

## AN OVERVIEW IN URBAN GEOLOGY AND URBAN GEOMORPHOLOGY

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### Abstract

*Worldwide is observed an expansion in urban areas. In Greece a proportional phenomenon is mentioned. More than 52% of the Greek population now lives in the two metropolitan municipalities of Athens and Salonica.*

*For this reason grows up the scientific interest to urban geology and urban geomorphology. Urban Geology is the application of geologic knowledge to the planning and management of metropolitan areas. Its domain spans both regional geology and applied geology. Urban Geomorphology is the study of man as a physical process of change whereby he metamorphoses a more natural terrain to an anthropogene cityscape. In such a context Urban Geomorphology is the surface component of Urban Geology, which is one of the important subfields of environmental geology.*

*The urban geomorphology is related with the management of natural hazards and the spatial planning. Engineering geology and urban planning need to interface with geomorphology in hazardous areas.*

**Key words:** urbanization, urban planning, geomorphologic hazards.

### Περίληψη

*Παγκόσμια παρατηρείται μια πληθυσμιακή ανάπτυξη στις αστικές περιοχές. Αντίστοιχα και στην Ελλάδα σημειώνεται ένα αντίστοιχο φαινόμενο. Περισσότερο από το 52% του ελληνικού πληθυσμού σήμερα κατοικεί στους δήμους των δύο μητροπολιτικών περιοχών της χώρας, του Λεκανοπεδίου Αττικής και της Θεσσαλονίκης.*

*Για αυτό μεγαλώνει το επιστημονικό ενδιαφέρον για την Αστική Γεωλογία και την Αστική Γεωμορφολογία. Η Αστική Γεωλογία είναι η εφαρμογή της γεωλογικής γνώσης σε σχέση με το σχεδιασμό και τη διαχείριση των αστικών περιοχών. Το γνωστικό αντικείμενο της εκτείνεται τόσο στην βασική γνώση της γεωλογίας όσο και στις εφαρμογές της. Η Αστική Γεωμορφολογία είναι η μελέτη του ανθρώπου και των δραστηριοτήτων του ως φυσική διεργασία αλλαγής, με την οποία μεταμορφώνει μια φυσική έκταση σε μια ανθρωπογενή παράσταση πόλης. Σε ένα τέτοιο πλαίσιο η Αστική Γεωμορφολογία είναι το επιφανειακό συστατικό της Αστικής Γεωλογίας, η οποία είναι ένα από τα σημαντικότερα υποπεδία της περιβαλλοντικής γεωλογίας.*

*Η Αστική Γεωμορφολογία σχετίζεται με τη διαχείριση των φυσικών κινδύνων και το χωροταξικό σχεδιασμό. Η Τεχνική Γεωλογία και ο Αστικός Σχεδιασμός είναι απαραίτητα να συνδέεται με την Γεωμορφολογία στις επικίνδυνες περιοχές.*

**Λέξεις κλειδιά:** αστικοποίηση, αστικός σχεδιασμός, γεωμορφολογικοί κίνδυνοι.

# 1. Urban expansion

The power of urbanization and a swiftly expanding chemical industry have been responsible for huge ameliorations in the quality of life over the last 160 years, on a global level. Paradoxically, these same forces now threaten the global environment. Urban areas are characterized by intense and often unregulated industrial activity, rapid and poorly planned growth, the fragmentation of natural habitats, and the degradation of surface and ground waters by a wide range of chemical contaminants (Eyles 1997).

More than 70 % of the world's population now lives in urban areas and there are more than 20 so-called "supercities" each containing more than 10% of their respective national populations. Examples include Mexico City (31 % of national population), Buenos Aires (42 %), Cairo (36 %), and Sao Paulo (17 %; Turner *et al.* 1990, United Nations Population Fund 1991). Whereas the growth of cities is the engine of the world economy and generates enormous social benefits by concentrating human creativity, most global environmental problems of the late 20<sup>th</sup> century can be linked directly to the massive transfers of resources and waste products required by large cities. Terms such as "urbanization" (Fig. 1), "economic imbalance", and "environmentally unsustainable" are becoming synonymous (Tabibzadeh *et al.* 1989, Stren *et al.* 1992, Socolow *et al.* 1994, Drakakis-Smith 1995). In 1950, there were 83 cities with populations greater than 1 million; today, there are more than 280 cities and this total will double by 2015. The ten largest supercities are listed in figure 2 (Eyles 1997).

In Greece, it is observed a proportional phenomenon. More than 52 % of the Greek population now lives in the two metropolitan municipalities of Athens and Salonica. Also the greater percentage of the immigrants lives nowadays in the Greek cities and towns. More than 40 % of the Greek population lives in the municipalities of Attica.

# 2. Urban geology

Urban geology is a specialty few geologists claim. Its domain spans both regional geology and applied geology. Some emphasis is usually assumed in the application of geological principles and knowledge to the solution of construction, and now environmental, problems in or near urban areas (Karrow and White 1998).

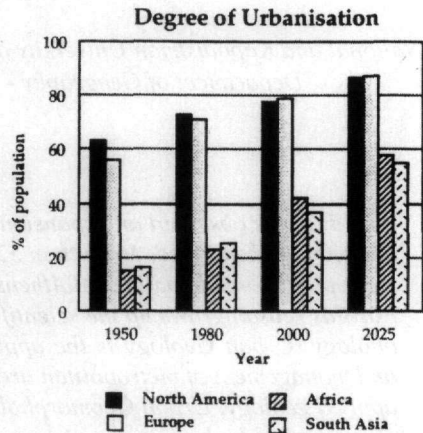


Figure - 1 Degree of urbanization (Mulder 1996)

## CITIES OF THE FUTURE

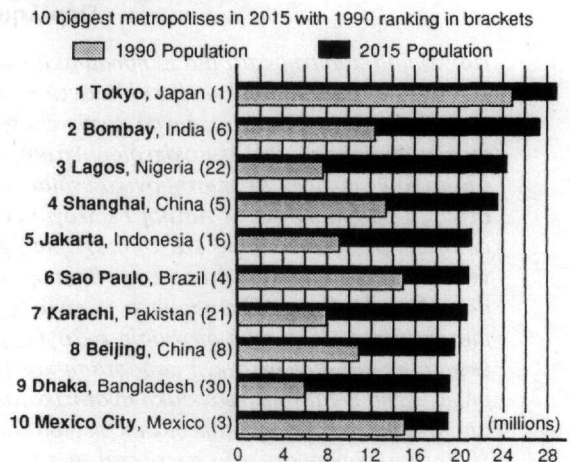


Figure 2 – Expected ten largest supercities as of 2015, with 1990 ranking in parentheses (Eyles 1997)

Whereas geologists have worldwide a long history of working in cities alongside engineers (e.g. Legget 1973, Leveson 1980), the artificial, built landscapes of urban areas have, by and large, been seen as “poor places to do geology” (Walton 1982).

Urban geology is the application of geologic knowledge to the planning and management of metropolitan areas. Involved in this field of geology are the subdisciplines that contribute to water supply and waste disposal, site investigation for hazardous conditions, and delineation of economic rock and mineral deposits. Most aspects of engineering geology are applied in the urban setting, including the analysis and interpretation of rocks, soil, and groundwater for the purposes of planning and design of engineering structures. Both engineering and urban geology are part of the wider field of environmental geology, which includes the study of resource exploitation, waste disposal, geologic hazards, medical geology, and the environmental impact of humans. Many of these problems are of prime importance in the urban environment, and since the introduction of the term “environmental geology” in the middle 1960s, the terms urban geology, applied geology, and, to a lesser extent, engineering geology, have been less frequently employed. Almost any traditional field of geology can contribute to environmental geology; the determining factor is a commitment to provide information on the geologic environment to serve society's needs (Utgard *et al.* 1978). It is mentioned that a standard metropolitan statistical area (SMSA) is defined by the U.S. Bureau of Census as a county or group of contiguous counties which contains at least one city of 50,000. In addition to counties containing such cities, contiguous counties are included in, an SMSA if, according to certain criteria, they are socially and economically integrated with the central city.

Traditional approaches to “urban geology” have focused mostly on the engineering behavior of the various geological materials below cities in terms of their stability for roads, foundations, etc. Provision of adequate construction materials has also been a major concern. The principal environmental geological concerns in urban areas includes the provision of sufficient drinking water, waste disposal, soil and landscape degradation, and the increasing vulnerability of densely populated urban areas to geological hazards and environmental disasters. Environmental geologists working on such problems are, in the main, employed by the environmental-consulting sector (Eyles 1997).

In Canada and USA, the public concern with urban environmental and health issues heightened and is reflected in new planning legislation and land use regulations. In turn, environmental geological investigations centered on urban areas encompass a very broad range of issues. There is increasing interest by private companies and financial institutions (particularly insurance and banking) concerned with the safety of investments arising from litigation over contaminated properties or geological hazards, and the need for clients to recognize and comply with environmental regulations.

Another growing recognition of the importance of urban environmental and engineering geology in Canada and USA, and the need for an increased body of professionals, is reflected in new programs in universities and colleges and the availability of textbooks.

### **3. Urban geomorphology**

Geomorphology is the science of landforms and the processes that create them. In the urban environment man is the creator of the landscape or “cityscape”. Thus, urban geomorphology is the study of man as a physical process of change whereby he metamorphoses a more natural terrain to an anthropogene cityscape. In such a context urban geomorphology is the surface component of urban geology, which is one of the important subfields of environmental geology (Coates 1976).

Man lives, works, and plays on the surface of the Earth and nearly all his activities transform the surface in some manner. Maximum distortion occurs, however, in urban areas where he has chosen to congregate and congest. The emphasis of urban geomorphology is on this unique geographic

setting where man has so thoroughly intruded that he has overwhelmed many of nature's physical systems. The study of these aberrations, some of which are deliberate while others are by-products, constitutes one of the subfields of geomorphology (Coates 1976). The urban geomorphologist can use his expertise to predict the kind of destruction that will ensue from man's construction enterprises when the type, degree, and magnitude of the environmental upsets are understood. It is not sufficient for the scientist to "merely know" what will happen, but he should become involved in decision-making matters. It is necessary to provide advice for those plans that seek alternate paths whereby man's activities can be consummated in a manner that will minimize environmental degradation (Coates 1976).

Urban geomorphology examines the changes caused by the requirements of urban residential, economic and traffic functions (Cooke 1976, Cooke *et al.* 1982). Towns are adjusted to the relief and the relief is also adjusted to the needs of construction and planning (Ahnert 1996). The changes that occur as a result of urban development are also influenced by their interaction with the disturbed geomorphological process response systems, such as weathering on building stone resulting from air pollution (Viles 1993).

Local landforms have played a central role throughout history in the choice of sites for settlements and their further development has often been influenced by the regional geomorphology. The location of Italian cities on defensive hill sites, the development of the Greek city states in fertile basins surrounded by hills, locations at easy river crossings, on terraces above flood levels, on bays, at the landward end of navigable estuaries or at the exit of large mountain valley systems on to a foreland are some examples. Villages located in spring hollows, along valley floors or on sandy upland bordering marsh areas all once took advantage of the local relief and hydrological conditions. Settlement geography is incomplete without taking into account the morphography and hydrology of the area (Ahnert 1996).

Erosion increases in urban areas when, for example, building activity bares the soil and causes extensive wash denudation. The streams become overloaded with sediment as a result and their cross-sections are changed (Wolman 1967, Wolman and Schick 1967). Road building has a similar effect, particularly the construction of multi-lane highways. As urban areas expand, more soil surfaces are sealed by buildings, streets, parking areas, industrial and commercial activity so that the surface runoff flows into the sewage system. Groundwater supplies are reduced as a result and flood frequency and the peak flood height are increased (Leopold 1968, Graf 1975, Sala and Inbar 1992). Gupta (1984) has discussed the special geomorphological and hydrological problems of cities in the tropics.

Human activity has increased the runoff maxima in many river basins, and this has been compensated for by the building of reservoirs which store the excess runoff and release it gradually. Reservoir basins are also sediment traps for all the bed load and at least part of the suspended load. Immediately below the dam the stream is practically free of solid load so that it picks up new load and erodes its channel bed downstream from the reservoir. The bed load is smaller than before because the high-water peaks are lower than before the dam was completed (Gregory and Park 1974, Gregory 1979).

Many articles have been written on various aspects of urban geomorphology. Three completed editions - books have been published on this subject by Detwyler and Marcus (1972), Coates (1974) and Legget (1973).

#### **4. A bibliographic review in urban geology**

The first urban geological activities traceable in literature date back as far as the end of 19<sup>th</sup> and the beginning of 20<sup>th</sup> century. The first urban geology studies they were worked out in Canada by H.M. Ami.

Although the 1900 paper by Ami "On the Geology of the Principal Cities in Eastern Canada" is often cited as the pioneering work, this paper was the culmination of his earlier papers dealing individually with the cities of Ottawa, Montreal and Quebec (Ami, 1885, 1891, 1892 and 1897); overlapping with these were papers by Dresser (1897) and Adams (1898) on Montreal (Karrow and White, 1998).

In more recent times, the distinguished spokesman for urban geology was R.F. Legget. His book "Cities and Geology" (Legget 1973) remains the best known on the subject. This internationally known authority delivered many invited lectures on urban geology, richly illustrated with examples from around the world. His brief brochure, simply titled "Urban Geology" (Legget 1969), was distributed by the National Research Council Division of Building Research, of which he was its founding and long-time Director.

In Germany, special soil maps were made to support urban planning (Hoyningen-Huene 1931, Stremme 1932). Towards the end of the thirties the Preussischen Geologischen Landesanstalt in Germany (Bruning 1940) combined detailed maps on scales of 1:10,000 and 1:5,000 with maps indicating the suitability for various kinds of land-use and compiled these into a "Bodenatlas" for urban expansion. As a result of the population explosion and the economic revival immediately after World War II, the amount of urban geological activities increased substantially in many countries, especially in Europe and North America. New systematic geological mapping programs were set up in, for example, Germany, Czechoslovakia and the Netherlands. These were intended to support physical planning and pay attention to physical properties of rocks as well as the succession of strata in the subsurface (Hageman, 1963). An excellent example of such urban geological activities was the detailed (scale 1:5,000) mapping of foundation conditions in the city of Prague. The numerous data and maps of this city are constantly updated (Legget 1973). For more than a dozen German cities atlases with thematic land-use maps have been prepared (Munchenhausen and Muller 1951). Although these were obviously intended for urban planning, their readability is generally poor. To economize on the high (color) printing costs, too much information was crammed into too few maps. Information about soil properties and suitability for various kinds of land-use was presented on the maps and in the explanatory notes in qualitative terms only. This was undoubtedly due to the very limited availability of geotechnical and geohydrological in-situ and laboratory test results (de Mulder 1996).

As a result of the explosive economic growth in the United States of America after World War II and the subsequent urban expansion, the number of geologists concerned with urban geology increased rapidly. For example, at the end of the sixties, about 150 geologists were employed in this field in the city of Los Angeles alone (McGill 1973). In the same period a break-through in the use of geological data for urban planning and management was achieved in Canada mainly on account of the publications of Legget (Legget 1973, White 1989). In industrialized countries concern about our natural environment grew, and the dangers of pollution caused by large-scale waste-disposal, predominantly in and around urban centers, became apparent in the seventies. Detection, immobilization and restoration of polluted areas and selection of appropriate sites for waste disposal opened up a new field of interest and created a new challenge for urban geologists. Geochemistry was added to their expertise and environmental geology became the focus for a rapidly accumulating number of new studies. This resulted in new ways of informing planners about the potentials and the limitations of the soil. "Geopotential maps", on which preferential land-use based on Earth-scientific and related discipline is indicated, were first introduced in the Federal Republic of Germany (Luttig, 1978). This mapping system was later applied in several other countries, for example Togo, India and Indonesia. Many urban geological maps were made and printed by the US Geological Survey during this decade (e.g. McGill 1973, Baskerville 1981, Merguerian and Baskerville 1987).

In various European countries special studies were carried out, mainly by geological surveys, in order to investigate the most appropriate way to present (processed) geological data on maps of

urbanized areas (e.g. Monroe and Hull, 1987, Forster *et al.* 1987, de Mulder 1986). In Spain, geotechnical maps for urban planning on a scale of 1:25,000 were made by the Instituto Geologico y Minero de Espana for the cities of Huelva, Granada, Palma de Mallorca, Almeria, Malaga, Cordoba, Alcoy, and Valladolid (Instituto Geologico y Minero de Espana 1984, Cendrero *et al.* 1987) and for the Madrid region on scales of 1:400,000 to 1:100,000 by the Instituto Tecnologico GEOMINERO de Espana (Ayala Carcedo *et al.* 1988). The increased use of geohydrological and geotechnical models from the end of the seventies onwards made it possible to predict and to quantify the effects of human interference in the geosphere. An example of this was the prediction of the harmful effects of land subsidence resulting from land reclamation in The Netherlands (de Mulder *et al.* 1994). The impact of geological processes such as erosion and sedimentation on cities has been effectively and extensively described by Douglas (1988 and 1990).

The introduction of electronic data files and Geographical Information Systems (GIS) greatly facilitated the presentation of data on maps and made new applications possible. This development marked the decline of traditional, printed geological maps with 'eternal' value and the onset of custom-made maps on cheap paper from the plotter and produced on request, with a temporary value only. Thus, thematic maps became more accessible to planners, decision makers, and engineers. This development was enhanced by deleting all kinds of marginal information which would not be understood directly by the target group (the users), and by presenting these data in a more quantified manner (e.g. de Mulder 1986).

A significant development in urban geosciences occurred in the early nineties when the British Geological Survey started the LOCUS (London Computerized Underground and Surface) Project. This ambitious project aims to produce urban geological maps on various themes for land-use planning, civil engineering, and for solving geo-environmental problems (de Mulder 1996). It is based on the development of a digital database comprising more than 20,000 borehole descriptions. Map production takes place from this database by means of a GIS (Ellison *et al.* 1993). The introduction of increasingly powerful computers encouraged the development of more complex models which are now capable of, for example, predicting the costs for municipalities for different kinds of land-use in different types of geological setting (de Mulder 1994).

Outside Europe and North America, urban geology began to develop from the mid eighties onwards in Southeast Asia and the Pacific. This was largely a response to the stimulus provided by the activities of the Economic and Social Commission for Asia and the Pacific (ESCAP, United Nations). Six volumes of the Atlas of Urban Geology, compiled by J. Rau and published by ESCAP in Bangkok, contain the results of special urban geological studies and state-of-the-art reports from the People's Republic of China, Bangladesh, Fiji, Indonesia, Malaysia, Nepal, Pakistan, Philippines, Republic of Korea, Sri Lanka, Thailand and Vietnam. A few decades earlier, urban geological studies for the city of Calcutta (India) were carried out and published (Dastidar and Ghosh 1967) followed by a number of urban geotechnical studies scattered all over this sub-continent (Raju 1987). De Mulder (1996) mentions that in Africa no major urban geological studies or geological studies for land management, apart from Togo (Allaglo *et al.* 1987), Morocco (Hafdi 1987) and Zaire (Tanania 1994), are known.

In Greece, some town's microzone studies had been carried out. But these studies are not urban geologic researches. The first completed urban geologic study was the "Geological, geomorphological and geographic study of the urban areas of Trikala Prefecture – Western Thessaly" (Bathrellos 2005). After this study, which was the author's PhD Thesis, a project has started by Direction of Mapping of Greek "Institute of Geology and Mineral Exploration". This project studies the geologic settings of four Greek towns. Beyond a few other studies have been published in which are performed some problems of various Greek towns and cities (e.g. Skilodimou *et al.* 2002, 2003, Rozos *et al.* 1992, Koukis *et al.* 1997, Bathrellos *et al.* 2005, Skilodimou 2002, Bathrellos *et al.* 2005).

## 5. The relation among urban geomorphology and spatial planning

Engineering geology and urban planning need to interface with geomorphology in hazardous areas. Urban geomorphological hazards can be divided into two broad groups: (1) hazards associated with city location, and (2) hazards created or accentuated by accelerated resource utilization and city metabolism (Gupta and Ahmad 1999).

It is an oversimplification to say that doing urban geomorphology is simply doing surface geology studies in cities. It is true that there are universal physical laws that operate on all land and water. However, in the urban environment man has supplanted or suppressed natural processes to such an extent that new or modified techniques are necessary to study this deformed system. For example, the concentration of population exerts increased demands on the land-water ecosystem, which is quite unlike that of other more natural geomorphic settings. Many imbalances occur in the surface water-ground water relationship with channelization and rerouting of normal streams (Coates 1976).

Urban geomorphology combines the ambient geology, landforms, and geomorphological processes with the evaluation of impacts brought to these by urbanization. The practitioners of urban geomorphology tend to concentrate on alteration, using the ambient physical environment as a baseline. A number of case studies from different parts of the world (dealing with topics such as slope instability, seismic hazards, increased flood problems, and land subsidence) have demonstrated the utility of urban geomorphology to engineers, city managers, and urban planners (Gupta and Ahmad 1999).

## 6. Conclusions

Worldwide is observed an expansion in urban areas. In Greece a proportional phenomenon is mentioned. More than 52 % of the Greek population now lives in the two metropolitan municipalities of Athens and Salonica.

Urban Geology is the application of geologic knowledge to the planning and management of metropolitan areas. Its domain spans both regional geology and applied geology. Urban Geomorphology is the study of man as a physical process of change whereby he metamorphoses a more natural terrain to an anthropogene cityscape. In such a context Urban Geomorphology is the surface component of Urban Geology, which is one of the important subfields of environmental geology.

Urban Geology and Urban Geomorphology are two subfields of geology, which are sufficiently developed worldwide. In contrary in Greece they have not been opened out. Author's opinion is that these subdisciplines of Geology may be developed, aiming at better management of natural hazards. Urban geology and geomorphology need to interface with spatial and especially urban planning in hazardous areas.

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