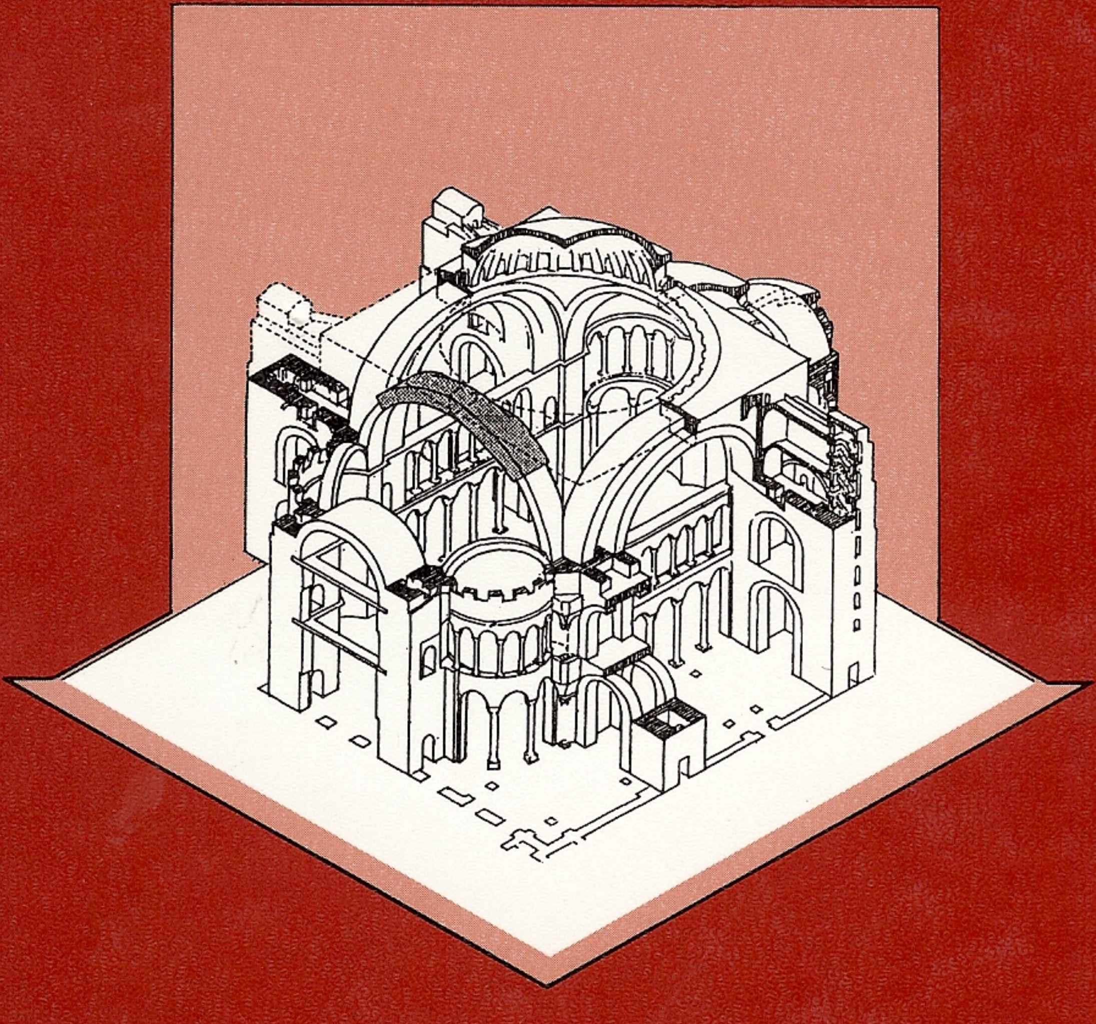
Structural Repair and Maintenance of Historical Buildings III

Editors: C.A. Brebbia, R.J.B. Frewer



Computational Mechanics Publications

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Stability and materials weathering conditions at the Symonos Petra Monastery of Mount Athos, Greece. Preliminary approach

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ABSTRACT

The Monastery of Symonos Petra, located in Athos mountain (Greece) was built, the first, around 1257 AC by the Blessed Symon, burnt down in 1891 AC and partially rebuilt. Today, 100 years after its burning down, national interest is attracted on restoration and conservation of that valuable piece of Byzantine cultural heritage.

In the present work stability and materials weathering conditions are under study. Materials characterization analysis, as well as a first macroscopic and microscopic estimation of weathering problems were performed.

Samples of mortars, as the critical factor of the masonry strength, were studied, regarding their origin and resistance to weathering.

The present study concerns the slope stability conditions of the rock-mass where the monastery is built as well. It is a preliminary investigation, thus no definitive results can be formulated at this moment.

INTRODUCTION

Construction materials weathering, and foundation rock stability conditions are of particular interest, especially in regions like the Mediterranean Basin, where climatic and active geotechnic conditions are favourable for these causes of monuments decay.

Building stones are susceptible to various atmospheric factors causing their destruction. The presence of harmful soluble salts in pore water, as a result of reaction of atmospheric gases with rock minerals, is one of the main factors of stone decomposition, especially in coastal areas.

On the other hand, most of the historical buildings were built without the geomechanical particularities and hydrogeological conditions of the construction area having been taken in mind, in advance. The leaning tower of Piza could be an excellent example for this case. Furthermore, the complicated geotectonical and active seismotectonical conditions, in Mediterranean Basin, change the stability conditions of the area where the monument is built.

In this framework, the Monastery of Symonos Petra, was investigated regarding the slope stability of the construction area as well as the weathering conditions of the older mortars, that consist the cementing material of the building stones and the critical factor of masonry strength.

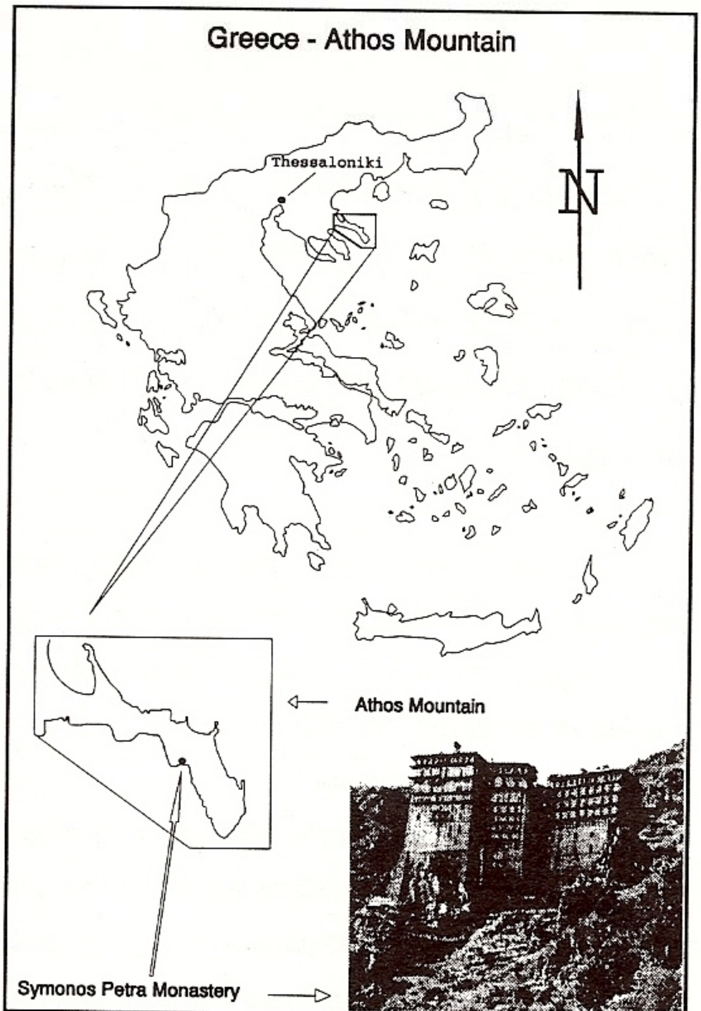

Figure 1. Location the Symonos Petra Monastery.

In the present study only a geotechnical site investigation was made, by rock-mass classification and slope stability analysis. It consists a preliminary approach to the problem, so as no definitive results can be formulated yet.

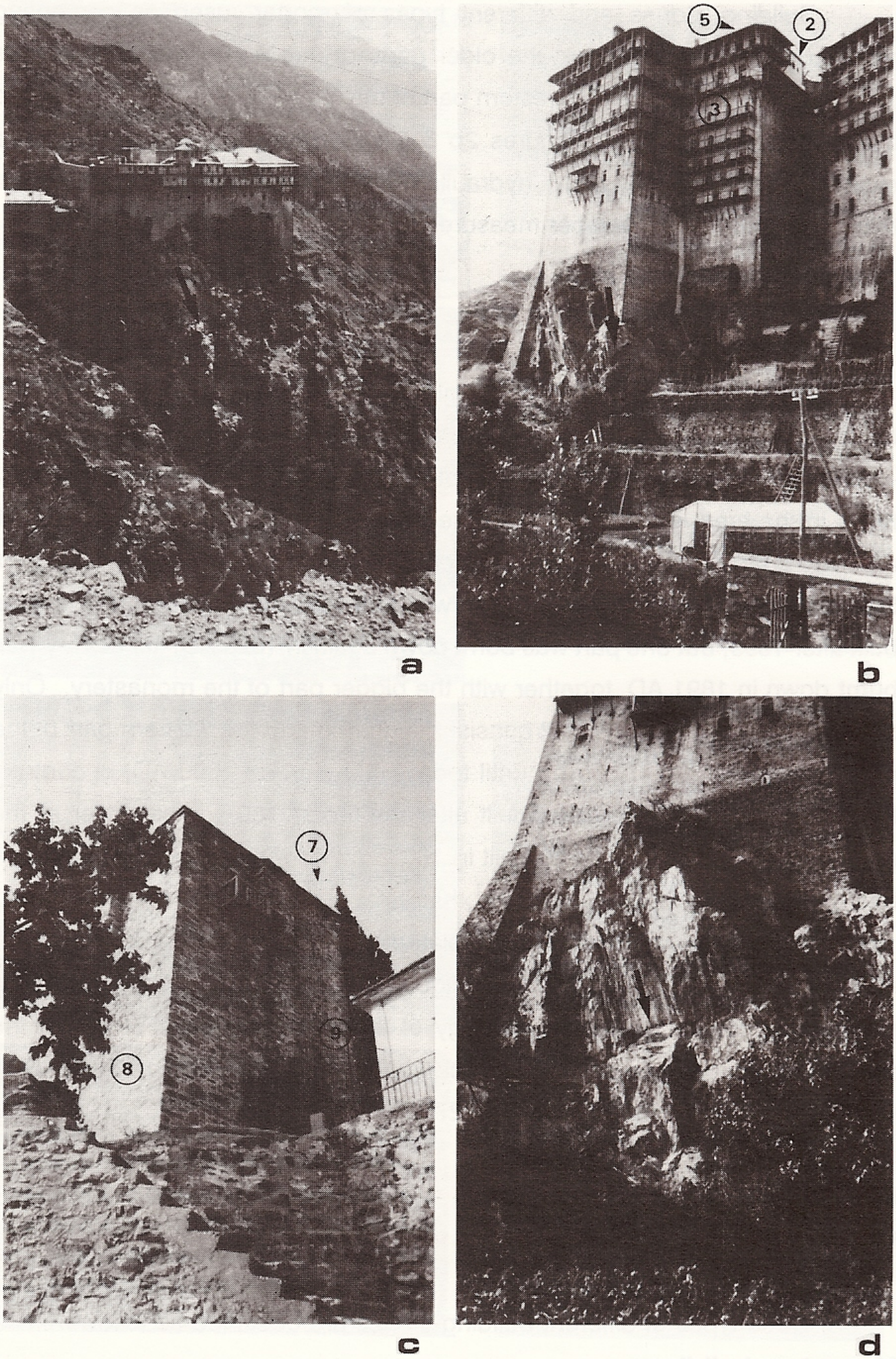

Figure 2. The Monastery. a: Western site - a probable fault (?, F), b: Southern site - important fractures; sites of sampling are also referred, c: Shipyard tower (arsenal) - sites of sampling & d: Southern site - a detail with a fracture.

Building stones and different types of mortar, used as cementing material, were collected from the older parts of the Monastery, such as the exterior southern side of the western part of the main building, the church and the tower of the shipyard (Figures 2b & 2c, Table I). These samples were examined regarding their origin, hydraulic characteristics and resistance to weathering so as the most proper measures for preservation to be taken.

THE MONASTERY

Mount Athos, also known as Agion Oros (Holy Mountain), is located in Northern Greece and belongs administratively directly to the Patriarchate.

The Monastery of Symonos Petra, is one of the first Cenobic Monasteries in the area; it is dedicated to the nativity of Jesus Christ and was built around 1257 AD by the Blessed Symon. It was renovated by the despot of Serbia Ioannis Ougles in 1364 AD. It was burnt down in 1580 AD and it was built after 1599, but one part was burnt down again in 1626 AD. Its Library was burnt down in 1891 AD, together with the bigger part of the monastery. Only some parts of the building that consist the church and the western part of the present monastery were saved until today. They are of 1600 AD, in contrast to the eastern part which was built after the fire of 1891. The tower at the shipyard of the Monastery was built in 1563 and no restoration activities have been done until today (Xygopoulos[1], Kadas[2]).

The Monastery is built up on an isolated and uplifted rock (altitude 305 m), at the S/SW side of the mountain (Figure 1). The construction presents a particularity caused to the morphology of the rock-hill. The first five of the seven floors were built around the rock, so as the lower parts of the building were founded at an altitude of about 270 m.

CONSTRUCTION MATERIALS - CHARACTERIZATION AND WEATHERING

Three types of different building stones are observed as follows:

Monastery buildings

a. **Granite**, petrographically characterized as biotite granite to granodiorite

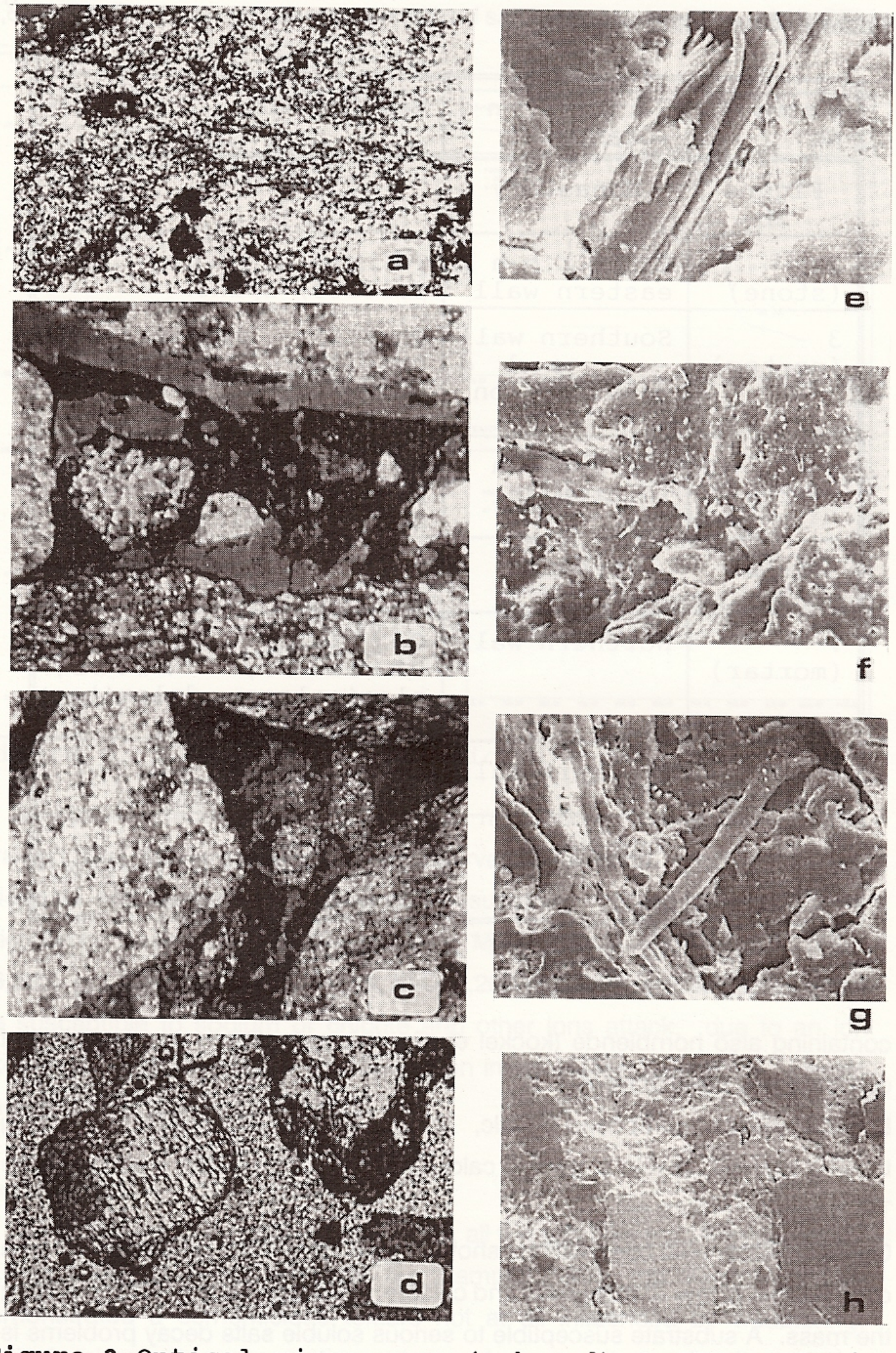

Figure 3.Optical microscopy (a,b,c,d) & SEM analysis (e,f,g,h):talc schist a(16x #), e(655x,Mon.-church)-cementicious mortar (b(16x #), f(373x,Arcenal)-cementicious mortar matrix and aggregate c(16x #), g(745x,Arsenal)-degrad.mortar d(16x //),h(46x,Mon.-church)

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Table I. X-Ray diffraction data.

Sample No	Sampling location	Composition
Figure 2b	**Monastery**	
2 (stone)	Church, eastern wall	Talc, chlorite, calcite, spinel
3 (mortar)	Southern wall – old construction	Quartz, plagioclase, calcite, feldspars, chlorite, halite, micas.
5 (mortar)	Church, internal	Calcite, quartz, plagioclase, chlorite, dolomite, micas.
Figure 2c	Arsenal	
7 (mortar)	Northern wall	Calcite, quartz, chlorite, micas, plagioclase, dolomite, talc.
8 (mortar)	Southern wall	Calcite, quartz, chlorite, dolomite
9 (mortar)	Eastern	Calcite, quartz, feldspars, chlorite, hornblend, micas.

containing also hornblende (kockel et al). It is superficially weathered, but compact and durable inner.

b. Talc schist, composed by talc, chlorite, calcite and spinell, according to XRD analysis, (Table I), poor in calcite (content up to 2,18% , according to TG analysis - Figure 4a).

Optical microscopic observations show (Figure 3a) a finely grained mass with oriented fine grains of muskovite and chlorite. Fe oxide veins are transpassing the mass. A substrate susceptible to serious soluble salts decay problems is indicated. However electron microprobe analysis does not reveal any Cl or S content (MgO: 30,16% ,Al_2O_3: 13,35% ,SiO_2: 45,02% ,CaO:0,70% ,Cr_2O_3:

0,60%, Fe_2O_3: 10,17%) nor any crystallized salt formation is observed by SEM (Figure 3e).

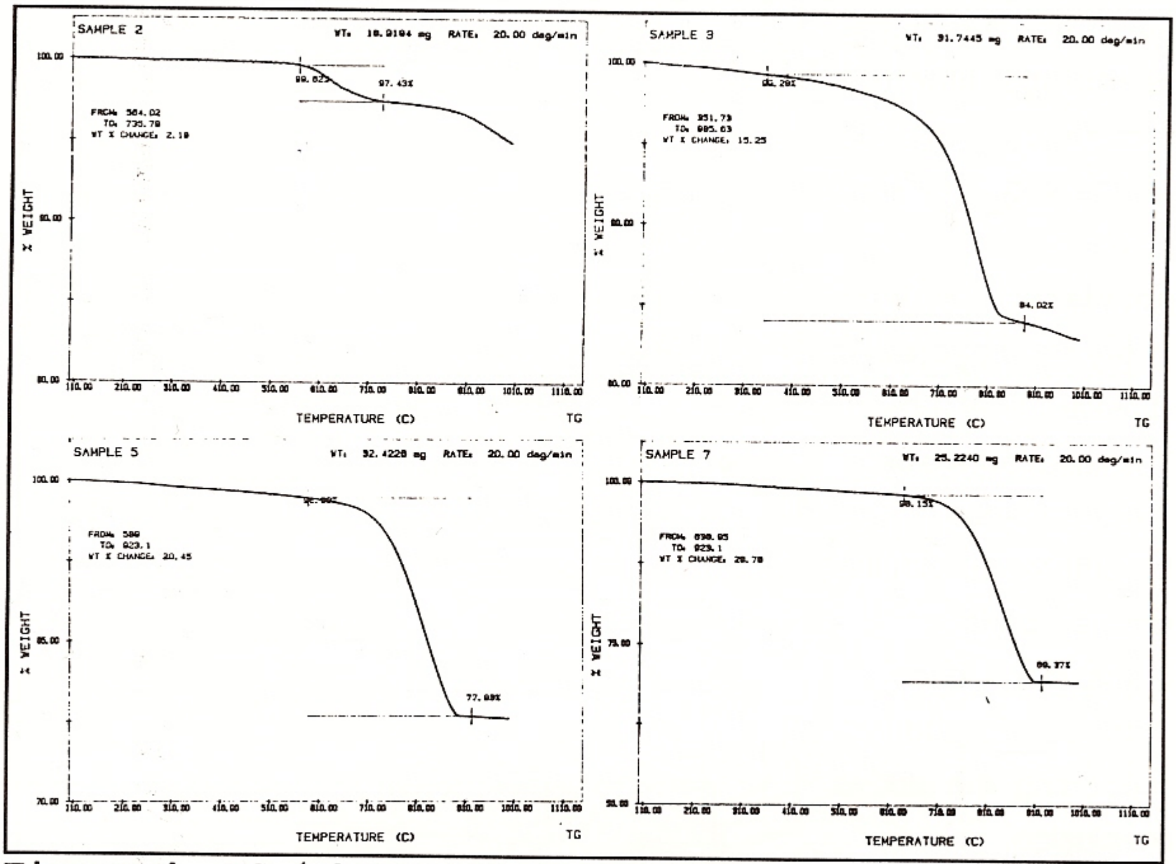

Figure 4. TG (Thermogravimetrical) – results.

c. **Amphibol, mica schist**. By polarized microscopy examination a finely grained and well oriented mass is observed:hornblende, quartz, biotite, feldspars and epidote are distinguished (substrate - Figure 3b). The EDX-microbrobe analysis shows (NaO: 1,64%, MgO: 2,58%, Al_2O_3:12,42%, SiO_2: 63,59%, K_2O : 2,47%, CaO: 13,05%, FeO: 4,26%). Even though feldspars could be susceptible to sodium or chlorite and other ions attack, due to an ion exchange mechanism, their fine dispersion into the mass, does not facilitate such a type of preferencial decay.

Mortars

Concerning the mortars examined, all the samples from the Monastery (2,3,5) were decayed, whereas the samples from the Arsenal (7,8,9) demonstrated a cementicious texture not at all influenced by weathering. Optical microscopy observations demonstrate a good adhesion of the cementicious mortars to the substrate (fig. 3b), whereas their scanning electron micrograph (fig 3f) seems to be similar to these of high pozolanic content, implying hydraulic character (Lewin,1981). The rounded shape of the aggregates (fig 3c) in comparison with the angular ones of the Monastery decayed mortars (fig 3d) is supporting the above conclusion.

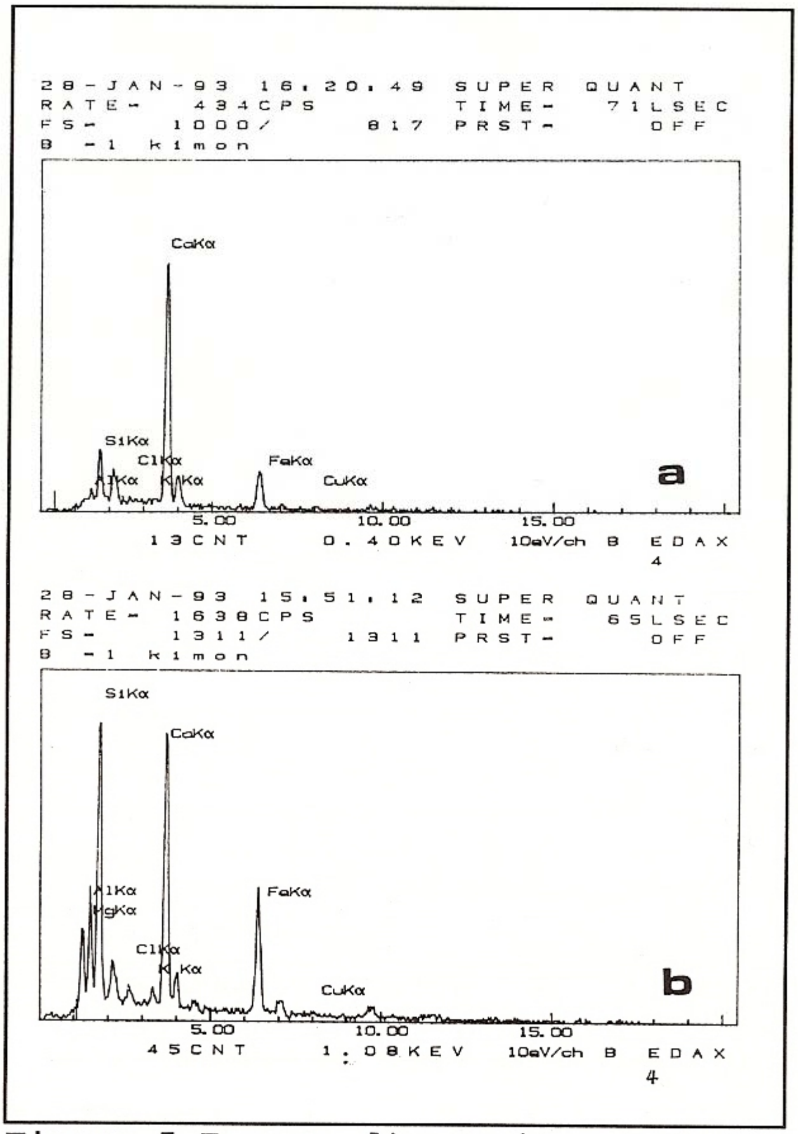

Figure 5. Energy dispersive analysis (overall results: comenting materials–aggregates) a: Monastery sample No 5, b: Arsenal sample No 8.

Even though calcite crystals elongate within the pores of the cementious matrix (Figure 3g), and calcite is identified in all the Arsenal mortars (Table 1 - XRD results),the energy dispersive (EDX) analysis show a low calcitic in contrast to the high Mg-Al-Si contents (MgO : 29,91% , Al_2O_3 : 7,99% , Si_2O : 56,12% , CaO : 0,13% , Cr_2O_3 : 0,30% , Fe_2O_3 : 6,25%), as far as cementing material is concerned. Comparing these data to the Monastery mortars (Figures 5), a considerably lower Sika - Alka and higher Caka peak is noticed. TG analysis however indicates considerable weight loss at the 910^o C, implying an aluminum- magnesium transformation which for the Arsenal mortars is almost double. Hence, cement mortars with hydraulic character and excellent adhesion to the building stones are not altered by weathering,

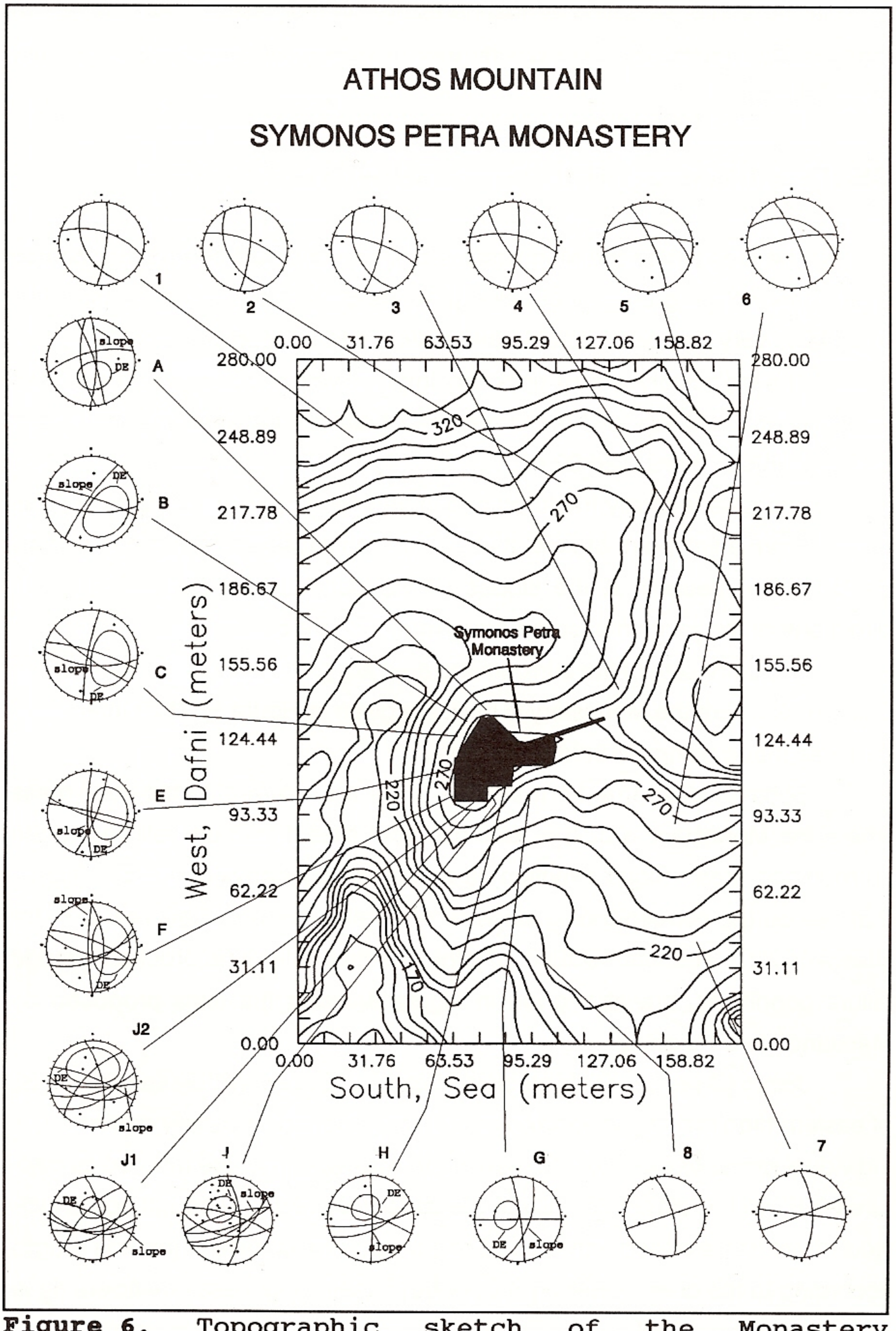

Figure 6. Topographic sketch of the Monastery surrounding area, with geotechnical data.

even in more intense saline atmospheres, like in the case of the Arsenal, in comparison with the Monastery, whereas the more calcitic mortars of the later are totally decayed.

GEOTECHNICAL CONDITIONS - SITE INVESTIGATION

The area where the Monastery is built, is consisted of a typical, coarse grain, dark colour granite, that belongs to the Serbomacedonian mass. The material is very compact, durable and resistant to the compression.

The Monastery is built on a very impressive isolated rock. The slopes of this rock are steep and the difference of altitude between the lower and higher points is more than 90 m.

The area is totally fractured and is traversed by joints of various directions. From a first point of view, these joints can cause unstable geotechnical conditions, especially at the slopes of the construction area. The main directions of the joints measured are given in Figure 6.

The Joint sets of the surrounding area are given in Figure 7 while those of the rock where the Monastery is built, are given in Figure 8. Their interpretation was made using Schmidt diagrams..

Schmidt diagrams from sites A to J2 are referred to the rock-mass where the Monastery is built while those from sites 1 to 8 are referred to the surrounding area. Slope direction as well as daylight envelope (DE) of joints that rise on the corresponding slope face are also given in Figures 6 & 8, for sites A to J2. The intersections of joint sets that determine probable wedge failure conditions, are also given in Figure 8, using the tests proposed by Markland[7] and Hocking[8].

Joints (J) are generally medium to closely spaced. Widely spaced joints, of eastern dipdirection, are occurred too. Their aperture is usually narrow. The individual joints, of big size and medium to wide aperture, are referred as fractures (FR), in the diagrams. Joints are usually unfilled. Although some individual fractures are filled with breccia of granite. The surface of joints is rough; according to the chart of Barton & Choubey[9], their roughness coefficient (I_f) is estimated about 16-18.

A probable fault (?, F) of SSW dipdirection, traverse the rock-mass at

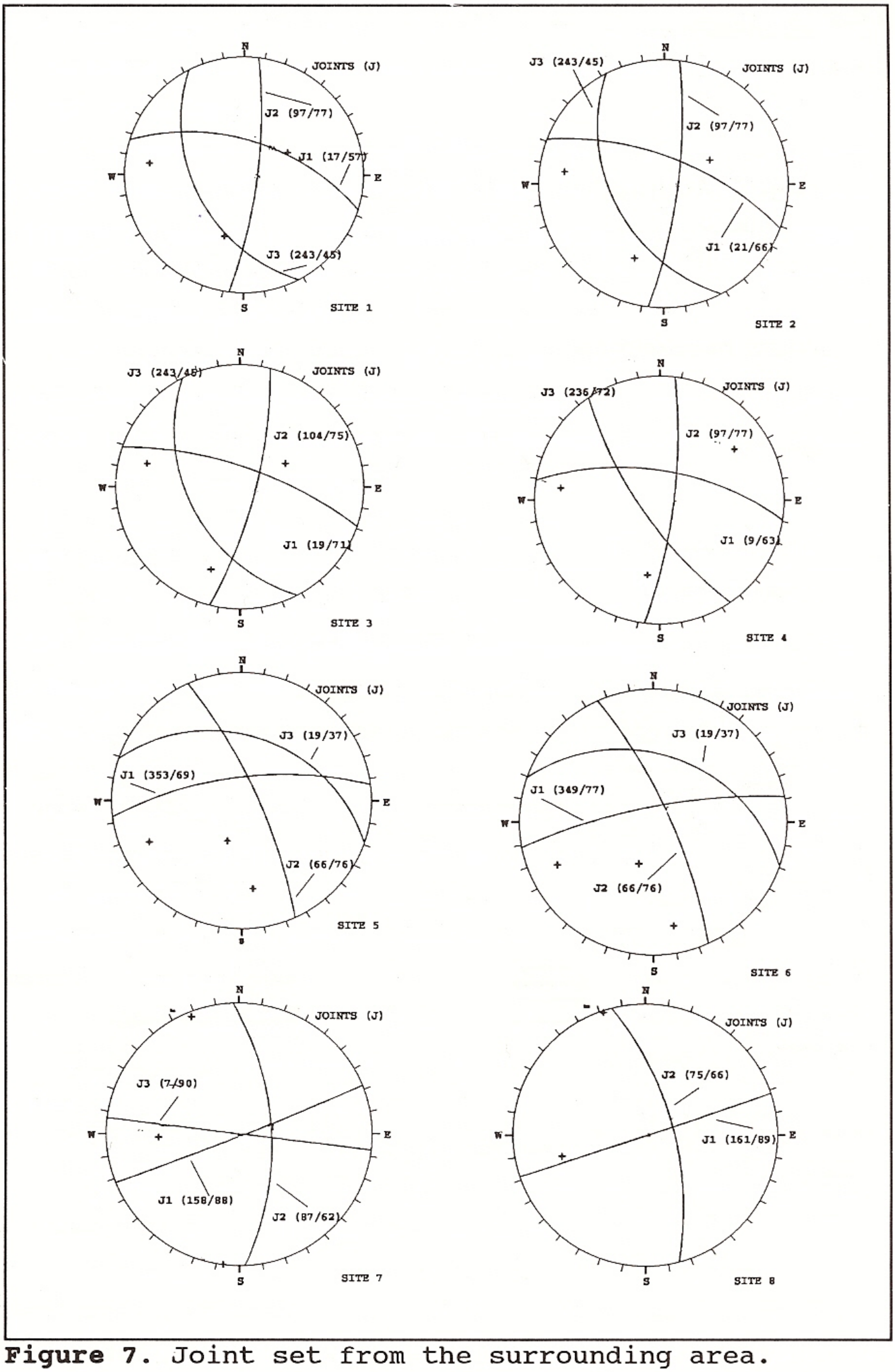

Figure 7. Joint set from the surrounding area.

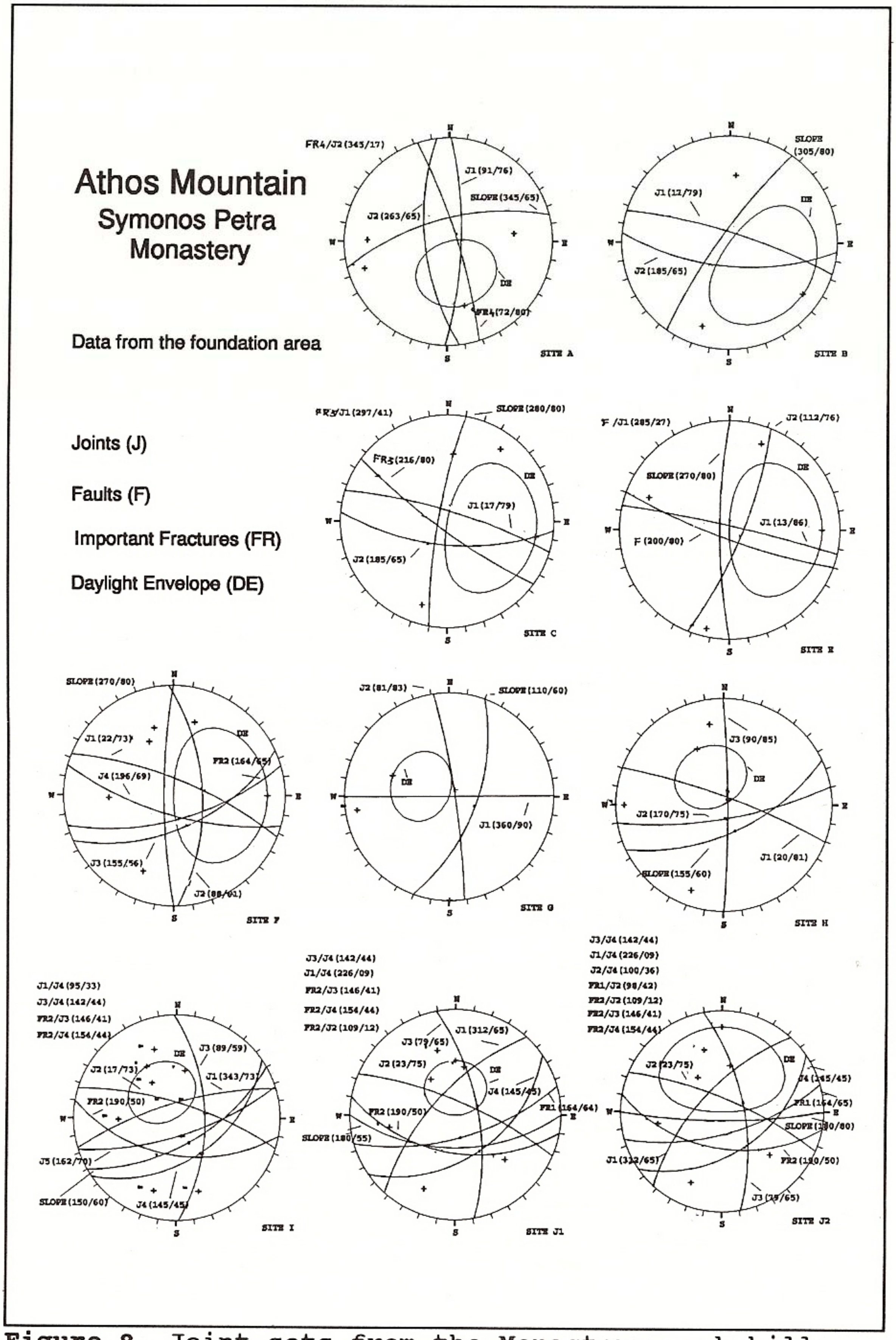

Figure 8. Joint sets from the Monastery rock-hill.

site E, causing damage to the foundation of the Monastery (Figures 2a, 6E, 8E). No farther investigation has been made yet to determine the nature and the origin of this discontinuity.

The statistical interpretation of the collected tectonic data provided that the southern part of the studied rock-hill, is probably the more unstable one. At the other sites, the poles of the calculated joint sets don't fall in the daylight envelope. Furthermore, the intersections of the joint sets don't correspond to unstable wedge failure conditions.

At the southern part of the Monastery, joints of SSW or SE dipdirection cause probable wedge or planar failures (Figures 2b, 2d, 8J1, 8J2). J1 position is very close to J2. The only difference is that the slope face is nearly ver tical at the lower part of the building (J2).

CONCLUSIONS

Different lithotypes like granite, talc schist and amphibol mica schist, even though with clear mineral phases orientation and texture susceptible to decay, do not present considerable degratation, appart from rather superficial alterations.

Main problems present the old calcitic mortars in the case of the Monastery structures, which are even absolutely decayed.
On the contrary, old Arsenal mortars, even in more intense saline environment, present an excellent cement behaviour and adhesion to the substrate . Further research on their hydraulic components would be of interest for restoration mortars, which are of need to the Monastery work.

The geotechnical site investigation at Symonos Petra Monastery showed the following:

- The rock-hill, where the Monastery is built, is totally fractured.
- An important discontinuity cut the western side of the rock-mass causing damage to the foundation of the Monastery.
- According to our preliminary collected data, the southern slope of the rock-hill presents, relatively, unstable conditions; further research on slope stability analysis lead to more proper preservation measures, which have to be applied.

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