Studio Anne Holtrop

ETH Zürich

design studio **HS20**

MATERIAL GESTURE:

STONE


KOMATSU

GNEISS QUARRY, Vals, 2020

CONTENTS

MATERIAL GESTURE:

STONE

‘To discover is to reveal by excavation’,

— Robert Macfarlane in Underworld, 2019

It all comes down to this: stone is a piece of rock made usable for men – a portion of rock used as building material.

Rocks can be defined as extensive mineral bodies, composed of one or more minerals in varying proportions. Minerals are the building stones of the earth’s crust. They are stony mixtures of one or more elements (from copper, to iron, sulphur, gypsum and carbon), that man has found in the earth’s surface and its rocks. Running to a depth from a minimum of four kilometres under the ocean to one hundred kilometres under the continents, the lithosphere constituting the 'crust' is made up of rock produced by solidified magma. The three main types of rock are igneous, sedimentary and metamorphic, and all result from a continuous geological cycle of being formed, worn down into pieces, and then formed again.

MATERIAL GESTURE AND SITE

In autumn 2019, we travelled to Japan's southern volcanic island, Kyushu. Our aim with the travel was to explore site not in the context we usually consider – as in the view, the vegetation or the relationship to a built environment – but rather, site from a geological perspective; how the landscape is formed, what the ground consists of, and how it is changing. We explored the geology of Kyushu: the soil, sand, stone, minerals, lava and ash, as well as the crust, faults, cracks, hills and craters. We studied the processes (the gestures of the volcano, so to speak) that have shaped the landscape as it is and that will continue to change it in the future.

The projects that were developed in the design studio were based on the materials and the volcanic processes that are present on the island, which were used or transformed to design a space for that site: a space that is born from the site in its material constituents and that is constructed on that site,

BEPPU, Kyushu Island, 2019

in harmony or contrast, to the previous gestures that have formed the geology of the place.

With our work for Kyushu, I realised that with material gesture, we always relate to a site. Looking at any building material, ‘a’ site is always present, namely, the place where we source our material from. Our mines, excavations and quarries are the source for building. In order to build, we mine. Therefore, we work on at least two sites: the place of sourcing our raw material and the place of building construction. All places in between, where the material is worked on and transformed, could be considered as sites as well.

Vernacular architecture is characterised by the presence of the site of raw material and the site of the building construction that is made in its vicinity: from the clay buildings in Mali or Yemen, to the travertine used in Rome, the coral stone material used traditionally in the Gulf or the gneiss stone used in the village of Vals.

The importance of sourcing the raw material brought architects and sculptors to the ‘other’ site. Bernini had built a house next to one of the travertine quarries in Tivoli (close to Rome) to supervise the selection of stone with which he built most of his architecture and sculptures. He contributed to a period spanning more than twenty centuries, in which travertine is the construction material for many monumental buildings in Rome, such as the Colosseum. Michelangelo, until his death in 1564, repeatedly spent many months in the marble quarries of Carrara, in order to secure the best sections of stone for his sculptures. He even had a road built to transport the gigantic blocks, which ended near what is today the bathing resort of Forte dei Marmi.

Peter Zumthor wrote in his recollections on his project for Vals, 'We walked around the village and, suddenly, everywhere there were boulders, big and small walls, loosely stacked rough plates, split material; we saw quarries of different sizes, slopes cut away, and rock formations'. In one sentence, Zumthor links the village, the building, the quarry and the landscape with its rock formations, all as sites with the same material presence. He shows the intrinsic links between the different sites of the gneiss stone.

Architecture made with locally sourced material has a strong site sensitivity that is generally considered to be 'good' and often relates nowadays to preservation and a sustainable idea of building. To preserve places with vernacular architecture, traditionally used local material is prescribed by authorities for new construction, as is the case in Vals for the use of gneiss stone. Contradictory to the wish for the use of local material, the quarries and mines for sourcing the raw material are seen as harmful to the environment. The 'other' site, necessary for our building, is often less wished-for, hence laws that require reclamation of the mountain landscape after sourcing the stone.

SITE AND NON-SITE

Nowadays, in our modern and industrialised world, and also throughout history, material has been displaced and disconnected from where it is sourced. Stones have been collected from all around the world to showcase the wealth and stature of the collector. Material has been shipped and traded for its specific qualities worldwide for thousands of years – think of the silk roads that began during the Han Dynasty in China and reached as far as Europe. Mostly with modernity, the sourcing of materials has increased significantly to keep up with the demands of building construction and other production.

The material sourcing and displacement in industrial quantities, therefore showcasing our current age, was an important influence in the work of

A NON-SITE (FRANKLIN, NEW JERSEY), Robert Smithson, 1968

the American artist Robert Smithson. He began, in the sixties, exploring industrial areas around New Jersey (where he was from) and was fascinated by the sight of dumper trucks excavating tons of earth and rock that he described as the ‘equivalents of the monuments of antiquity’. This resulted in a series of works titled ‘Non-sites’ in which earth and rocks collected from a specific area were installed as sculptures in exhibitions.

The Non-sites were presented as simple containers of painted or galvanised steel that contained the raw material, such as rocks, gravel and salt, collected from distant sites. Next to this collection of raw material, maps were shown indicating the mines, excavations or quarries from which the materials had been taken. The maps were crucial as they directed the viewer to the original site and established the ‘dialectic’ between site and non-site. Smithson noted in his own comparison that a site is about scattered information (‘The site is a place you can visit and it involves travel as an aspect too’) and a non-site is about contained information.

The relationship that Smithson established between site and non-site introduced an understanding of process, the passage between the two locations, and threw emphasis on time and duration. The ‘in-betweenness’

TRISHA DONNELLY AT MATTHEW MARKS GALLERY, New York, 2019–2020

destabilises our understanding of site as one place and brings forward multiple places, with links to each other brought forward by the presence of the material. Much like the recollection of Zumthor, the material presence is in multiple sites from the rock formation, the quarry, the building and the village. They all build up to an understanding of all sites in which the material is a constant.

The key to the idea of Non-sites is the displacement; how the meaning and value of an object is changed by removal to another site. The focus of this semester is to take all sites into consideration when working with the material of stone. Stone can be understood here as a metaphor for site. We will study the traces in the material in its geological formation, traces in the ways of quarrying it, traces in the displacement and traces in its assembling and finishing. We are interested in the dialectics of change that is brought forward by the displacement of material through its different sites and how all of these 'traces' can be used and transformed in our way of working with it.

Anne Holtrop

DESIGN STUDIO

When we take all aspects of the material into consideration – the geology, the sourcing, the industry, the different properties, the craftsmanship, the specialised techniques and the cultural significance – we can deploy the full potential of the inherent qualities of the material itself and our way of working it in what we call MATERIAL GESTURE.

In this design studio, you will define your gestures of making and working with material(s) through research and experiment, and in response to the topic of the studio. You are required to produce an architecture that results from your specific engagement with the material and the spatial condition you construct with it. The architecture that results from this approach does not reference or represent something, but simply attempts to exist as a physical spatial reality in its own right.

Your research should be supported by the knowledge made available by our studio, and engaged through you with the use of available resources and facilities at departments of the ETH and from external specialists/fabricators.

Throughout the whole semester, and for your final presentation, we require that you work with physical (fragment) models of your building in the actual material(s). It is important, in this design studio, not to make a complete building, but to show and support the found values of the material engagement in a spatial way, based on the full potential of the inherent qualities of the material itself and your way of working it.

ASSIGNMENT

In this studio, we work in a workshop and laboratory-like setting where you research, design and test the proposed material. The material and the ways of making are not a presentation outcome of the design studio but rather, an integral part of a process of working, researching and designing. You are required to work individually in the design studio.

There is no given program for the space. This can be chosen at any time in the development of your project and should support the spatial and material conditions that you have set out.

For the final presentation, you are required to make a physical model of your work, or a fragment of it, in a scale of 1:15. The model should show the material and the gestures (the ways of making) and the specific spatial

conditions it constructs. This is the key element of your presentation, along with samples of the material research and test models. You are required to display the material gesture research, drawings of the project and photos of the model alongside your model on portrait A2 sheets.

The A2 material will be collected in print and digitally in PDF format for the material gesture archive. A semester result book will be made after the presentation. From a selection of a maximum of three projects, the models and material research will be crated and archived for future exhibitions.

SCHEDULE

INTRODUCTION
Sep 15 & 16, 9–18 h

On the first day, we will give an introduction on MATERIAL GESTURE and the specific topic of this design studio. Afterwards, we will visit the Department of Earth Sciences in EHT. Dr. Stefan Heuberger will give an introductory lecture on stones and minerals and later Dr. Claudio Madonna will show us around RPM Lab.
On the second day, an artist, Aglaia Konrad, will give a presentation about her work, Carrara, and her films will be shown. And this will be followed by a presentation by Mitul Desai and us on the other quarry sites. We will conclude with presentations by each student on a work they like or their own work.

STUDIO WEEK 2
Sep 22 & 23, 9–18 h

Individual discussions with Stephan

FIRST REVIEW (via Zoom)
Sep 29 & 30, 9–18 h

Research and First Experiments.
You will present the material research and the first experiments with the material and ways of making. A first architectural spatial element – think of a column, a room, a window, a floor, a roof, a wall, etc. – should be made in a scale of 1:15 and should relate to the material engagement. In this review, your material research will be discussed, and you will have to present the sources and the specialists/ ETH departments involved that are essential for your research. The material research and experiments are documented through photography, material samples, writing and drawing.

STUDIO WEEK 4
Oct 6 & 7, 9–18 h

Individual discussions with Stephan

SECOND REVIEW
Oct 13 & 14, 9–18 h

Space. You will be required to present an architectural space that fully exploits the material gesture in a spatial way. We will discuss the architectural articulation and cultural significance in relationship to the material research and ways of making.

SEMINAR WEEK
Oct 18–23

The studio's field trip is in Graubünden and Ticino, in the company of stone experts, a stonemason, Annika Staudt, and geologists Filippo Schenker and others. Our interest in this trip is in exploring relationships of geological formation and consistence, and engaging in specialised practices with stone.

STUDIO WEEK 7
Oct 27 & 28, 9–18 h

Individual discussions with Stephan

INTERMEDIATE REVIEW
Nov 3 & 4, 9–18 h

Construction. In this review, we will elaborate more in depth the construction techniques and applications that you will develop out of your material research and their spatial consequences.
You will be required to present your projects through architectural drawings – floor plans and sections – and first detailed construction drawings.
Guests are Fabio Gramazio on the 4th, and Elias and Yousef Anastas on the 3rd and 4th.
Gramazio and Anastas will give lectures starting at 18:00 on the 3rd about their own work related to stone.

STUDIO WEEK 9
Nov 10 & 11, 9–18 h

Individual discussions with Stephan

FOURTH REVIEW
Nov 17 & 18, 9–18 h

Structure. We will continue our discussion of the previous reviews and aspects of your work together with the structural aspects, construction techniques and organisation.
Guests will be structural engineers Joseph Schwartz (TBD), professor at ITA in ETH Zürich on Tuesday 17th and Mario Monotti, professor at the Accademia di architettura in Mendrisio on Wednesday 18th. Monotti will start the day with a lecture on stone structure.

STUDIO WEEK 11
Nov 24 & 25, 9–18 h

Individual discussions with Stephan

FIFTH REVIEW (via Zoom)
Dec 1 & 2, 9–18 h

Full Preview. The aim of the fourth review is to have a semi-final presentation of your project. The minimum requirements are: introductory text that explains the concept of the project, drawings of a site plan, floor plan, and technical horizontal or vertical section, (fragment) model of your work with the chosen material(s), material experiments and photography. It is important to show and support

the found values of the material engagement in a spatial way, based on the full potential of the inherent qualities of the material itself and your way of working it.

STUDIO WEEK 13
Dec 8 & 9, 9–18 h

Individual discussions with Stephan

FINAL REVIEW
Dec 15 & 16, 9–19 h

Together with Stephan, you will work on the final presentation with an exhibition of the final models, material samples and A2 drawings and photos. Guests will be announced during the semester.

EXPERTS

ELIAS AND YOUSEF ANASTAS

Elias and Yousef Anastas studied architecture in Paris, before returning to work in Bethlehem. Their studio brings together architecture practices, furniture-making, research projects and cultural initiatives.
They founded Local Industries, an industrial furniture-making network, in 2012 and SCALES, a research department, in 2016.
Their most recent works include Qamt, a stone bench acquired by the Victoria and Albert Museum, the Hebron courthouse, and the ongoing Stonematters, an experimentation-based research around the possibilities of stone usage in contemporary architecture.
They co-founded Radio alHara – a community based online radio - and are about to launch The Wonder Cabinet in Bethlehem, a multipurpose cultural platform bringing together artisans and artists.

MITUL DESAI

After graduating from Washington University in St. Louis in 2008 with M.Arch, Mitul joined Studio Mumbai for an internship. This engagement evolves and continues as a collaborator for publications, exhibitions and installations in India and abroad. Mitul has his own architectural practice and continues to engage with various design institutions in his hometown, Surat. A self-taught photographer, he rigorously documents the everchanging Indian landscape. Cities, urban fringes, industrial landscapes, demolition, material studies and informal architecture are few of many photographic interests that he considers crucial for his ongoing dialogue with Bijoy Jain. Architecture, photography, research and teaching are seamless and interdependent entities for his ever-growing interest in culture, anthropology and habitat.

FABIO GRAMAZIO
Gramazio is an architect with multi-disciplinary interests, ranging from computational design and robotic fabrication to material innovation. In 2000, he founded the architecture practice Gramazio & Kohler, in conjunction with his partner Matthias Kohler, where numerous award-wining designs have been realised. Current projects include the design of the Empa NEST research platform, a future living and working laboratory for sustainable building construction. Opening also the world's first architectural robotic laboratory at ETH Zürich, Gramazio & Kohler's research has been formative in the field of digital architecture, setting precedence and de facto creating a new research field merging advanced architectural design and additive fabrication processes through the customised use of industrial robots. This ranges from 1:1 prototype installations to the design of robotically fabricated high-rises. His recent research is outlined and theoretically framed in the book The Robotic Touch: How Robots Change Architecture (Park Books, 2014). From 2017 to 2019, Fabio Gramazio was Director of Studies for Bachelor and Master Architecture.

STEFAN HEUBERGER
(Winterthur, 1976)
Heuberger graduated from ETH Zürich with a diploma in Earth Sciences in 2001. From the same institution, he then earned a PhD focusing on geological field studies in the Hindu Kush and Karakoram Mountain Ranges in Pakistan. After these studies at ETH Zürich, he spent 12 years working as a consulting geologist in different industry projects in Switzerland. There, he first worked in the fields of analysis of rare, extreme natural disasters like earthquakes for reinsurance applications and for safety measures of nuclear power plant sites. Then, he focused on geological exploration studies and projects for geothermal energy and the nuclear waste disposal industry. Since 2017, he is back at the ETH Zürich Department of Earth Sciences as head of the Georesources Switzerland Group, which conducts applied research in the field of mineral and energy resources of Switzerland and strongly collaborates with the Swiss Federal Office of Topography (swisstopo) and the Swiss Federal Office of Energy.

AGLAIA KONRAD
Austrian born, self-taught as an artist, since the early 90s, Konrad has developed a strong interest in urban space, architecture and sculptural architecture. Metropolitan urban space forms a key focus in her photographical work; she has been exploring the post-war

urban landscape and its various forms and manifestations in a wide array of mega cities on different continents. Her work comes about in various media, like photography, film, video, printed publications and installations. She has participated in many international group exhibitions, such as Documenta X and Cities on the Move, and has had solo shows in numerous venues, including Museum M, Leuven; Fotohof, Salzburg; Netwerk, Aalst; Sainsbury Centre for Visual Arts, Norwich; Museum für Gegenwartskunst, Siegen; Camera Austria, Graz; and Luminair City, Lisbon. A selection of her published books includes: Elasticity (2002); Iconocity (2005); Desert Cities (2008); Carrara (2011); Zweimal Belichtet (2013); Aglaia Konrad: From A to K (?); SCHAUBUCH: Skulptur (2017) and upcoming Japan Works (2020). She lives and works in Brussels and teaches at the LUCA School of Arts.

CLAUDIO MADONNA
(Locarno, 1983)
In 2013, Madonna obtained his PhD at ETH Zürich with his thesis "Laboratory Measurements of Seismic Attenuation and Computation of Elastic Moduli of Reservoir Rocks". At present, he is lab manager of the Rock Physics and Mechanics Laboratory and senior researcher at ETH Zürich. His competence in the SCCER-SoE group focuses on research and development in experimental rock physics on material properties and geomechanical processes relevant to deep geoenergy reservoir engineering. Design of, and participation in studies that allow bridging small-scale rock properties and deformation experiments with larger-scale properties and behaviour of underground rock laboratories.

MARIO MONOTTI
(Locarno, 1975)
Monotti graduated from Zurich Polytechnic with a degree in Civil Engineering and subsequently, earned a PhD in Technical Sciences where he focused his research on the plastic analysis of reinforced concrete slabs. Since 2009, he has held the position of Professor of Structural Design at the Accademia di architettura in Mendrisio, Switzerland. He is also the founder and owner of the Monotti Ingegneri Consulenti SA in Locarno. His company specialises in structural design in architectural contests in the public and private sectors on national and international levels. Mario Monotti works collaboratively with young architects. His name is associated with the school of Leutschenbach of C. Kerez (European steel design award 2011), the House on Two Pillars of C. Scheidegger and J. Keller (Betonpreis 2017), the National Pavilion of the Kingdom of

Bahrain for Expo Milano 2015 of Anne Holtrop, and many other project and exhibition pavilions.

FILIPPO SCHENKER

(Basel, 1983)
Schenker is a field geologist with a strong background and expertise in structural geology, metamorphic petrology, geochronology and numerical modelling. His research interests include the study of geological processes from the micrometre to the kilometre scale, combining geological mapping with analytical and numerical techniques. In 2013, Filippo received a PhD in structural geology and tectonics at ETHZ with his dissertation focusing on mechanical and thermal aspects of extensional migmatitic domes in compressional orogens. From 2014–15, he was a postdoctoral researcher at the University of Lausanne and coordinator of the Doctoral Programme in Mineral Sciences (Programme doctoral en Sciences des Minéraux) of Western Switzerland. Since 2015, Filippo is researcher at SUPSI, and he is associate editor of the "Bolletino della Società ticinese di scienze naturali" since 2016.

ANNIKA STAUDT

Staudt is a self-employed stonemason and sculptor, based in Düsseldorf. Her Atelier was founded by the sculptor Friedrich Meyer in 1967 and her aim is to pursue and develop the strong sculptural language of this Atelier. The work focuses on massive stoneworks and can be self-contained, as well as responding to natural and architectural space. The shape and surfaces arise through long-developed craftsmanship and careful observation of the process. For more than five years, she worked at the Atelier of Peter Zumthor in Haldenstein, with responsibility for the model workshop. Throughout this experience, she was in close exchange with architects and architecture, thinking and developing intervention in stone. Lectures, workshops and teaching assignments include: Maastricht Academy of Architecture with Jos Bosmann (2019), Hogeschool Rotterdam with Groothuijse/ de Boer (2018), TH Köln with Nikolaus Bienefeld (2017), Accademia di Architectura Mendrisio with Quintus Miller (2016/17) and with Francis Kèrè (2017), ETH Zürich with Gion Caminada (2015) and Akademie für Handwerksdesign (2015).

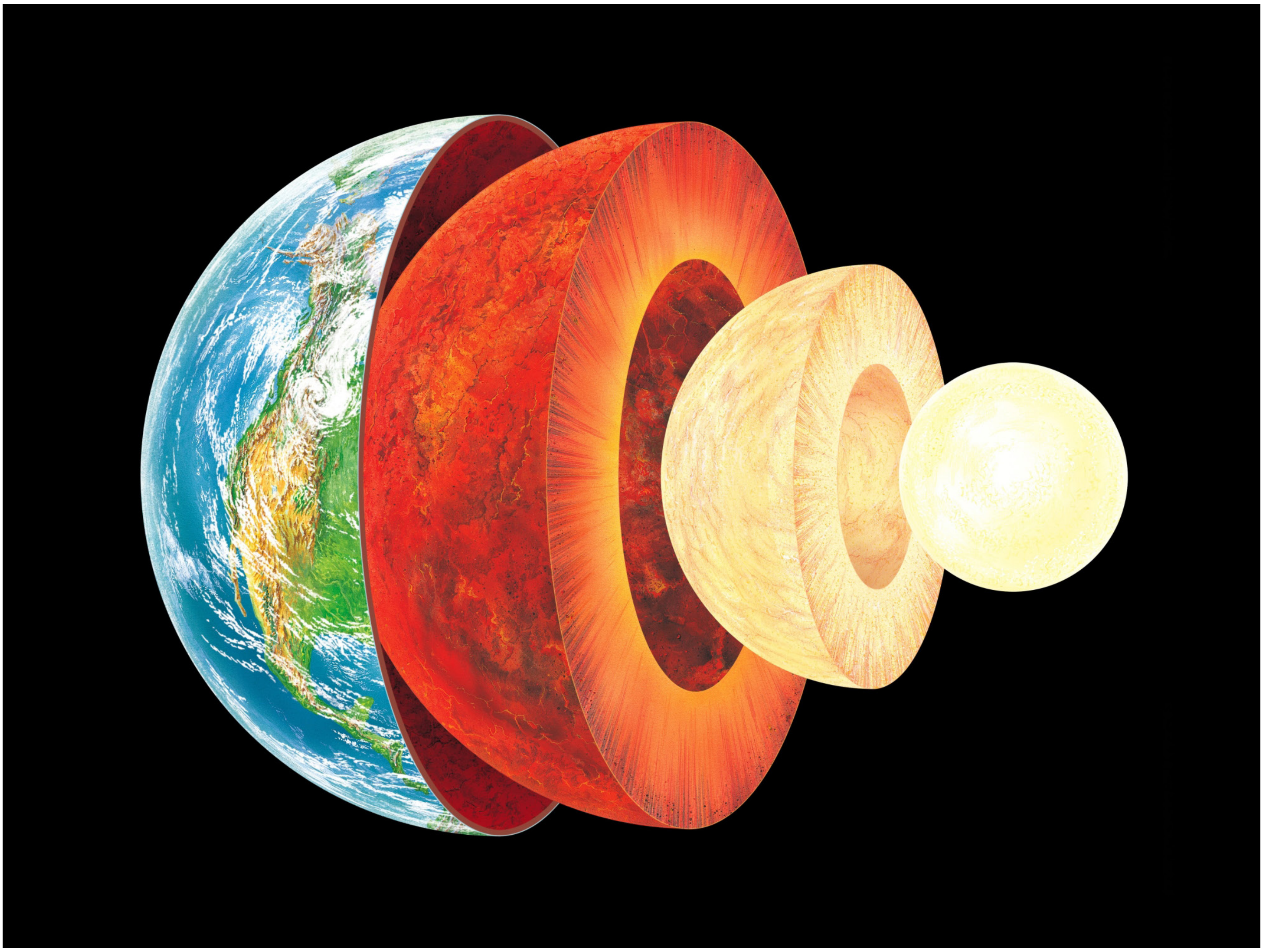
ROCKS AND MINERALS

TYPES OF ROCK

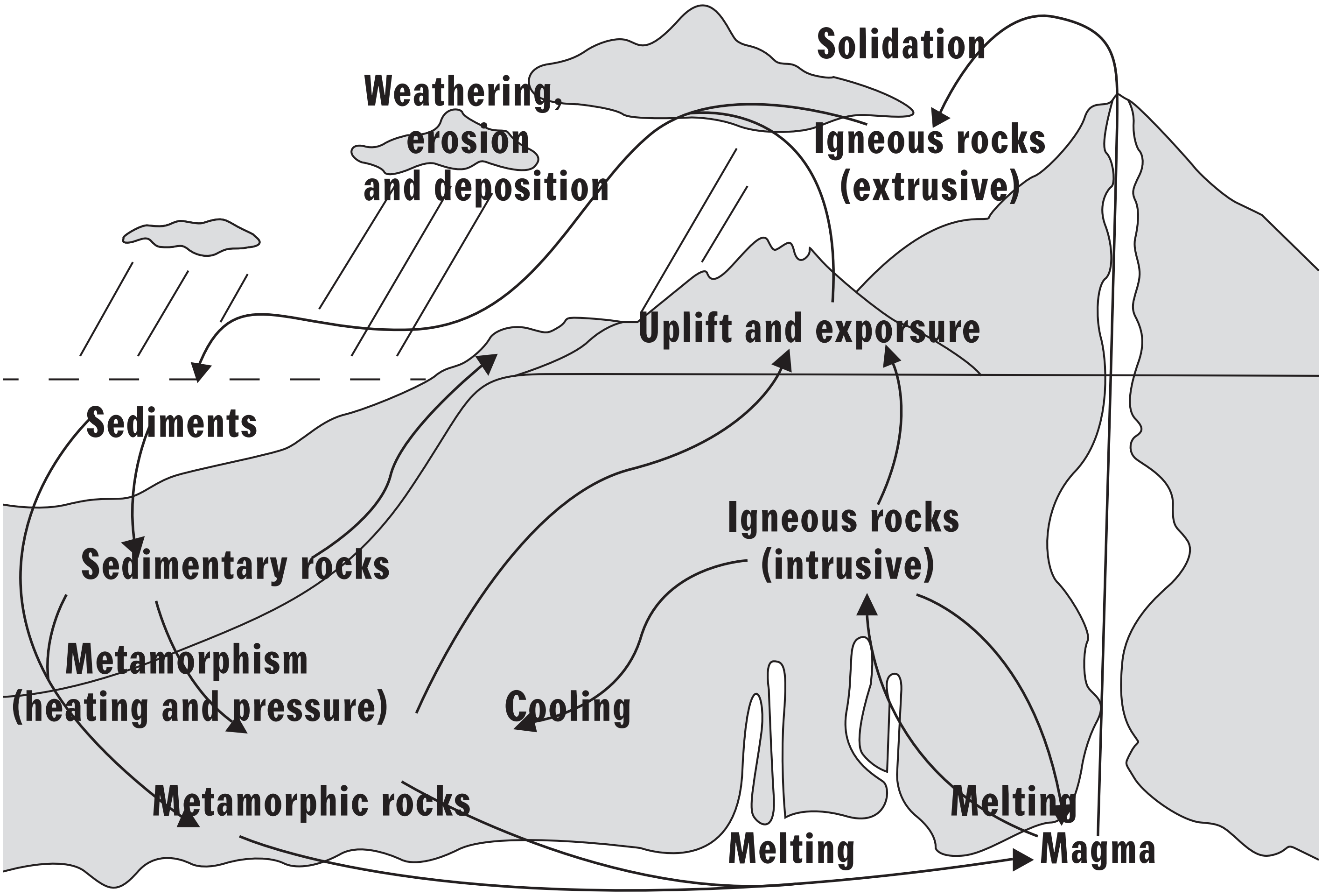
Rocks are confined to the earth's crust, which is the thin, light outer solid skin of the earth, ranging in thickness from 40–100 kilometres (25 to 62 miles) in the continental blocks to 4–10 kilometres in the ocean basins. Underneath the earth's crust is another layer of mostly solid rock, called the mantle.

Rock is always being formed, worn down into pieces and then formed again. This is called the rock cycle. Rock wears down through erosion. Pieces of rock then settle and slowly become sedimentary rock. If sedimentary rock becomes deeply buried, it may melt into magma. Then the magma may return to the surface as igneous rock. Deeply buried rock may also become metamorphic rock. The rock cycle takes many millions of years.

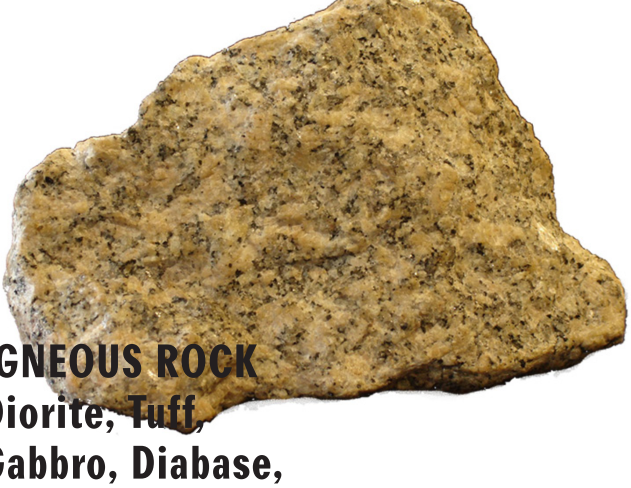
Rocks are broadly classified into three types: igneous, sedimentary and metamorphic. This classification is made on a basis of origin and does not take into account mineralogic composition or physical properties. These names describe how each type of rock was formed.



CRUST, MANTLE, OUTER & INNER CORE

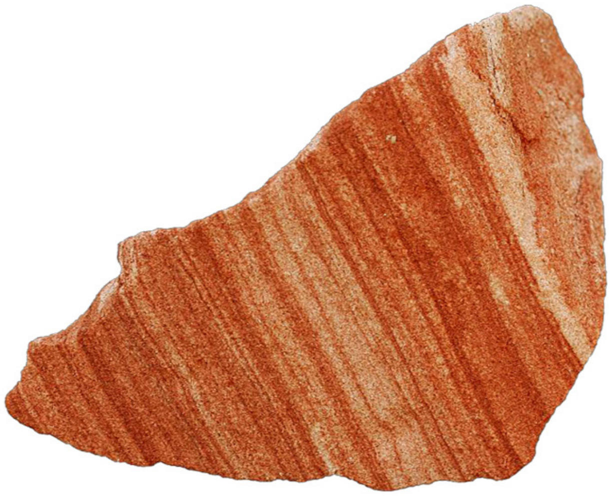


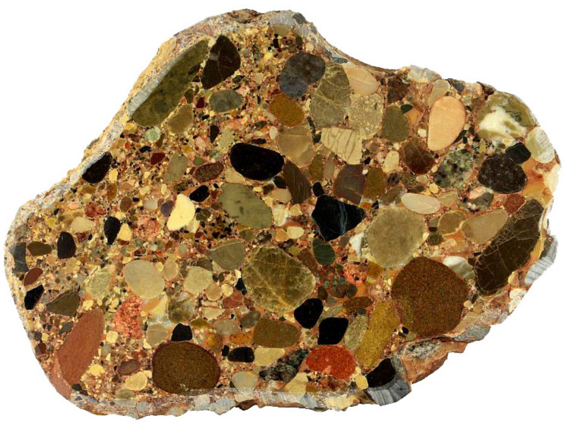
THE ROCK CYCLE



IGNEOUS ROCK
Diorite, Tuff,
Gabbro, Diabase,
Granite, Syenite

**Rhyolite, Trachyte,
Basalt
37**



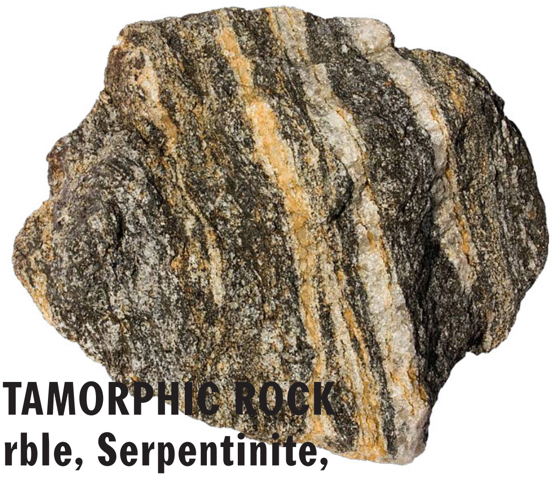


SEDIMENTARY ROCK
Breccia, Sandstone, Conglomerate, Chert, Limestone, Dolomite

Travertine, Mudstone,
Shale
39








METAMORPHIC ROCK
Marble, Serpentinite, Migmatite, Granulite, Schist, Soapstone

Slate, Gneiss, Quartzite
41

ENO	ERA	PERIOD	EPOCH	BEGINIG	MAJOR EVENTS	ROCKS
Phanerozoic	Cenozoic (age of mammals)	Quaternary	Holocene	11,700	present climate; only modern human	Boulder clays associated with the movement of glaciers.
			Pleistocene	2,600,000	recent ice ages: various human species	
		Tertiary	Pliocene	5,300,000	near-human species and other near modern mammals	Gneiss stone in Alps
			Miocene	23 ,000,000	apes flourish: savanna grazing animals evolve	
			Oligocene	33,900,000	monkeys, apes, and other mammal families evolve	
			Eocene	55,800,000	prosimians flourish; possible early monkeys	
			Paleocene	65,500,000	earliest primates (proto-prosimians)	
	Mesozoic (age of reptiles)	Cretaceous		145,500,000	archaic mammals and birds begin to replace dinosaurs; first flowering plants	
		Jurassic		199,600,000	dinosaurs dominant: primitive mammals spread; toothed birds	Carrara marble

		Triassic		251,000,000	first dinosaurs and first egg-laying mammals; vast forests of ferns, conifers, and cycads	Volcanic activity produced vast quantities of plateau basalts in Siberia and South Africa.
		Permian		299,000,000	spread of reptiles and insects; first mammal-like reptiles	New red sandstone
		Carboniferous		359,200,000	amphibians dominant; forests flourish; reptiles and mordern insects appear	
		Devonian		416,000,000	fish dominant: amphibians appear; first forests	Old red sandstone
		Silurian		443,700,000	fisf with jaws: first air breathing animals	
		Ordovician		488,300,000	invertebrates dominant; first vertebrates(jawsless fish): first land plants	
		Cambrian		542,000,000	explosion of life forms; invertebrates dominant(worms, jellyfish, trilobites, etc.)	Widelyspread flooding of continents, producing large areas of limestones.Shales and sandstones also common.
Precambrium	Proterzoic (earliest life forms)			3,000,000,000	protozoa, sponges, and algea: oxygen begins to accumulate in the atmosphere	Sedimentary, igneous and metamorphic
				3,500,000,000	first clear evidence of life(one called bacteria)	
	Azoic (no life form)			4,543 ,000,000	origin of the earth	Mostly metamorphic

INGENIOUS ROCK

Rocks crystallise from magma. Magma may escape through cracks in the earth's crust. It may also come to the earth's surface when a volcano erupts. As the escaped magma cools, it hardens into solid rock. Granite and basalt are examples of igneous rock.

SEDIMENTARY ROCK

Rocks form by weathering and erosion of pre-existing rock to make sediment, which is then lithified (cemented) into rock. In a process called erosion, wind and water slowly break the rock into tiny pieces. Water washes the pieces into rivers. Loose layers called sediment settle softly along the river bed, in the lake and in the sea. Over millions of years, the sediment builds up, hardens and becomes solid rock. Sandstone is a sedimentary rock that forms in this way. Sedimentary rock may also form from the remains of dead animals or plants. Limestone is a sedimentary rock that is made up of the shells and stony skeletons of certain kinds of living things.

METAMORPHIC ROCK

Rocks form by the deformation and/or recrystallization of pre-existing igneous or sedimentary rocks due to changes in temperature, pressure and/or chemistry. Great heat and pressure inside the earth's crust can shape old rock into metamorphic rock. Water can dissolve minerals in old rock or carry new minerals into it to form metamorphic rock. The heat of magma can also change old rock into metamorphic rock. Marble and slate are examples of metamorphic rock.

GEOLOGICAL TIME SCALE

The oldest dated earth mineral (4–4.2 billion years old) are small zircon crystals, originally formed in magmas, which are found in the sedimentary rocks of Western Australia. The Isua Greenstone Belt located in Greenland is one of the oldest rock formations on earth, aged between 3.7 and 3.8 billion years old. Marble in Carrara was formed in the Mesozoic era (200–145million years ago). Gneiss stone in the Swiss Alps was formed in the Tertiary era (60–2.5 million years ago).

MINERALS

If you take a rock, any rock, and look at it though a hand lens or microscope, you will see that it is made up of a mosaic of interlocking particles. These particles are the minerals. We can define a rock as a naturally occurring solid made up of an aggregate of one or more minerals.

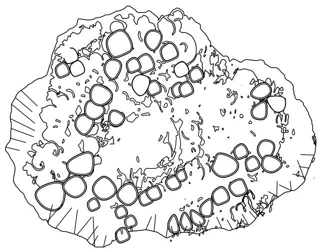
For example,

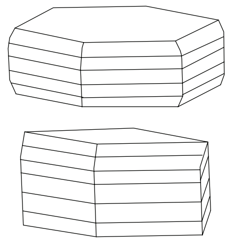
- limestone is composed of only one mineral: calcite,
- basalt is commonly composed of three main minerals: feldspar, pyroxene and olivine,
- granite is commonly composed of five minerals: two kinds of feldspar, mice, amphibole and quartz.

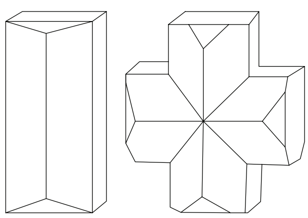
There are over 3500 different types of minerals and approximately 50 more are discovered each year. Each of them has unique chemical compositions and atomic structure. The classification of minerals currently used is that proposed by Professor James Dana of Yale University in 1848. The Dana system of Mineralogy divides minerals into basic classes: native elements, silicates, oxides, sulfides, sulphates, halides, carbonates and phosphates.

NATIVE ELEMENTS: Copper (Cu), Silver (Ag)

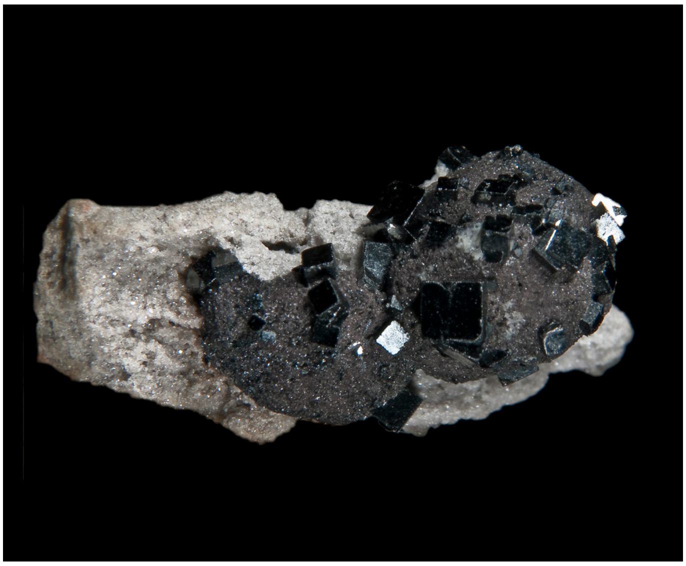
SILICATES: Hyalite opal, Muscovite,



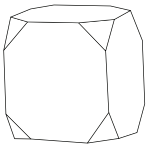
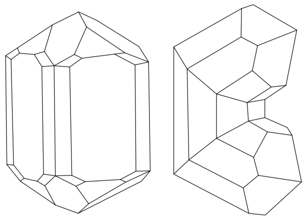


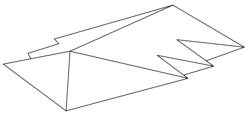
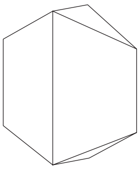


Staurolite



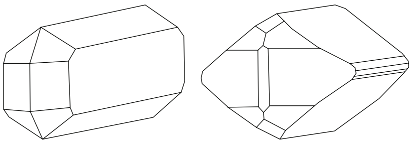
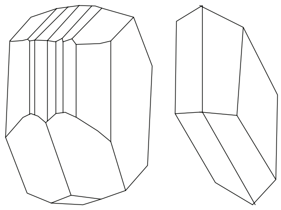

OXIDES: Bixbyite, Rutile

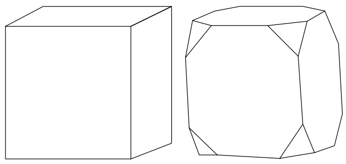



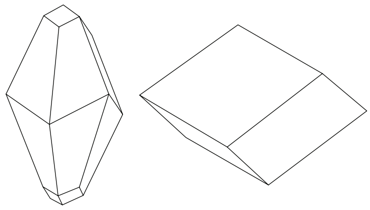

SULFIDES: Arsenopyrite, Molybdenite


SULPHATES: Antlerite [$Cu_2(SO_4)(OH)_4$], Gypsum ($CaSO_4 \cdot 2H_2O$)

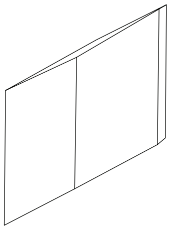



HALIDES: Halite

CARBONATES: Calcite ($CaCO_3$)

PHOSPHATES: Turquoise [$CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$]

NATIVE ELEMENTS

This is the pure category. It is often metal that is seen in this category, such as gold, silver, platinum, iron and lead, but nonmetals are also in its ranks, like sulphur and carbon (as graphite).

SILICATES

This is the largest group of minerals. Silicates are made from metals combined with silicon and oxygen. There are more silicates than all other minerals put together. By themselves, they make up over 90% of the weight of the earth's crust. Most rocks are composed mainly of this class of minerals. As examples, quartz, ammonite, olivine, mica, labradorite and biotite are in this category.

OXIDES

Oxides form from the combination of a metal with oxygen. This group ranges from dull ores like bauxite to gems like rubies and sapphires.

SULFIDES

The sulfides are made up of sulfur combined with another mineral, usually a metal. Many of the world's primary metal ores belong to this group. The chart below lists some of these metal ores and the metal that is produced from them.

SULPHATES

Sulphates are made of compounds of sulphur combined with metals and oxygen. They are a large group of minerals that tend to be soft and transparent or translucent. This class of mineral tends to be evaporites or forms from volcanically heated water.

HALIDES

This group is formed by metal and one of the halogen elements. They are very soft and easily dissolved in water. Halite (NaCL), known as table salt, is so common that it is found in huge deposits all over the world.

CARBONATES

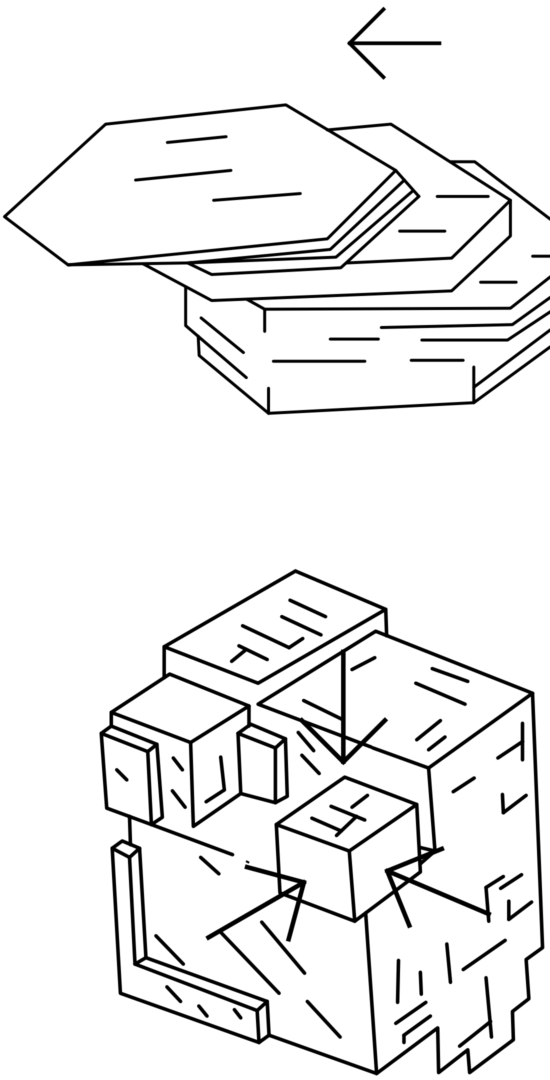
These are made of carbon, oxygen and a metal. This group is soft and easily dissolved by even mildly acidic rain. Calcite ($CaCO_3$) known as calcium carbonate, is the most common in the carbonate group.

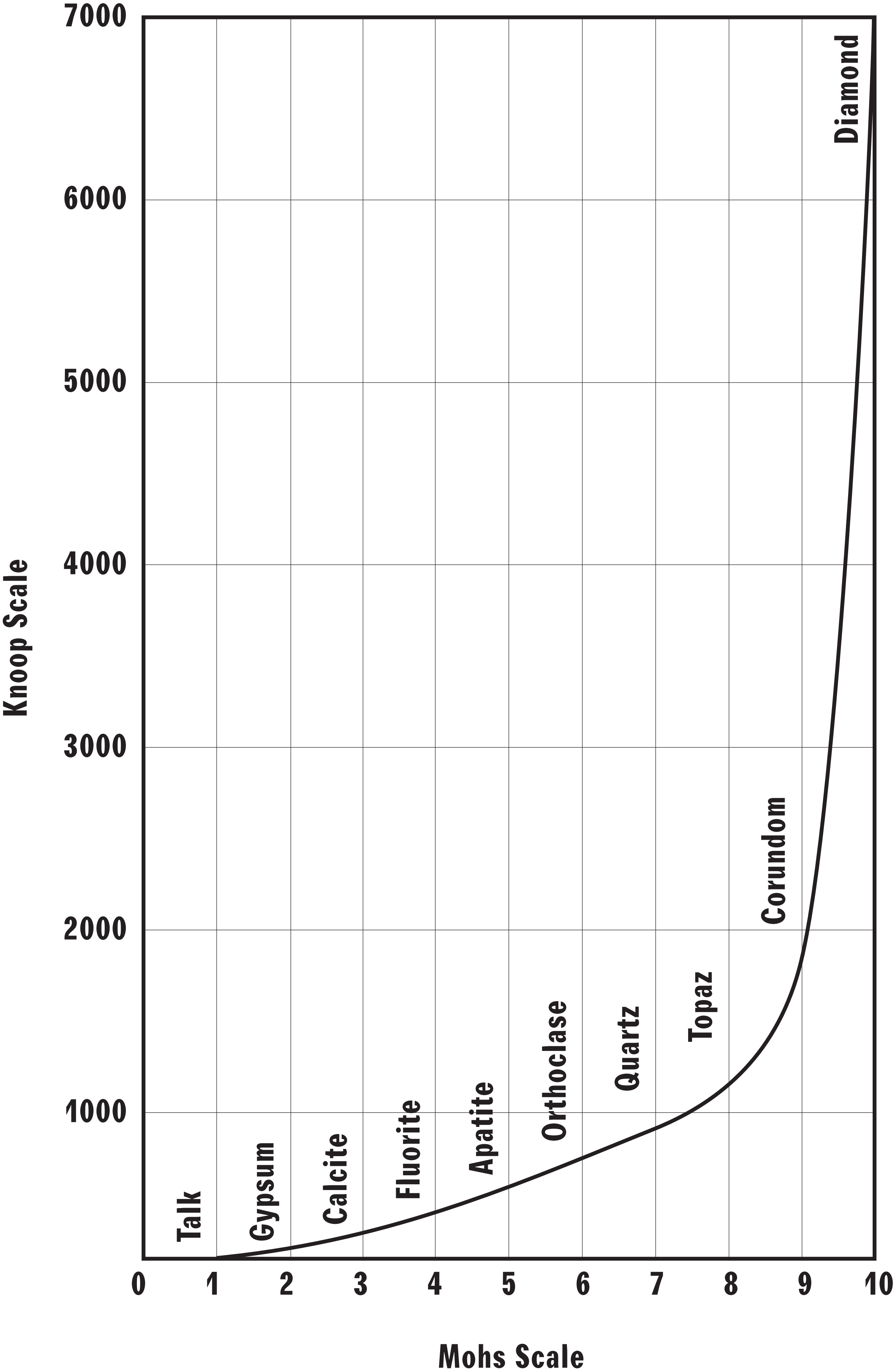
PHOSPHATES

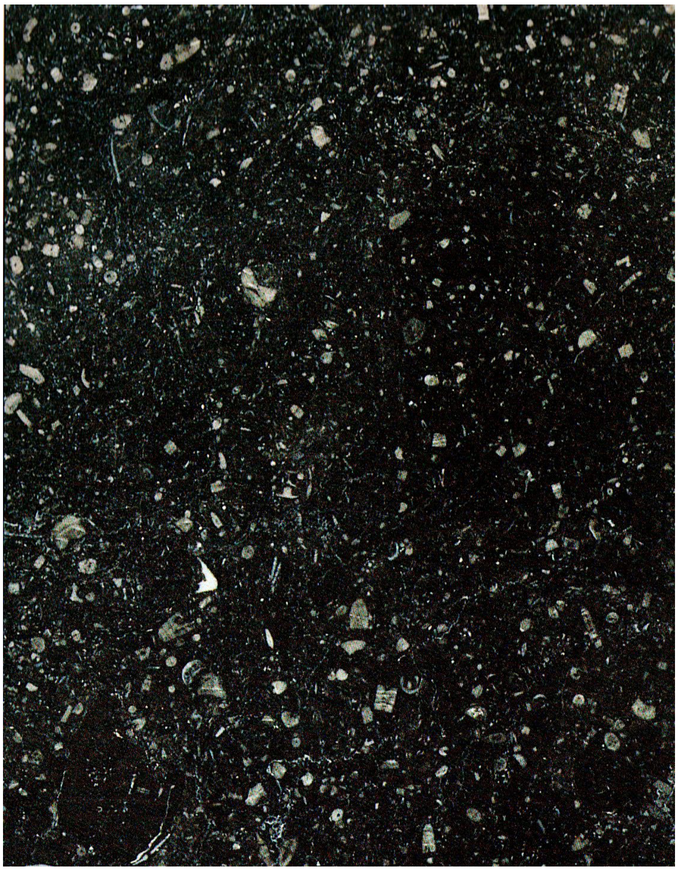
This group is not as common in occurrence as the other families of minerals. They are often formed when other minerals are broken down by weathering. They are often brightly coloured.

PHYSICAL PROPERTIES OF MINERALS

Physical properties play a significant role in the recognition of minerals. The most important are shape, colour and lustre, cleavage or fracture, hardness, specific gravity, and other properties such as magnetic and thermal properties, etc.

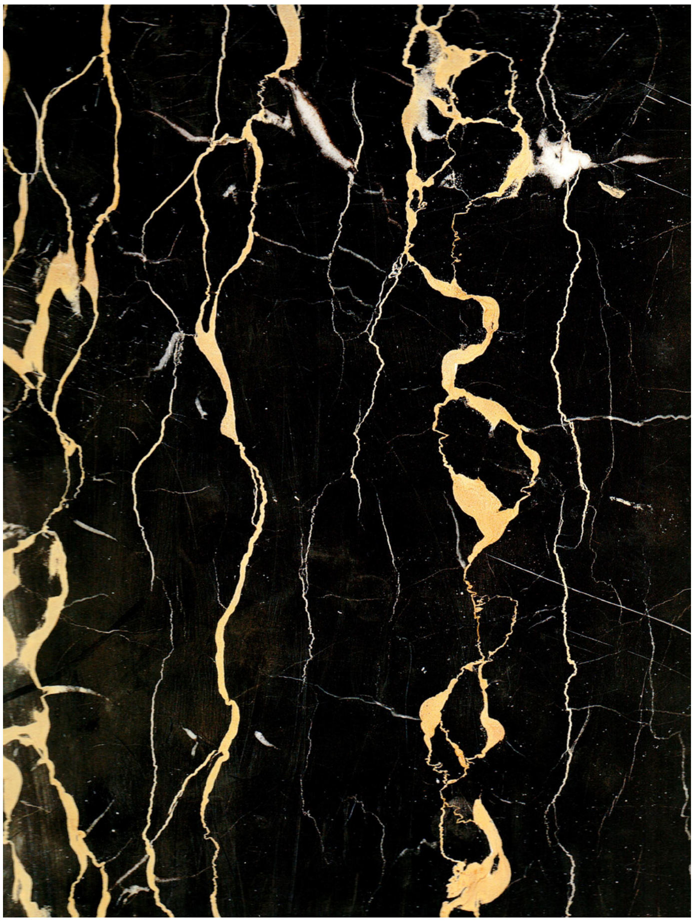



7000
6000
5000
4000
3000
2000
1000
Knoop Scale
Diamond
Corundum
Topaz
Quartz
Orthoclase
Apatite
Fluorite
Calcite
Gypsum
Talk
0 1 2 3 4 5 6 7 8 9 10
Mohs Scale

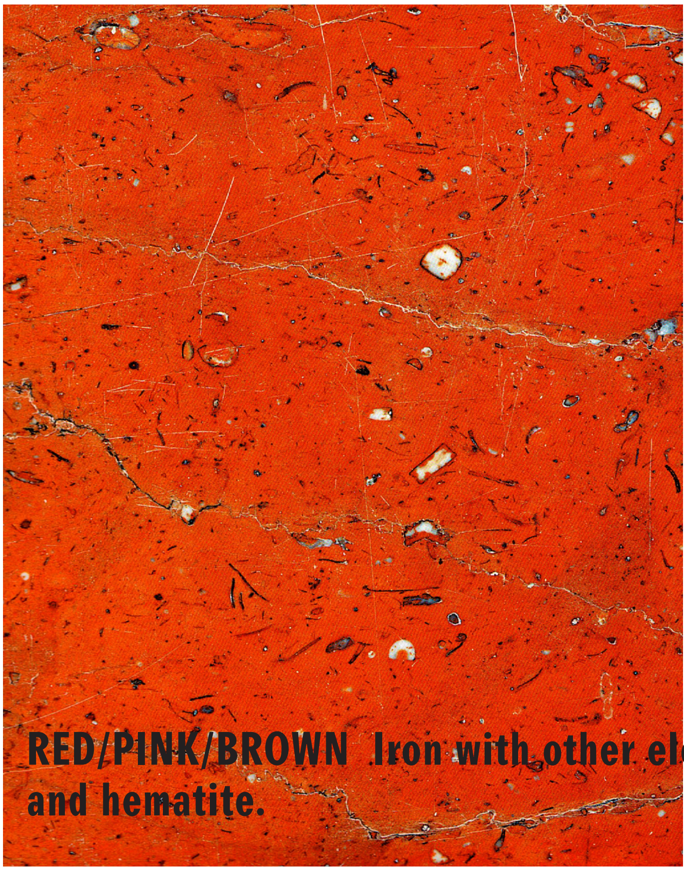


BLACK/GREY Carbon. Often a bituminous coal deposit exists near quarries of black marble, such as in Belgium and Tennessee (USA).

THE DARK STRIPES OF CIPOLLINO Mica, chlorites and talc.



DARK GOLDEN YELLOW VEINS IN PORTOR Spathic iron.



RED/PINK/BROWN Iron with other elements, such as hornblende, sulphides and hematite.

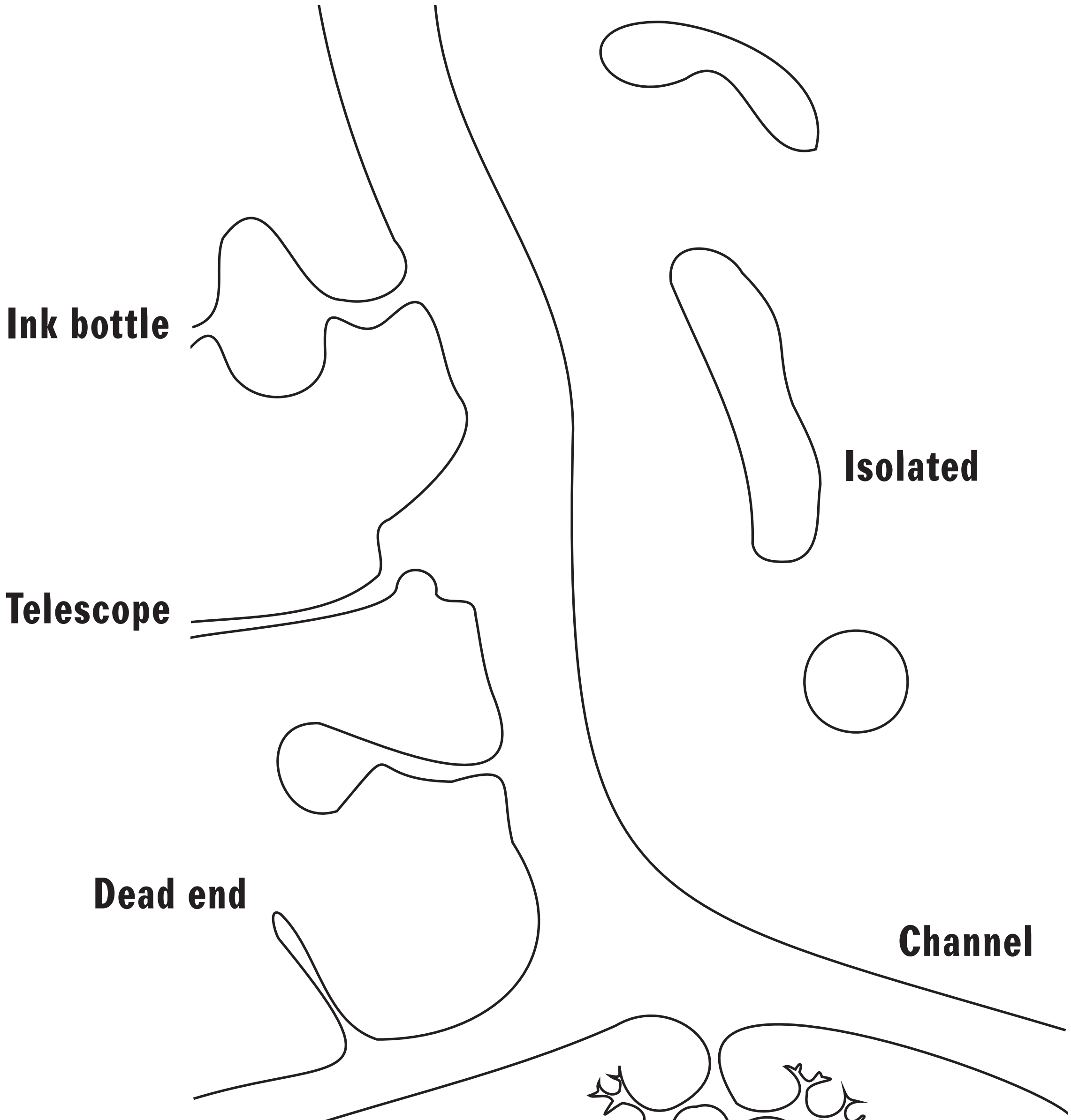
YELLOW Most often iron oxide.

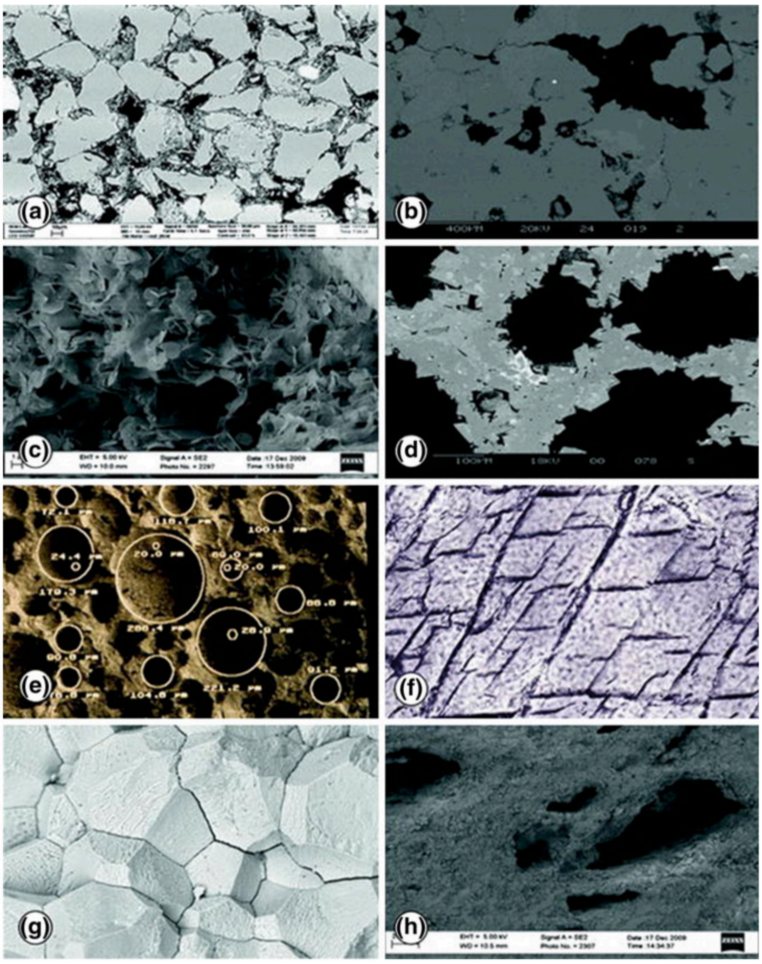
CLEAVAGE
If a mineral is allowed to grow unhindered, it will develop a characteristic three-dimensional shape; a crystal. Unfortunately for the geologist, minerals hardly ever form good crystals. When a rock forms, all the chemical components organise themselves into minerals, which grow crammed up against one another. Only if a mineral can develop in a fluid, uncluttered by other solid matter, does a good crystal form develop. Minerals tend to break along flat surfaces, like peeling off a sheet of paper or breaking like a cube. It depends on how its atoms are bonded or joined together.

HARDNESS
An early definition of a mineral was given by Friedrich Mohs (1773–1839), a German scientist, who defined minerals as 'inorganic products of nature'. We can amplify this definition to 'a mineral is a naturally occurring, solid, homogeneous, crystalline, chemical element or compound'. Mohs is most famous for his scale of hardness based on the ability of one mineral to scratch another. There are ten minerals in the Mohs scale: talc (the softest), then gypsum, calcite, fluorite, apatite, orthoclase, quartz, topaz, corundum and diamond (the hardest). The logic of the Mohs scale is that any mineral can scratch any mineral below it on the scale, and conversely, can be scratched by any mineral above it. This scale can include everyday items like: 2.5 Fingernail, 4 Copper coin, 5 Glass, 5.5 Penknife blade, 6.5 Steel file.

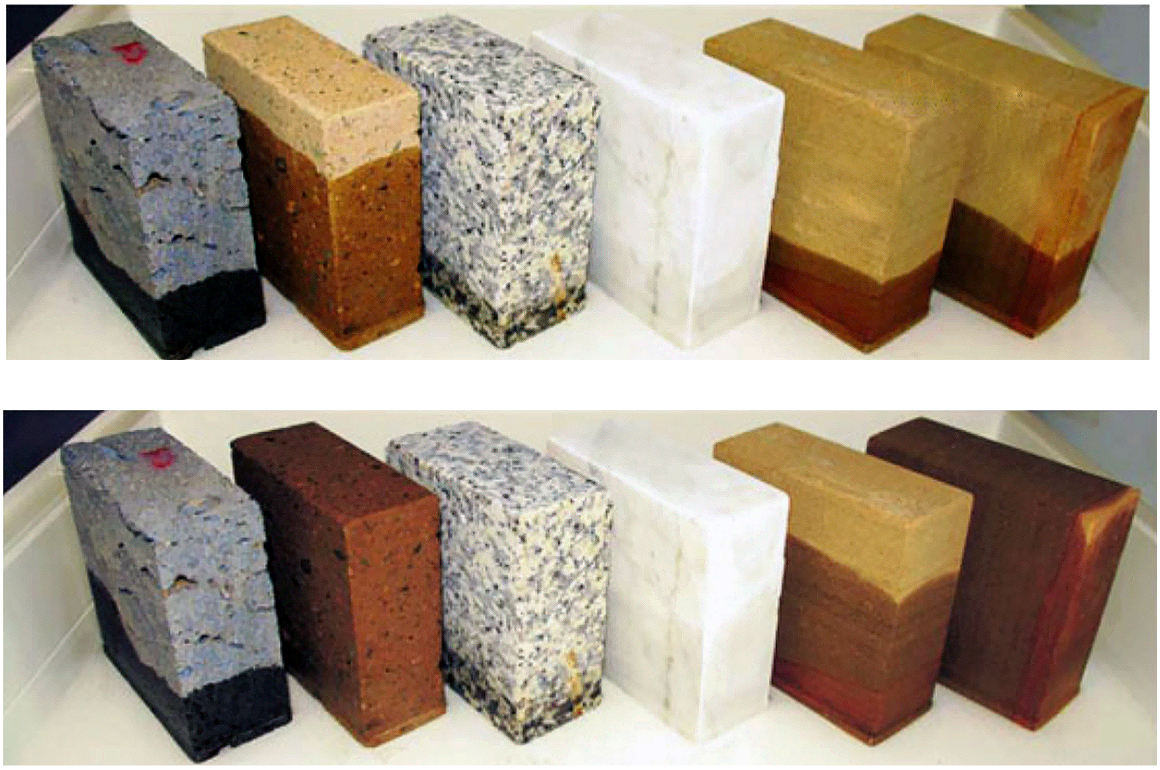
COLOUR
Colour is the first property noted when we look at a mineral. It is, in most cases, the result of the inclusion of an accidental impurity. The primary component of marble is Calcite ($CaCO_3$) and marble usually contains other minerals. These other minerals affect colouration. In general, iron oxides give red and brown. Carbonates and Sulfides create grey and blue. Very light colour and white indicate absence of Iron. Besides colour, fossils and wavy drawings on the stone show us where and how the stone was formed.

MECHANICAL PROPERTIES OF ROCKS

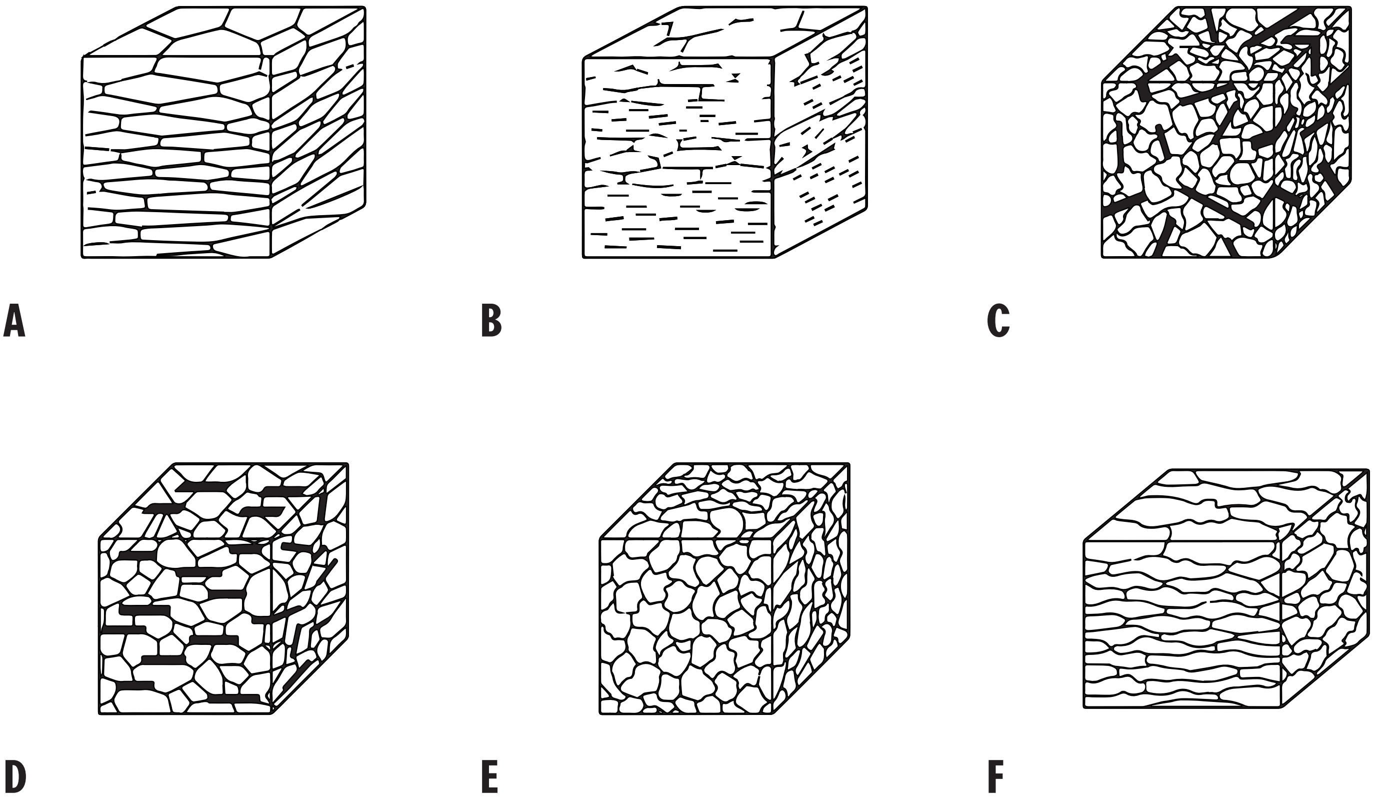

Ink bottle
Isolated
Telescope
Dead end
Channel
Pigeon hole



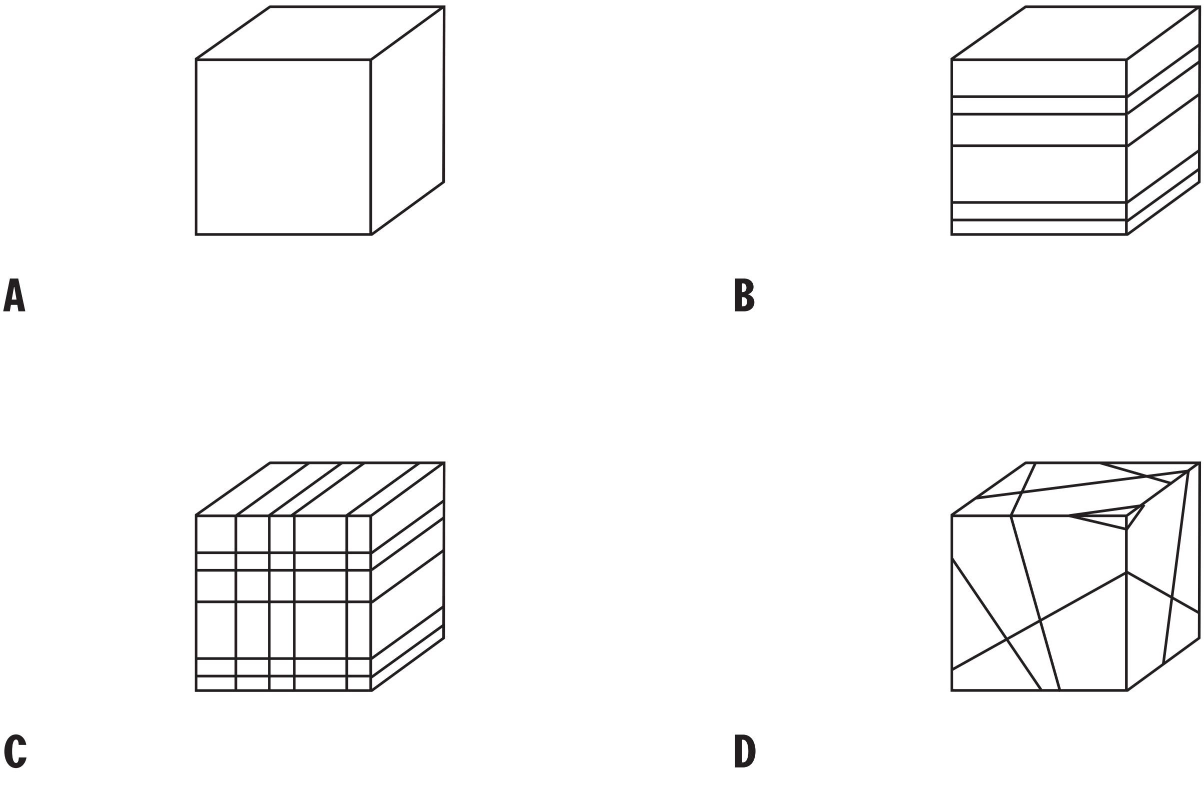
SEM IMAGES
Rocks with their different pore space and porosity



CAPILLARY WATER ABSORPTION
After 60 minutes and 12 hours



SCHEMATIC REPRESENTATION OF VARIOUS ROCK FABRICS



FOUR MAIN TYPES OF NATURAL FRACTURING

POROSITY

The porosity of rock is defined by the ratio of the pore volume (e.g. pores, open cracks) to the volume of the whole rock. Porosity has a direct and indirect effect on most of the physical properties of rocks. Increasing porosity has an unfavourable influence on weathering characteristics. Pore space and porosity are different on each rock and they also affect water absorption.

ROCK FABRICS

In surface exposures, rocks show planar and linear structures (different types of foliation, bandings, bedding, lineation, etc.), which are often related to structures (rock fabrics), ranging from the microscopic to the macroscopic scale. Simply, rock fabric means orientation of mineral grains in the rock. It influences the rock's mechanical properties.

ROCK FRACTURING

Rocks exposed at the earth's surface are almost invariably fractured. Fractures form in the crust as a result of applied stresses over geological time: they may form early in the rock's history during its burial, later during various tectonic events that affect the rock over geological time, or during the exhumation of the rock which brings it back to the earth's surface. And it should be noted that over geological time, rock masses have been subjected to a variety of natural factors during and after their formation, especially natural stresses in the rock which have changed their properties, and which now have a significant influence on the quarrying process.

SEM IMAGES SHOWING ROCKS WITH THEIR DIFFERENT PORE SPACE AND POROSITY

A & B Sandstone with open pores (black) interconnected by open cracks C Clay mineral-rich sandstone with very heterogeneous pore sizes, ranging from micro to macropores. D Dolomitic limestone with nearly spherical pore shapes and dolomite crystals. E Volcanic tuff with intraparticle pores of different sizes. F Open cleavage cracks and transgranular cracks in hornblende minerals, also known as platy pores. G Open grain boundaries in weathered marbles. H Pores in travertine with a heterogeneous pore size distribution ranging up to several centimetres in size

CAPILLARY WATER ABSORPTION

Different rocks after 60 minutes and 12 hours. For the sandstone sample, two specimens were used: one with the sedimentary layering parallel and the other perpendicular to the water level. From left to right: basalt

lava, tuff, granite, marble, sandstone (horizontal layering), sandstone (vertical layering).

SCHEMATIC REPRESENTATION OF VARIOUS ROCK FABRICS
A Planar layering caused by shape-preferred anisotropic minerals; B Material-structural fabric anisotropy created by shape-preferred anisotropic minerals, connected by the intercalation of different layers; and C Polymineralic rocks (e.g. granites) without; and D With an arrangement of shape-anisotropic minerals (e.g. mica); monomineralic rocks (e.g. marbles); E Without; and F With a shape-preferred orientation. In contrast to the equidimensional grains in E, the grains in F are distinctly elongated in a cigar-like way (modified from Passchier and Trouw 1996).

FOUR MAIN TYPES OF NATURAL FRACTURING
A Isotropic. No fractures and mechanical properties are the same in all directions, e.g. an unfractured granite rock mass or a massive limestone or sandstone.
B Transversely isotropic. One set of fractures. Properties are the same in the horizontal directions, but different in the vertical direction, e.g. unfractured but bedded strata.
C Orthotropic. Three sets of mutually perpendicular fractures. Properties are different in the three perpendicular directions, e.g. a sedimentary bedded rock with two sets of fractures perpendicular to each other. It is generated by burial and subsequent exhumation.
D Random. Many sets of fractures in different directions. Properties are different in all directions, e.g. a rock mass which had deformation events over geological time.

THREE SITES

A stone quarry is a place where the stone is mined. The products of stone quarries are prismatic blocks of rock. In this chapter, three different stone quarries are introduced: Carrara in Italy, which has one of the most famous marble quarry complexes, a red sandstone quarry at Jodhpur in India, which has impressive red sandstone due to the presence of iron, and a local small-scale quarry at Vals in Switzerland. Types of rock, topographical and cultural conditions determine methods of extraction, processing and transportation at each site.

CARRARA

Most quarries in Carrara are open-cast quarries on mountain slopes and some also have underground quarries.

Open-cast quarrying is a surface mining technique. It is advantageous due to the wide and uniform banks of rock which can be excavated gradually and evenly. The methods of quarrying assume tremendous importance in the way excavation work is conducted. To determine the procedure and sequence adopted to exploit a stone layer, it is essential to analyse its form, its dimensions, the morphology of the surrounding territory and the intrinsic territories of the stone to be excavated.

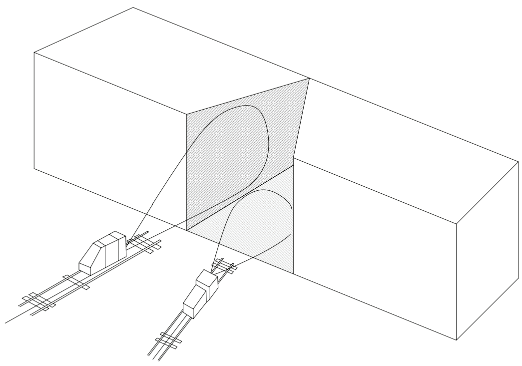
In Carrara, a diamond wire saw has been used for excavation since 1960s. The wire has encrusted inserts at frequent intervals. This method of in-situ cutting and extraction of the marble is versatile and efficient.

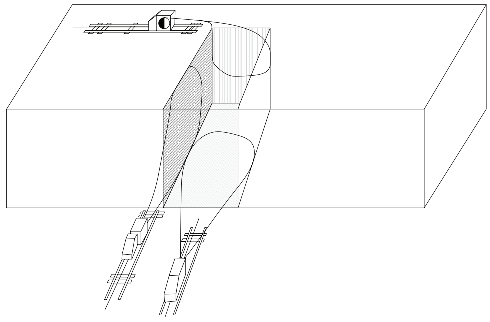
The underground quarry in Carrara is spectacular as well. It is distinguishable by the spatial configuration of the quarry, like a cavity with large pilasters, or with chambers and pilasters, or with long faces. The excavation of stone from the underground involves working inside the rocky mass. It is a much more limited area compared with open quarries, since the impending stone mass seals the workspaces both laterally and above. Quarrying can continue all year whatever the weather conditions, and the landscape is modified little. In order to ensure safety in the workspaces, geological analysis and structural design for voids and stone pilasters are important. The infrastructure at Carrara quarries is configured by steep winding roads. Trucks, each loaded with a 20-ton block of marble, drive down the roads.

The bench wall, once separated from the mountain, is firstly handled or divided into square or rectangular blocks to be moved, in order to make easier the transportation from the mountain to the plain, where marble is processed or continues its journey to the port of Carrara to reach buyers all across the world.

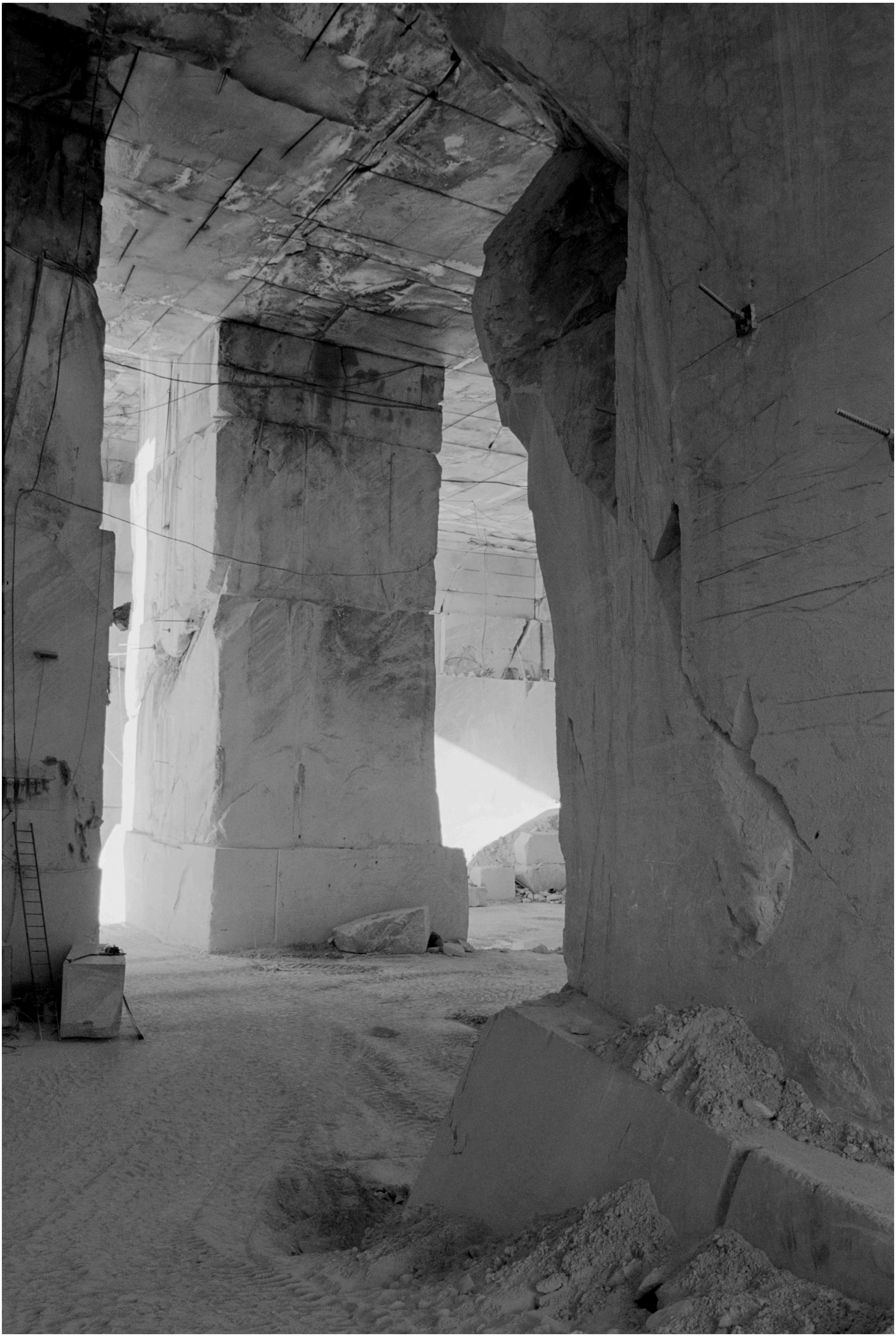
In ancient times, marble blocks were handled through the use of slides. Nowadays, modern heavy-duty machines are used to handle the blocks. The production cycle in the quarry ends with the lifting by crane of the blocks that are loaded on the vehicles which transport them to the plain. In the past, the transportation of blocks was done with carts pulled by oxen. Finally, the blocks arrived to areas closer to the sea, such as Avenza and Marina, where they were sorted and sent either towards the coast facilities or boarded in the port.

Photos by Aglaia Konrad





V-SHAPE & U-SHAPE CHANNEL




BL

THINK SPACE REMOVAL, INFORMED DUST, LANDSCAPE

Text by Angekika Stephen

"Located at the foot of the Apuanian Alps, this city owes its fame to the white marble found here." This is roughly how every travel guide on Carrara begins. The city of 65,000 inhabitants is situated approximately 60 miles northwest of Florence on the Versilia coast, which extends 18 miles south to Viareggio, Tuscany's fashionable swimming resort since the late 18th century. Each year, around 2.5 million tourists, including a recent boom in Russians, flock to the privatized sandy beaches to catch a tan with the Apuanian Alps in the background, whose peaks are as high as 1,800 meters. Motorists can see the "white gold" on the distant mountains as soon as they turn into the long access road from the sea that leads to Carrara; it always looks like snow, regardless of the season. Marble is precious; marble—particularly the white Statuario of Carrara—has helped write art history, having provided the material for classical sculpture from the Greeks to the present day. Since the 1960s, for instance, the American grand dame of contemporary sculpture, Louise Bourgeois, has repeatedly worked with white Carrara marble in the ateliers of the neighboring Pietrasanta.

Marble is also heavy, hard, and costly; mining it is difficult. The three main marble basins of Carrara—Ravaccione, Fantiscritti, and Colonnata—contain around 150 quarries and can be reached by car or bus. The mountains harbor a wealth of reportedly 60 billion cubic meters of Carrara marble. The stone is comprised of layers of calcite deposits and marine organisms that accrued after the continental shelves of Africa and Europe shifted 30 million years ago. A type of limestone with a crystalline structure, it is harder than travertine and can be sanded and polished. Mineral inlays vary its coloration. Today, five million tons of this limestone are mined from the Carrara quarries each year. Three-quarters of it is exported, half of that to Arabic countries, where it adorns mosques, fair buildings, and airports. One cubic meter of Carrara marble weighs approximately 2.8 tons; it is traded at prices of up to 2,500 euros. 140 years ago, one tenth of Carrara's 100,000 inhabitants at the time worked in and lived from the quarries. Today, 1,000 people are employed there. One worker mines approximately 1,500 tons of marble per year.

Hardly any other natural resource, apart from gold and silver, embodies the classical and classicist notion of the "noble" value of aesthetic production to the extent that white polished marble does. Even today, the first thing that comes to mind when marble is mentioned is Michelangelo; then come stairwell tiles. Even before this stone was discovered during the second century B.C. in Luna near Carrara, it had been mined in the Greek city of Patros as the raw material for prestigious buildings and sculptures. While the precious metals gold and silver are largely limited to the miniature form, marble is the material for life-sized figures and architecture and hence a medium of political representation and the generation of ideological value. The Roman emperor Trajan commissioned a victory column in Carrara marble nearly 100 feet high; it was inaugurated in 113 A.D. and consists of 29 layered blocks of stone with an overall weight of 1,100 tons. Its spiral frieze, which is almost 200 meters long, depicts the victorious wars against the Dracians; the Roman emperor himself is portrayed 60 times, and to this day, Trajan's Column is one of Rome's main tourist attractions.

Until his death in 1564, Michelangelo repeatedly spent many months in the marble quarries of Carrara in order to secure the best sections of stone for his sculptures, which not infrequently broke during the dangerous transit from the basins. He even had a road built to transport the gigantic blocks, which ended near what is today the bathing resort Forte dei Marmi. In 1506, a marble work had been rediscovered, a copy of the legendary Laocoon group of Roman times that became the point of reference for emerging classicism in the 18th century. Today, the sculpture, in which the archaeologist Johann Joachim Winckelmann (1817–1868) detected the "pain of the body and the greatness of the soul," belongs to the Vatican museum. The glorification of marble was continued into the 20th century: Carrara marble was used in Mussolini's monumental buildings; both Silvio Berlusconi and Pope Johannes Paul II. commissioned portrait statues in Carrara marble, George W. Bush and Saddam Hussein as well, allegedly at the same time and in the same workshop in Pietrasanta.

The view of the Apuanian Alps near Carrara is strikingly monumental and unsettling in a lingering way. The view generates afterimages that interfere with your sight even after you’ve long since changed location. In the mountains of Carrara, you see what you can no longer actually see: millions of tons of mined marble that have found a form and a location somewhere in the world, or have been wasted, reduced to rubble. You see the remains of mountains, their insides that would otherwise be invisible; you see incisions, streets, serpentines, and bridges, and when you get closer, you hear the noise of the saws, the excavators, and the trucks.

Presence and absence become equally important; aesthetics and overexploitation two sides to the monumentality of marble. Already the first shimmer of summer snow at a height of 1,000 meters causes coded habits of seeing to collide, unleashing a continuous chain reaction of thought: am I looking at mountains, or am I looking at the missing parts of mountains, at no longer existing mountains that no eye can possibly reconstruct? Does the charm of a landscape always derive from a distanced view, from a desire to get closer? Why do I want to see a landscape that is primarily a site of industrial work? Why does the space around the marble quarry excite the eye in such a different way than, say, in a brown coal mine? Is white always clean and brown always dirty? Does the white marble dust shine with the light of the Enlightenment? Does Michelangelo’s David aesthetically alter my view of the mined Apuanian Alps? Am I looking at a gigantic historical project of Land Art? Or at a battlefield of ruthless ecological destruction, or at the birthplace of a 2,000-year-old European art history?

For centuries, tens of thousands of workers toiled away their lives in the quarries; hundreds, thousands died there. To this day, fatal accidents are reported when workers are squashed to death by the marble blocks, as happened on October 13, 2010 and on May 19, 2011. In the city of Carrara and in the small mountain village Colonnata, commemorative plaques honor the victims, as well as the women of Carrara that resisted the German army on July 7, 1944 and refused to evacuate their city, even as the entrepreneurs of the marble industry were helping to finance the fascist movement.

The marble quarries of Carrara are an ever-expanding space that have arisen over a span of 2,000 years, the result of markets and power relationships, of resistance, technologies, and topographies, of the attribution of value, of crises and imaginary ideas. It is a voluminous, empty space with legible surfaces into which natural history, economy, and aesthetics have inscribed themselves into what is a natural stone, clearly not made by humans. Contrary to appearance, the marble quarries of Carrara are not a success story; the quarries lay abandoned for decades, centuries. Trade in Lunense marble and its shipment to Rome were completely halted in the year 600. It was only in 1250 that the quarries were reopened with the arrival of commissions for the Cathedral of Pisa. Over the 400 years that followed—during the Renaissance and the Baroque period—marble once again experienced a boom. But the people who made the most money from it were the merchants in Genoa, who had a monopoly over its trade. Marble export became a main source of income; customs taxes were high inside of Italy and freight costs expensive.

Classicism also celebrated white marble. In 1789, the Accademia di belle Arti di Carrara was founded, which exists as an art academy to this day. Under Napoleon’s rule, the mining once again came to a halt around 1800. When steam power and electricity were invented, human labor in the quarries was reduced. In 1861, 10,000 stone workers were employed in Carrara; women and children hacked out the tiles, and 600 quarries were opened. It was only in the 1960s that the massive supply of Carrara marble finally corresponded to a massive demand, with an overall production of 500,000 tons per year. The harsh and dangerous working conditions of the stonebreakers repeatedly led to workers' struggles and anarchist movements in the city. In 1968, the International of Anarchist Federations was founded in Carrara, where it has its headquarters to this day, visible from afar in the city center.

It was only in July 2009 that a movement to save the Apuanian Alps—"Salviamo Le Apuane"—formed on Facebook, giving a forum to the protest of various local initiatives against the "largest ecological disaster in Europe." The criticism is that the monoculture and industrialization of the marble mining in Carrara is irreversibly destroying a natural, ecological, botanical, cultural, historical, and anthropological resource. The city's water supply is in danger, because the mountains' capillary system is being destroyed. And then there is the huge waste involved: two-thirds of the marble mined today ends up as rubble in the form of marble dust, pebbles, or chippings, while one and a half tons wind up in Italian toothpaste. When one travels from Pietrasanta to Carrara today, the streets are lined in gigantic blocks of marble, sample slabs, and cranes—just as garden dwarves can be seen everywhere along the German-Polish border. In Carrara, the melancholy of weight is accompanied by the grief over the destruction of the environment.

Photography is a distancing medium. Whether a butterfly is photographed from close up or the Apuanian Alps from a helicopter, the photographer is using a camera; he is not reaching for the butterfly or the marble. If he or she uses an analogue camera of the kind Aglaia Konrad uses, he looks through the lens at a rectangular frame. The camera is an image-generating machine; the "pencil of nature" draws the light image. Photography is both a trace of the real and a simulation of nature. With the onset of photography came a massive tendency towards the rectangular frame of view as well as the mass reproduction of the same or similar images. Not to mention the image refuse that was incurred, the billions of substandard images not used or archived for private or commercial purposes. Sculptures were transformed into images: Trajan's Column, the Laocoon group, Michelangelo's Pietà are all well known from school books, encyclopedias, and travel guides, although the space they inhabit is usually screened out. It was only after the marble blocks and the photographic images that masses of people also began to move across great distances. The camera was invented at the time the industrialization of marble mining began, while photography is a time-based medium that records the world in a fraction of a second. In the Apuanian Alps, 30-million-old mineral sediments encounter two thousand years of marble mining with the speed of a camera's shutter while 60 billion assumed tons of Carrara marble find expression on a single sheet of paper.

In the mid-1960s, the American artist Robert Smithson coined the phrase "nonsite" when he left the gallery spaces of the cities to look for places where the landscape did not appear as an exterior, scenic beauty, but rather as a destroyed, pulverized, dislocated space whose appearance and perspective provided no clear order. The gaze had revealed itself as an act, as a simulacrum. Smithson worked sculpturally in these "nonsites" and photographed them, according the photographs documentary and artistic value. In 1981, in his essay Site/Nonsite[1], Lawrence Alloway wrote that Smithson equated geological change with the thinking process. Thus, landscape became analogous to human existence or at least its communication. In his writings and works, Smithson "recognized complexity and contradiction as a working condition."

1) Alloway, L. (1981) "Sites/Non-Sites" in Robert Hobbs (ed.) Robert Smithson: Sculpture, London: Cornell University Press, pp. 41–46.

How is space organized, how is the gaze organized, the photographic image? Looking at Aglaia Konrad's photographs, the eye does not become lost in a single motif, neither in the micro or in the macro view. It encounters the image, encounters itself in its exclusivity, its an-aesthetic. The gaze is not satisfied by seeing. It is called upon to create complexities out of fragments, to give meaning to profane crops, to "read" the image as structural information of the visible elements of time-space. Looking at Aglaia Konrad's photographs does not become alleviated by the images' motifs; the gaze requires a construction of meaning. Image production is image construction. Landscape is space formed or disfigured, used and exploited or removed over the course of centuries. Marble itself is a construction material; the marble quarries are deconstructed nature. In Carrara, landscape is workplace and architecture—an architecture of removal and not of building. The marble mountains of Carrara are a dusty, dispersed landscape, negative space and expanded space; they are both material body and missing part, and thus present themselves as incoherent.

Aglaia Konrad's photographs of the marble quarries of Carrara are also dramatic, even when they do not follow a narrative, shun criticism, and refrain from a subjectivity of perspective—the result, apparently, of the camera's disinterested lens. According to Aristoteles, the main characteristic of drama is the representation of an act through dialogue. The marble quarries of Carrara are a monumental space for action in which thousands of wordless dialogues are reflected and into which they continue to be inscribed. With time, this space expands as layers are continuously removed to reveal newer visibilities. The photographic act adds a presence to this complexity, while space itself becomes visible as an act and the gaze is no longer affected by the image.

JODHPUR

Geologically, Rajasthan is the largest sandstone-producing state of India where sedimentary formations are exposed. Over 90% of the deposits of Indian red sandstone are in Rajasthan. This quarry is in the vicinity of Jodhpur and the sandstone occurring in this area is popularly known as Jodhpur sandstone, which has been quarried and used for centuries in buildings, forts, palaces and monuments. Today, Jodhpur sandstone is exported to Sharjah, Dubai, Korea, Singapore and the USA in processed form.

Manual labour is very active at stone quarries in India. Monoliths are separated from rocks and they are manually split into smaller blocks by iron wedges. Splitting stone using wedges, a three-piece set known as feather and wedges, is the most cardinal technique. The stone is first examined to determine the direction of the grain and to identify any potential defects. After the location of the intended split is chosen, a line is scored on the surface on the stone. A number of holes are then cut or drilled into the stone face along the scored line, approximately 10–20 cm apart. Wedge and feather sets are then inserted and struck with a hammer in sequence. An audible tone from the wedges changes to a 'ring sound' when the wedges are tight. A pause of several minutes allows the stone to react to the pressure. Eventually a crack appears along the line that was scored on the surface and the stone splits.

In this quarry, stone-quarry pavilions are scattered around for workers to rest. They are built by taking stone pieces from infinite leftovers found just there. Each shelter is unique. The pavilions are simple but also strongly engaged with the site and the users.

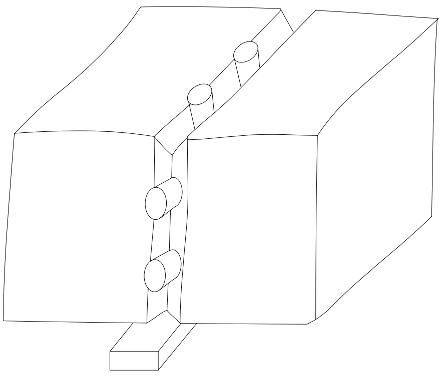
STONE-QUARRY PAVILIONS

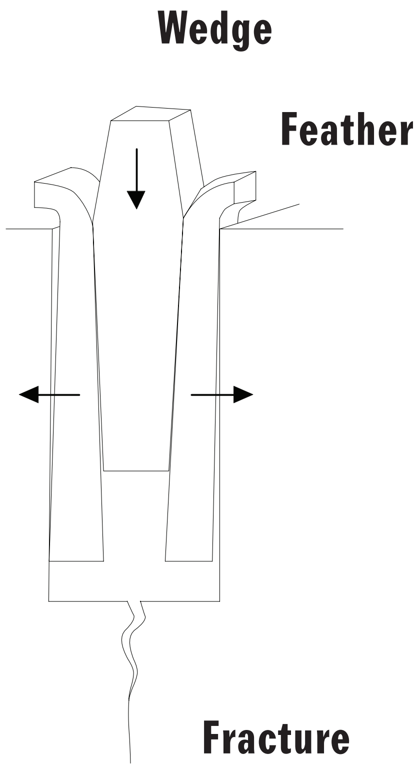
Text by Studio Mumbai

Workers relentlessly cut stone, pausing briefly for shade and water. The only places of respite for them in this vast heat-bowl are these elemental stone pavilions which crop-up from the stones lining around.

They are quickly put together by the workers as direct response to the hostile heat, dust and noise. The pavilions reflect an intuitive understanding of siting, orientation, material, purpose and frugality. Each pavilion is tuned to its user and the immediate situation through subtle mutations that give each one its distinction.

Photos by Mitul Desai for Studio Mumbai




Wedge
Feather
Fracture

VALS

A small-scale quarry of gneiss stone, Truffer AG, in a Swiss village, Vals, at 1,250 metres above sea level. The quarrying site is very steep and is located right next to a waterfall.

The gneiss stone, metamorphic rock, has developed over millions of years in the course of the Alpine folding under high pressure and temperature deep below the earth's surface. It has reached the surface of the earth through geological processes such as tectonic plate displacements and erosions. The Vals natural stone is traditionally used locally as a long-lasting roof covering, and nowadays, it is prescribed by the municipality.

Two extraction methods, diamond wire cutting and blasting in drilling holes, are used in combination at this quarry. In principle, diamond wire is used in the direction perpendicular to the rock layers and the cut surface is smooth. Blasting leaves lines of drill holes on the cut surface. Preparation of building stone is done next to the extraction site. Extracted stone blocks are processed into slabs and roof slate. The quarry has various types of machine and craftsmen for the almost limitless possibilities that clients require.

The stone can be split easily by hand into sheets. It splits along the cleavage planes which have been formed during the metamorphism. Splitting is done by skilled experts. Every stone is different and wants to be treated individually. For the stone splitter, the first step is to look for the best separation layer. Then, he hits the stone briefly with a chisel and hammer. If a crack has developed, he continues with a thin steel blade. Like a tuning

fork, he strikes the blades that have been driven into the stone and must recognize the elasticity of the stone from their sound. What emerges is the impression of a sweaty concert – depending on the acoustic feedback, he drives the blades in deeper and deeper until the stone finally splits.

Vals stone is prepared not only by splitting, but also by milling from large stone blocks. The big difference between milling and splitting is availability for thinner plates.

A wire saw can slice big pieces of a stone block while a blade saw has limited depth and can cut only to the maximum radius of the blade. A multi-blade saw plays a part in efficiency.

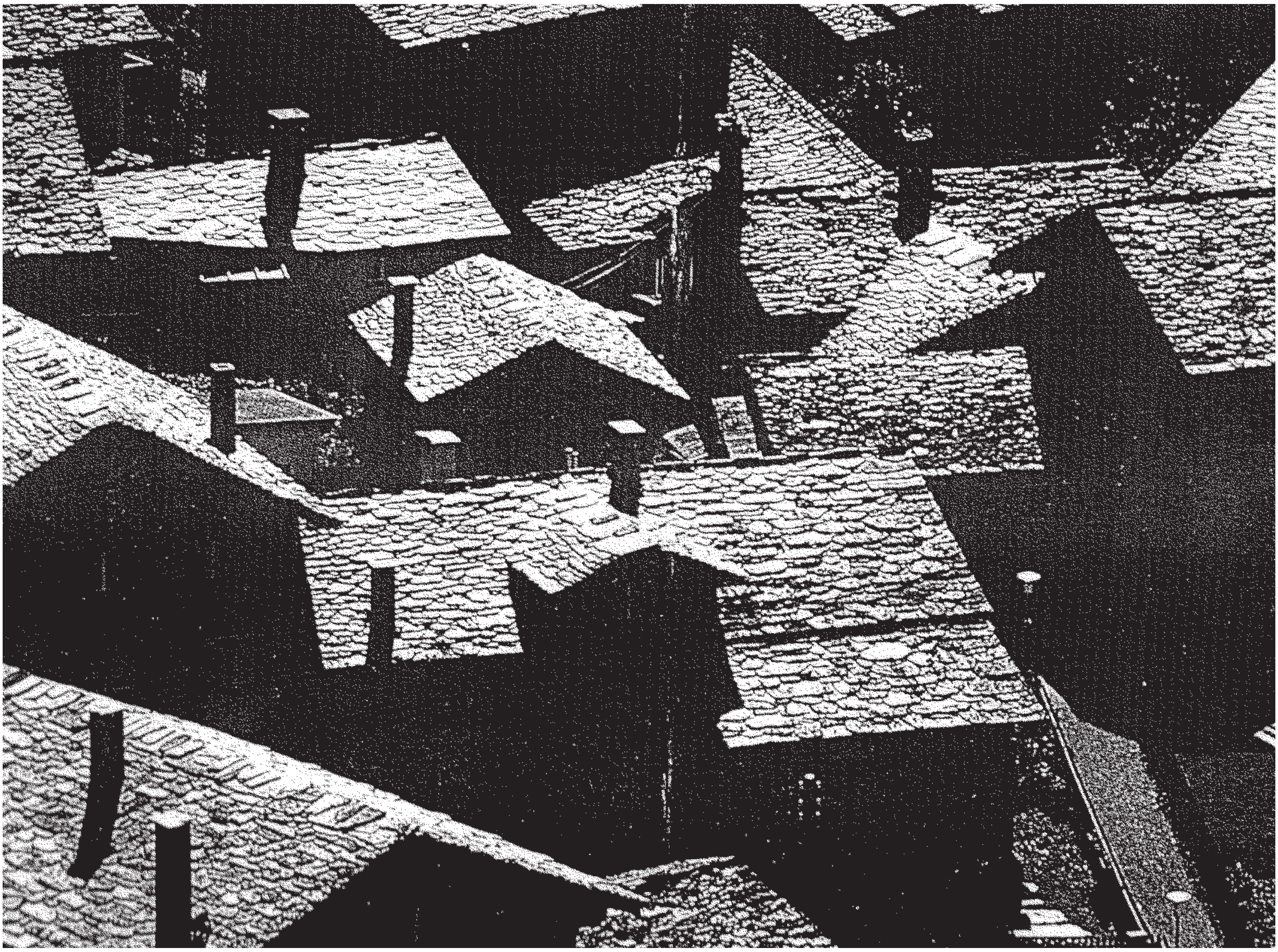
A variety of surface finishes, like polishing, sand blasting and texture elaborations are done by a combination of machines and hand work.

ESSAY BY SIGRID HAUSER

The special advantage of the Vals stone roof is that it is fire- and weatherproof. In the 1950s Albin Truffer founded his own quarry company in Vals, providing a one-hundred-year guarantee for his roofs. They are still considered indestructible, impervious to frost, and absolutely watertight. Originally, anyone could quarry rock by hand from any extraction site if it was for his or her own house. Division of labor gave rise to individual professions like the slab maker and the stone roofer. All buildings except for the church, all houses, stables, alpine cabins, are roofed with gneiss or mica slate slabs, wrote Johann Josef Jörger in 1913, and added: These stone roofs have been built relatively flat and constructed so solidly that you can run upon them like on a paved road. The split product used for this traditional building method is called broken or natural-broken. The next generation of the Truffer AG purchased the company’s first milling machine, says Pius Truffer, the milling of Vals rock into slabs was once considered as inconceivable as what was later

constructed with these slabs. Diamond-tipped circular saws are used to cut into the layers, producing different lineations and marbling patterns. Slabs of different thicknesses are stacked in front of the production hall to a wait further processing, specially selected slabs are prominently displayed again the walls of Dinking Stone of the Therme Vals. The petrological classification of this Vals rock is gneiss, which is a metamorphite, that is, rock produced through changes in temperature and pressure, it can also be referred to as orthogneiss, or depending on its particular structure AUGEN GENEISS/AUGEN GNEIS. Its principal constituents are feldspar, quarts, and mica. The geologist Peter Eckardt estimates the age of the original rock to be roughly 300 million years, the formation of the Alps, which began approximately 50 million years ago, altered it or metamorphosed it: the thrust to the north and the stacking of rock units produced temperatures of up to 500°C and pressures of up to 15 kilobar. The augen - lenticles of individual minerals surrounded by the rock matrix - were deformed, stretched, and flattened, thus it is presumably possible to recognize movement patterns from the Stone Age in them.

Vals gneiss, also called Vals quartzite, is an exceptional, very versatile building material due to its outstanding flexural and tensile strength and its resistance to frost and mechanical abrasion. The masonry stones are categorised according to their method of processing - milled, brocken, cleft - the surface finishes of the slabs include roughly ground, bush-hammered, sandblasted, finely ground, polished. Today this stone is exported throughout the world, the construction of the Therme Vals made it famous: 60,000 individual stone slabs were utilized. But it has also had to endure being transformed into items of a very different sort: tables, bowls, dinner plates, Röteli drinking cups, egg cups, bottle coolers, storage vessels, wash basins, oil-burning lamps, candle holders, vases, quick-change picture frames, palisade fences, birdbaths...



ESSAY BY PETER ZUMTHOR

Recollections. We observed the place, its surroundings. We were interested in the stone roofs, their structure reminiscent of reflexes on water. We walked around the village and, suddenly, everywhere there were boulders, big and small walls, loosely stacked rough plates, split material; we saw quarries of different sizes, slopes cut away, and rock formations. Thinking of our baths, of the hot springs pushing out of the earth behind our building site, we found the gneiss in Vals more and more interesting; we started looking at it in greater detail - split, hewn, cut, polished: we discovered the white ‘eyes’ in what is called augen gneiss, the mica, the mineral structures, the layers, the infinitely iridescent tones of grey.

As we became more involved in our material, in the physical presence of the baths, we gradually learned to put more and more faith in our stone. We were not always convinced that only stone from the valley should be used.

There was a phase, about halfway through the project, when we considered summoning a sister from abroad - as we phrased it - to join our native stone and add a second voice: the solid mass of the building out of gneiss from Vals paired with a thin membrane on the floors of pieta dorata, stone from Italy. But we soon summoned renewed courage to rely exclusively on “our stone” and the atmospheric qualities it had already demonstrated.For early on, we had constructed a stone model out of local gneiss and filled it with water for a town meeting in Vals: in architecture, stone and water can enter into a natural, and even charmed relationship. Stone loves water. And water loves stone, perhaps even more than any other material. The pictured models bear witness: stone forms a room; the room of stone contains water; light filters through in chosen places and the stone lights up; the water begins to shine, sometimes like mirror, sometimes like a solid mass - and there it is, this ambience, this special atmosphere. One must simply have an eye for it. It is a gift.

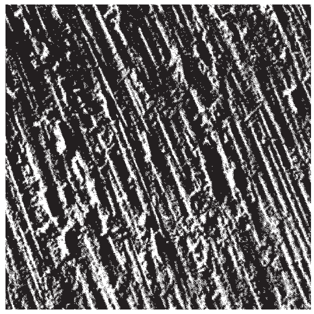
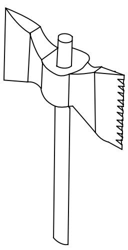
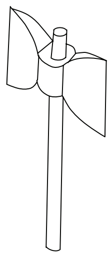
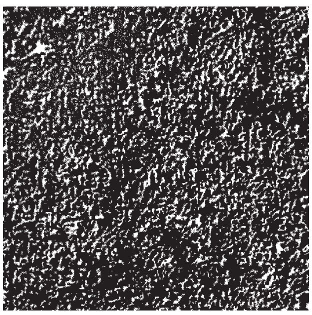
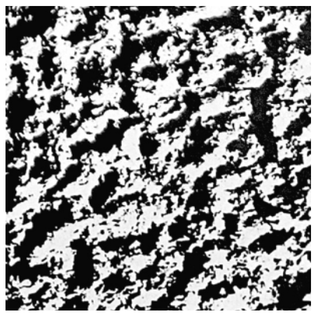
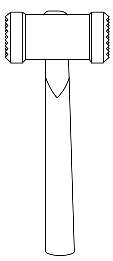
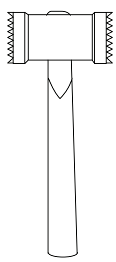
And for the stone to caress the human body, it has to be heated, made to feel as if it had been warmed by the sun. The stone must be allowed to make its own impact; not too many architectural shapes and sculptural visions should be imposed on it; the mass, large and serene, should be left alone so that the presence of the stone is felt, so that it can exert its own effect on our bodies.

The more we trusted the stone and allowed it to play the leading role, the more it began to reveal its subtleties, its grain, its structures, its beauty.

Lines by drilling holes for blasting, smooth surface by diamond wire cut





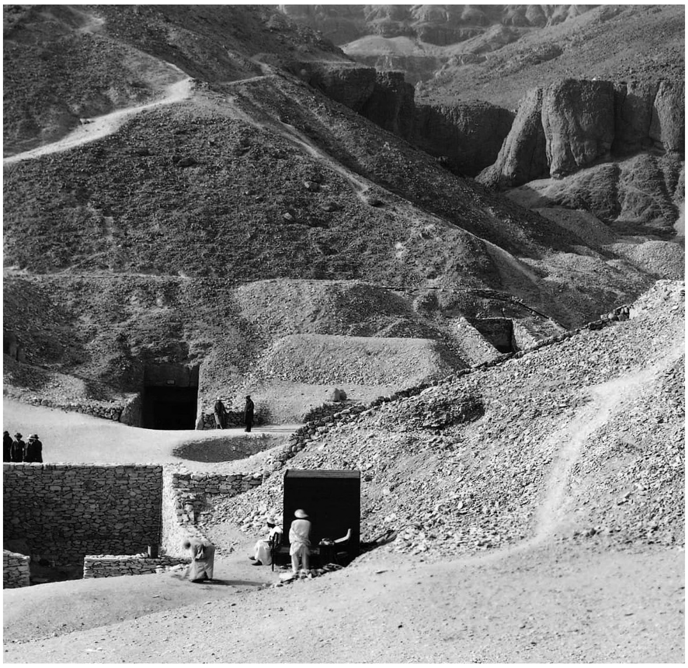








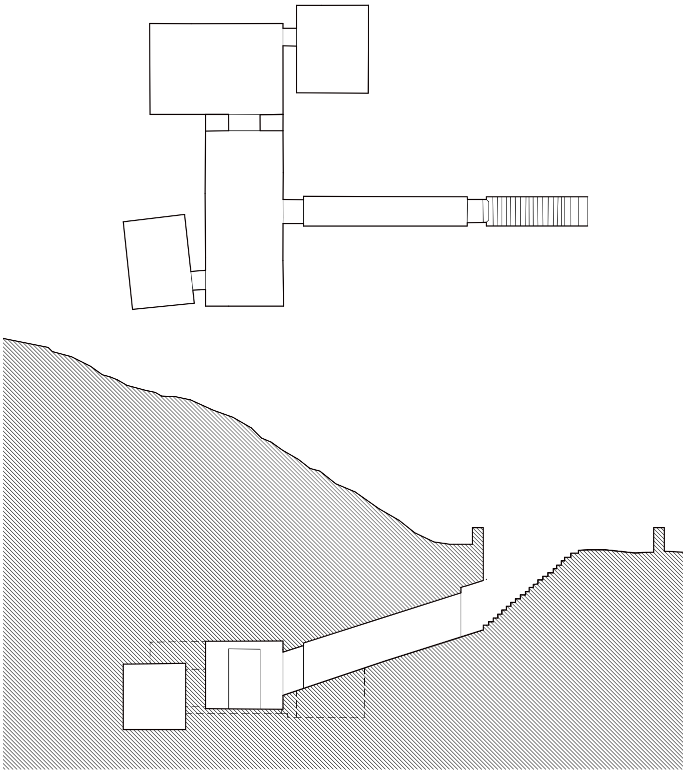
BUILDING

ROCK-CUT

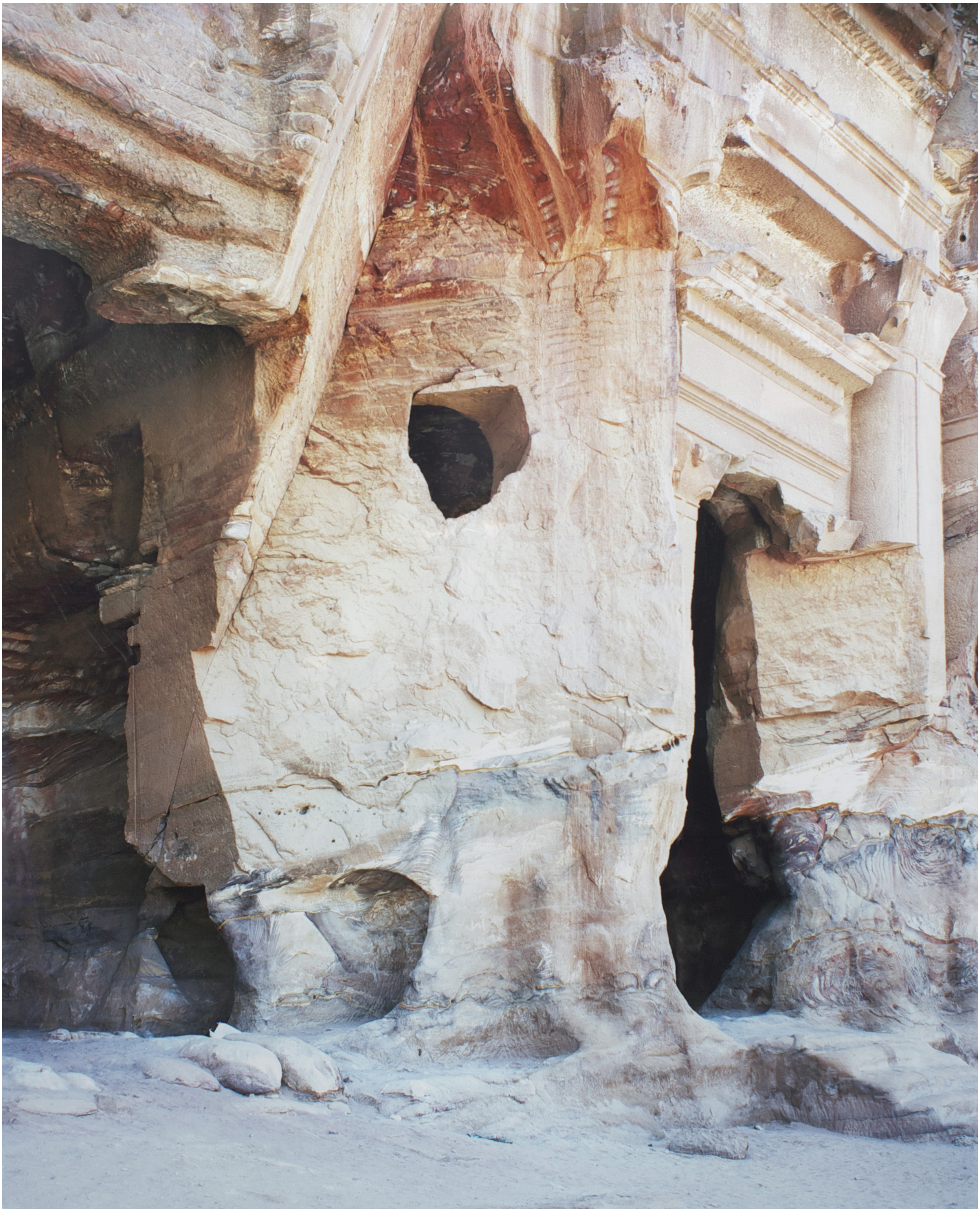
Humans found ways to create spaces for habitation and worship from large rock formations by the act of curving. This method, called rock-cut, takes the opposite process from the usual building process today.

The rock-cut process is the removal of all unnecessary materials, instead of adding and assembling materials. Eventually, only the necessary elements remain and create seamless space.

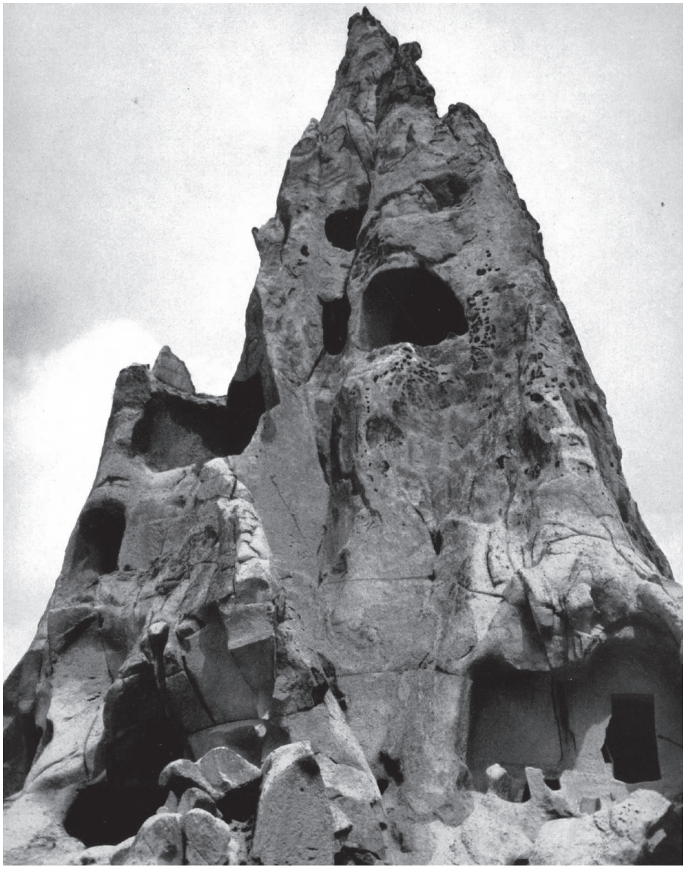
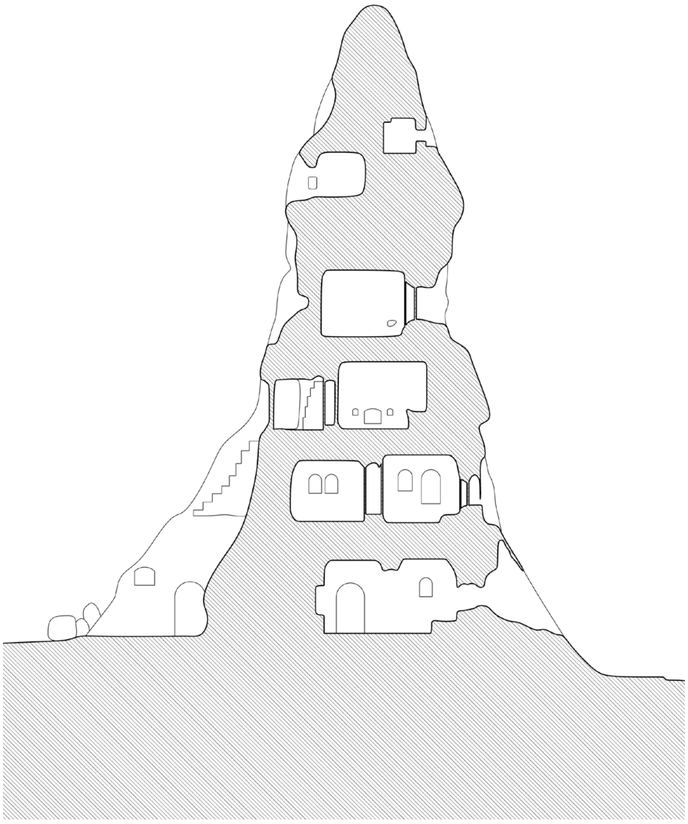
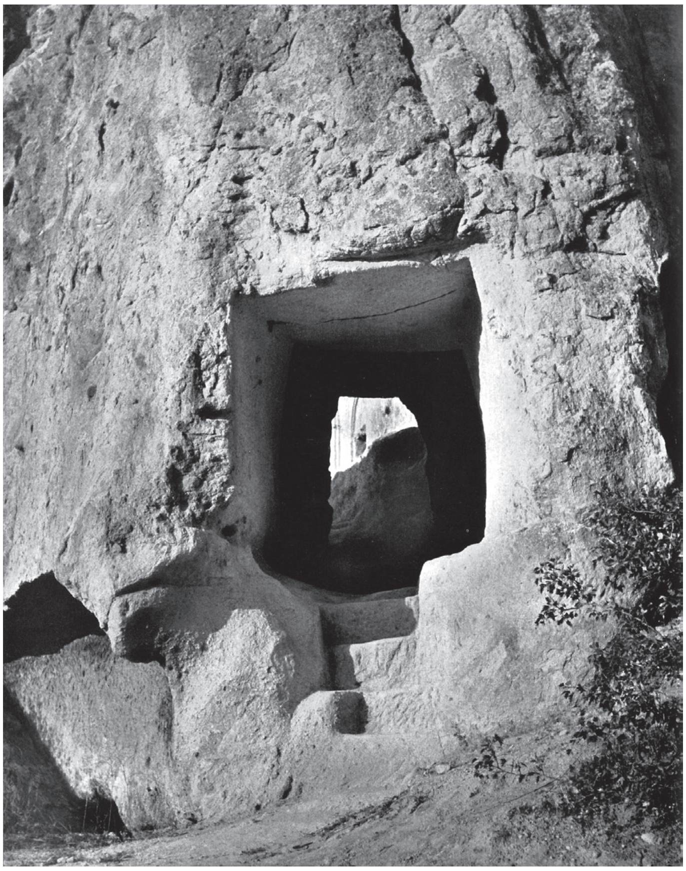




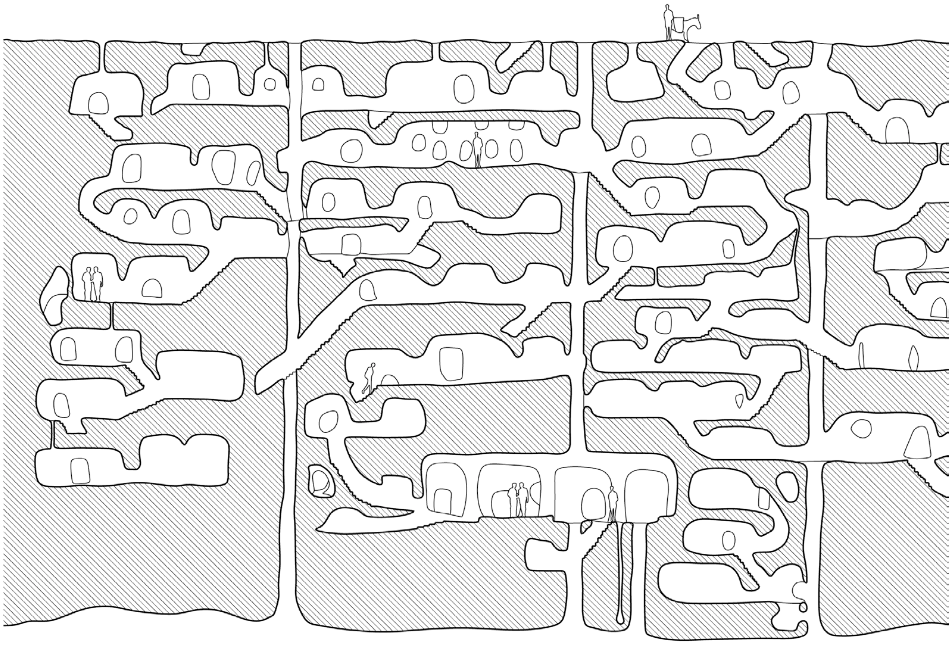
TUTANKHAMUN’S TOMB, **Valley of the Kings, Luxor, Egypt, 16th–11th centuries BC**



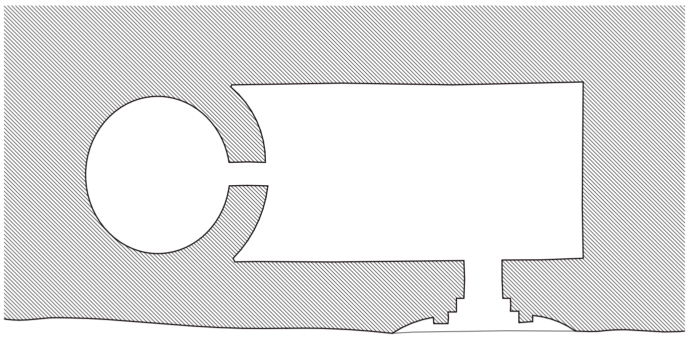
PETRA, Southern Jordan, 400 BC

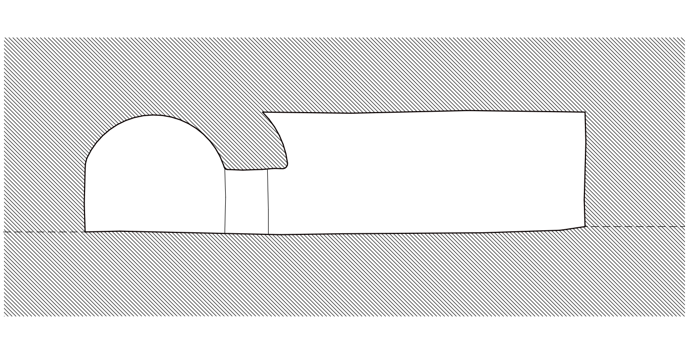




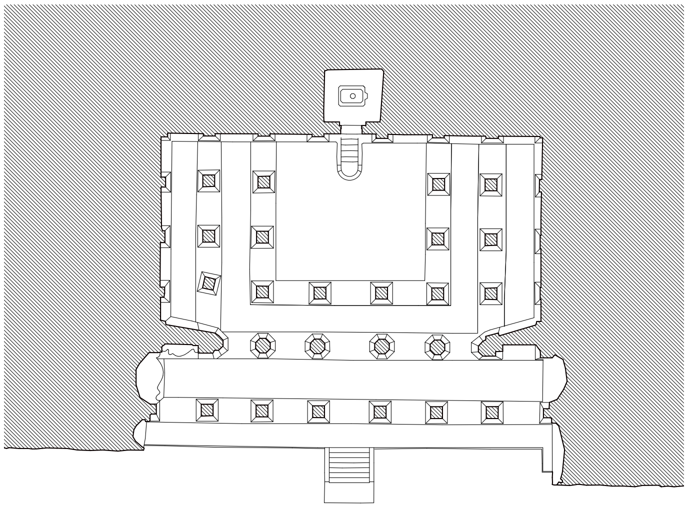

CAPPADOCIA TUFF DWELLINGS, Turkey, 8th century BC–1180



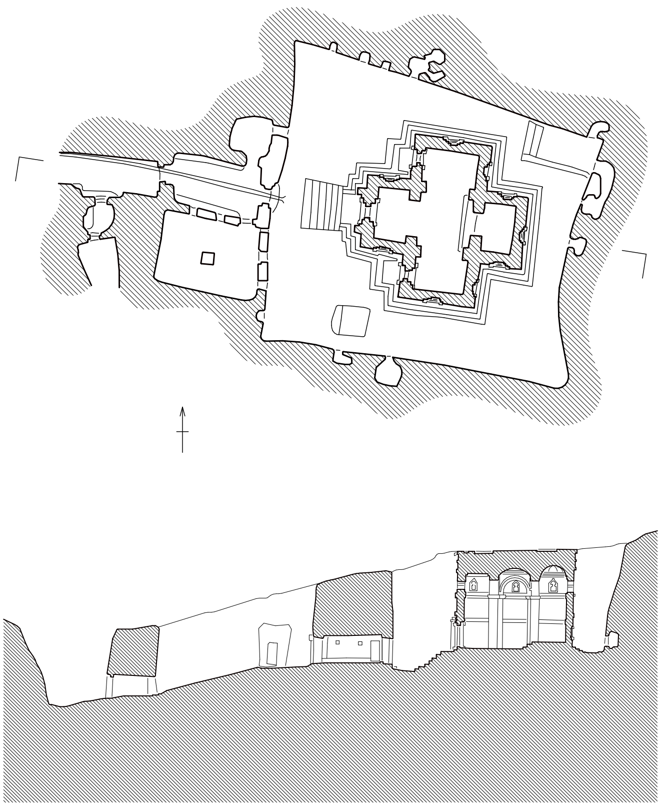
BARBAR CAVES, Makhdumpur, Janabad, India, 322–185 BCE



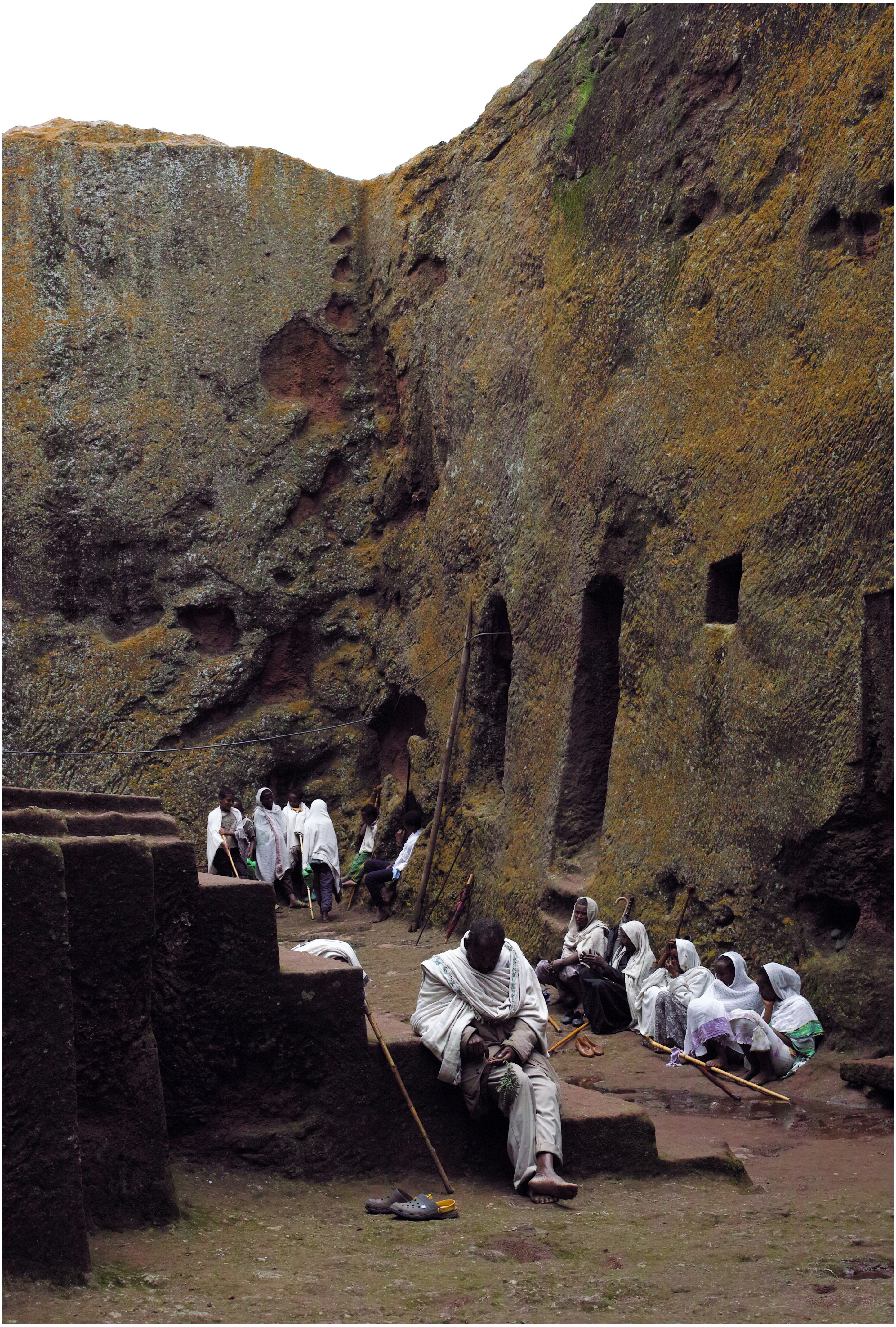




BADAMI CAVE, Bagalkot district of Karnataka, India, 543 AD



BIET GIYORGIS (Church of St. George), Lalibela, Ethiopia, 12th century AD



CA’N TERRA, Ensamble Studio, Menorca 2018

TUTANKHAMUN'S TOMB
Valley of the Kings, Luxor, Egypt, 16th–11th centuries BC

The Valley of the Kings is situated over 150 metres of limestone and other sedimentary rock on the west bank of the Nile. Tutankhamun's tomb is one of 63 rock-cut tombs discovered in the valley. The cluster of tombs is adapted to the contours of the land. Inside Tutankhamun's tomb, from the entrance, 16 stairs and a corridor lead about 10 metres deep and four chambers appear. Three rooms are filled with 700 objects and furniture, and the walls are plastered. One room is the burial chamber, the only chamber decorated with wall paintings.

PETRA
Southern Jordan, 400 BC

Petra is an ancient city, half-built, half-carved into the rock, and is surrounded by mountains riddled with passages and gorges from the Dead Sea to the Gulf of Arab. Nabataeans – the ancient Arab people who inhabited northern Arabia and Southern Levant – built Petra, allowing the land's unique red sandstone formations to shape their construction techniques. The rock-cut façades are mainly conceived as an independent screen set in the front of the building, rather than as an organic or logical element of the structure as a whole. The façade's carving procedure was a method most of the time done from top to bottom. As a first step, a flat, narrow, smooth working surface of the façade was created in front of the desired tomb façade after quarrying away the stone of the cliff's natural slope, followed by the carving of the details. The worker's mobility was facilitated by a series of slots, functioning as footholds and as the foundation for a lightweight changeable socket in the diagonal cantilever scaffolding system.
Photo by Bas Princen

CAPPADOCIA TUFF DWELLINGS
Turkey, 8th century BC – 1180

Rock-cut architecture in central Turkey includes living and workspaces, as well as sacred buildings that were carved out of the soft tuff landscape. The first excavated tuff dwellings in Cappadocia may have been established by the 8th century BC. Cappadocia is a special geological zone in Anatolia. Volcanos covered the region with a layer of tuff stone over the course of a twenty-million-year period, ending in prehistoric times, after which erosion created the rock formations of the region. Tuff is a soft stone, easy to work, that was traditionally worked using short pickaxes, sledgehammers and chisels. Once the dry, hardened outer centimetres of volcanic rock are broken through, the tuff beneath becomes softer and easier to work. Rock-cut architecture progressed to living complexes, monasteries and underground cities. The underground cities were designed for protection against attacks. The cities descended up to twelve stories over 10 metres deep.

BARBAR CAVES
Makhdumpur, Janabad, India, 322–185 BCE

The Barbar Caves are the oldest surviving rock-cut caves in India. The technique of cutting into rock to create artificial cave-temples influenced Indian architectural practice for over a thousand years. Most caves at Barbar consist of two chambers, a large vaulted room and a semi-hemispherical sanctum. Caves are carved entirely out of granite with a highly polished internal surface. The polished surface is probably for a mirror and the echo sound effect in the temple. Tools that were probably used were a chisel and an iron mallet. To create the first chamber, the workmen commenced by carving a tunnel as tall as a man into the rock beneath the place where the ceiling would be. This was then widened and deepened by cutting steps. On each level the stonemason who did the rough work was followed by another artisan who cleaned and polished the walls.

BADAMI CAVE
Bagalkot district of Karnataka, India 543 AD

The Badami cave is a cluster of four Hindu and Jain cave temples excavated into the monolithic soft and red sandstone. It locates above of a man-made lake. The space is constituted by the extraction of rock-mass. The space is formed by the remaining architectural elements from the process of extraction left for the structural and spatial quality necessary. The result is a solid mono material building from exterior to interior.

BIET GIYORGIS
(Church of St. George)
Lalibela, Ethiopia, 12th century AD

The town of Lalivela, a place of great pilgrimage, is situated at an altitude of 2,630m. Biet Giyorgis is part of a complex of eleven rock-hewn Coptic Christian churches entirely carved out of hard volcanic tuff. The entrance is located in the lower part of the courtyard, where water is collected and channelled into a drainage conduit that passes below

the threshold. The church is a Greek cross in plan and has twelve sides with windows and a door. The interior has no pillars, but four cross-shaped pilasters connected to the corners of rock walls. They support the four arches that separate the central part from the side arms. The church is unique for its pure harmonious proportions within the surrounding environment.
Photo by Anne Holtrop

CA'N TERRA
Ensamble Studio, Menorca, 2018

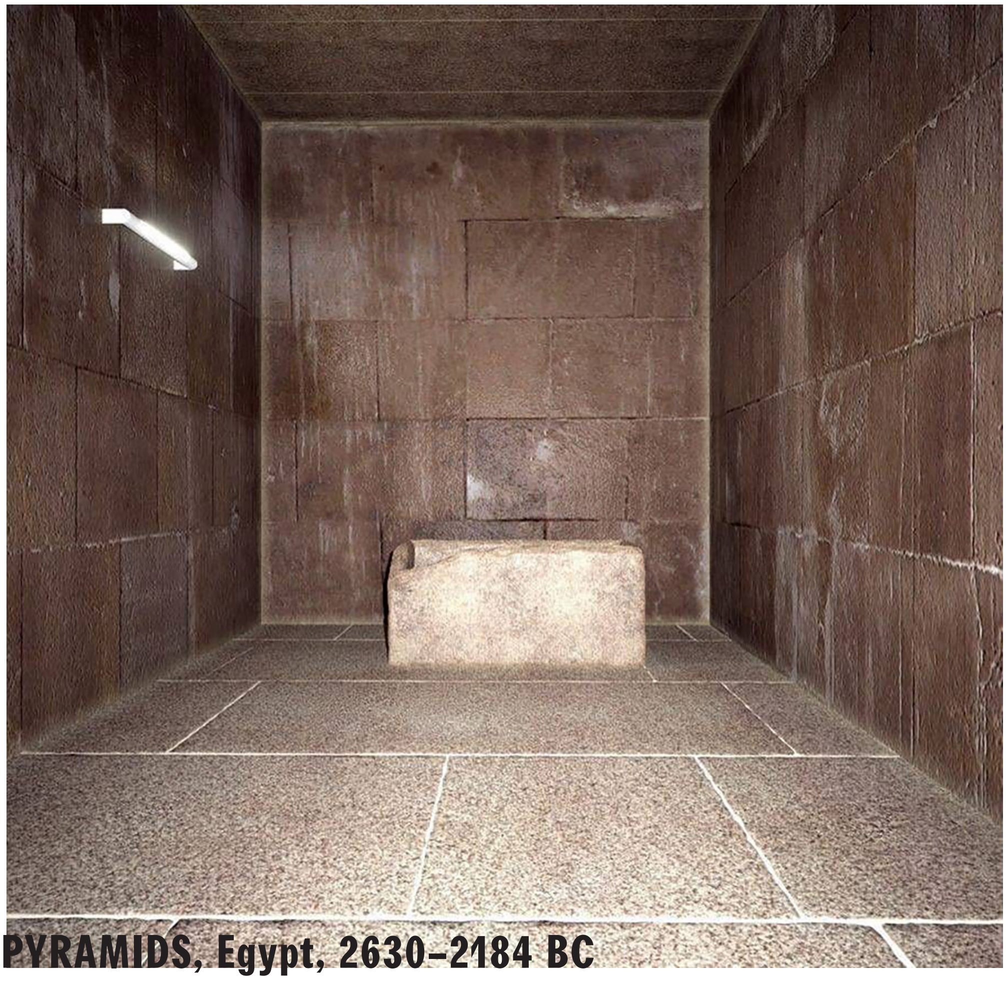
Ca'n Terra is the house of the earth. The fruit that nature gives us, as a found space; which requires tillage and cultivation to imbue the received offering with domesticity. If the history of civilization has greatly evolved transforming ideas into built work, in Ca'n Terra, the process is inverted and history interpreted to transform it into architecture.
The transfer from drawing to built mass gives way to the translation of given matter to digital data through the architectural reading of a geological discovery. The discovered space has industrial logic as former Mares stone quarry, artistic potential as sublime cavern carved by hand, and mineral nature as extract of the stony landscape on the island of Menorca. Finding this excavated space in the guts of the earth and reinventing its use implies writing a new story that can rescue it from its abandonment. As first contact we enter the space like explorers would do, equipped with the technology that expands our vision in the dark; throwing millions of laser points on the wrinkles of the continuous stone surface we register with millimetric precision the solid structure that was built for us and is now ready to be polished and inhabited. Behind the scan, the architect's eye, directing, interpreting, creating the space again. That's why the discovery is considered a new work, destined this time to become a room to contemplate nature. In lieu of an imposing action that many times architecture exerts on the environment, we propose a trip to the interior being of matter, and recognize the freedom with which it gives us spaces to live.
Text by Ensamble Studio

DRY STONE CONSTRUCTION

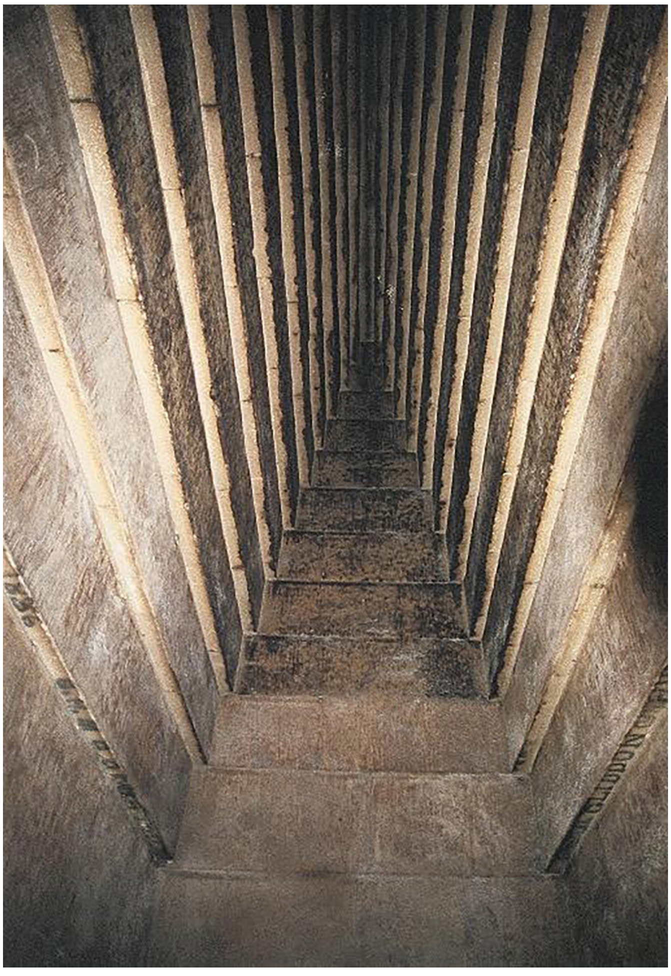
Dry stone is a type of construction used in building walls and other structures by carefully layering stone. It was traditionally done in geographic areas with lots of stone as a natural resource.

The construction method is done without mortar. Instead, the position and weight of the stones themselves keep the structure in place. It requires highly-skilled craftsmanship, heavy labour and time, however, the results last for a very long time.

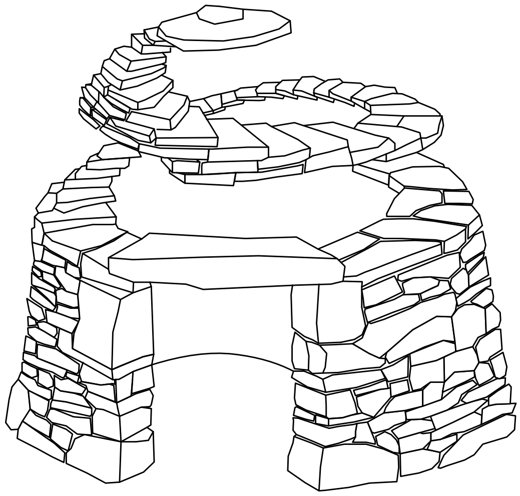
Nowadays, dry stone construction has been reconsidered positively from the environmental aspect. It plays a role in preventing landslide and floods, and enhancing biodiversity for agriculture.

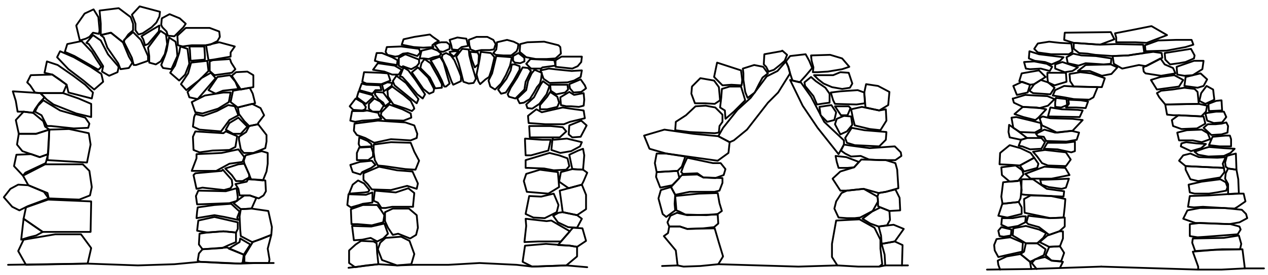


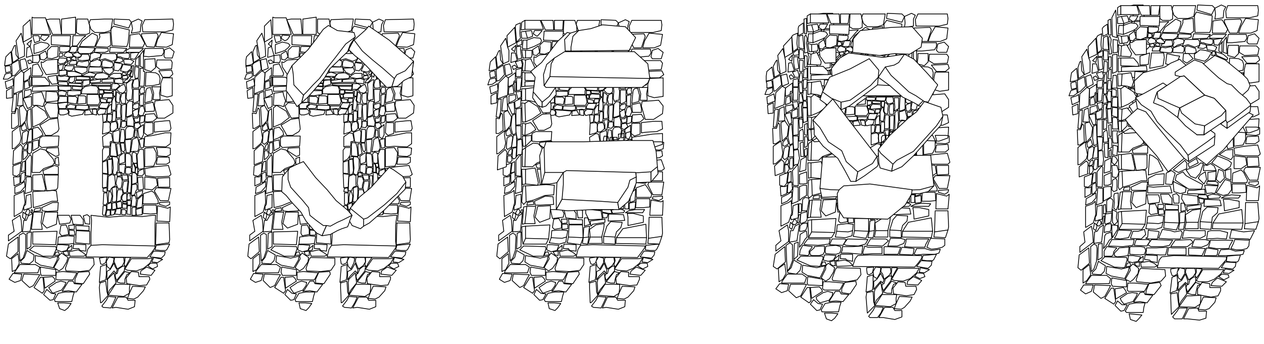
EGYPTIAN PYRAMIDS, Egypt, 2630–2184 BC



ANGKOR WAT, Cambodia, 1113–1150 AD





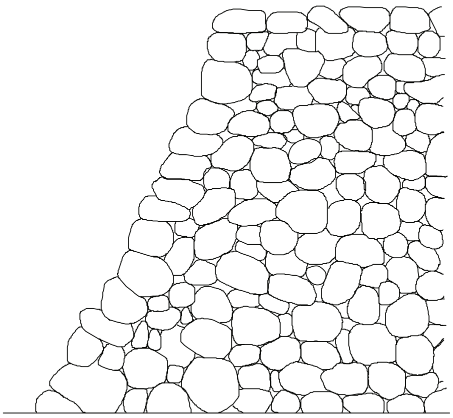


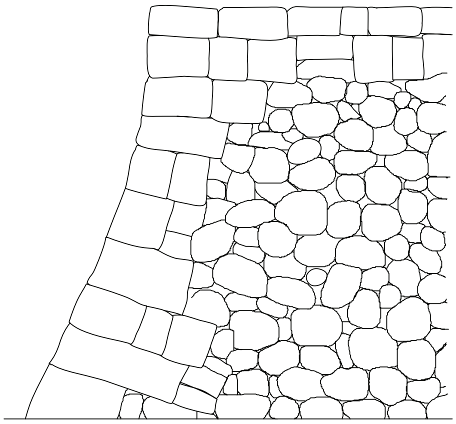
THE BORIES VILLAGE, Gordes, France, 7th–15th centuries

INCA WALLS, Peru, 15th century

FETEHPUR SIKRI, Mughal Emperor Akbar, India, 1571–1585

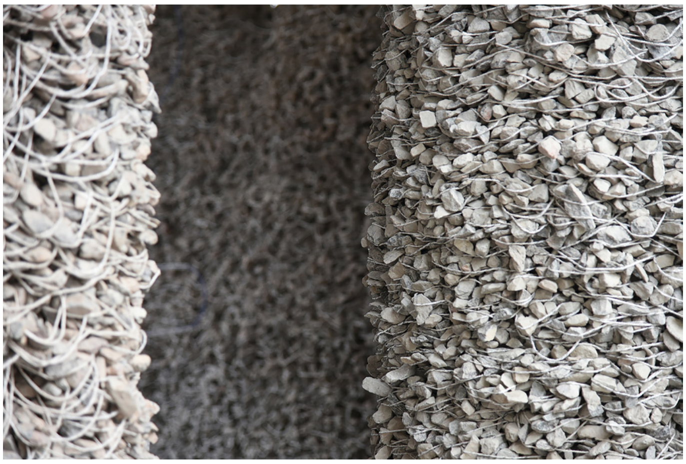
FORTIFICATION OF JAPANESE CASTLE, 15th–19th centuries





Field & dimension stones

VATICAN CHAPEL, Eduardo Souto de Moura, Venice Biennale, 2018



ROCK PRINT PAVILLION, Gramazio Kohler Research,
ETH Chair of Architecture and Digital Fabrication, 2018

EGYPTIAN PYRAMIDS
Egypt 2630–2184 BC

Archaeologists have currently identified a total of 118 pyramid tombs in Egypt. The shape of a pyramid is also thought to be representative of the descending rays of the sun, and most pyramids were faced with polished, highly reflective white limestone, in order to give them a brilliant appearance when viewed from a distance. Egyptian pyramid construction techniques have always been a controversial subject. These techniques seem to have developed over time; later pyramids were not constructed in the same way as earlier ones. Most of the construction hypotheses are based on the belief that huge stones were carved from quarries with copper chisels, and these blocks were then dragged and lifted into position.

ANGKOR WAT
Cambodia, 1113–1150 AD

The complex of Angkor Wat was built to honour the Hindu god Vishnu in the 12th century, but 14th century it was converted into Buddhist temple. The main material of the building is sandstone. These sandstone blocks were quarried at the Kulen Hills, about 30 km to the north. A series of canals were used to transport the blocks to Angkor Wat. They also used elephants, coir ropes, pulleys and bamboo to carry the blocks. The stones are as smooth as polished marble and they were laid without mortar with very tight joints that are sometimes hard to find. Even the tower 60m high was also built with our mortar and reliefs were carved after it built up.

THE BORIES VILLAGE
Gordes, France, 7th–15th centuries

An ancient village of drystone huts in Gordes, France. The villagers built the houses with simple tools and material using the dry stone technique. They gathered the field stone that was already on the ground, and from the selected and cut stones, they built the structure, without using mortar. The large, flat, thick stones were placed one above the other and once the wall achieved a certain height, large slabs were put on top of them to form a roof. The huts have a doorway and a small window. Some bories have a chimney, more than one room, and also bories with an upper floor are noticed. The floor is made by putting stone slabs on oak beams. The inhabitants of the Bories Village were modest farmers who lived from agriculture. It is difficult to say which period they belonged to, but it is most likely that the village was inhabited and rebuilt several times between the 15th century and the 19th century. This type of vernacular dry stone buildings are found in Spain, Italy, Switzerland, Greece, Croatia and others, not only France. Each place has slightly different masonry techniques.

INCA WALLS
Peru, 15th century

The Inca Empire built its cities with locally available stones, usually limestone or granite. Their dry stone architecture is known for its fine masonry which features precisely cut and shaped stones closely fitted without mortar. And usually the Inca walls are wider at the bottom than at the top. These two construction methods led Incan buildings to have a peerless seismic resistance. During an earthquake with a small or moderate magnitude, masonry was stable, and during a strong earthquake, stone blocks were “dancing” near their normal positions and lay down exactly in the right order after an earthquake. Stonemasons worked with stone hammers, crowbars and chisels of bronze.

FETEHPUR SIKRI
Mughal Emperor Akbar, India, 1571–1585

The Fatehpur Sikri complex was built as the capital of the Moghul Empire. The building material used is the locally quarried red sandstone, known as “Sikri Sandstone”. The complex presents a combination of the trabeate (of pillar and beam) and arcuate (using arches and domes) construction and has colonnaded and flat-roofed structures. The different parts of the building were separately constructed and then put together. The stones of the building are so cunningly fitted that the joints are scarcely visible. No lime was used to fix them together. Iron clams and iron string were fixed to join stones together. The colour of the stone, which is all red, also produced the same effect of uniform solidity. Photos by Mitul Desai.

FORTIFICATION OF JAPANESE CASTLE
15th–19th centuries

A Japanese castle typically stands on a fortification called Ishigaki, made out of compacted earth and stones. Building an Ishigaki is an enormous undertaking involving sophisticated engineering, endless labour and a dry stone construction method. There are diverse styles of Ishigaki, from modest to superior appearance. One is ornamented using different colours of stones, collected from across Japan, which manifests the authority of the empire, while another is mixed leftover sculpted stone from local field stones.

VATICAN CHAPEL
Eduardo Souto de Moura,
Venice Biennale, 2018

A chapel built of limestone from Vicenza, named Vicenza stone. Walls are assembled using an interlocking joint mechanism that is reminiscent of the Incan dry stone wall. The joins are stabilised by the weight of the slabs. The outer surface is rough, almost damaged with visible marks of the sawing blade. Interior walls are honed leaving a more delicate impression.

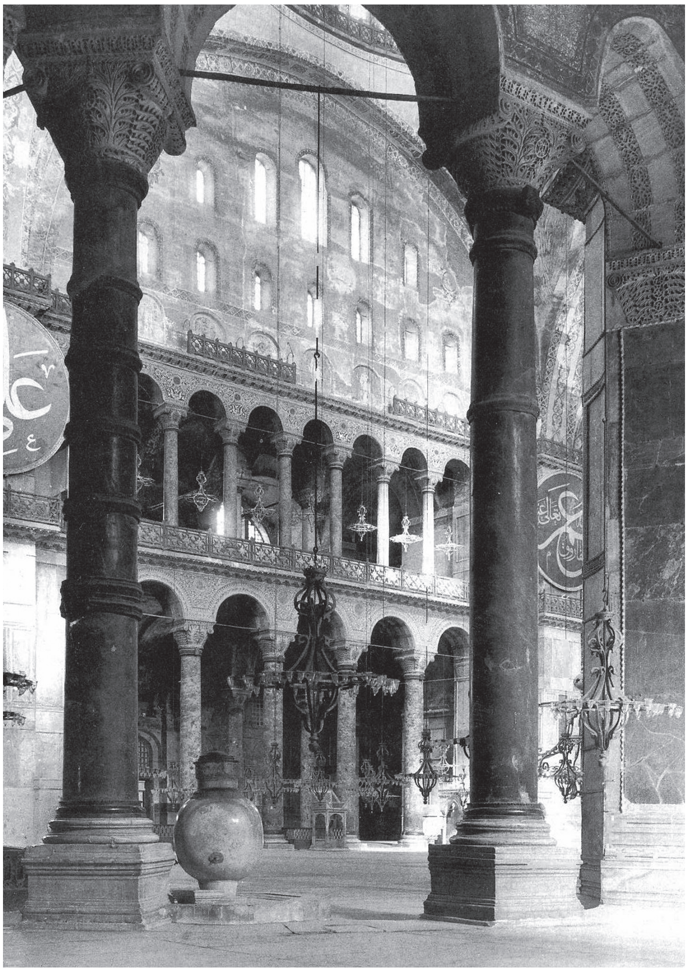
ROCK PRINT PAVILION
Gramazio Kohler Research,
ETH Chair of Architecture and Digital Fabrication, 2018

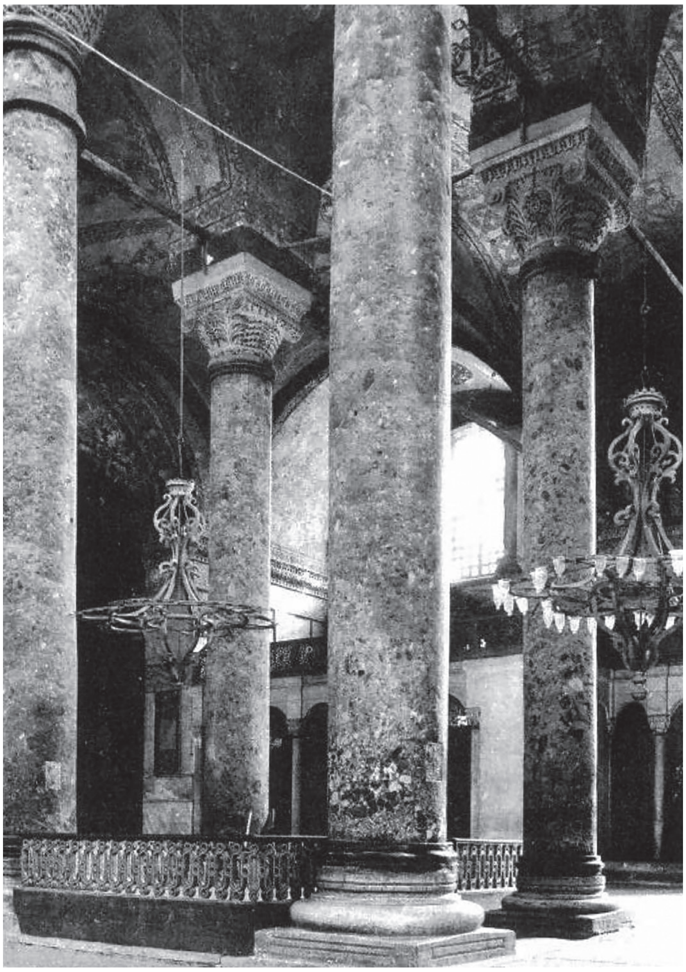
A construction robot built a pavilion using thirty tonnes of loose stones and 120 kilometres of string. The Gramazio Kohler Research team at ETH Zurich showed their work as part of an exhibition at the Gewerbemuseum in Winterthur. Over four weeks, the construction robot "In situ Fabricator" worked to construct a total of 11 three-metre-high pillars. The string and the rocks of The Rock Print are stable enough to support an eight-tonne steel roof. The loose stones interlock together; when combined with the arrangement of string between the gravel layers – which is continuously calculated by the robot – they create a stable, highly durable structure.
The Rock Print Pavilion is exploring the possibilities offered by digital and robotic manufacturing. Recycling is also embedded into the project: the components can be easily dismantled and the material reused.

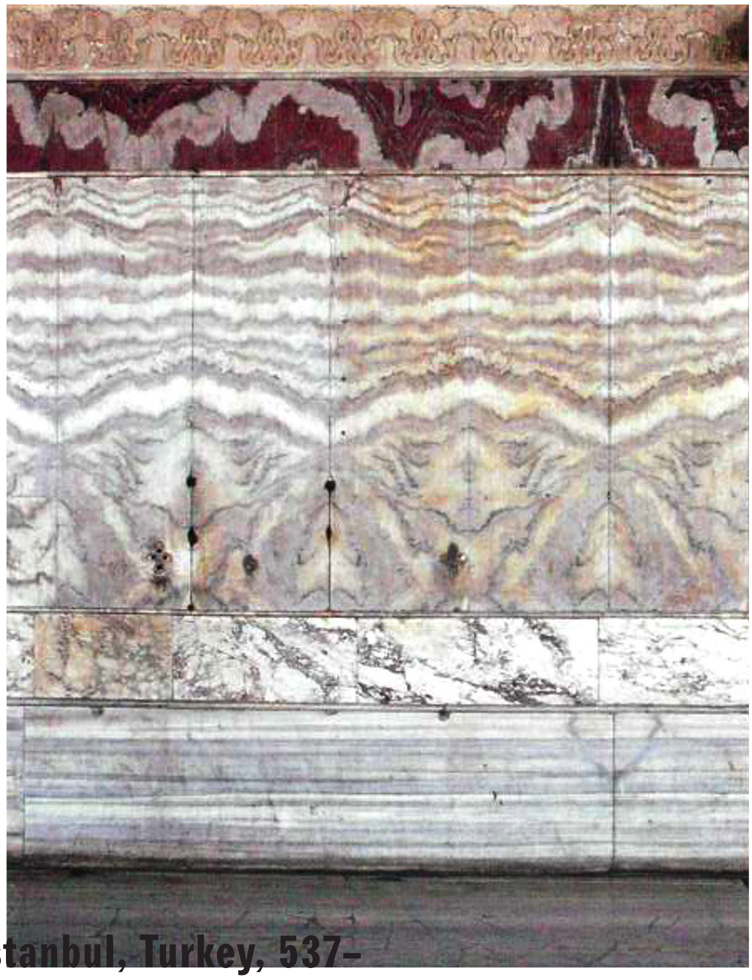
DRESSING

Stone is also used for nonbearing purposes, such as an aesthetic purpose.

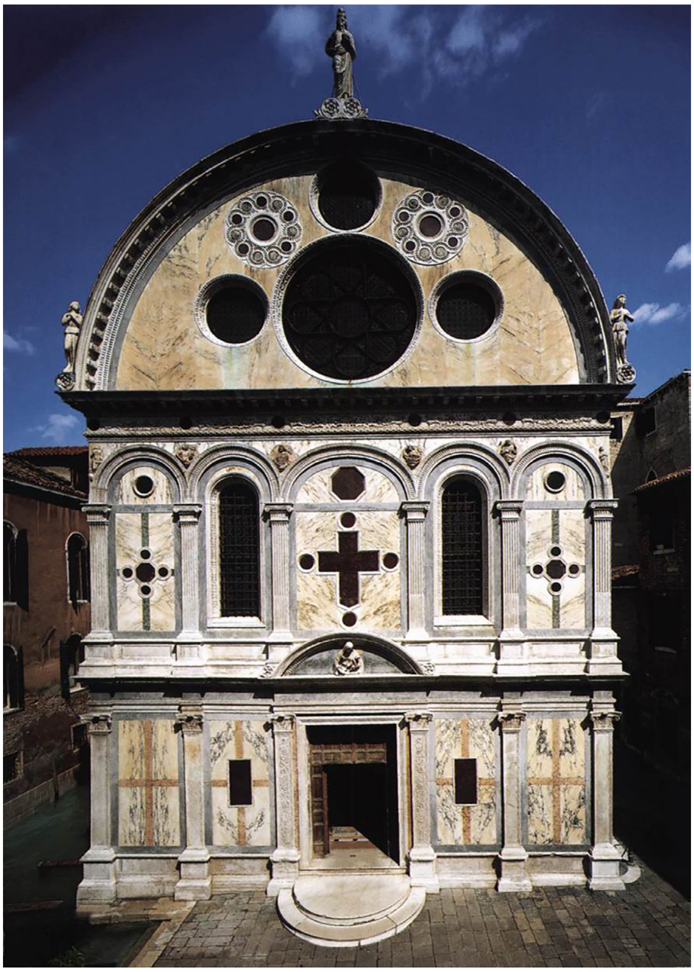
The geological condition influences the appearance and properties of stones. The unique characteristic of stone is found attractive to elaborate particular spatial conditions and façades.

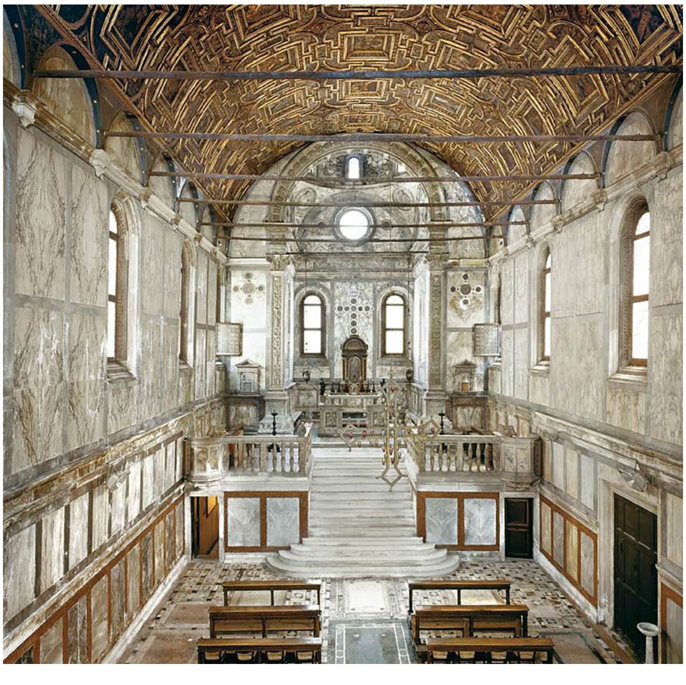




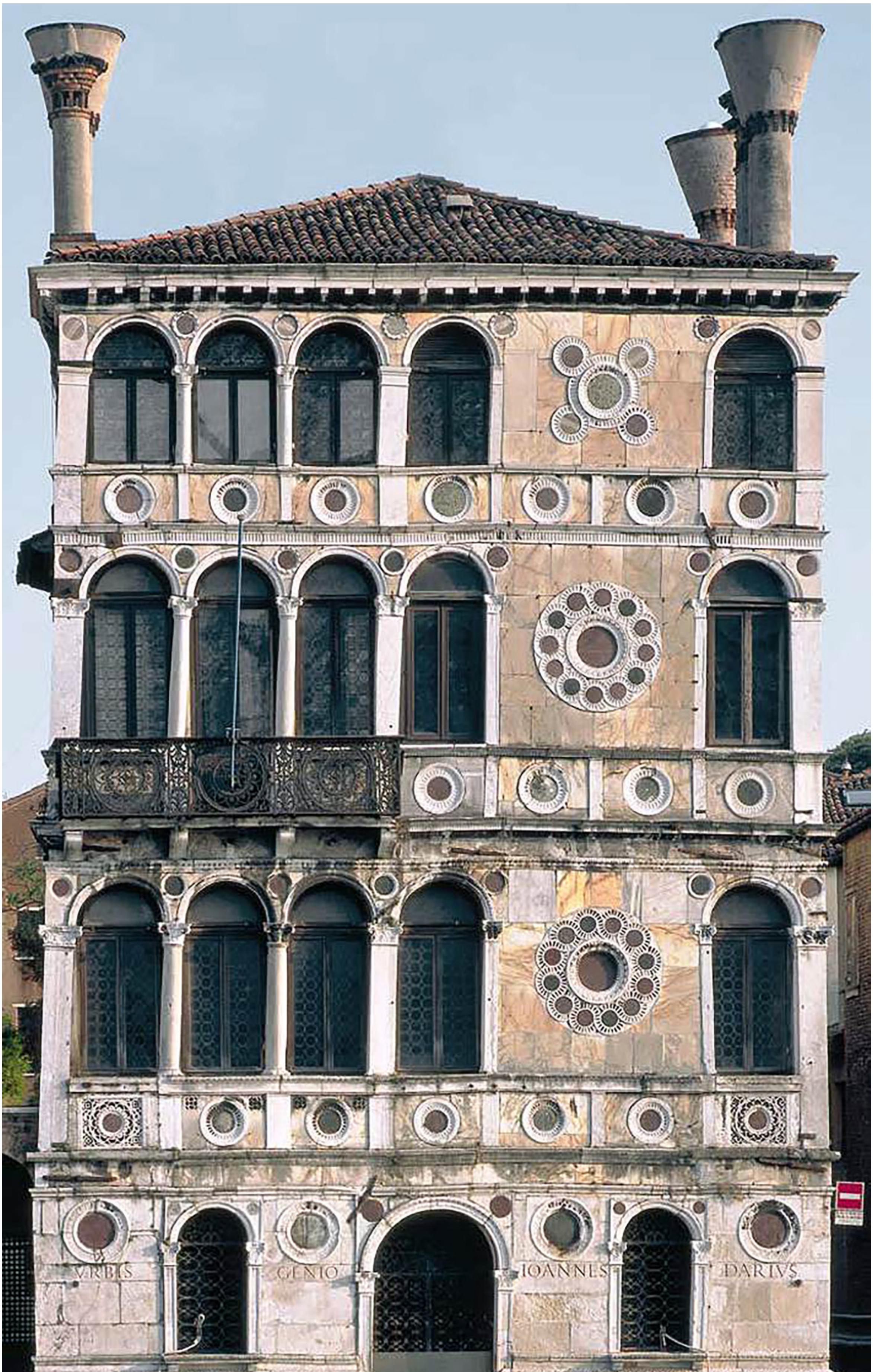


HAGIA SOPHIA, Istanbul, Turkey, 537–

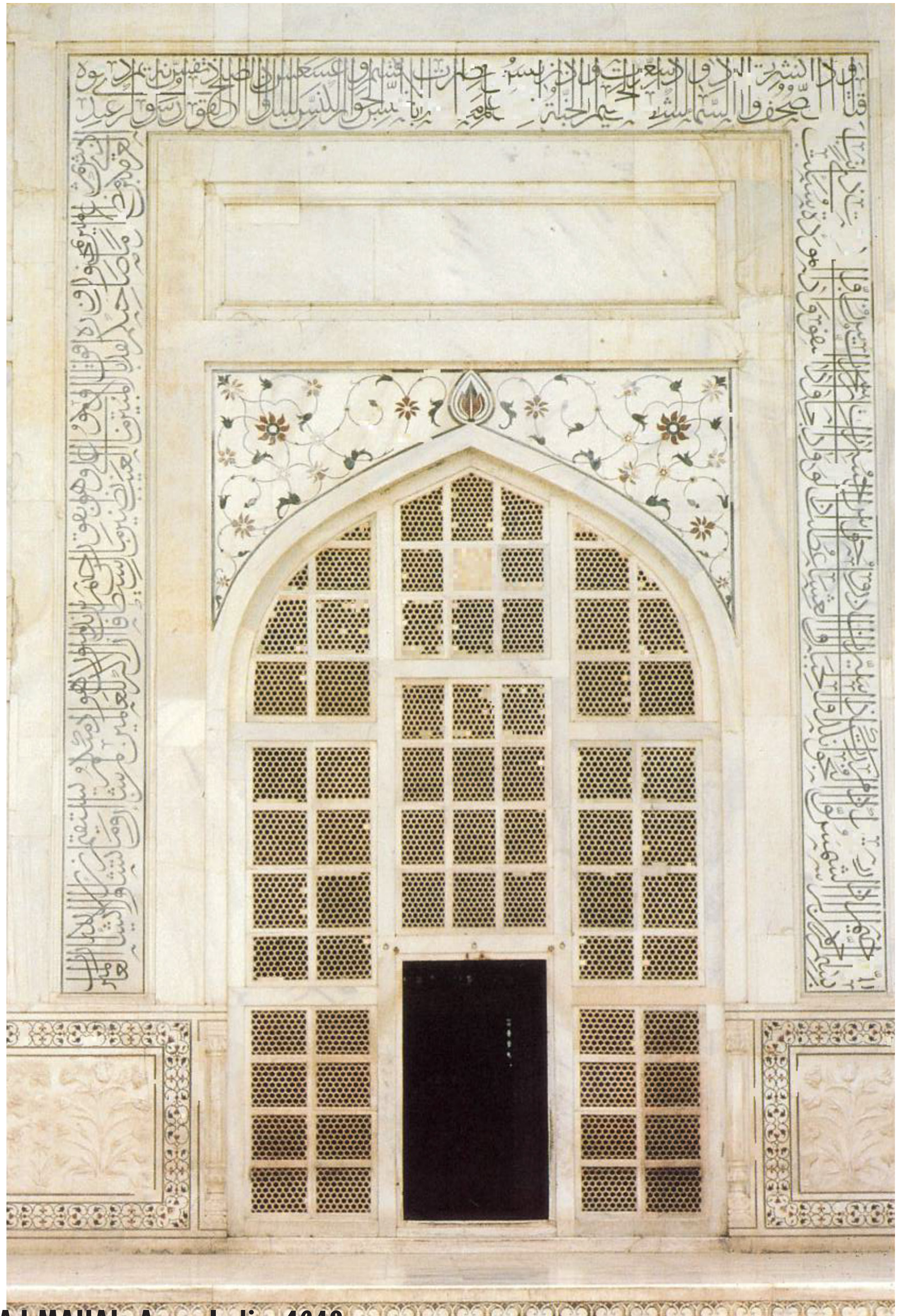




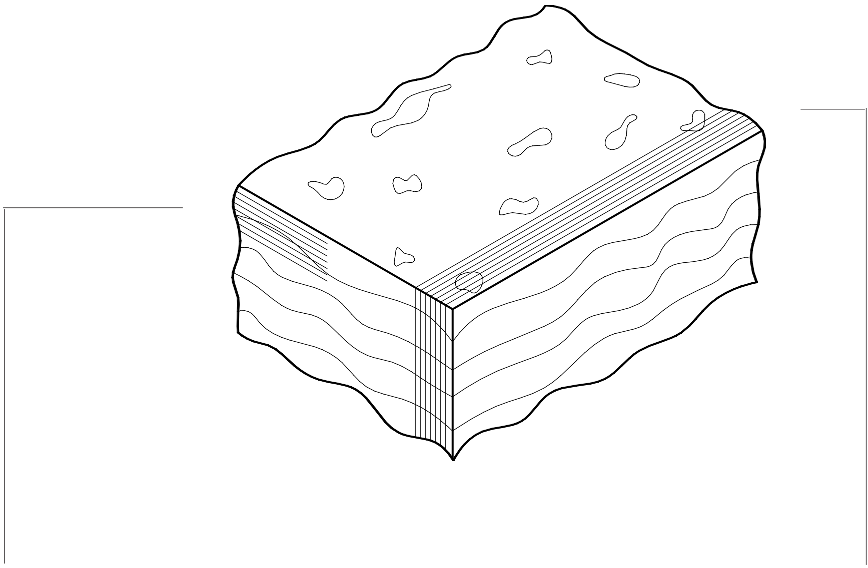
SANTA MARIA DEI MIRACOLI, Pietro Lombardo,
Venice, Italy, 1489



CA DARIO, Pietro Lombardo, Venice, Italy, 1479



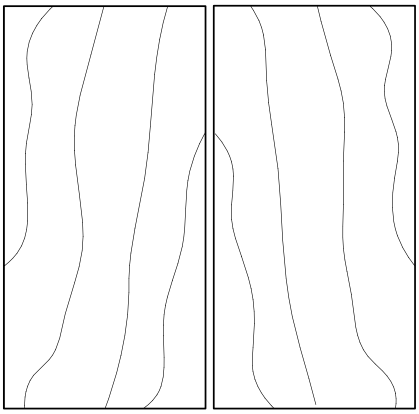
TAJ MAHAL, Agra, India, 1648

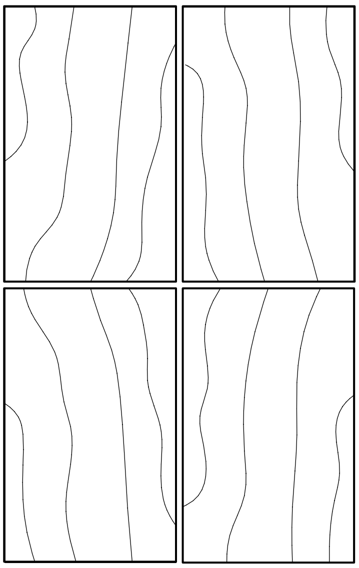


Cross cut with the bed

Vein cut across the bed

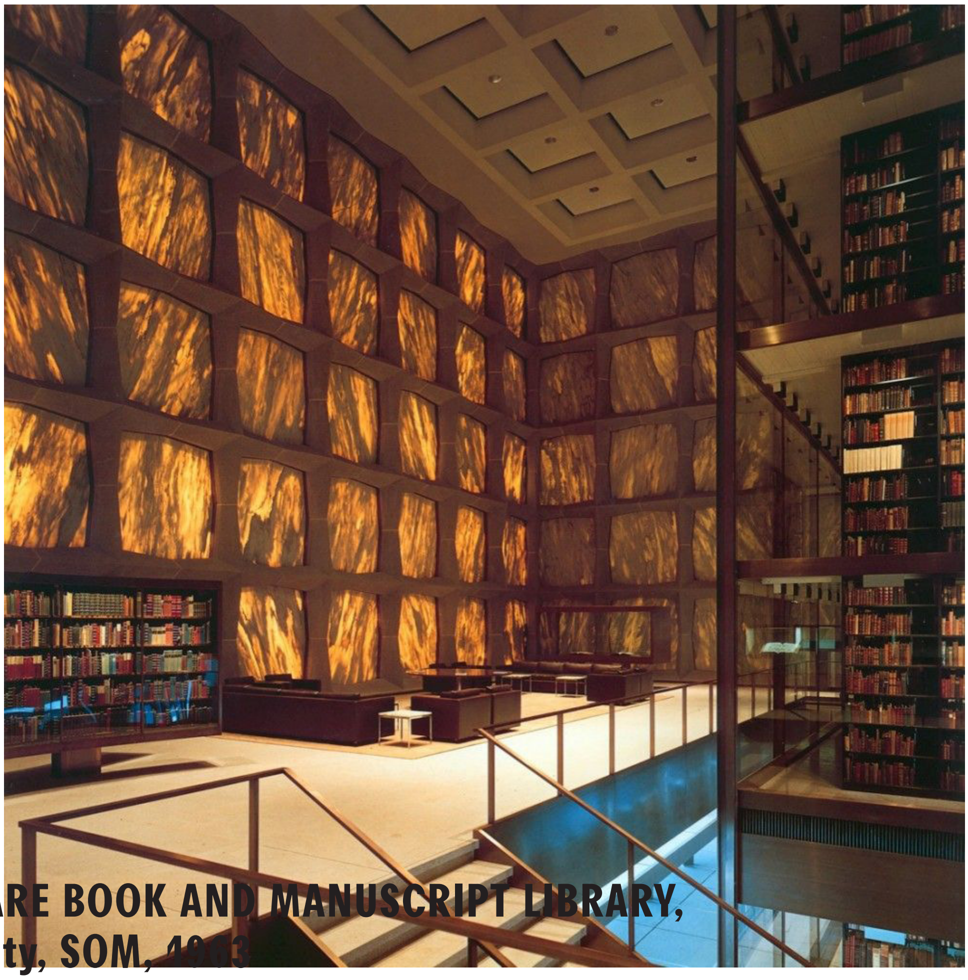
BARCELONA PAVILION, Ludwig Mies van der Rohe and Lilly Reich, Barcelona, Spain, 1929



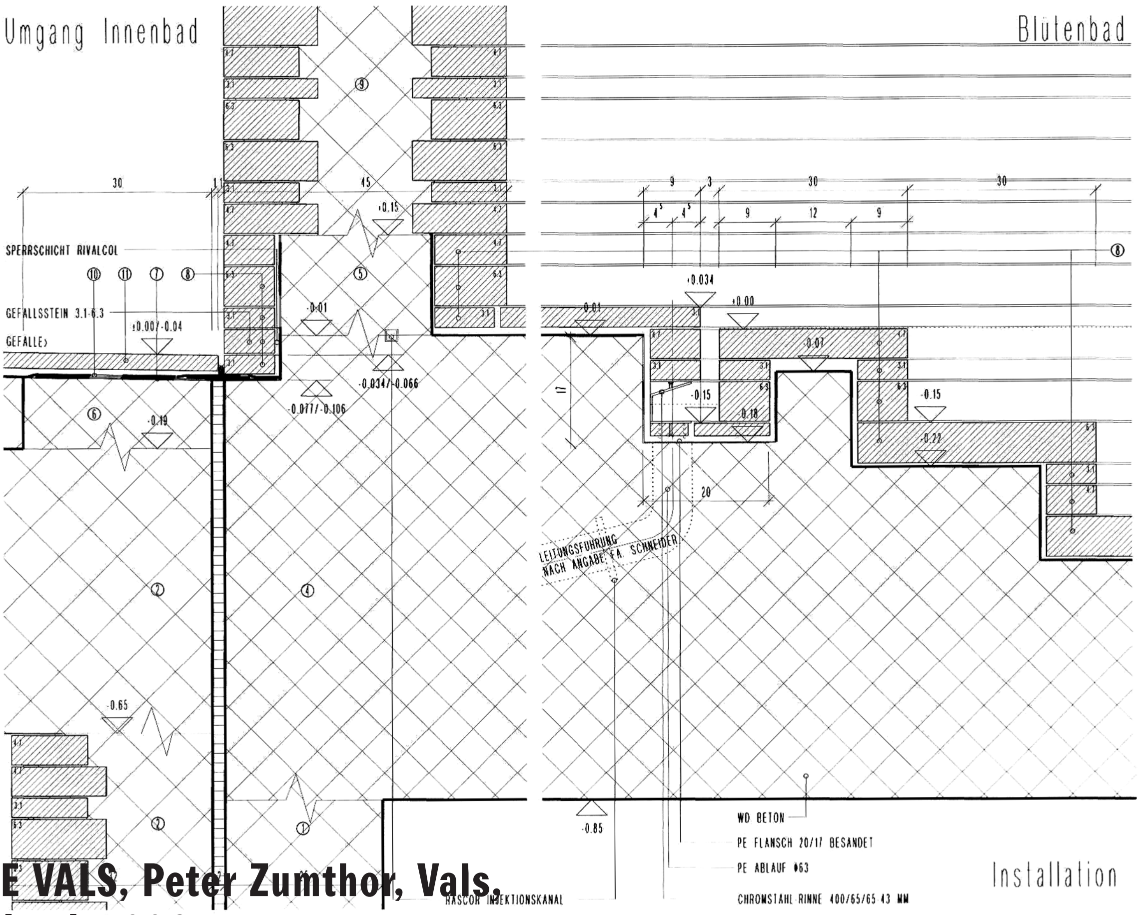


Book match pattern

Diamond match pattern



BEINECKE RARE BOOK AND MANUSCRIPT LIBRARY,
Yale University, SOM, 1963



THERME VALS, Peter Zumthor, Vals, Switzerland, 1996

DOMINUS WINERY, Herzog & de Meuron, California, USA 1998

GANGA MAKI TEXTILE STUDIO, Studio Mumbai, Bhogpur Village, India, 2017

HAGIA SOPHIA
Istanbul, Turkey, 537–

The Hagia Sophia (Ayasofya in Turkish) was originally built as a basilica for the Greek Orthodox Christian Church. However, its function has changed several times in the centuries since; later, as an Ottoman mosque (1453–1931) and currently, as a museum. And now, recovering it as a mosque has been discussed. The interior of Hagia Sophia is fabulously panelled with marble. The marble used for the floor and ceiling was produced in Anatolia (present-day eastern Turkey) and Syria, while other bricks came from as far away as North Africa. And the Hagia Sophia’s 104 columns were imported from the Temple of Artemis in an ancient Greek city, Ephesus, as well as from Egypt.

SANTA MARIA DEI MIRACOLI
Pietro Lombardo, Venice, Italy, 1489

The church is known as the “marble church”. It is one of the finest early Venetian Renaissance building. Pietro Lombardo, leading sculptor and architect of Venice in the 15th century, designed the building and sculptures. Both the interior and exterior were sheathed with colourful marble, and these marble slabs were surrounded by intricately carved cornices and several reliefs of saints and prophets. The church was restored during 1990 to 1997. The marble cladding contained 14 percent of salts, and was on the point of bursting, when restorers began the desalination and cleaning process. All marble cladding was removed, and cleaned in stainless steel tanks, in a solution of distilled water.

CA DARIO
Pietro Lombardo, Venice, Italy, 1479

Another beautiful building designed by Lombardo for Giovanni Dario, a rich merchant from Dalmatia. Structural parts were built with Istrian stone, which is a dense type of limestone commonly used in the architecture of Venice, Istria and Dalmatia and decorated with fine polychrome marble details. Marble cladding came back in fashion in Venice with the Lombardo family from Ticino, having previously been popular in the 1200s. Marble façades were very expensive and so an excellent way to show off wealth. The rumour about Ca Dario is that anyone who comes to own the building will be haunted by tragedy, such as violent death or bankruptcy. The building is so beautiful, superstitions started to circle around it and people started to believe it was haunted.

TAJ MAHAL
Agra, India, 1648

The Taj Mahal was built by Mughal Emperor Shah Jahan in memory of his wife Mumtaz Mahal, with construction starting in 1632 and completed in 1653. It is renowned for its Mughal architecture, although its style combines elements from Persian, Ottoman, Turkish and Indian architecture. The central feature of the building complex was constructed from a brick and rubble core, veneered with white marble, secured by metal dowels. The huge pieces of white marble were made in Makrana, southwest of Jaipur, about four hundred kilometres away. Semi-precious stones are used for construction and rare unusual stones are used in marquetry. Marquetry is an inlay art technique called Pietra Dura, derived from the Italian art world with the meaning of “Hard Rock” or “Hard Stone”. The technique includes cutting, fitting, polishing and drawing pictures on the coloured stones. The white marble used throughout the Taj Mahal reflects the changing light, allowing a subtle range of tones that lend the whole complex an ethereal tranquility.

BARCELONA PAVILION
Ludwig Mies van der Rohe and Lilly Reich, Barcelona, Spain, 1929

It was designed as the German national pavilion for the 1929 Barcelona International Exhibition. After the closure of the exhibition, the pavilion was disassembled in 1930. Four different kinds of stone; Roman travertine, green Alpine marble, ancient green marble from Greece and golden onyx from the Atlas Mountains, were used besides grass and steel in the building. However, the impression of the marble is glamorously ornamental. Marble slabs are put together by a vein matching technique called Diamond Match, in which continuous faces of adjacent slabs are “unfolded” over two perpendicular axes. Travertine used in the pavilion exposes the veining of the material. This pattern appears on the slab when it is cut from the stone block perpendicular to the natural bedding (vein-cut). Cross-cut (fleuri cut) is the process of cutting the block of stone parallel to the natural bedding plane. The effect is a mottled or cloud-like appearance. For travertine materials, cross-cut is most often used.

BEINECKE RARE BOOK AND MANUSCRIPT LIBRARY
Yale University, SOM, 1963

To bring natural light inside the building and to protect the rare books collection, the architects used external stone and steel curtain walls. The building's volume is enclosed in sheets of translucent white Vermont Montclair Danby marble, held in frames. The 3.18 cm marble plates are thin enough to transmit light. During the daytime, the stone appears as an opaque mass on the exterior, while sunlight highlights the coloured veining of the stone from inside. At night, the relationship is reversed, transforming the enclosure into a glowing lantern. The thermal qualities of the marble are similar to those of a single pane of glass, i.e. it is not a good insulator.

THERME VALS
Peter Zumthor, Vals, Switzerland, 1996

Gneiss from Vals has a flat, long-grained mineral structure; it is easy to split and can be cut economically into thin slices of considerable length. These slices are relatively elastic and not overly sensitive to impact. Sixty thousand gneiss slabs are used for the inside and the outside of the building. The monolithic appearance, Artificial Monolith, is a design achieved through layering of long, thin slices of stone. Stone slabs and concrete are combined in a special way known as Vals Compound Masonry. The method is not cladding or covering the surfaces of the building. As seen in the detail plan, section by section, stone slices of different widths and lengths are stacked on top of each other, with concrete poured onto the back creating a firm bond between the stone slices and the "liquid stone". On the exposed side of the wall, the slabs are stacked flush on top of each other, but they are staggered in the back where the concrete is poured.

DOMINUS WINERY
Herzog & de Meuron, California, USA. 1998

In front of the façades, we placed gabions, a device used in river engineering, that is, wire containers filled with stones. Added to the walls, they form an inert mass that insulates the rooms against heat by day and cold at night. We chose local basalt that ranges from dark green to black and blends in beautifully with the landscape. The gabions are filled more or less densely as needed so that parts of the walls are very impenetrable while others allow the passage of light: natural light comes into the rooms during the day and artificial light seeps through the stones at night. You could describe our use of the gabions as kind of stone wickerwork with varying degrees of transparency, more like skin than like traditional masonry. Text by Herzog & de Meuron, 1997

GANGA MAKI TEXTILE STUDIO
Studio Mumbai, Bhogpur Village, India, 2017

Thinly sliced stone slabs are put on the windows. The translucent stone changes expression throughout the day, or even seasons, depending on the intensity of the sunlight outside. Photos by Mitul Desai.

BIBLIOGRAPHY AND FILMOGRAPHY

Milena Batistoni. A GUIDE TO LALIBELA. Fourth edition, 2012.
Ethiopia. Arada Books, 2008

Sigrid Hauser, Peter Zumthor, Hélène Binet. PETER ZUMTHOR THERME VALS.
Third edition, 2011. Zurich. Verlag Scheidender & Spieles, 2007

Roger Caillois. THE WRITING OF STONES. d'Art Albert Skira, 1970

John A. Hudson, John W. Cosgrove. UNDERSTANDING BUILDING STONES AND STONE BUILDINGS. London. Taylor & Francis Group, 2019

Jenelle Porter, Trisha Donnelly. TRISHA DONELLY.
Institute of Contemporary Art, University of Pennsylvania, 2008

Dougal Dixan. THE PRACTICAL GEOLOGIST. New York.
Simon & Schuster Inc., 1992

Jacque Dubarry de Lassale. IDENTIFICATION DES MARBLES.
Éditions Vial, 2016

Robert Smithson, Jack Flam. ROBERT SMITHSON: COLLECTED WRITINGS.
University of California Press, 1996

Studio Anne Holtrop, ETH Zürich. MATERIAL GESTURE: SITE KYUSHU, WORKS DESIGN STUDIO HS19, 2019

Aglaia Konrad. CARRARA. Roma Publications, 2011

Fernando Márquez Cecilia & Richard Levene. STUDIO MUMBAI 2012–2019. IN-BETWEEN SPACES. Madrid. El Croquis, 2019

Chris and Helem Pellant. ROCKS AND MINERALS: A PHOTOGRAPHIC GUIDE. London. Bloomsbury Publishing Plc., 2014

Gilles Perraudin, CONSTRUCTING IN MASSIVE STONE TODAY. Les Presses du réel, 2013

Frederick H. Pough. A FIELD GUID TO ROCKS AND MINERALS. Third Edition 1900. The U.S.A.. Houghton Mifflin Company Boston, 1953

Albert Renger-Patzsch. GESTEIN. C.H. Boehringer Sohn Ingelheim Am Rhein, 1966

Henry Russell. ENCYCLOPEDIA OF ROCKS, MINERALS, AND GEMSTONES. Thunder Bay Press, 2001

Siegfried Siegesmund, Rolf Snethlage. STONE IN ARCHITECTURE: PROPERTIES, DURABILITY. Fifth edition. Berlin Heidelberg. Springer, 2014

Yuri Ancarani, Pietro Savorelli. IL CAPO. Film 15 min. Italy, 2010

Armin Linke, Guiseppe Ielasi, Renato, Rinaldi, Piero Zanini. ALPI. DVD 60min. LP 32’18. Geneva. JRP-Ringier, 2011

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In this exceptional situation, with travel restrictions due to Covid 19, the physical presence of Anne Holtrop in Zürich is limited to once every four weeks. In between, teaching days are held online via Zoom. In case of easing on the current situation, his physical presence will be increased accordingly. Stephan Lando will be present every week at ETH.

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