

## RECORDING THE DAMAGES OF NATURAL STONES

Jürgen Heckes, Landolf Mauelshagen, Mustapha Skalli

Deutsches Bergbau-Museum  
Am Bergbaumuseum 28, D-4630 Bochum  
Federal Republic of Germany  
Commission V / CIPA

### Introduction

Since more than 100 years the monument term has been under discussion by those, who work on the preservation of monuments in Germany. As an important distinguished feature the monument term was crystallized as historical originality, authenticity of the work of art or building. The value of monument documentation was emphasized, and the monuments were postulated to be testimonies of the historical background. The consequence of this deepened consciousness concerning the monument was the perception of the uniqueness, the irreplaceability and the non-repetition of the historical original. Today the preservation of monuments is still fighting for authenticity and originality of monuments.

Just in the last decades of the 19. century it became conscious and evident, that the increasing stone decay cannot only be traced back to the normal weathering of stones but to the influence of air pollution. The idea to promote a collaboration of curators and natural scientists, as chemists, mineralogists and geologists dates back to that time. But it lasted until the end of sixties of the 20. century that curators and scientists met again for joint questions and research to find solutions and to overcome the burning problems. Nowadays the situation has changed and a set of different research programmes has been started (c.f. /Backes 1986/).

The discussion about environmental protection and the rising consciousness on historical values produce many questions about the reasons of stone decay. One of the central topics within that scope becomes the relationship between air pollution and decay. Stone decay can have many shapes at different stone types, above all the variety of sediments, such as efflorescence, staining, cracking, rupture, alveolar erosion, friability, delamination/scaling and micro-organisms growth. The proneness of stone to weathering primarily depends on its chemical and physical properties. Furthermore, environmental factors are important, such as anthropogenic immission, meteorological situation and specific employment of the stone. But at first the fact has to be stressed that weathering of stone is a fundamental phenomenon. The weathering means an adaptation of the stones to the physical and chemical conditions on the surface of the earth, since in general the stones are not formed on the surface but in the upper earth crust in a depth of several hundred meters and kilometers.

Chemical weathering covers the chemical reactions in the stone, which consists of different minerals and contains also liquid and gaseous fillings in the pores between the mineral grains. It can be caused by environmental factors or the thermodynamical instability of some of the mineral components.

Physical weathering means the mechanical deterioration, which is based on the loosening and separation of the mineral components and on breaking and splitting the minerals themselves. The causes may be outside and internal stresses as well as the water absorption, freeze, penetration, transport and salt actions.

The biological stone decay is often considered as a third kind of weathering. But the influence of micro-organisms (bacteria) can be conducted back to the two above mentioned mechanisms.

A particular kind of physical weathering can be observed at sandstones, when stone-cutting work has been done, which causes a strain in the upper stone crust and leads to a faster weathering (scaling).

The natural stone decay is a relatively slow process, with regard to human and not geological time scale. However since the industrialization in the past century a rather rapid growth of stone weathering can be observed. Anthropogenic pollutants, which are transported by the air and in the water, must be regarded to cause the increasing stone decay as well as the industrial dust. All the chemical and physical reactions and processes in the minerals and in their components and the further resulting deteriorations are not completely understood as yet and very often, in addition, they are only detected, when they are already in a progressed stage (c.f. /Mirwald et al. 1986, Vieser 1987/).

The different factors and their complex correlations are the aims of research programmes, which are funded by various authorities and agencies in the FRG and in Europe too. Terrestrial and close-range photogrammetry can support this fundamental work.

### **Examples of research**

The town of Lippstadt/FRG began in 1987 with the preparations to restore its Great Maria Church (Fig. 1). The restoration is supported by the parish, the church surveyor's office, the office for preservation of monuments and the chemical-mineralogical and photogrammetric department of the German Mining Museum.

A short time after the foundation of the town about 1185 by Bernhard II. zur Lippe the construction of that cross-shaped hall building in Roman style was begun. In the following centuries the edifice, which belongs to the most famous sacred buildings in Westfalia, received various construction phases and some Gothic and late Gothic alterations and was completed in the early 16. century.

In the course of a planned perfect restoration of all outer facades of the church extensive investigations and documentations will be conducted, which in cooperation of all contributing authorities and institutions shall lead to a logical overall concept. With the help of photogrammetry a lot of fundamentals can be produced for damage assessment and damage mapping (c.f. /Carbonnell 1976a and 1976b, Dallas et al 1987/), for the appointment of various stone types, plaster and mortar analysis, appointment of pigments and binders, investigations into the layer sequence of the up-going masonry and finally the art- and architecture-historical integration. The actual amount of all outer walls of the church were recorded by terrestrial photogrammetry (see Fig. 1 - 3). A partial-metric camera Rollei 6006 Réseau with automatic aperture, using the lenses Distagon 40mm and Planar 80mm, and a Wild P31 with a lens of 45 mm were at disposal. To avoid invisible spaces and much too oblique photographs a ladder of the fire-brigade was in use, which served for shooting photos (free positioning)



Fig.1 Great Maria Church at Lippstadt, a view from the North-East, dating to the early 16. century (photographed 1937)



Fig.2 The southern transverse building of the Great Maria Church at Lippstadt

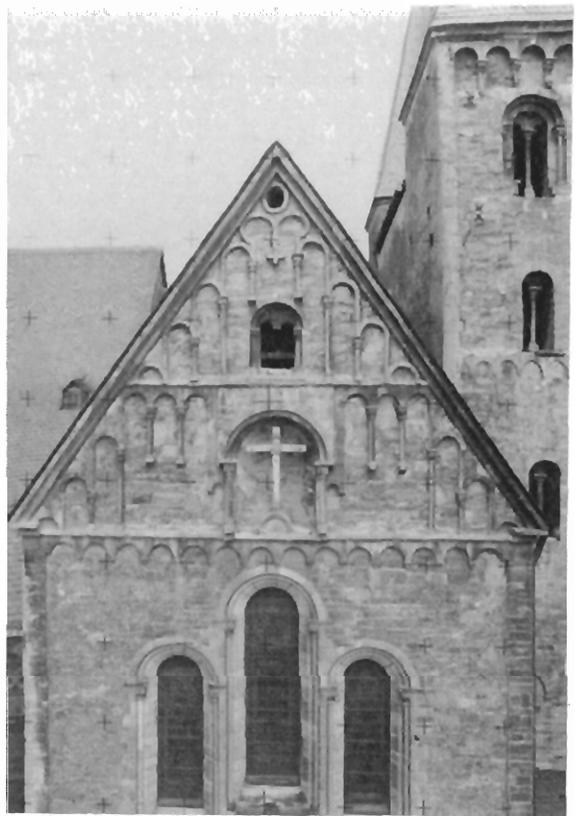


Fig.3 The gable front of the lateral building from the Great Maria Church at Lippstadt



Fig.5 Details of stone damages at the upper gable of the church

Fig.4 Stone damages at the upper gable of the church

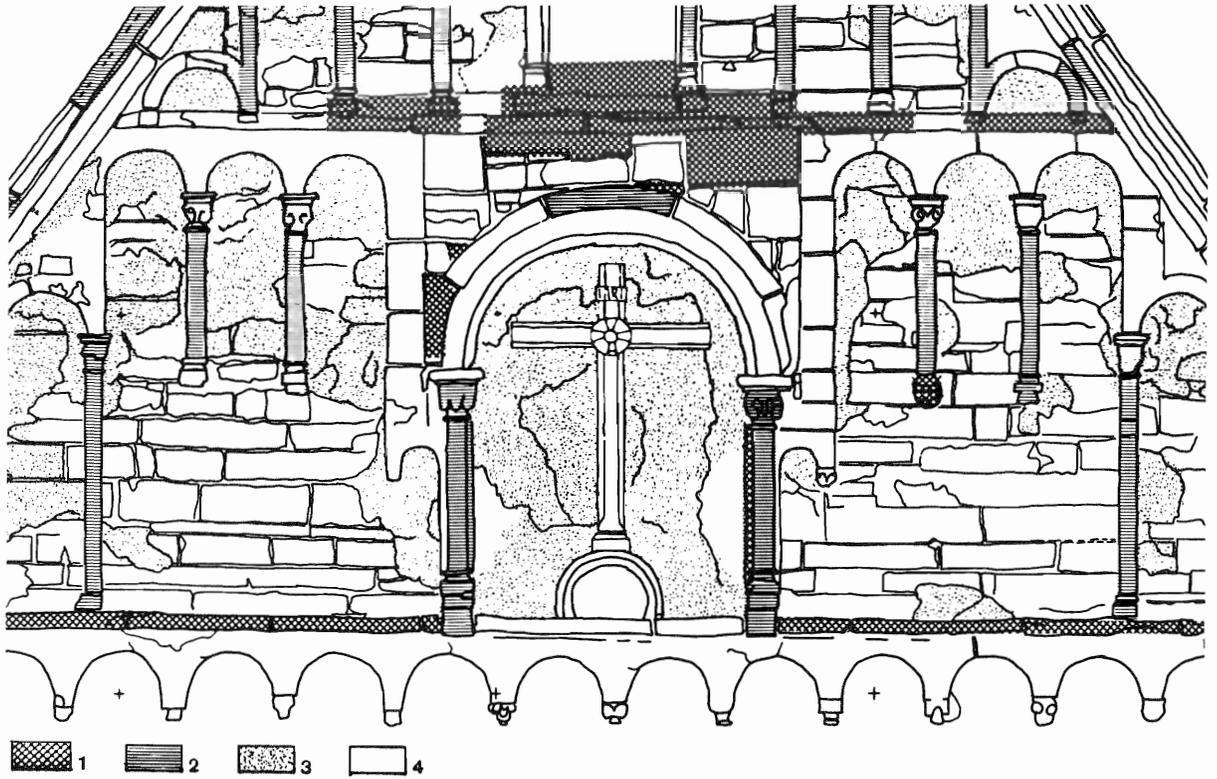


Fig.6 Detailed photogrammetric mapping of the different stone damages at the gable of the church: 1.. big damages, 2..middle damages, 3..plaster, 4..in relatively good condition

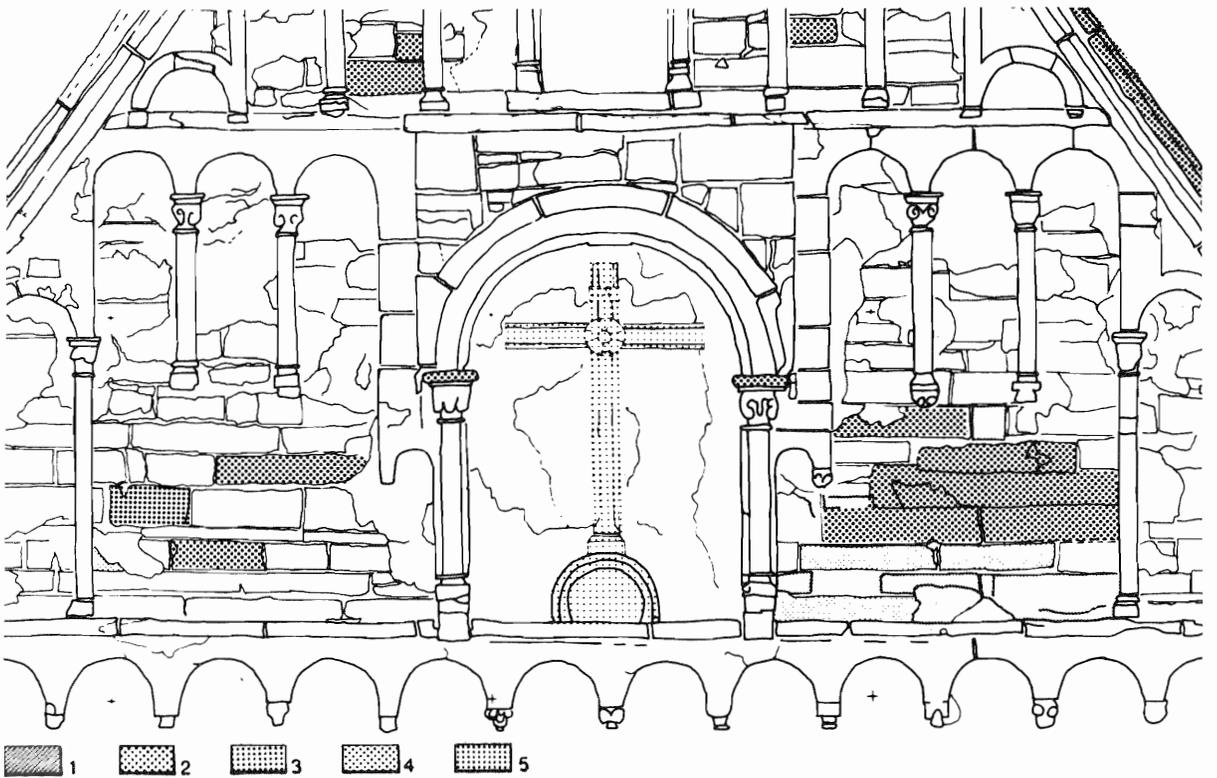


Fig.7 Detailed photogrammetric mapping of the individual stone types at the gable of the church: 1..green sandstone of Soest - clayey, 2..green sandstone of Soest - limy, 3..green sandstone of Soest - limy with iron crust, 4..plänér limestone, 5..sandstone - beige

of the higher parts of the walls and the towers. As the signalized geodetic control points were distributed densely enough, the two photo rings could be processed by simultaneously calibrating bundle triangulation (programme MOR, c.f. /Wester-Ebbinghaus 1985/), thus densifying the net of natural control points for detailed stereoplotting. The overall and particular photogrammetric drawing was done at an analytical plotter Zeiss Planicomp 100. The plans were revised by an architect. All participants of that projekt, such as architect, conservationist, curator and restorator, need these plans. Stone damages and decay (Fig. 4 - 6) as well as types of stone (Fig. 7) were mapped in detail directly at the desired object areas by a geologist for the restoration work (c.f. /Heckes et al. 1987/), which will become a special solution. By and by the whole frame will be filled up with all the interdisciplinary components and features.

With reference to air pollution and stone damages all experiences of the last years and the ambitions of various researchers and specialists guided to a high sophisticated research programme, which was initiated by the Ministry for Science and Technology of the FRG. There is a need to bring more light into formulation of questions concerning individual stone decays as they have been mentioned above.

For that purpose ten individual stone types (sediments) of a prismatic shape (Fig. 8) have been exposed to the open air at six sites in the FRG with an official weather and emission measuring station, different pollutant emissions and meteorological conditions. One of each stone specimen was leaved naturally, fourteen additional specimen were treated with stone preservatives. The preservatives are composed of varieties of two different compounds: silicon-organic and chemical reacting resp. physical drying systems. One prism side has been lightly stone-cutted for studying the influence of mechanical treatment at the surface to the weathering reaction. Two inclined holes at one prism facet shall simulate a long-term accumulation of moisture (backwater). Before being exposed to natural conditions all samples were stereophotogrammetrically documented from either side with regard to shape and colour. A Rolleiflex 6006 Réseau partial-metric camera with a Distagon 80 mm was used at a base-distance-ratio of 1 : 5 or less. As the lens can be focused at the respective distance the earlier close-range problems caused by metric cameras with ancillary lenses are overcome. This fact is even more important for the following example of application. For checking the calibration of the camera by bundle adjustment before, during and after the recording period a control point frame (Fig. 9) was photographed. The degree of surface weathering shall be determined in regular intervals, above all if the samples show a strong reaction. The surfaces will be described and plotted by digital models and/or contour lines and/or profiles.

Another study was performed to get an idea how and to what extent chemical and physical reactions are occurring in the structures of the mineral crystals and in the pores between the grains at the surface. Because of the long-term process of the weathering small individual sediment stone platen (volume: 4 cm x 4 cm x 0.5 cm) were put into a weather simulating installation (self-produced by the chemical-mineralogical department), where special weather conditions can be produced and different pollutants can be used in test series to shorten the weathering time scale. The surface structures of the platens are recorded by macro-photogrammetry (Fig. 10 and 11) before and after certain tests. For that purpose a stable bench mounting was arranged. The individual fine-mechanical measuring instruments from the manufacturer Spindler & Hoyer/Göttingen were assembled by a precision mechanic. Measuring by micrometer screw the manufacturer guarantees a setting accuracy of 2 microns at the distance scale and 2 seconds at the angle dial.

As it is impossible to get some metric information from the object space, the outer orientation angles

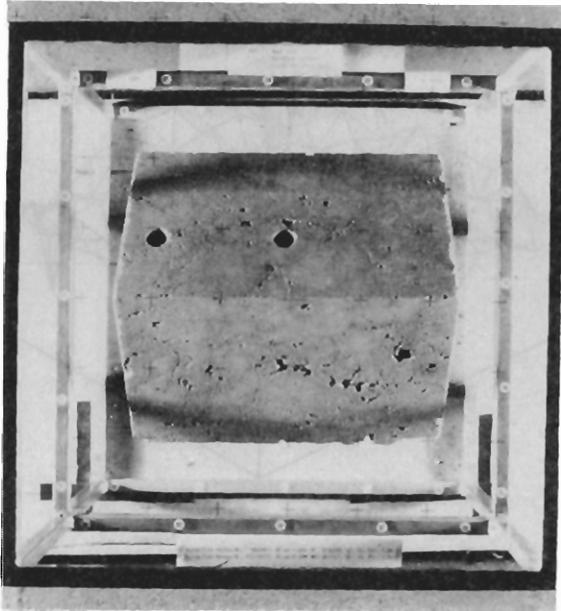


Fig.8 Stone prism of limestone ("Auer Kalk") inside the check point frame

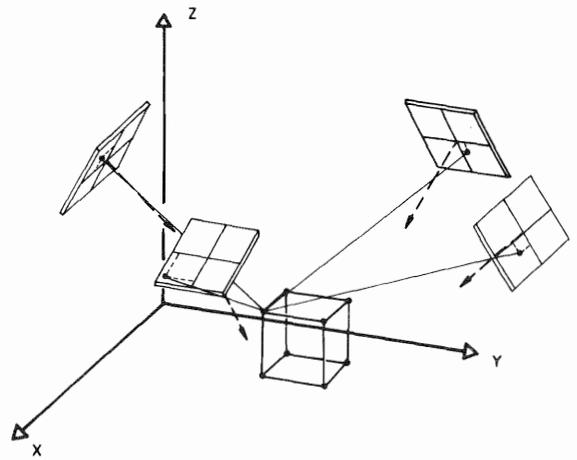


Fig.9 Configuration of photos for the bundle triangulation process, c.f. /Wester-Ebbinghaus 1986/

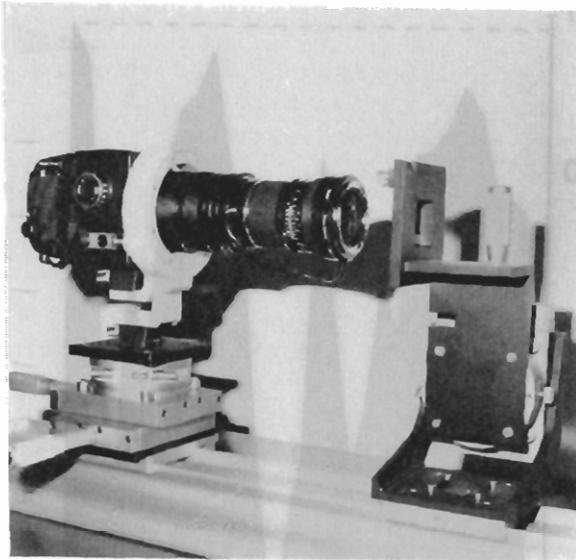


Fig.10 Bench mounting for photographing the small sandstone platen (Rollei 6006 Réseau with extension tubes and retro-adapter)

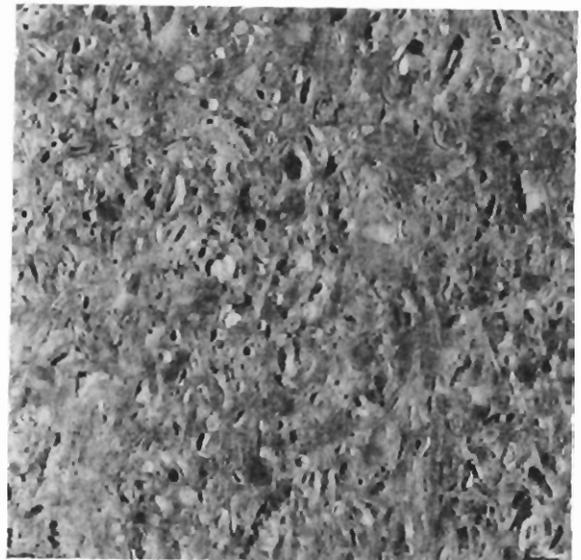


Fig.11 Enlargement of a shell lime stone platen (conglomerate), scale ca. 4:1

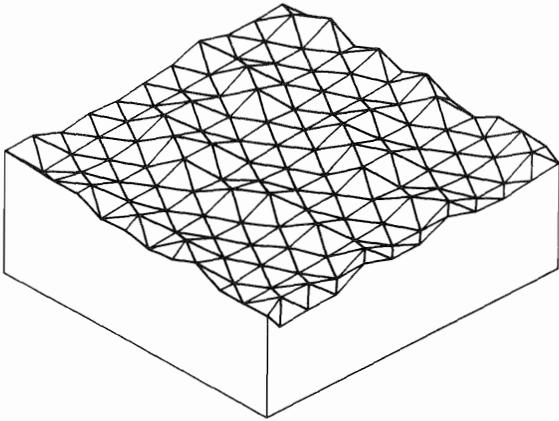


Fig.12 Plot of a simulated smooth stone surface

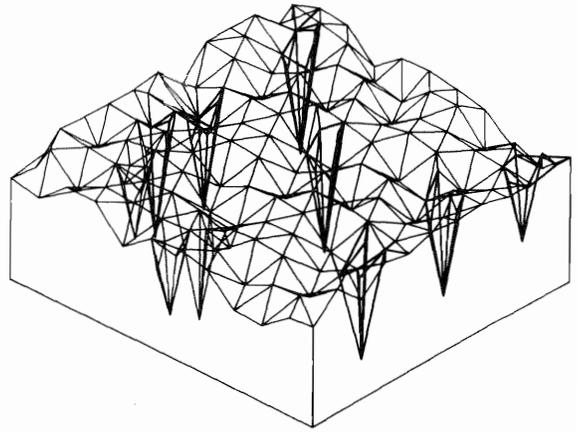


Fig.13 Plot of a simulated rough stone surface with cuneiform holes

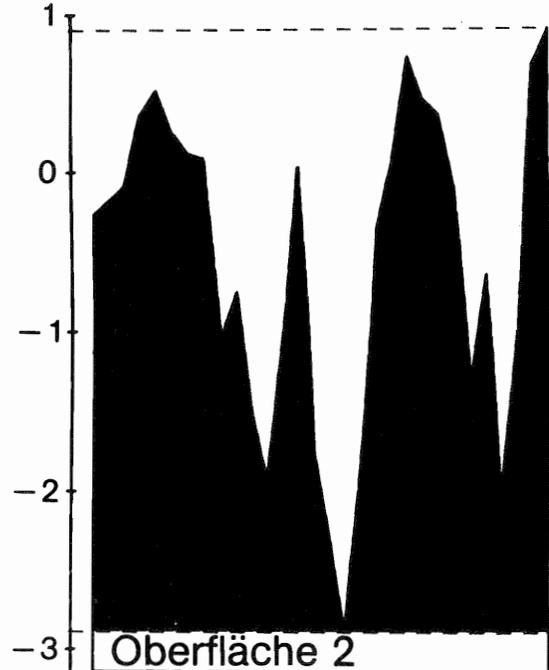
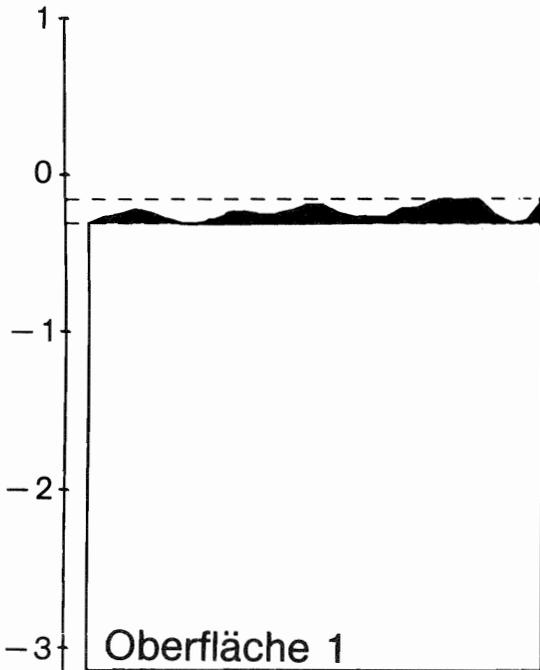


Fig.14 Cross sections of the simulated smooth and rough stone surfaces

and the base length have to be defined by the measuring devices. It was necessary to make the recording configuration reproducible. The used partial-metric camera Rollei 6006 Réseau can be equipped with extension tubes and retro-adapter. Taking a Distagon 50 mm lens and four tubes the photo scale is 4 : 1, but the depth of field is only very small. The digital models of the surfaces produced by the analytical plotter Zeiss Planicomp 100 will be plotted by a CAD-system to get a quantitative analysis (e.g. changing grain structure, erosion, change of volume) and to compare the results to other registration methods, as hologram interferometry, which is worked out by the University of Oldenburg. For testing the adapted plotter software simulated digital model data were used (Fig. 12 - 14).

## References

- Backes, M., 1986: Historische Originalität und materielle Substanz; Sonderheft "Bausubstanzerhaltung in der Denkmalpflege", Verlag Rudolf Müller, Köln
- Carbonnell, M., 1976a: Mesure photogrammétrique de l'alteration superficielle des pierres malades - bilan de l'étude en Avril 1976; Rapport de l'Institut Géographique National, Paris
- Carbonnell, M., 1976b: Technical progress in architectural photogrammetry; Invited Paper, ISPRS-Congress, Commission V, Helsinki
- Dallas, R.W.A., Morris, A.H., Phillips, A.D., 1987: "The heart of Yorkshire": surveying the west window of York Minster; Photogrammetric Record 12
- Heckes, J., Mauelshagen, L., Weisgerber, G., 1987: Photogrammetrie beim Deutschen Bergbau-Museum; Der Anschnitt 5 - 6, Bochum
- Mirwald, P.W., Zallmanzig, J., 1986: Der Einfluß von Schadstoffen auf Naturstein; Th. Goldschmidt AG, Essen
- Vieser, H., 1987: Wenn die Sterne sterben; Bild der Wissenschaft 12, Deutsche Verlags-Anstalt GmbH, Stuttgart
- Wester-Ebbinghaus, W., 1985: Bündelausgleichung mit gemeinsamer Ausgleichung photogrammetrischer und geodätischer Beobachtungen; Zeitschrift für Vermessungswesen 3
- Wester-Ebbinghaus, W., 1986: Ingenieur Photogrammetrie - Mathematische Ansätze und instrumentelle Voraussetzungen; Presented Paper, XVIII. FIG-Kongress, Toronto