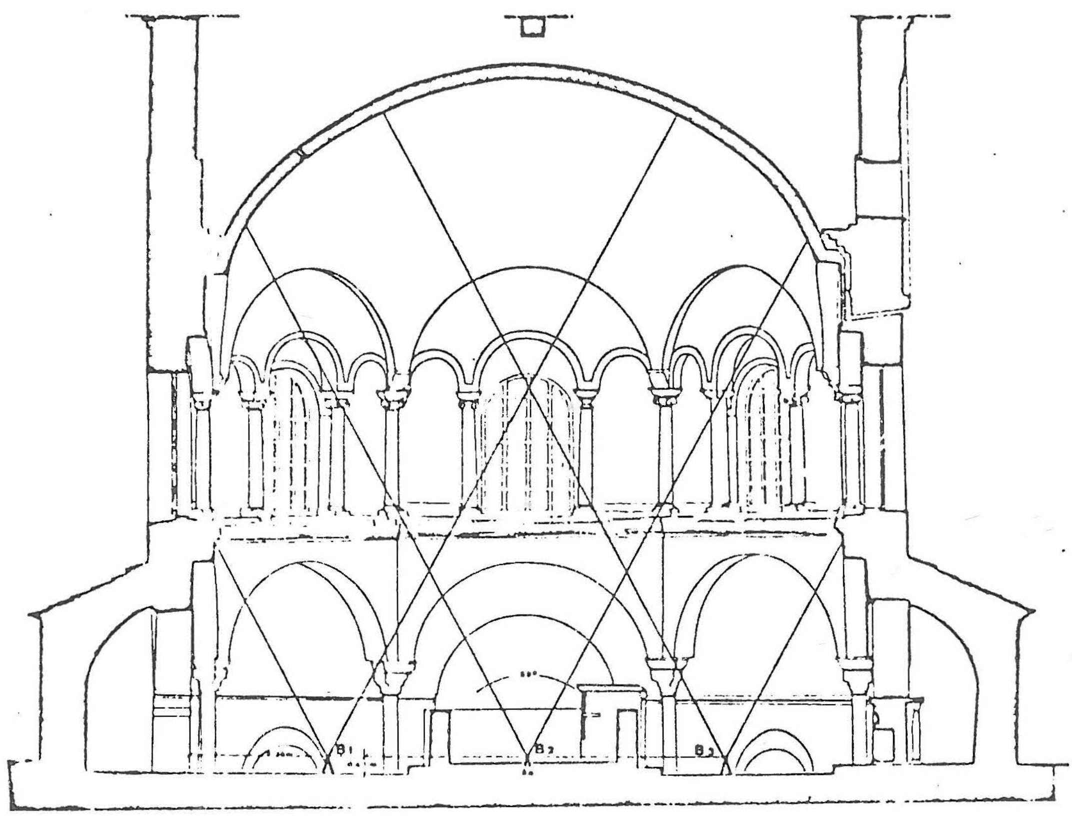
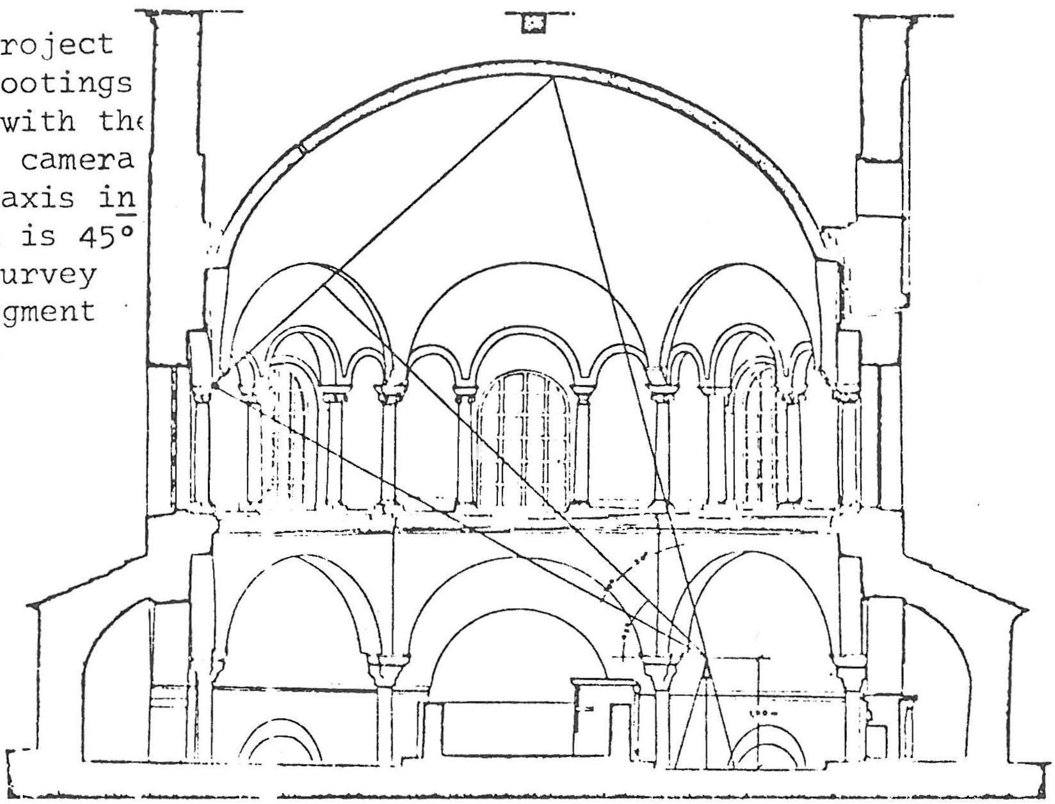


Fig. 2 - Front view of the cones of the zenithal final shootings executed with the Galileo Veroplast camera.

Fig.3 - Project of the shootings executed with the Wild P.31 camera (optical axis inclination is 45° for the survey of the segment of vault.



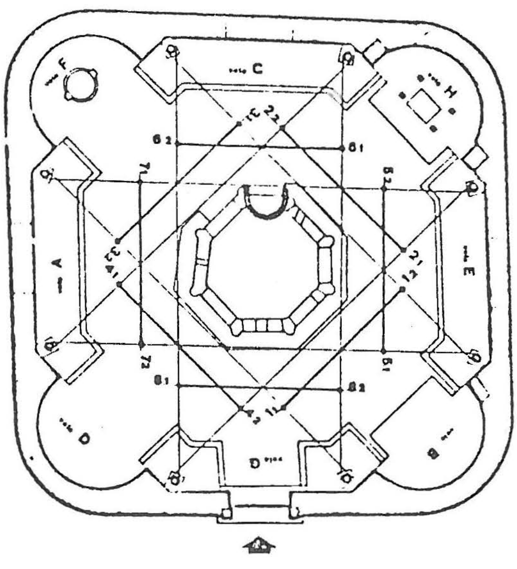
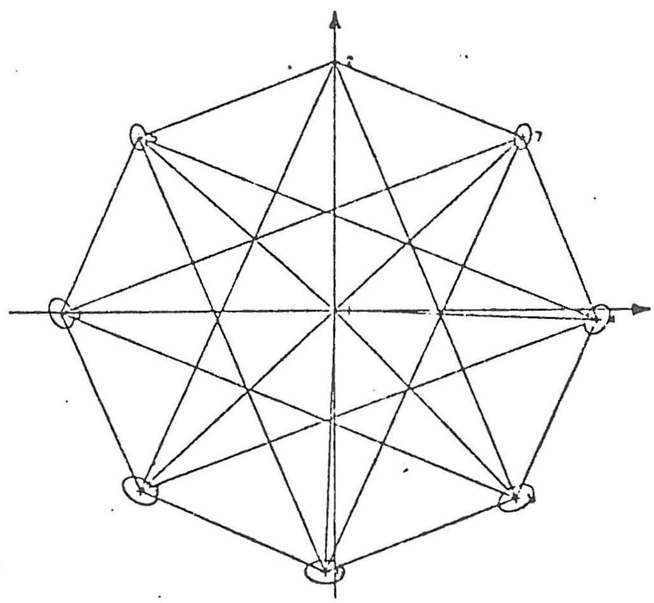


Fig.4 - Front view of the optical cone of shootings executed with the Wild P.31 camera for the survey of the segment of vault.

Fig.5 - Graph of the polygonal and error ellipses.



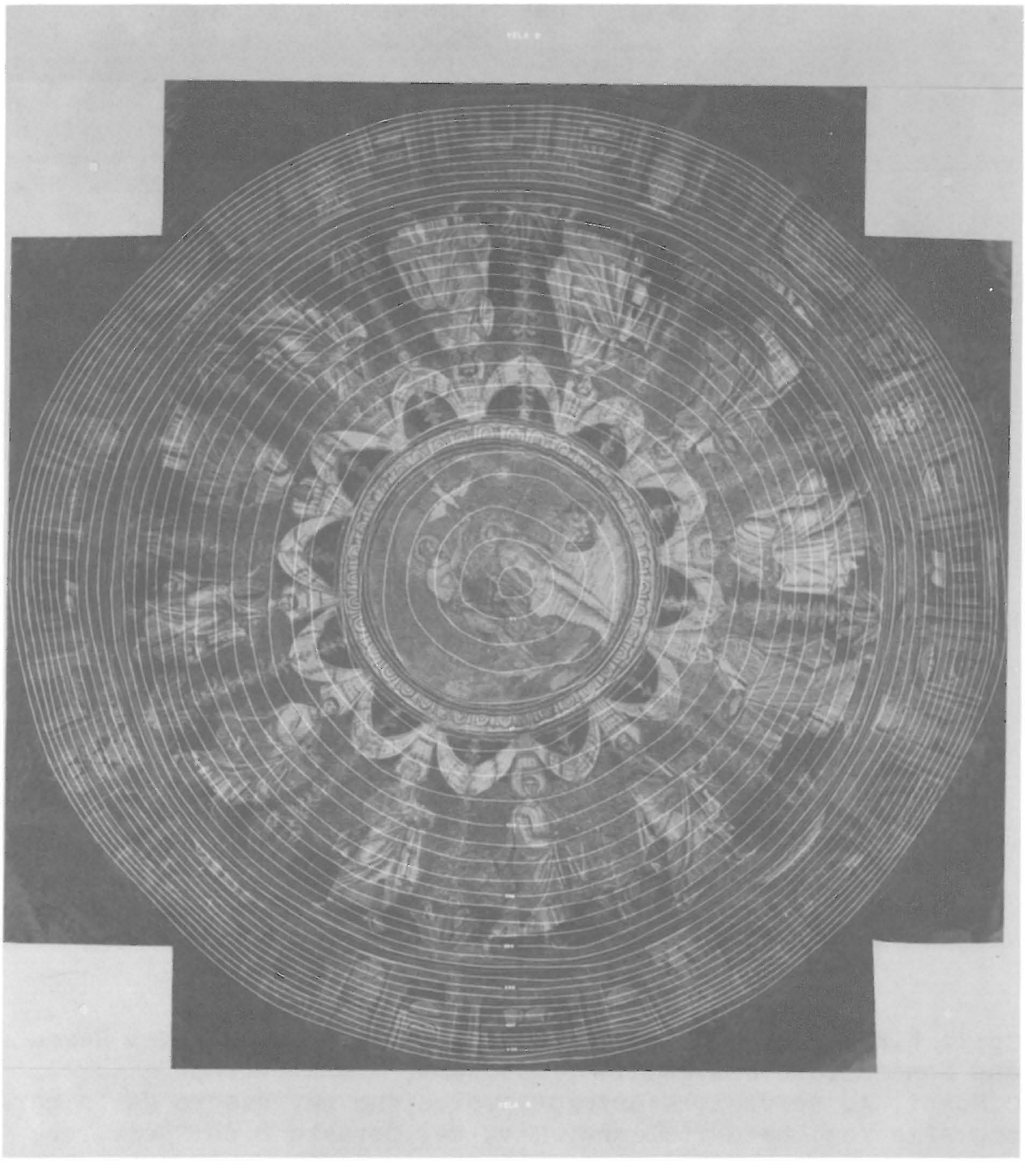
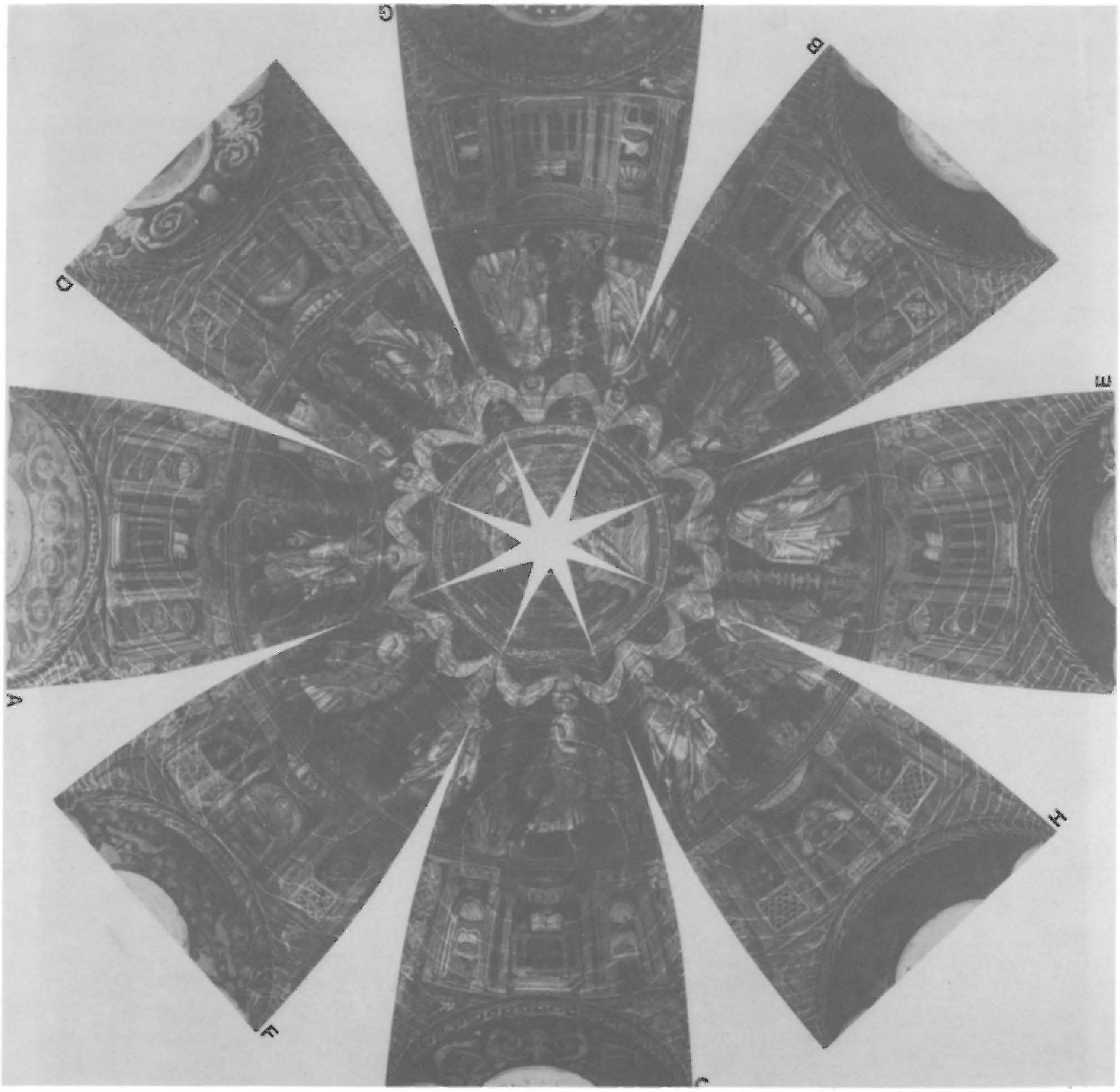


Fig. 6 - Orthophoto map of the whole vault.

Fig.7 - Orthophoto map of the single segment of vault.



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