The material listed below has been collected in 2010 by Kathryn N. Barnard and Erica A. Medley, Engineering Geology students of Prof. Scott Burns at Portland State University (USA) in the framework of a students assignment. The material has not yet been screened and commented nor approved by the C16 chair and membership

Journal Articles

Durability of carbonate rock as building stone with comments on its preservation
F. G. Bell

Environmental Geology Volume 21, Number 4, 187-200, DOI:10.1007/BF00775905

Abstract
Carbonate rocks have been extensively used as building stones because of their availability, workability, and attractiveness. Unfortunately, however, some stones suffer from chemical attack or freeze-thaw activity. The environmental affects, especially those due to pollution of the atmosphere, are discussed in terms of weathering processes, salt crystallization, and acid deposition. A review of some recent research in relation to deterioration of stone in urban environments is given and carbonate rocks are classified in relation to position within a building, geographical location, and degree of pollution. Some comments on stone preservation are provided, especially in terms of the properties a preservative should possess.

Naturstein in Dresden; Nutzung, Verwitterung und Erhaltung an historischen Bauwerken. Translated Title: Building stone in Dresden; use, weathering and maintenance at historic buildings.

Siedel Heiner

Deutsche Gesellschaft fuer Geowissenschaften Berlin, Federal Republic of Germany.
2009

Abstract
Natural stone has been used for construction purposes in Dresden over centuries. Sandstone from the Cretaceous of the Elbe valley is the dominant building stone from the very beginning of stone construction until the 20th century. Granites from Lusatia and the Meissen region as well as dolerites from Lusatia appear on facades and monuments only at the middle of the 19th century. Following an excursion route through the city centre of Dresden, the utilization of natural stone for construction elements, the weathering behaviour of different stone types, and methods for maintenance and restoration of damaged stone surfaces are demonstrated.

Post-depositional modification of atmospheric dust on a granite building in central Rio de Janeiro; implications for surface induration and subsequent stone decay.

Smith B J; McAlister J J; Baptista Neto J A; Silva M A M.

Geological Society Special Publications. 271; Pages: 153-166; 2007.

Abstract
Extensive contour scaling of a 200 year old granite church is associated with the breaching of an apparently iron-rich crust and the widespread deposition of atmospheric dust within the canyon-like streetscape of Rio de Janeiro. Contemporary dust, accumulated dust from within a depression on the building surface, the surface crust and the underlying granite are examined by a combination of total element analysis and sequential extraction, X-ray diffraction and energy dispersive X-ray fluorescence. Results indicate an increase in total organic carbon and marked decrease in pH within the accumulated dust, and a rapid mobilization of anions and cations from the water-soluble and carbonate phases. It is considered that the latter is linked to salt accumulation within and eventual salt weathering of the granite. Post-depositional alteration of the dust is also linked with the de-silicification of clay minerals (illite to kaolinite) and the loss of silica from the amorphous Fe/Mn phase of the accumulated dust under the initially saline and progressively more acidic conditions experienced at the stone-atmosphere interface. This mobilization of silica is associated with the formation of what is, in effect, a thin silica-rich surface crust or glaze. Within the glaze, accessory amounts of extractable iron are concentrated within the amorphous and crystalline Fe/Mn phases at levels that are significantly elevated with respect to the underlying granite, but much lower than in the equivalent phases of the accumulated dust from which it is principally assumed to derive. The protection afforded to the stonework by the crust is not, however, permanent and within the last 15 years it has been possible to observe a rapid increase in the surface delamination of the church close to street level.

Laboratory evaluation of building stone weathering.

Bortz Seymour A; Wonneberger Bernhard.

Geotechnical Special Publication. 72; Pages: 85-104; 1997.

Abstract
Dimension stone is among the most durable materials, but the process of weathering has shown that some types of stone, even of the same variety, are more durable than others. At present there is little information available about the durability of dimension stone on a building facade. Designers generally select a particular stone for its aesthetic qualities, with casual reference to basic parameters such as porosity, pore size, moisture absorption, and other critical physical and chemical parameters. Generally, when there is reference to weathering, the recommendation is to inspect another building with the same variety of stone. The recommendation does not consider the fact that stone, being a natural material, can vary considerably, even from one place in a quarry to another. Thus, in addition to observing weathering history in the field, we must determine how rock weathering can be recreated in the laboratory. This paper attempts to provide background regarding the environmental processes that cause stone weathering in the field, such as acid rain (chemical), thermal (temperature changes), and freeze-thaw of absorbed water. We

compare laboratory to field data that indicates accelerated durability testing can provide reliable information to long-term behavior of dimension stone.

Oxford stone revisited; causes and consequences of diversity in building limestone used in the historic centre of Oxford, England.

Gomez-Heras Miguel; Smith Bernard J; Viles Heather A.

Geological Society Special Publications. 333; Pages: 101-110; 2010.

Abstract
Stone decay is the result of the interaction of stone with its environment. It is therefore important to understand why certain materials, sometimes not the most suitable, were used to shape the built heritage of specific areas. The historical evolution of these areas conditioned many of the combinations of materials we see today, which in some cases can interact to accelerate decay. These combinations were driven by availability during construction, architectural fashion or the simultaneous utilization of materials that are aesthetically similar but differ significantly in their physical and chemical properties. A microcosm of the complex decisions that determine stone selection and subsequent interactions is provided by the City of Oxford, which is an excellent example of how such historic evolution can work with material characteristics to accelerate decay.

The 19th century Corsi collection of decorative stones; a resource for the 21st century?

Prikryl Richard (editor); Torok Akos (editor).

Geological Society Special Publications. 333; Pages: 185-195; 2010.

Abstract
The Corsi collection of decorative stones is arguably the most important and certainly the most diverse and well known of similar collections in Europe. Formed in Rome in the first quarter of the 19th century it consists of 1000 polished sample blocks (c. 15 X 7.5 X 4 cm) of natural decorative and semi-precious stone. All the blocks were acquired by Faustino Corsi through other persons, usually a dealer or stonecutter who had them cut to approximately the dimensions of the first model. More than 300 are from stone that had been used in ancient Rome; the others are from stone quarried at a later date. The collection, which is complete, has been in the possession of Oxford University since 1827. The reasoned catalog by Corsi sheds light on early 19th century ideas about mineralogy and many of the types of stone in use in Rome. Hand specimens are not as important as they used to be for teaching undergraduates, and the decorative arts have little place in modern science. Recent work on provenance, type of stone and nomenclature greatly increase the value of the collection as a resource for identification of ornamental stone used in historical buildings, sculpture and the decorative arts in the 21st century.

The stone structural system in historic buildings.

Zambas C

Institute of Geology and Mineral Exploration Athens, Greece. Pages: 163-185; 2001

Abstract
Stone and wood are the main diachronic natural structural materials. Stone constructions have been survived for many centuries and they compose the great majority of world architectural heritage. The stone has been used treated or untreated, sometimes with mortar use and others with dry assemblage. This paper deals with the stone structural system which is formed dryly of stone blocks or drums with or without connective elements among them. It is about the structural system which resembles to the contemporary prefabrication system and is found in monumental constructions around the world from pre-historic ages until modern years (Architecture in Egypt, Greece, Roman World, American continent, Europe etc). The behavior of the stone structural system is examined through static and dynamic aspects. In both cases the behavior is mainly affected by the discontinuities at the joints positions. In the first case, the joints condition between the surfaces specifies the distribution of the mechanical stresses in the material, while in the second one, the joints affect the distribution and the magnitude of the seismic loading. Finally, there are presented the basic recommendations for the restoration of the stone structural system of the monuments, with the less possible interventions. The initial structural system must be respectable, as it is established by the internationally approved principles of restoration deontology.

La pierre de construction, materiau du developpement durable. Translated Title: Building stone, a sustainable development material

Dessandier David; Sayagh Shahinas; Bromblet Philippe; Leroux Lise

Geosciences Orleans. 10; Pages: 8-15; 2009.

Abstract
Since prehistoric times, mankind has regularly quarried stone for daily needs, always regarded it as a reference building material and used it extensively until it was replaced with concrete. The considerable diversity of France's geological formations has provided a wide assortment of stones disseminated over the whole country that exhibit varying technical characteristics suited to different types of building uses. Stone has also been called on for decorative purposes. However, it is a fragile resource that must be managed sensibly. Some deposits have already run out, whilst others are no longer accessible. Furthermore, quarries are subject to strict regulations, which are becoming increasingly stringent as years go by, while they also continue to be viewed as negatively impacting the environment. With modern air pollution, buildings that heretofore had withstood the test of time have significantly deteriorated today, especially in urban areas. Still, stone is the only material that has shown itself to be resistant in the long term. Finally, in these early years of the 21st century, stone, a natural substance per se and irreplaceable in former times, now must prove that it complies with the principles of sustainable development if it is to retain its good standing amongst building materials for the future.

Geology of Greece and the building stone in monuments.

Matarangas D; Varti-Matarangas Myrsini.

Institute of Geology and Mineral Exploration Athens, Greece. Pages: 57-68; 2001.

Abstract
The relation of Geology with the building stones and in general with the monuments promotion and protection is fundamental, given the fact that: a) monuments are built of natural building material, stones, b) their present stability depends on different geological phenomena, such as earthquakes, volcanic activity, landslides, alterations of the sea level, river alluviums, etc. and, c) any kind of human intervention to the monuments requires perfect knowledge of the monuments' deterioration reasons. The use of "epichorion lithon" which is well known since Pafsanias era, demands the exact and detailed knowledge not only of the lithological formation of the area where the monument is situated, but also of the geological formation of the wide area. The Greek land in its entity consists of the Hellenides mountains range and has traditionally been formed in geotectonic zones, which are geological sections with common lithological , palaeo-geographical, stratigraphical and tectonic characters and the Servomakedon and Rhodopes metamorphic masses. Definitely the present geographical allocation of the zone formations is complicated, because they have gone through intense tectonism, and as a result entire zones lay tectonically on top of others. According to their evolution we distinguish them to internal and external.

Predicting the frost resistance of building stone.

Ingham J P.

Quarterly Journal of Engineering Geology and Hydrogeology. 38; 4, Pages: 387-399; 2005.

Abstract
Frost attack is a major cause of building stone decay whose mechanisms are not yet entirely understood. Direct accelerated frost tests were developed locally to match regional environmental conditions and there have been considerable difficulties correlating between the results of different national standards. The European Committee for Standardization (CEN) introduced a direct test in 2001, however little guidance for the interpretation of the test has been made available to date. In this investigation, a trial was conducted to compare a direct accelerated frost test to indirect methods of stone durability assessment, for building stones of known historical performance. The frost test proved to be unsuitable for the assessment of porous limestone, with durable stones failing the test while less durable stones passed the test and modes of deterioration observed bore little relation to those seen on stone buildings. It was concluded that direct accelerated frost tests were unlikely to adequately reflect natural processes to accurately predict durability. Certain indirect methods of stone durability assessment that investigated the pore properties of the stone were found to be a more reliable predictor of frost resistance. Petrographic examination was found to be of value in the determination of intrinsic rock properties and for observation of changes caused by frost action.

Effect of long-term changes in air pollution and climate on the decay and blackening of European stone buildings.

Grossi C M; Brimblecombe P.

Geological Society Special Publications. 271; Pages: 117-130; 2007.

Abstract
This paper reviews the long-term effects of past, present and future air pollution and climate on the decay of stones from historic buildings. It summarizes the historical effects as well as causes and consequences of damage. The most significant change in terms of pollution has been a shift from high levels of sulphate deposition from coal burning to a blackening process dominated by diesel soot and nitrogen deposition from vehicular sources in cities. Blackening of light-coloured fabric eventually reaches a point where it becomes publicly unacceptable. Public opinion can assist the development of aesthetic thresholds and derive limit values for elemental carbon in urban air. Public perception is also affected by the pattern of blackening. This century new climate regimes will cause dramatic changes in blackening patterns by wind-driven rain. Climate changes, most particularly changes in temperature, humidity stress and time of wetness, can also affect the weathering of stone in terms of responses to frost and soluble salts. Future pollution and climate are relevant considerations in the management of historic buildings.

Geostatistical evaluation of dimension-stone quarries

E. Tercan′ and Y. Özçelik

Engineering Geology, Volume 58, Issue 1, September 2000, Pages 25-33

Abstract
This paper addresses the two problems that arise in evaluating dimension-stone quarries: absence of a single quality variable and classification of blocks of stone. In constructing the single variable, an approach considering multivariate spatial relations of a number of variables that affect quality of dimension-stone is proposed. The multivariate spatial relations are defined by variogram matrices. In classification of the blocks, a decision analysis approach that rests on two key concepts, cumulative conditional distribution function and loss function, is introduced. The approaches are applied to an andesite quarry located in Ankara, Turkey: one level of the quarry is chosen to be a test area from which 108 rock samples are taken at 20 m regular intervals. The rock samples are tested for some of the mechanical properties of andesite that control the economics of extraction process, and a quality index is produced using test data. The application area is then divided into 1862 5×5 m square blocks, and the conditional distribution functions for these blocks are estimated by indicator kriging. Finally, the blocks are classified as exploitable and non-exploitable on the basis of minimization of economic losses.

Evaluation of dimension stone in gneissic rocks — a case history from southern Finland

H. Luodes′ ′ [a], O. Selonen′ [b] and K. Pääkkönen

Engineering Geology, Volume 58, Issue 2, November 2000, Pages 209-223

Abstract
A dimension stone prospect in southern central Finland was assessed by a detailed mapping, geo-radar survey, and core drilling. The prospect is a veined and bedded garnet–cordierite gneiss, consisting of a dark schistose medium-grained palaeosome and a light coarse-grained granitic leucosome. Both components are found mainly as thin units, but the leucosome can occur as individual veins several metres thick, which leads to disturbing variations in the appearance of the stone. The soundness of the stone is defined by the amount of tight, but open cracks in the palaeosome and weakness zones in the weathered leucosome. As a whole, the soundness is diminished down to 10 m below the outcrop surface. Furthermore, a subhorizontal body of younger granite is identified at approx. 8–20 m depth. Consequently, the prospect is not feasible for production of dimension stone.
The core drilling was decisive in the final evaluation of the prospect because the true density of the cracks and the subsurface granite were identified by the method. Only with the use of core drilling could the proper interpretation of the characteristics of the prospect be made, demonstrating the importance of three-dimensional investigation of a dimension stone prospect.