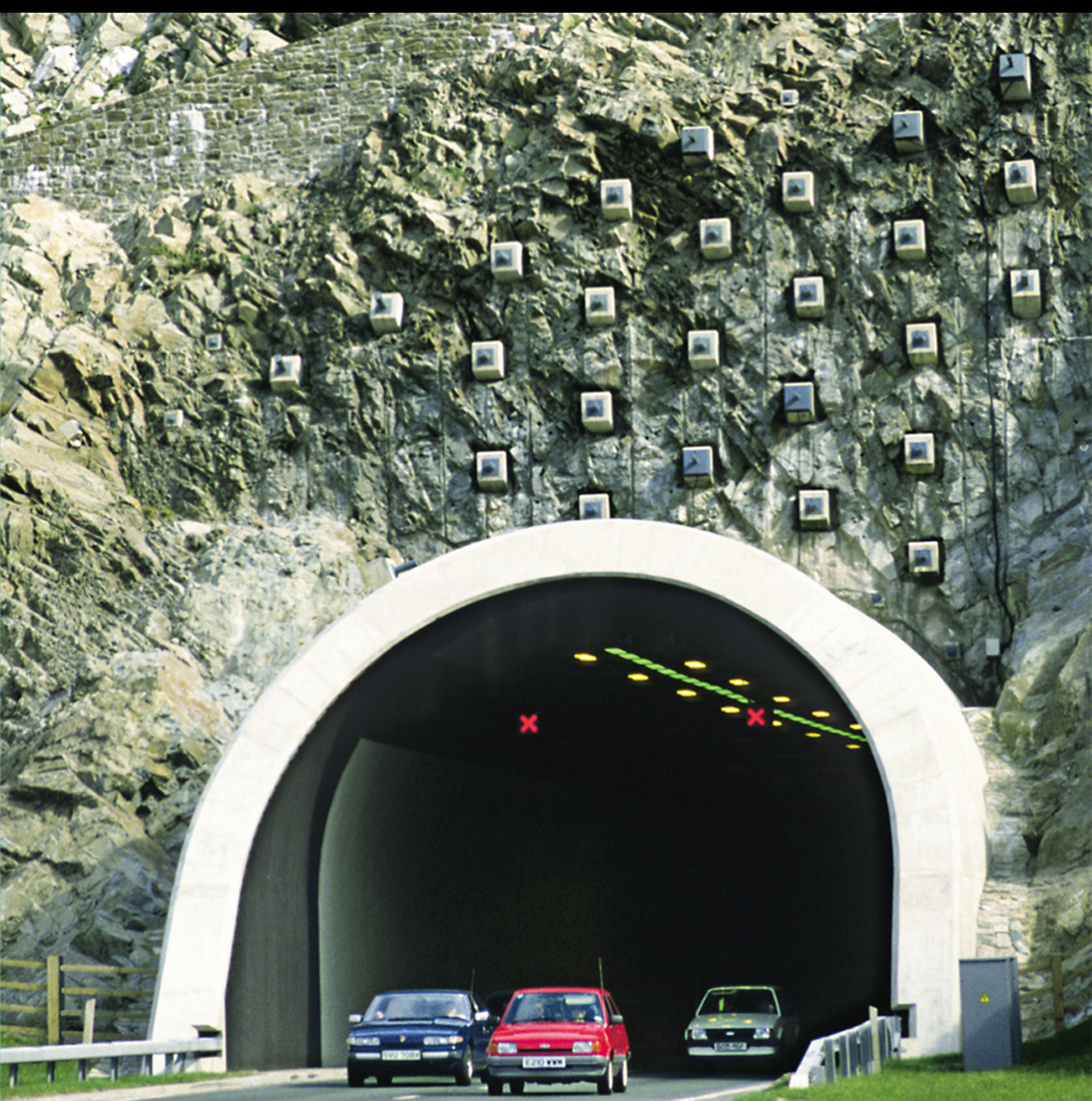

FOUNDATIONS OF ENGINEERING GEOLOGY

TONY WALTHAM | THIRD EDITION

Spon Press

Foundations of Engineering Geology

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Third Edition

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Preface

Civil engineering is an exciting combination of science, art, professional skill and engineering achievement which always has to rely on the ground on which its structures stand. Geology is therefore vital to success in civil engineering, and this book brings to the reader those many aspects of the geological sciences specifically relevant to the profession.

This book is structured primarily for the student of civil engineering who starts with no knowledge of geology but is required to understand the ground conditions and geological processes which, both literally and metaphorically, are the foundations of his future professional activities. It also provides an accessible source of information for the practising civil engineer.

All the material is presented in individual double-page spreads. Each subject is covered by notes, diagrams, tables and case histories, all in bite-sized sections instead of being lost in a long continuous text. This style makes the information very accessible; the reader can dip in and find what he needs, and is also visually guided into relevant associated topics. There is even some intended repetition of small sections of material which are pertinent to more than one aspect within the interrelated framework of a geological understanding.

The contents of the book follow a basic university course in engineering geology. The freestanding sections and subsections permit infinite flexibility, so that any lecturer can use the book as his course text while tailoring his programme to his own personal style. The single section summarizing soil strength has been included for the benefit of geology students who do not take a comprehensive course in soil mechanics within a normal civil engineering syllabus.

The sectionalized layout makes the information very accessible, so that the practising engineer will find the book to be a useful source when he requires a rapid insight or reminder as he encounters geological problems with difficult ground. Reference material has therefore been added to many sections, mainly in tabulated form, to provide a more complete data bank. The book has been produced mainly in the inexpensive soft-bound format in the hope that it will reach as large a market as possible.

The mass of data condensed into these pages has been drawn from an enormous variety of sources. The book is unashamedly a derived text, relying heavily on the world-wide records of engineering geology. Material has been accumulated over many years in a lecturing role. A few concepts and case histories do derive from the author's personal research; but for the dominant part, there is a debt of gratitude acknowledged to the innumerable geologists and civil engineers who have described and communicated their own experiences and research. All the figures have been newly drawn, and many are derived from a combination of disparate sources. The photographs are by the author.

Due thanks are afforded to the Department of Civil and Structural Engineering at the Nottingham Trent University where the engineering and teaching experience was gained, to Neil Dixon for his assistance with the gentle art of soil mechanics, to the staff of Blackie in Glasgow who made the innovative style of the book possible, and to the many colleagues and friends without whom nothing is possible.

T.W., 1994.

Preface to the Third Edition

The third edition of this book has again retained the format and structure that has proved so accessible and so popular, but it has been carefully updated and improved with additional paragraphs that reflect ongoing changes within the profession of civil engineering.

Progress within the printing industry has allowed this edition to enjoy the benefits of full colour without any immediate increase in cover price. Diagrams have been improved now that they can be in full colour; some have retained the earlier line structure, but many have been redrawn to show extra features. Geology is a very visual subject, so some extra pages have been introduced to present selections of the author's photographs, with the intention of drawing the reader out into the world of reality, where the endless variations within terrain conditions make an understanding of the geology so very important to all civil engineers.

This book was never intended to be a handbook with all the answers and all the procedures. It aims to introduce the critical aspects of geology to the student of engineering, though it does appear to act as a convenient reminder for the practising engineer. To enhance its role as a source book, a long list of further reading is appended. This cites the useful key texts in each subject area, and also refers to the primary papers on case studies used within the text, in both cases without any need to include conventional references that can disrupt a text.

As in the earlier editions, cross references to other pages are not used in order to explain terms. The index is intentionally comprehensive, so that it can be used as a glossary. Each technical term in the text does appear in the index, so that the reader can check for a definition, usually at the first citation of a term.

Sincere thanks are recorded to Rob Gill of Geosec Slides (Mull) who provided the photomicrographs in plain light to demonstrate rock textures, and also to Ian Jefferson, John Arthur, Simon Cooke, Jenny Walsby, Keith Westhead, Richard Cartlidge, George Tuckwell, Peter Fookes and various others who have contributed to the revisions within this third edition.

It is then appropriate to again thank David McGarvie, one-time editor at Blackie, who was the author's key support, in the face of some opposition, in making possible this slightly unconventional style of textbook. The success of the concept is reflected in the forthcoming book by Ian Jefferson and colleagues on the *Foundations of Geotechnical Engineering*, which will be a companion book in the same format. It is hoped that both volumes will make the pressured lives of students of civil engineering just a little bit easier.

T.W., 2008.

Contents

01 Geology and Civil Engineering

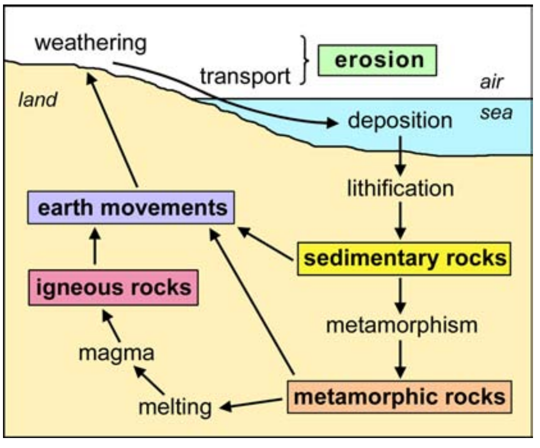
THE GEOLOGICAL ENVIRONMENT

Earth is an active planet in a constant state of change. **Geological processes** continually modify the Earth's surface, destroy old rocks, create new rocks and add to the complexity of ground conditions.

Cycle of geology encompasses all major processes, which are cyclic, or they would grind to an inevitable halt.

Land: mainly erosion and rock destruction.
Sea: mainly deposition, forming new sediments.
Underground: new rocks created and deformed.

Earth movements are vital to the cycle; without them the land would be eroded down to just below sea level.
Plate tectonics provide the mechanism for nearly all earth movements (*section 09*). The hot interior of the Earth is the ultimate energy source, which drives all geological processes.



Geological time is an important concept. Earth is 4000M years old and has evolved continuously towards its present form.
Most rocks encountered by engineers are 10–500M years old. They have been displaced and deformed over time, and some are then exposed at the surface by erosional removal of rocks that once lay above them. Underground structures and the ground surface have evolved steadily through geological time.
Most surface landforms visible today have been carved out by erosion within the last few million years, while older landforms have been destroyed.
This time difference is important: the origin of the rocks at the surface may bear no relationship to the present environment. The classic example is Mt Everest, whose summit is limestone, formed in a sea 300M years ago.
Geological time is difficult to comprehend but it must be accepted as the time gaps account for many of the contrasts in ground conditions.

Concepts of scale are important in geology:
Beds of rock extending hundreds of kilometres across country.
Rocks uplifted thousands of metres by earth movements.
Rock structures reaching 1000 m below the ground surface.
Strong limestone crumpled like plasticine by plate tectonics.
Landslides with over 100M tons of falling rock.
Earthquakes a million times more powerful than a nuclear bomb.
And the millions of years of geological time.

Endless horizontal rocks exposed in Canyonlands, USA.

SIGNIFICANCE IN ENGINEERING

Civil engineering works are all carried out on or in the ground. Its properties and processes are therefore significant – both the strengths of rocks and soils, and the erosional and geological processes that subject them to continual change.
Unstable ground does exist. Some ground is not 'terra firma' and may lead to unstable foundations.
Site investigation is where most civil engineers encounter geology. This involves the interpretation of ground conditions (often from minimal evidence), some 3-D thinking, and the recognition of areas of difficult ground or potential geohazards.
Unforeseen ground conditions can still occur, as ground geology can be almost infinitely variable, but they are commonly unforeseen simply due to inadequate ground investigation.
Civil engineering design can accommodate almost any ground conditions that are correctly assessed and understood prior to and during construction.

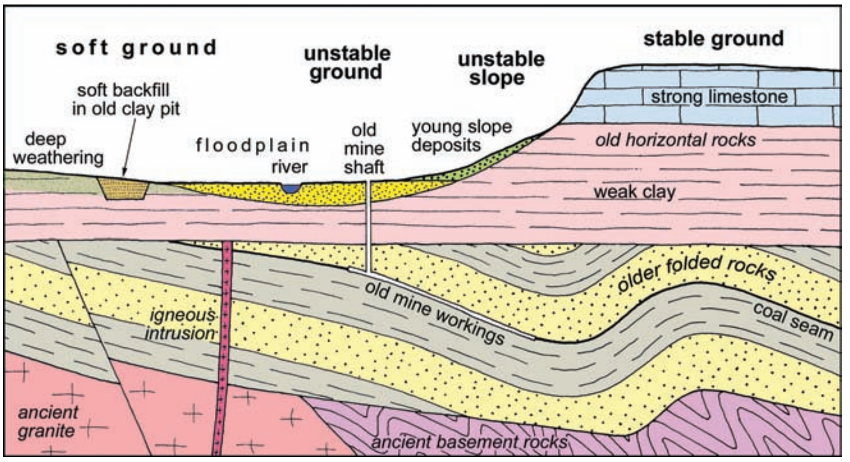
Components of Engineering Geology

The main field of study:	Sections in this book
Ground materials and structures	02–06
Regional characteristics	09–12
Surface processes and materials	13–18
Ground investigations	07, 08, 19–23
Material properties	24–26, 39
Difficult ground conditions	27–38

Other aspects of geology – fossils and historical studies, mineral deposits and long-term processes – are of little direct significance to the engineer, and are not specifically covered in this book.

SOME ENGINEERING RESPONSES TO GEOLOGICAL CONDITIONS

Geology	Response
Soft ground and settlement	Foundation design to reduce or redistribute loading
Weak ground and potential failure	Ground improvement or cavity filling; or identify and avoid hazard zone
Unstable slopes and potential sliding	Stabilize or support slopes; or avoid hazard zone
Severe river or coastal erosion	Slow down process with rock or concrete defences (limited scope)
Potential earthquake hazard	Structural design to withstand vibration; avoid unstable ground
Potential volcanic hazard	Delimit and avoid hazard zones; attempt eruption prediction
Rock required as a material	Resource assessment and rock testing



Ground profile through some anonymous region within the English Midlands.
Most rocks were formed 200–300M years ago, when the area was near the equator in a deltaic swamp, disturbed by earth movements then left in a shallow sea.
The ground surface was shaped by erosion within the last million years, when the slope deposits and the alluvium partly filled the valley that was largely cut by river erosion.
The more difficult ground conditions are provided by the floodplain, soft sediments, the areas over deep rockhead, unstable slopes, old mines and the backfilled quarry.

Folded rocks in the Hamersley Gorge, Australia.

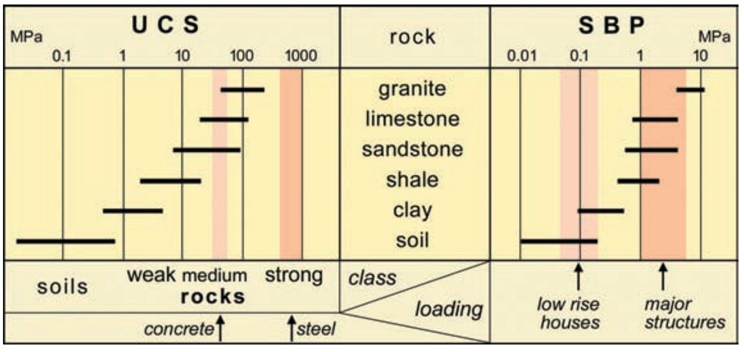
STRENGTH OF THE GROUND

Natural ground materials, rocks and soils, cover a great range of strengths: granite is about 4000 times stronger than peat soil.
Some variations in rock strength are summarized by contrasting strong and weak rocks in the table.
Assessment of ground conditions must distinguish:

- Intact rock – strength of an unfractured, small block; refer to UCS.
- Rock mass – properties of a large mass of fractured rock in the ground; refer to rock mass classes (*section 25*).

Note – a strong rock may contain so many fractures in a hillside that the rock mass is weak and unstable.
Ground conditions also vary greatly due to purely local features such as underground cavities, inclined shear surfaces and artificial disturbance.

Strong Rocks	Weak Rocks
UCS > 100 MPa	UCS < 10 MPa
Little fracturing	Fractured and bedded
Minimal weathering	Deep weathering
Stable foundations	Settlement problems
Stand in steep faces	Fail on low slopes
Aggregate resource	Require engineering care



UCS:
Unconfined (or uniaxial) compressive strength: load to cause failure of a cube of the material crushed between two flat plates with no lateral restraint. (Strong and weak limits are simplified; *see section 24 for BS criteria*.)

SBP:
Safe (or acceptable) bearing pressure: load that may safely be imposed upon rock in the ground: the estimated (or measured) ultimate bearing pressure to fail the rock (allowing for fractures and local zones of weakness) divided by a safety factor of between 3 and 5.

ROCKS AND MINERALS

Rocks: mixtures of minerals: variable properties.
Minerals: compounds of elements: fixed properties.

Rock properties broadly depend on:

- strength and stability of constituent minerals;
- interlocking or weaknesses of mineral structure;
- fractures, bedding and larger rock structures.

All rocks fall into one of three families, each with broadly definable origins and properties.

Most rock-forming minerals are silicates – compounds of oxygen, silicon and other elements.

Rock properties can show extreme variations. It is useful to generalize, as in the table below, in order to build an understanding of geology, but it must be accepted that rocks are not engineered materials and their properties do vary from site to site.
For example, most sedimentary rocks are quite weak, and limestone is a sedimentary rock, but some of the limestones are very strong.

Rock family	**Igneous**	**Sedimentary**	**Metamorphic**
Material origin	Crystallized from molten magma	Erosional debris on Earth's surface	Altered by heat and/or pressure
Environment	Underground; and as lava flows	Deposition basins; mainly sea	Mostly deep inside mountain chains
Rock texture	Mosaic of interlocking crystals	Mostly granular and cemented	Mosaic of interlocking crystals
Rock structure	Massive (structureless)	Layered, bedded, bedding planes	Crystal orientation due to pressure
Rock strength	Uniform high strength	Variable low; planar weaknesses	Variable high; planar weaknesses
Major types	Granite, basalt	Sandstone, limestone, clay	Schist, slate