INTRODUCTION: ENVIRONMENTAL AND ENGINEERING GEOLOGY

Fred G. Bell
Blyth, Nottinghamshire, United Kingdom

Keywords: geology and planning, geological maps, geohazards, risk assessment and hazard reduction, land degradation and restoration, volcanic activity, earthquakes, mass movements, river action and flooding, marine action and tsunamis, hazard zoning and maps, origin of soil, soil erosion and conservation, construction materials, hydrological cycle, dispersal of precipitation, reservoirs, dams and dam sites, groundwater, aquifers, wells, water quality, irrigation, pollution, subsidence, waste material, mine effluents, spontaneous combustion, gases, mineral dusts, types of waste, sanitary landfills, leachate, gases, landfill construction, hazardous waste, radioactive waste, underground storage chambers, site characterization, remote imagery, aerial photographs, maps, desk studies, preliminary reconnaissance, subsurface exploration, *in situ* testing, geophysical exploration, open excavation, drilling and blasting, ripping, digging, slope stability, groundwater control, tunneling, geological conditions, highway construction, embankments, ground improvement, footings, rafts, piles, ground movements, ground treatment

Contents

Summary

Environmental and engineering geology represent applied aspects of geology that are important in terms of planning, development, and construction. They consider the changes brought about, and the hazards represented, by geological processes, and the effects these have on the environment. Of equal importance is the effect that human activity has on the environment. Obviously, the latter is likely to increase in significance as the human population continues to grow. In addition, since engineering geology is intimately linked with construction, and also with mining, it must consider those geological conditions that influence and affect such operations. Resources, notably soil and water, need to be developed, wherever possible, in a sustainable manner. Soil erosion and water pollution are very much influenced by human activity but can be remediated or, better still, avoided. This requires an understanding of the role that geology plays in their development. The environment has been and continues to be

disfigured by certain human activities such as mining and waste disposal. Accordingly, restoration and conservation measures need to be undertaken. This, like resource development, requires land evaluation. Construction is an essential part of the human environment and a site investigation must be carried out prior to the commencement of any project so that the design of the project relates to the ground conditions. In this way the construction project should be undertaken with safety and the completed structure should survive its design life without significant adverse affects. If ground conditions are unsatisfactory for a particular project, then they may be improved by some method of ground treatment.

1. Introduction: Environmental and Engineering Geology

Environmental geology has been defined by the American Geological Institute as the application of geological principles to problems created by the occupancy and exploitation by humankind of the physical environment. However, environmental geology is not simply concerned with the impact of humans upon the physical environment, it also involves the impact of the geological environment upon society. The origins of natural geological hazards such as earthquakes, volcanic eruptions, floods, landslides, and marine surges and tsunamis are, with some exceptions, independent of humankind but can have a disastrous effect upon society. In addition, humankind’s primary activities in the form of agriculture, mining, and industry can have a notable impact upon the geological environment such as soil erosion, land degradation, groundwater pollution, and the like. Accordingly, both are the concern of environmental geology. As such, environmental geology is of fundamental importance in relation to how humans plan and develop the environment so as to reduce the number of adverse environmental impacts of the geological environment on society or of society on nature. Therefore, environmental geology has to be intimately involved in the planning process by providing basic information necessary to develop acceptable conditions in which people live and prosper. Furthermore, the increasing public awareness of the importance of the environment requires a deeper understanding of the geological processes within the environment. It is at times claimed that environmental geology is synonymous with urban geology, it is not. Urban geology is only part of environmental geology, admittedly an important part of environmental geology since most people live in urban areas. In this context, the problems of urban areas are likely to increase as the world population continues to grow, with most urban development taking place in developing countries and the prospect of megacities becoming a reality. Consequently planning, and with it environmental geology, will become increasingly more important in the development of urban areas. Be that as it may, the rural environment is also important not just for food production but also for leisure activities, and so must not be degraded. In particular, areas of outstanding scenic beauty and scientific interest must be preserved for future generations to enjoy.

Engineering geology has frequently been defined as the application of geology to engineering practice; in other words it is concerned with those geological factors that influence the location, design, and construction of engineering works. As such, it draws upon several geological disciplines such as petrology, sedimentology, structural geology, geomorphology, and to a lesser extent stratigraphy. Engineering geology is intimately associated with environmental geology, and both are associated with hydrogeology.

Furthermore, rock mechanics and soils mechanics play an important role in engineering geology.

2. Geohazards

Geohazards, whether natural or due to humans, are of importance in both environmental and engineering geology. Geological processes become a hazard when they have adverse impacts upon human society and the environment, causing destruction of property, loss of life, or environmental degradation. Therefore it is important, whenever possible, to assess the risk that a particular hazard poses so that measures can be taken to reduce the risk. If this is to be done effectively, then adequate data must be gathered. None the less, some large-scale geohazards will bring about destruction of both the human and natural environment.

Humankind, for example, cannot prevent volcanic eruptions, earthquakes, or tsunamis but can plan to avoid suffering their worse effects by the development of warning systems. But even warning systems are likely to be ineffective where large urban areas with notable populations are likely to be affected. In effect, the best way of dealing with a geohazard is to avoid it. This should be taken note of in future developments but is of little relevance in developed areas or areas where hazards have not been recognized. Furthermore, the position may be further complicated by the fact that the occurrence of one type of geohazard may trigger another to take place. For instance, earthquakes frequently give rise to landslides, and fires in pillared coal mines caused by spontaneous combustion weaken the pillars, which may lead to their failure and consequent subsidence at the ground surface.

One of the first steps in the planning process is to produce hazard maps, which usually zone an area according to the susceptibility to a particular hazard. However, more than one hazard may be taken into consideration in the production of such a map or, more likely, a series of different hazard maps may be produced for the same area if several hazards exist.

The prediction of the exact time of the occurrence of a geohazard and its magnitude may be impossible, as in the case of volcanic eruptions and earthquakes, although the prediction of floods is more achievable. Nevertheless, there are precursors that indicate that an event is likely to occur and that therefore it should be monitored. Even though exact prediction may be impossible, scientific investigation of geohazards is a necessity if they are going to be understood. This is the only way that mitigation methods can be effectively devised and planned, and then put into effect.

-
-
-

Bibliography

Alexander D. (1993). *Natural Disasters*, London: University College Press.

Allum J.A.E. (1966). *Photogeology and Regional Mapping*, London: Pergamon.

Attewell P.B. and Farmer I.A. (1976). *Principles of Engineering Geology*, London: Chapman and Hall. *

Bell F.G. (1980). *Engineering Geology and Geotechnics*, London: Butterworths. *

Bell F.G. (1983). *Fundamentals of Engineering Geology*, London: Butterworths. *

Bell F.G. (1993). *Engineering Geology*, Oxford: Blackwell Scientific Publications.

Bell F.G. (1993). *Engineering Treatment of Soils*, London: E. & F.N. Spon.

Bell F.G. (1998). *Environmental Geology: Principles and Practice*, Oxford: Blackwell Scientific Publications. *

Bell F.G. (1999). *Geological Hazards: their Assessment, Avoidance, and Mitigation*, London: E. & F.N. Spon.

Bell F.G. (2000). *Engineering Properties of Soils and Rocks*, (Fourth Edition). Oxford: Blackwell Scientific Publications. *

Bell F.G., Culshaw M.G., Cripps J.C., and Lovell M.A. (eds.) (1988). *Engineering Geology of Underground Movements: Engineering Geology Special Publication No. 5*. London: Geological Society. *

Bennett M.R. and Doyle P. (1997). *Environmental Geology: Geology and the Human Environment*, Chichester, UK: Wiley.

Bentley S.P. (ed.) (1996). *Engineering Geology of Waste Disposal*, *Engineering Geology Special Publication No. 11*, London: Geological Society. *

Blyth F.G.H. and De Freitas M.H. (1984). *A Geology for Engineers*, (Seventh Edition). London: Arnold.

Cairney T. (ed.) (1993). *Contaminated Land*, Glasgow: Blackie. *

Clayton C.R.I., Simons N.W., and Matthews M.C. (1996). *Site Investigations: a Handbook for Engineers*, (Second Edition). Oxford: Blackwell Scientific Publications. *

Coates D.R. (1981). *Environmental Geology*, New York: Wiley.

Cooke R.U. and Doornkamp J.C. (1990). *Geomorphology in Environmental Management*, (Second Edition). Oxford: Clarendon Press.

Crawford J.F. and Smith P.G. (1984). *Landfill Technology*, London: Butterworths.

Cripps J.C., Bell F.G., and Culshaw M.C. (eds.) (1986). *Groundwater in Engineering Geology: Engineering Geology Special Publication No. 3*, London: Geological Society. *

Culshaw M.G., Bell F.G., Cripps J.C., and O'Hara M. (eds.) (1987). *Planning and Engineering Geology, Engineering Geology Publication No. 4*, London: Geological Society. *

Davidson D.A. (1980). *Soils and Land Use Planning*, Harlow, UK: Longman.

Davis S.D. and De Weist R.J.H. (1966). *Hydrogeology*, New York: Wiley.

Dent D. and Young A. (1981). *Soil Survey and Land Evaluation*, London: Allen and Unwin.

Eddleston M, Walthall S., Cripps J.C., and Culshaw M.G. (eds.) (1995). *Engineering Geology of Construction*, *Engineering Geology Special Publication No. 10*, London: Geological Society. *

Fitzpatrick E.A. (1986). *An Introduction to Soil Science* (Second Edition). Harlow, UK: Longman.

Flawn P.T. (1975). *Environmental Geology*, New York: Harper and Row.

Fookes P.G. and Vaughan P.R. (eds.) (1986). *A Handbook of Engineering Geomorphology*, London: Surrey University Press.

Freeze R. A. and Cherry J.A. (1979). *Groundwater*, Englewood Cliffs, NJ: Prentice Hall. *

Griffiths J.S. (ed.). (2001). *Land Surface Evaluation for Engineering Practice: Engineering Geology Special Publication No. 18*, London: Geological Society.

Hamil L. and Bell F.G. (1986). *Groundwater Resource Development*, London: Butterworths.

Hawkins A.B. (ed.). (1986). *Site Investigation Practice: Assessing BS 5930, Engineering Geology Special Publication No. 2*, London: Geological Society. *

Howard A.D. and Remson I. (1978). *Geology in Environmental Planning*, New York: McGraw-Hill.

Hudson N.W. (1981). *Soil Conservation*, London: Batsford.

Jefferson I., Murray E.J., Faragher E., and Fleming P.R. (eds.) (2001). *Problematic Soils*, London: Thomas Telford Press.

Johnson R.B. and De Graff J.V. (1988). *Principles of Engineering Geology*, New York: Wiley.

Keller E.A. (1992). *Environmental Geology* (Sixth Edition). New York: Macmillan.

Krynine P.D. and Judd W.R. (1956). *Principles of Engineering Geology and Geotechnics*, New York: McGraw-Hill. *

Legget R.F. (1973). *Cities and Geology*, New York: McGraw-Hill. *

Legget R.F. and Hatheway A.W. (1988). *Geology and Engineering* (Third Edition). New York: McGraw-Hill. *

Legget R.F. and Karrow P.F. (1983). *Handbook of Geology in Civil Engineering*, New York: McGraw-Hill. *

Lerner D.N. and Walton N.R.G. (eds.) (1998). *Contaminated Land and Groundwater: Future Directions, Engineering Geology Special Publication No. 14*, London: Geological Society. *

Leverson D. 1980. *Geology and the Urban Environment*. New York: Oxford University Press.

Mather J., Banks D., Dumpleton S., and Fermore M. (eds.) (1998). *Groundwater Contaminants and their Migration*: *Special Publication No 128*, London: Geological Society. *

Maund J.G. and Eddleston M. (eds.) (1998). *Geohazards in Engineering Geology: Engineering Geology Special Publication No. 15*, London: Geological Society. *

McCall G.J.H., De Mulder E.F.J., and Marker B.R. (eds.) (1996). *Urban Geoscience*, Rotterdam: Balkema.

Morgan R.P.C. (1995). *Soil Erosion and Conservation* (Second Edition). Harlow, UK; Longman.

Oweis I.S. and Khera R.J. (1990). *Geotechnology and Waste Management*, London: Butterworths.

Price M. (1985). *Introducing Groundwater*, London: Allen and Unwin.

Rahn P.R. (1996). *Engineering Geology: An Environmental Approach* (Second Edition). Upper Saddle River, NJ: Prentice Hall.

Reynolds J.M. (1997). *An Introduction to Applied and Environmental Geophysics*, Chichester, UK: Wiley*.

Robins N.S. (ed.) (1998). *Groundwater Pollution, Aquifer Recharge, and Vulnerability: Special Publication No. 130*, London: Geological Society. *

Sabins F.F. (1996). *Remote Sensing: Principles and Interpretation*, San Francisco: Freeman. *

Todd D.K. (1980). *Ground Water Hydrology* (Second Edition). New York: Wiley.

Utgard R.O., McKenzie G.D., and Foley D. (eds.) (1978). *Geology in the Urban Environment*, Minneapolis: Burgess.

Waltham A.C. (1989). *Ground Subsidence*, Glasgow: Blackie.

Walton W.C. (1970). *Groundwater Resource Evaluation*, New York: McGraw-Hill. *

Whittacker B.N. and Reddish D.J. (1989). *Subsidence: Occurrence, Prediction, and Control*, Amsterdam: Elsevier. *

Zaruba Q. and Mencl V. (1976). *Engineering Geology*, Prague: Academia.

*More advanced text

Biographical Sketch

Fred Bell graduated with a B.Sc. and M.Sc. from the University of Durham and received his Ph.D. from the University of Sheffield, United Kingdom in 1974. More recently, he received a D.Sc. from the University of Natal. He is a fellow of the Royal Society of South Africa, a fellow of the Institution of Civil Engineers and the Institution of Mining and Metallurgy, and a fellow of the Geological Society, being both a chartered engineer and a chartered geologist. He is the recipient of several awards.

Professor Bell now is a Visiting Research Associate at the British Geological Survey. Previously, he was Professor and Head of the Department of Geology and Applied Geology, University of Natal, Durban, South Africa, during which time he was also a Distinguished Visiting Professor, Department of Geological Engineering, University of Missouri-Rolla, USA.

Professor Bell's research subjects have included ground stability, subsidence, ground treatment, engineering behavior of soils (clays, expansive clays, saprolites, tills, laminated clays, dispersive and collapsible soils, sands), engineering behavior of rocks (sandstones, carbonates, evaporites, shales, basalts, dolerites, granites), cement, lime and PFA stabilization of clay soils, acid mine drainage, mining impacts, landfills, derelict and contaminated ground, rock durability in relation to tunneling, slope stability, aggregates, building stone, and geohazards.

In his professional activity Professor Bell has been involved in a variety of work in the UK, southern Africa, and Malaysia concerning site investigations; foundations; settlement problems on clays, fills and sands; old mine workings and subsidence; longwall mining and subsidence; ground treatment;

groundwater resource assessment; slope stability; use of mudrocks for brickmaking; assessment of various rock types for aggregates; contaminated ground; acid mine drainage; landfills; and dam sites.
Professor Bell is author/editor of 17 books, several reprinted, one in its fourth edition, one translated into French, two into Italian and yet another into Malay, and an Indian edition (in English). He is also author of over 200 papers on geotechnical subjects. He has served on the editorial boards of five international journals and has been a series editor for three publishers.