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Landscape Perceived, a painting by Abdul Mati Klarwein, of the *cala*, or cove, at Deia, Mallorca, 1963

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The Old Stone Road, a section from Beniraix to Puig Mayor on the island of Mallorca. photo: T L

INSIDE BACK COVER:
Fountainhead Rock, Santa Fe, New Mexico

stone (ston) n.
1. a. Concreted earthy or mineral matter; rock.
   b. Such concreted matter of a particular type. Often used in combination.
2. A small piece of rock.
3. Rock or piece of rock shaped or finished for a particular purpose, especially a piece of rock that is used in construction.

nex-us (nek' sas) n., pl. nexi or nex-us-es.
1. A means of connection; a link or tie.
2. A connected series or group.
3. The core or center.

mag-a-zine (mag-úh-zeen), n.
1. A periodical containing a collection of articles, stories, pictures, or other features

PHOTOS TO THE EDITOR

CAMBODIA

right: Makara, a mythical creature, half elephant, half fish. Banteay Srei

below: War elephant. Bayon

opposite top: Apsaras, celestial maidens. Angkor Wat

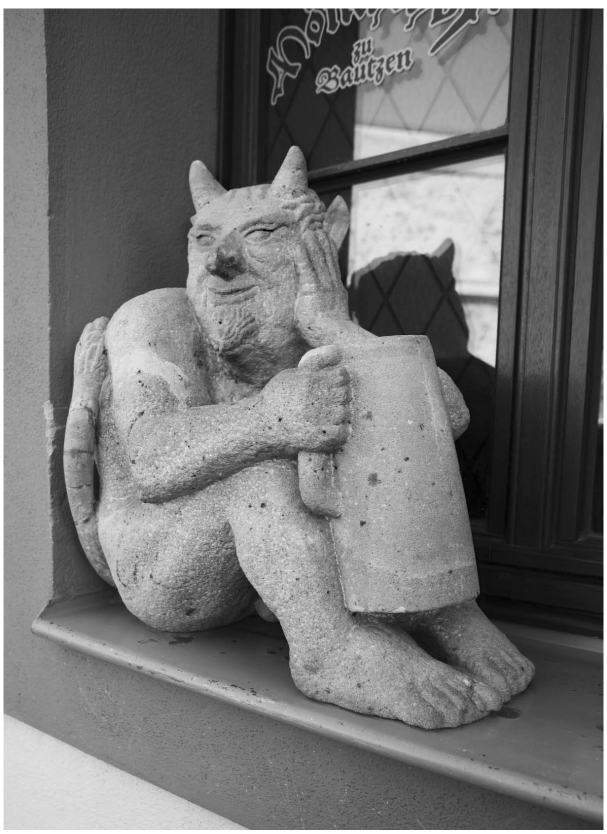
opposite bottom: Giant stone faces, believed to be representations of Lokesvara, combined with the features of King Jayavarman VII, the last great ruler of Angkor before it fell into decline. Lokesvara is revered in Mahayana Buddhism as the Bodhisattva of compassion. Angkor Thom

photos: Julie Kandyba

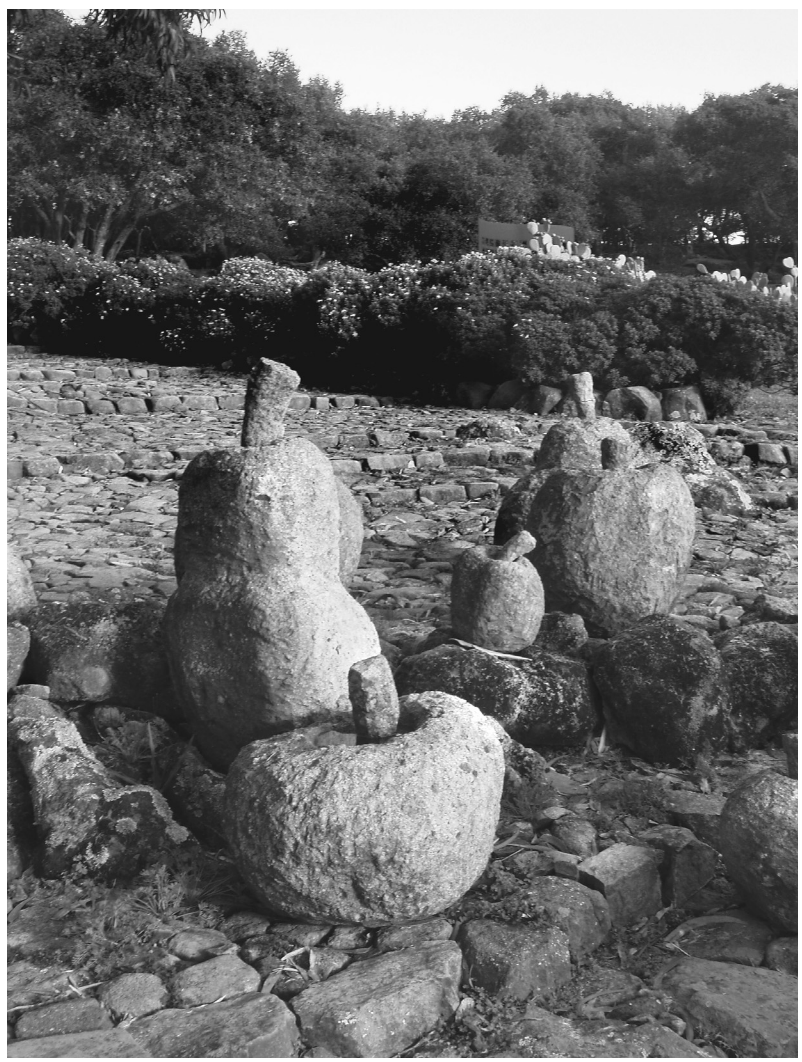
Q: Why *didn't* the turkey cross the road?

A: Because it was petrified with fear.

Perth, Ontario, Canada
photo: John Scott

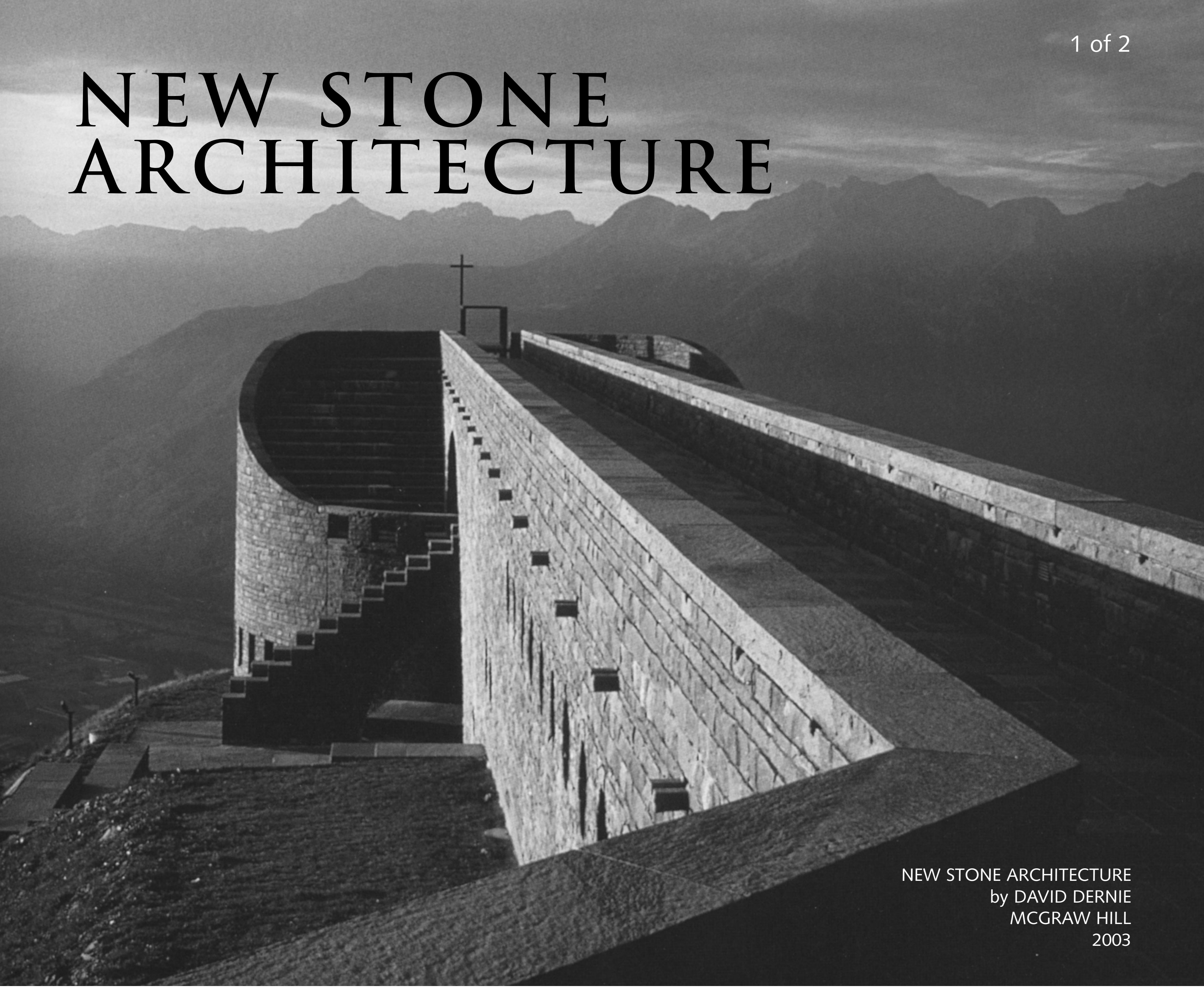


Bautzen, Germany
photo: Frazer Muirhead



stone fruit, St. Helena, California
photo: Michel Giannesini

NEW STONE ARCHITECTURE

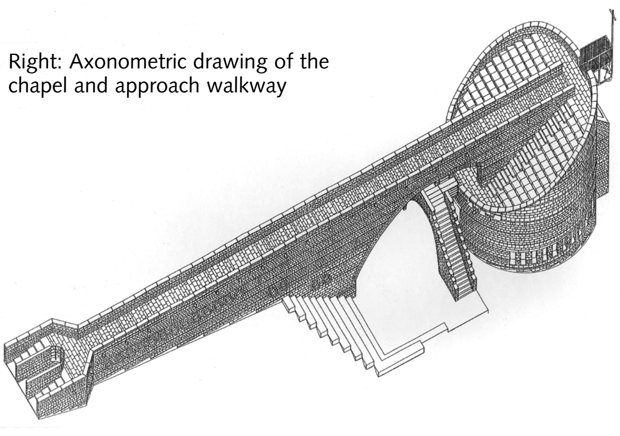


NEW STONE ARCHITECTURE
by DAVID DERNIE
MCGRAW HILL
2003

Chapel of Santa Maria degli Angeli, Monte Tamaro, Switzerland
Architect: Mario Botta, 1996

reviewed by
Devendra Contractor

Right: Axonometric drawing of the chapel and approach walkway



". . . with perseverance and imagination great and humble stone buildings of great enduring beauty can be constructed—are being constructed—all over the world."

For me, an architect and a former stone mason 'New Stone Architecture' is an ongoing source of delight and inspiration.

Most architects and stone masons that I know lead full, busy lives. There is work to be done, life to live and then we have our set prescriptions of diversions and vices. There are books to read, publications, ongoing education, and a host of other commitments: these are busy times for our kind and we are bombarded with way too much information to ingest. So when my dear friend Tomas Lipps

David Gentleman

A Cross for Queen Eleanor

The story of the building of the mediaeval Charing Cross, the subject of the decorations on the Northern Line platforms of the new Charing Cross Underground Station

Printed to mark the occasion of the opening of the Jubilee Line on 30 April 1979 by HIS ROYAL HIGHNESS THE PRINCE OF WALES.

Reprinted here by permission of the author

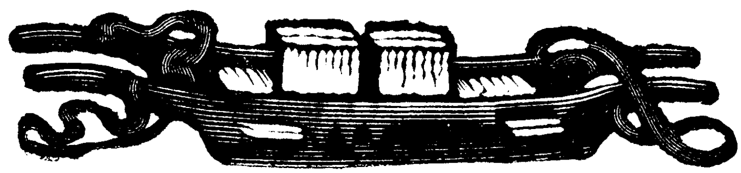
Author’s note

When London Transport commissioned me to design the mural decorations for the Northern Line platforms at Charing Cross station, I chose as the subject the building almost seven hundred years ago of the original Charing Cross in what was then the village of Charing. In the course of the task I had to find out about the methods and organization of the craftsmen who built the Eleanor Crosses, and also discovered their significance in the architecture of their time. This book is the fruit of that research.

It is not a scholarly treatise. It attempts, like the decorations, to give the interested Londoner (and visitor) some idea of the working lives and the skills of the craftsmen of an earlier time and, in a way, to acknowledge our debt to them.

The illustrations are enlarged from prints from wood engravings which were made on boxwood blocks. For the station decorations, similar prints were further enlarged and screenprinted with great skill and care by Perstorp Warerite Limited on to the wall panels which run from end to end of the platforms.

I would also like to record my debt to the many medieval illustrators and to the historians and scholars whose works made my task possible, some of whom are mentioned in the bibliography; and to thank Herbert Spencer for his invaluable help in designing this book.



Charing Cross to most Londoners means only a hazily-defined area somewhere between Trafalgar Square and the Thames, with a hotel, a hospital (now moved to Hammersmith) and a number of stations with, until recently, a confusing variety of names. But long ago it meant something much more tangible and precise. For three and a half centuries, a real solid Charing Cross stood where the statue of Charles I stands now, one of the great sights of London, as familiar in its time as the nearby Nelson’s Column is in ours: the tall and splendid monument which had been built in Charing village to remind Londoners of their resourceful and faithful Queen, Eleanor of Castile.

Eleanor was the beloved wife of King Edward I. She married him at Burgos in Spain in 1254 when both of them were very young; she accompanied and sustained him on his Crusade; it was said that when he was wounded by an assassin, she saved his life by sucking the poison from the wound; she traveled with him on his perilous expeditions to Wales; and during their thirty-six years of marriage she bore him fifteen children. It was written of her that ‘to our nation she was a loving mother and the column and pillar as it were of the whole realm.’ During these years her husband became not only an energetic and powerful warrior king but also a remarkable builder; the Tower of London and eight great castles in North Wales stand as his own most solid and striking memorial. Eleanor the Faithful died at Harby in Nottinghamshire in 1290. Her body was taken to nearby Lincoln where her heart and entrails are buried; then the body was embalmed and, accompanied by the King and his court, was taken in a great funeral cortege to Westminster. At each of the twelve stopping-places on the road the King selected a place to build a monumental cross to her memory; they came to be called the Eleanor Crosses. Three of them still survive, at Geddington in Northamptonshire, at Northampton and at Waltham Cross in Hertfordshire. Her body lay at last in Westminster Abbey, under the bronze effigy which suggests to us, as vividly now as it did almost seven hundred years ago, a graceful and serene woman. The stone tomb encasing it was made by the King’s mason, Richard of Crundale, and he it was who, at the King’s mews in the nearby village of Charing, built the last and most splendid Eleanor Cross of all: Charing Cross.

No one knows exactly what it looked like. The Puritans pulled it down in 1647 and used the stones to pave the ground outside White Hall, and the few surviving drawings of it tell us very little. It seems probable that, like the eight-sided Northampton cross, it was a tall polygonal structure carrying six or eight statues of the Queen, that it stood on a stepped plinth, and that a large cross stood on top of its spire. The Victorian 'Charing Cross' in the Strand outside the Southern Region Station is not a restoration or even an accurate reconstruction but a Gothic Revival work of the imagination, built in 1865 by the railway company; of the genuine crosses, Waltham Cross has been much too thoroughly, even disastrously, restored to retain any feel of the original. But by looking at the beautiful crosses at Northampton and Geddington we can guess at the elegance of Charing Cross itself. The time was ripe for building it; indeed, at about this time, 1290-94, the most active developments in Gothic architecture were no longer taking place in France (its original source) but had shifted to England; building here over the following twenty or thirty years reached a peak of invention and achievement whose influence was to spread through Europe.

Self-confidence and stability under King Edward played a part in this architectural upsurge, but the underlying reasons for it stretch back to the Normans, whose determination and efficient organisation had transformed English building. Norman vigour and enterprise had flourished in an increasingly, if only relatively, stable and prosperous country. To establish their supremacy and prestige here, the newcomers had had to build castles, monasteries, and great churches; they had organised adequate and reliable supplies of stone, first from Normandy and then from newly-developed English quarries; and having at first brought over their own Norman masons, they had then set in train enough work to call forth great numbers of skilled English carpenters and masons. As these skills developed, there grew an astonishing mastery of construction, in which clever and complex ideas were closely matched by skilled and developing craftsmanship, for in Gothic architecture idea and execution were inseparable. Buildings were designed not by architects who had been sheltered by education and upbringing from practical building work, but by highly skilled masons, with great breadth of experience; the same men knew how to design and erect castles, houses, churches, to build, in short, for kings and cut-throats. There was no practical reason for them to specialize, and masons' guilds had not yet invented one by dividing the craft into strictly demarcated functions. Master masons were concerned not with any aesthetic style as such, nor with following any classical model, but only with building as practically and efficiently as they knew how. And since the skills of artist, craftsman and technologist, which we now generally assume to be separate and distinct, were only just beginning to be differentiated at all, a mason was, as has been well said, at the same time composer, conductor and member of the orchestra.

Stone

A SUBSTANTIAL WITNESS

PHOTOGRAPHS BY DAVID SCHEINBAUM

MUSEUM OF NEW MEXICO PRESS   SANTA FE

"If stone is," in the words of Chile's Nobel Laureate Pablo Neruda, "a substantial witness" to the "trembling world," then the photographic images presented in this volume intimately capture the enduring qualities and varied uses of stone in the prehistory and history of geographically separate and diverse human cultures. The upright bluestones of Stonehenge, the repeated notes of the Tower of Pisa and the towering, marble-faced Washington Monument were all inspired by an intensity of human commitment and achieved in a common material: stone.

This, the first paragraph of the introduction by Jo Anne Tilburg to David Scheinbaum's book, "STONE," is an apt preface to the procession of images, one per page, in what is an eloquent pictorial monograph devoted to stone, to the presence of stone, to the iconic ways in which stone serves to embody spirit.

In her essay Ms. Van Tilburg identifies the ways humankind has, over the ages, related to stone: as a material for carving and building, a medium of expression, a repository of power, a presence in the landscape, and a substantial witness to, and expression of, our "trembling world."

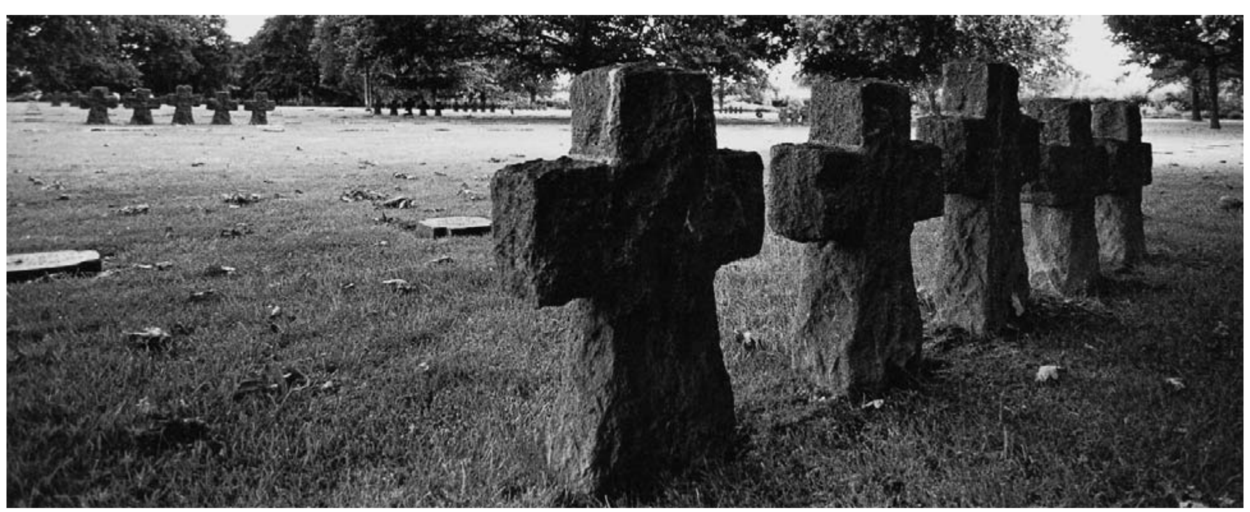
These selected photographs are an intimation of the broad and eloquent range of the images to be found in the book. ■

T L

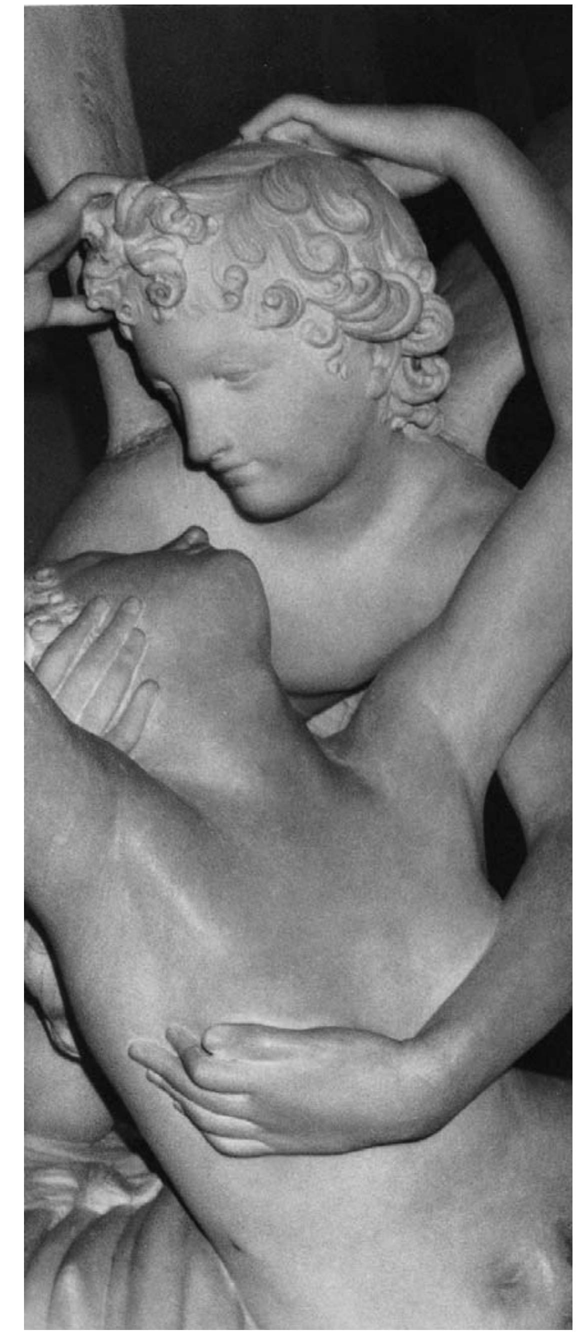
TOFUKU-JI TEMPLE
KYOTO, JAPAN, 2000

RANO RARAKU, EASTER ISLAND
(RAPA NUI) 200

CHACO CANYON
NEW MEXICO, 1999



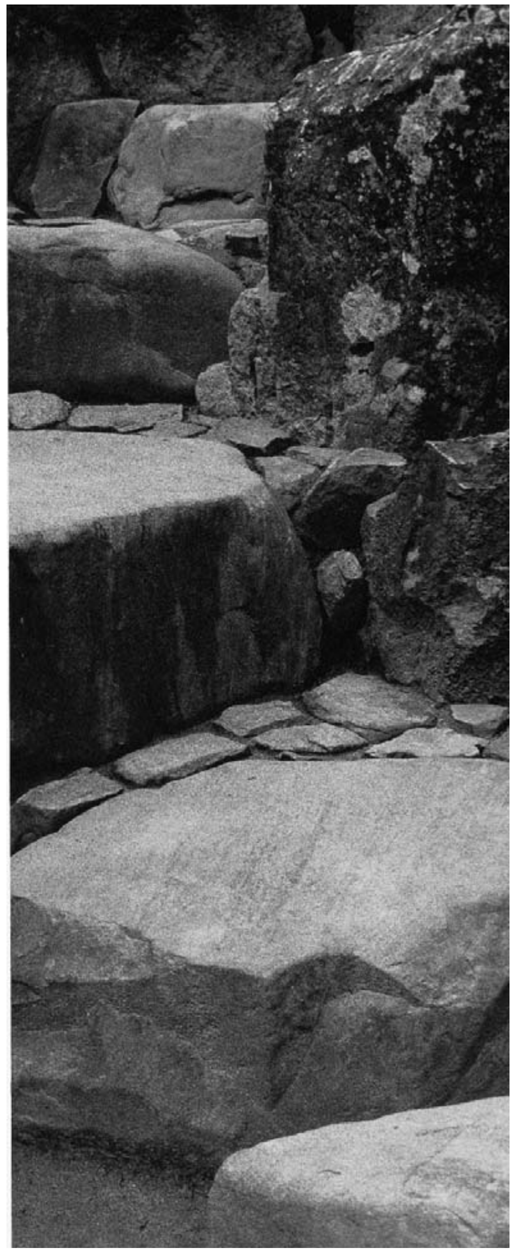
GERMAN CEMETERY
LA CAMBE, FRANCE, 1994



PSYCHE REVIVED BY CUPID'S KISS
THE LOUVRE, PARIS, FRANCE 1997

GOPURAM,
MADURAI, INDIA, 2000

MONUMENT VALLEY, NAVAJ0 NATION
UTAH/ARIZONA, 1999



GINKAKU-JI TEMPLE
KYOTO, JAPAN, 2000

SUPREME COURT
WASHINGTON DC, 2001

THE MORTAR STORY

CHRONOLOGICALLY,

the OPC[1] Era, what might be called the Pseudolithic Age, is a mere blip on the long and honorable historic continuum of the use of lime mortar in masonry structures.

VOLUMETRICALLY,

however, it is a monstrous phenomenon that has pushed aside the traditional ways of building with stone and brick and come to dominate the masonry aspect of the contemporary construction industry. Cement based mortars, CMUs (concrete masonry units) and reinforced concrete are the norm. Stone, once a Primary building material has largely been reduced to a Tertiary role; not structural, but something applied to structures: cladding.

The current dominance of OPC extends not only beyond the horizon, into the foreseeable future, but it has infiltrated the past by its indiscriminate use on historic structures—to detrimental effect, and in many cases severe detrimental effect.

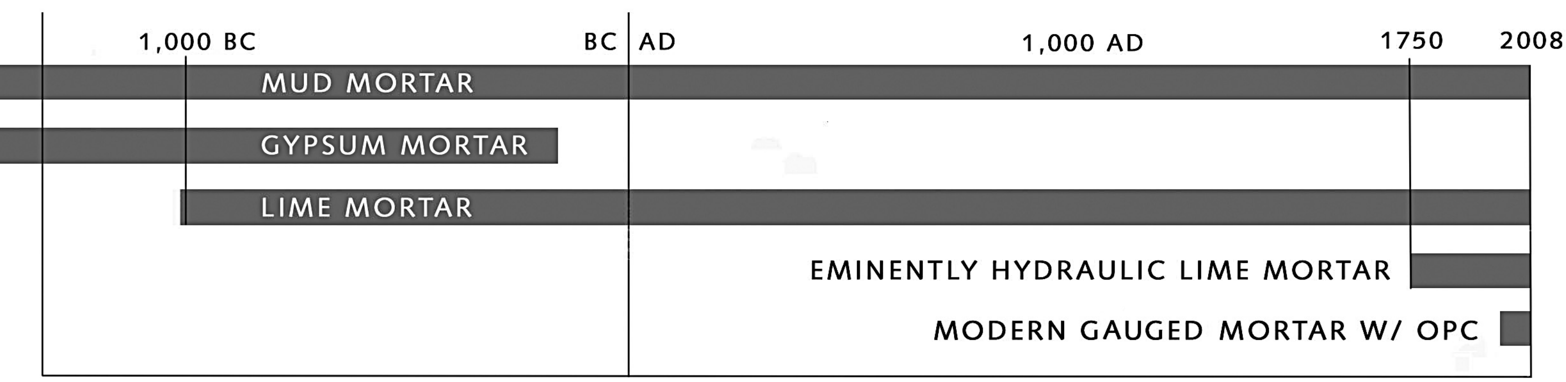
The OPC Monster has BAD breath. The manufacture of cement and lime accounts for 10% of the entire world's contemporary carbon emissions. It must be said, however, that making hydraulic lime and quicklime requires less heat and produces less carbon dioxide. And, to their credit, lime mortars readsorb carbon from the atmosphere as they set and harden, through the process called carbonation, thus ameliorating harm to the environment .

As the drawbacks of modern mortars have become evident, the values of traditional lime mortars are being rediscovered and they are once again being used, particularly in restoration work, and in new construction as well. As might be expected, this is happening to a greater extent in Europe than in America, but the New World is also realizing the value of Old Style mortars, realizing that they make sense: structural, ecological, even economical sense. What costs less—in labor and materials—is not, in all ways, best (nor, to be sure, is what costs most.)

At STONEWORK SYMPOSIUM 2006, the Stone Foundation's annual gathering that year in Hood River Oregon, Blair Bates, restoration contractor and loyal SF member, delivered a presentation on "The Mysteries of Mortar" that was interesting and intriguing and in less that an hour provided more information than one could possibly take in. An article in these pages was called for and Blair's response follows here, augmented by consultation with Patrick McAfee, Mark Liebman and others, as well as a distillation of the fruits of my own research.

First, a History Lesson:

MORTAR TIME LINE CHART



It can be said that masonry began when mud was used as mortar unifying blocks, bricks and stones to form a regular, composite mass.

Over the ages, other indigenous materials were combined to create mortar. The Babylonian and Sumerian masons mixed naturally occurring bitumen with clay, certain earths and plant fiber. Masons in Mycenean Greece had a bituminous clay at their disposal.

Cooking food must have been the first way by which early man altered the chemistry of substances for a practical purpose. Cooking rocks may have been the second. Egyptian masons early on learned to burn gypsum and use the resulting material to make mortar and plaster, but lacked the fuel supply to produce the higher heat necessary to render limestone into quicklime. Lime mortar was "born" not in Egypt[2] as is popularly believed, but in Minoan Crete about three thousand years ago. Besides combining slaked lime with aggregate to make mortar, Minoan masons added ground fired clay (bricks and tiles) and a more durable mortar evolved.

SO already, here, at a point of origin, the duality of lime mortar is in evidence. Mortars were created that achieved their set in two different ways: by hydration—a chemical reaction stimulated by the water used to mix them; and/or by carbonation—interacting with air, the atmosphere, absorbing carbon dioxide to form stable state calcium carbonate.

The Roman masons, building on what they learned from their Greek neighbors, made a science of the craft. They, who had also used ground fired brick and tile, further transformed the element of mortar by introducing volcanic sand or ground volcanic rock to the lime in precise proportions.[3] These materials are called pozzolans[4] after the volcanic sand from Pozzuoli (a former Greek colony) on the Gulf of Naples. Mortars made in this way did not need air to achieve their set and harden. They can do so under water, which is why we call them hydraulic mortars today. Early pozzolanic mortars were only slightly or moderately hydraulic but they set sooner, were harder and had greater compressive and tensile strength than the non-hydraulic (air) lime mortars.

Lime has continued to be burned for mortar in the western world and elsewhere from the Roman times until now, generally in local kilns still found today, in various stages of ruin, wherever limestone was prevelant.

Then, in the late 18th century British engineers achieved major technological developments that rival gunpowder and the infernal combustion engine in the beneficial yet devastating effects they have had on our world. The brilliant John Smeaton, who was commissioned to (re)build the famous Eddystone Lighthouse on the southwestern tip of England, in his attempt to find the ultimate 'water lime'—they were not called hydraulic limes until French civil engineer, bridge and road builder Louis Vicat applied the term 50 or so years later)—succeeded. He discovered that clay and limestone in certain proportions, those found in Blue Lias limestone, an argillaceous limestone prevalent in England, would, if heated to a certain temperature, produce what we know today as Eminently Hydraulic Lime. It was he, Smeaton, who first likened hydraulic lime to the prized Portland stone, for its solidity and durability and, as well, its color.

Smeaton broke ground for a number of entrepreneurial emulators, inventors who came up with, and took out patents for, marketable products such as "Roman Cement," "British Cement" and "Portland Cement" the latter being a term applied by a bricklayer named James Aspdin to what was simply another eminently hydraulic lime formulation. The discovery of true Portland Cement was due to providential accident on the part of a chemist in the employ of one of Aspdin's competitors. Isaac Charles Johnson (1811-1911) set out to discover Aspdin's carefully guarded secret and in the process accidentally over-fired some clay-bearing limestone past the point where it was transformed into clinker. The clinker was considered worthless and most of it was thrown away, but Johnson ground some and immersed it in water and was amazed to find the resulting material was actually harder than the Aspdin's hydraulic mortar.

And so it began.

T L

The Eddystone Light

[1] OPC = Ordinary Portland Cement.

[2] "The mortar employed in ancient Egypt before Graeco-Roman times was of two kinds depending on the nature of the construction, namely, clay for use with sun-dried bricks and gypsum for use with stone. The former is still used for sun-dried bricks at present day and is still the most suitable material for the purpose, but gypsum is not now employed as a mortar, haven given place to the more recent lime-sand mixture or to the still more modern cement.
No instance of the use of lime mortar in Egypt, or of lime in any form, is known to the author as occurring before the time of Ptolmey I (323 to 285 BC). From this period and from later periods it has however been found and, from the few specimens analysed, it appears to have been, as is only to be expected, of much the same composition as the lime mortar of today."A. Lucas and J. R. Harris.

[3] "If to river or sea sand, potsherds ground and passed through a sieve, in the proportion of one third part, be added, the mortar will be the better for use." Vitruvius, *De Architectura*, 1 BC.

[4] Burnt rice hulls are also a pozzolan.

Sources:
C.H. Mattus and T.M. Gilliam, *Sensitivities and Effects upon Solidification/Stabilization in Cement-Based Matrices*, ORNL/TM12656. Pub.1994 by the U.S. Department of Energy.
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John Henry Parker, *The Archaeology of Rome*, 1874
W. H. Chaloner, *People and Industries*, 1963

NEW VS. HISTORIC MORTARS

by Blair Bates

SO WHAT'S THE DIFFERENCE AND WHAT SHOULD I USE?

In today's modern-paced world there is a continual striving for mortars that are technologically superior to what is currently available. In the rush for improvements, however, we have forgotten many of the durability aspects that thousands of years of history have shown us mortar can provide.

This paper hopes to take the mystery out of mortar mixes and encourage a new appreciation for old style mortars.

WHAT IS OLD (HISTORIC) MORTAR?

It was discovered that when limestone was burnt and then combined with water, it produced a plastic material that would dry and then harden with age. The lime mortar used before the 20th century was simply an aggregate and a binder. The binder was lime, obtained by burning limestone or sea shells. The aggregate was sand or earth. As a binder in masonry construction, lime is generally considered inferior to Portland-cement based mortars, though limestone (calcium carbonate) is a raw material for both.

Lime may be weaker, take longer to set, set in a different way, and require a higher level of skill or understanding to use properly, but it has distinct long-term advantages. These include: greater compatibility with soft materials, good workability, increased initial adhesion, flexibility, greater porosity (breathability) and better weathering properties. The mortar lets moisture out as well as in. Cement mortars lock the moisture in so that the only way it can escape is through the brick or stone, deteriorating it in the process.

Lime mortar is self-healing. Movement in masonry structures may result in large individual cracks where hard cement mortars are used, but lime mortar will develop multiple fine cracks. The lime mortar possesses a unique capability known as *autogenuous healing*, the process whereby free lime in the mortar combines with water and CO_2 from the atmosphere and through carbonization is transformed into calcium carbonate which seals the minute fissures that occur as the mortar flexes.

Old time mortars were used in masonry construction not as glue, but as a gasket or separator between the individual masonry units. The purpose of this gasket (just like in an automobile engine) was to absorb small amounts of movement yet keep the pieces together. It is important to note that, while the lime mortar and masonry unit are not glued together, there is a bond between them and this bond has helped masonry walls to resist expansion and contraction, wind shear, and seismic as well as gravity loads.

Bricks and stones bonded with lime mortars, unlike those glued together with cement mortars, can be recycled.

WHAT IS OLD (HISTORIC) MASONRY CONSTRUCTION?

Until the 19th century, masonry buildings were just that—solid masonry structures. All loads placed on the building were transferred to and through the masonry. In proper stone masonry, the stone was laid to a dry stone standard and properly bonded as the first level of strength with the mortar being used in a subsidiary role—to hold the stones in place and transfer the loads more uniformly. Many historic structures were built with lime/rubble infill between walls of solid masonry. The result was more like a lime concrete, though often little effort was made to consolidate it or insure consistency of the materials.

WHAT IS NEW MORTAR?

New masonry mortars are commonly used in veneer construction for brick and stone buildings.

Initial attempts to use pure Portland cement and sand mortar mixes were quickly discounted due to workability issues. New mortars are designed to a specific performance or proportion criteria known as ASTM C-270. This allows the mortar manufacturer to either use an exact blend of lime and Portland cement or to blend any of a number of materials into the mortar to meet specific requirements. These additives are used to extend or shorten the set time, add waterproofing, increase workability for the mason and to achieve ultimate strength earlier.

Some new developments have resulted in mortars which count on other materials for their workability. There may be little or no lime at all in the mix.

WHAT IS NEW MASONRY CONSTRUCTION?

In modern (post-early 1900's) building, the masonry, once the primary material, is now used as cladding applied to the structural elements, such as steel, wood, cement blocks or concrete, which are hidden underneath it. With such a thin cladding masonry system, the requirements for the mortar are very different from historic masonry, even when the cladding is adhered to structural, load-bearing block construction.

WHAT ARE THE PROPERTIES OF MORTAR?

The properties of mortar that are most important in mix design considerations are:

(1) **The Coefficient of Expansion:** The amount a material moves as a result of temperature change. A 200 foot stone wall that sees an annual temperature low of -20°F and a maximum stone surface temperature of 160°F could expand/contract as much as an inch and a half. Something needs to accommodate this movement. If this movement is not accommodated by the mortar, the wall will crack.

(2) **Compressive Strength:** The ability of the mortar itself to hold a compressive load without failure. This is normally tested at a 28 day strength, which is a standard for Portland cement-based products, but has little relevance to lime based mortars that need time to carbonate, as much as a year per inch.

(3) **Ductility:** Basically, the mortar's ability to deform under stress without failure.

(4) **Porosity:** The mortar's ability to pass moisture through it. In new mortars porosity is minimal. The porosity of old mortars enables the masonry to dry out or "breathe."

(5) **Bond Strength:** The mortar's ability to adhere to the masonry unit, normally measured in psi (pounds per square inch).

(5) **Modulus of Elasticity:** A mortar's ability to allow for minor movements without cracking, an important factor in building without construction joints or expansion joints.

(6) **Tensile Strength:** The mortar's ability to take a tensile (pulling) force without failure.

Natural hydraulic lime mortars are more frequently being used—not only in the repair of historic structures, but in new ones also.)

Pozzolanic Lime: Pozzolans are defined as materials which, though not cementitious in themselves, contain constituents which will combine with lime at ordinary temperatures in the presence of water to form stable insoluble compounds possessing cementing properties. Natural pozzolans are materials of volcanic origin. Artificial pozzolans are mainly products obtained by the heat treatment of natural materials, such as brick dust, fly ash, rice hull ash and china clay.

Non-hydraulic Lime: This is lime (less than 95% calcium hydroxide) made by hydrating or "slaking" the quicklime of relatively pure limestone, which hardens by "carbonation". Two forms are available:

Lime Putty: Ordinary (non-hydraulic) lime produced by slaking fresh quicklime in an excess of water to form a putty. Intense heat is created in the process and because of the danger involved, specialist training is required. Lime putty is matured for at least three months (the longer the better) in pits or under a thin film of water to prevent carbonation, and during this process the lime crystals change shape, becoming smaller and flatter, thus aiding workability.

Lime putty mixed with sand and hair was commonly used for internal plastering. For this purpose it was sometimes gauged with gypsum plaster. If non-hydraulic lime and sand mixes were used externally, a pozzolan was commonly added to increase its set and resistance to frost. Non-hydraulic lime and sand mixes are generally not suitable for modern thin wall construction.

Dry Hydrated Lime: Ordinary (non-hydraulic) lime produced as a dry powder by hydrating the quicklime with just enough water to convert the calcium oxide to calcium hydroxide. Also known as "bagged" or "masons" lime, it was developed to increase the workability of cement and sand mixes.

"Site-Batched" Lime Putty: The simple way of making lime putty is to add 5 gallons of water to one bag (50 lbs.) of dry hydrated "type S" lime. The sooner the lime is obtained after it leaves the kiln, the better the lime putty will be. Hydrated lime that is six or more months old, or lime that has been improperly stored, or lime in a broken bag should not be used.

A minimum of 24 hours will produce a wonderfully behaving lime putty with which to mix mortar. This is easier said than done though, as considerable care has to be given to proportioning, mixing procedures, moisture content of materials at the time of mixing, curing and other factors.

SO, HOW DOES ONE CHOOSE WHICH MORTAR TO USE ON A GIVEN PROJECT?

The Appendix of ASTM C-270 developed in 1951, provides a reference to which mortar type should be used in some general applications. A synopsis of this is:

Exterior, above grade: (Load-bearing wall, Non-load bearing wall, Parapet wall) Type "N".
Exterior, at or below grade: (Foundation wall, Retaining wall, Sewers, Pavements, Walks, and Patios) Type "S" or "M".
Interior, load-bearing wall: Type "N", "S" or "M".
Interior non-load bearing wall: Type "O" or "N".

These ASTM recommendations are based on newer construction standards and the philosophy of "stronger, harder and denser is better". What is not shown in these recommendations is the necessity

The fallacy of compressive strength requirements: This staircase enclosure weighs 112,000 pounds (56 tons). It is 10 feet in diameter and 25 feet tall with 1 foot thick walls (a total footprint of 31 square feet or 4464 square inches). Therefore, the total load at the silo base is only **25 lbs. per sq. inch**. Clearly, Type M mortar at 3500 psi, Type S at 2448 psi, and Type N at 1245 psi are excessively strong.

of incorporating multiple expansion joints throughout the structure (commonly at 20 foot vertical intervals and one at each floor level) to accept the movement that the mortar cannot due to its rigidity.

These expansion joints (which are, it must be said, frequently insufficient to accommodate movement) are then sealed with caulking compounds that have a maximum life expectancy of 20 years, which makes no sense when the potential durability of a properly mortared structure would be 100 years or so until overall maintenance of the mortar is required.

Lime mortars have shown impressive durability expectations over 3,000 years of use in masonry construction, while modern mortars have proven to be less durable during the 100 years in which they have been used, and they are still being modified and understood.

We have been given multiple choices of mortar for our masonry work. One way is to get it done quickly, i.e. using quick setting modern Portland cement based mortar. Another is to use a more 'green' construction material such as lime mortar, which may slow down our building process but give us an environmentally friendly and long-lasting mortar.

THE DECISION IS OURS. REMEMBER, WHEN WE USE LIME MORTAR, HISTORY IS ON OUR SIDE. ■

THE BROTHERHOOD OF THE HAMMER

HAMMER THROWING
By Jim Underwood

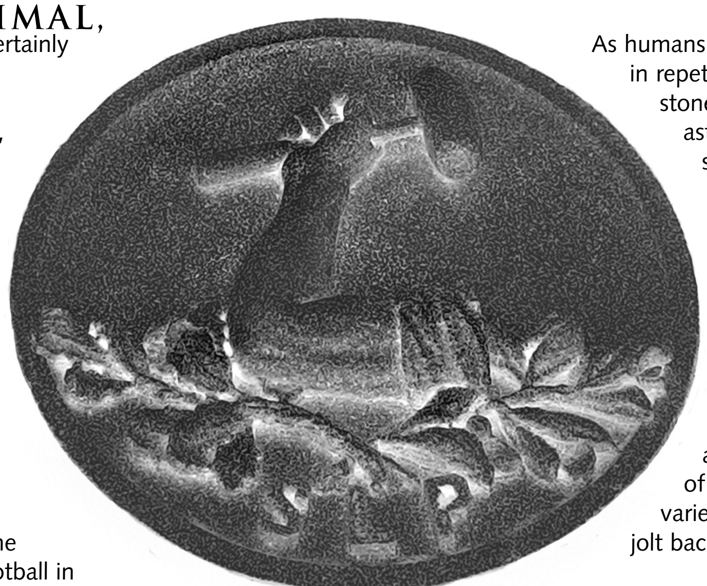
Blacksmith and woodworker as well as a stonemason, Jim Underwood was fascinated by the kinesthetic act of hammering and did not need much encouragement from me to begin work on an article about it. But not long after producing the first draft Jim took sick and, last winter, he died. Jim was, if not one of the Stone Foundation's founding fathers, one of its nurturing uncles. He was a good man and will be missed.

Publishing his unfinished (and unedited) draft seems good way to honor him. In this work in progress, his presence is palpable.

Jim intended to solicit comments from artisans of various persuasions, though he only got around to asking Ken Follet and myself. Our comments are included here as postscripts and I am asking a few other practiced hammerers to add some of their reflections on this elemental act so integral to our craft. If you also have thoughts on the subject, please do share them with us.

T L

THROWING IS PRIMAL, probably predating language and certainly tool-making as the brain evolved. Hammering is just another form of throwing. When you throw a stone, all your control has to be concentrated in a fraction of a second of muscle sequencing; usually you know in that instant whether the throw will be a "sweet" one or not. It's the same with hammering – once the momentum of the hammer is established, there is little (though some) subsequent control possible, and you know when the swing is sweet.



I suspect in all of this a theory on the attraction of baseball and (USA) football in modern society - those great at throwing were the evolutionary genetic heroes.

There has always been primal magic in the old blacksmith's art of bringing iron ore through a smelter to the forge and then to tools. I now suspect that there is primal response in the visual act and the sound of hammering as well, whether by the black or stone smith. Response in both the hammerer and the observer.

In the practice of their trades stone smiths and blacksmiths alike combine hammering (very lateral left brain, motor sequencing) with spatial relationship sensibility (very lateral right brain, artistic). From elemental materials we create useful and beautiful things.

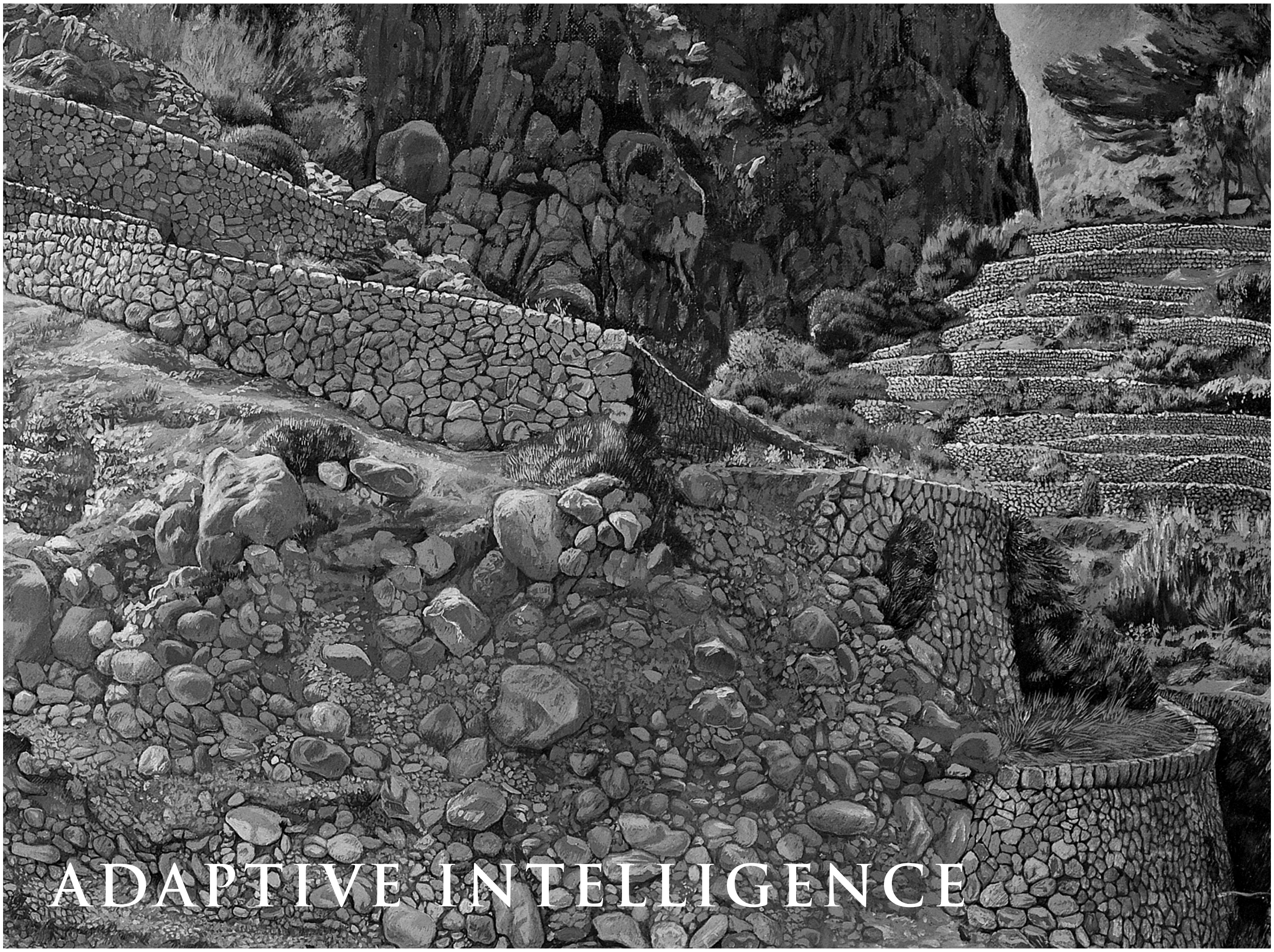
There is a rhythm in hammering that can be harmonic to the body and the ear, or disharmonic to both. Stonemasons know this, and blacksmiths, carpenters and tinsmiths – even shoemakers. There is a brotherhood of the hammer, who have learned to work the arm all day and still hoist a pint in the evening. We could define an apprentice as one who hammers all day and uses the *other* arm to hoist the pint.

As humans evolved we did not often engage in repetitive motions such as blacksmiths, stonemasons and many sports enthusiasts do today. The human arm seems to have evolved to throw things and accomplish tasks in coordination with the eye through certain well-wired pathways in our body and brain. Our aim can become very accurate, whether we are throwing rocks at game or using a throw-stick or a bow to launch spears or arrows. The advantage to the arm of this kind of throwing is that there is irregular, varied motion and little if any stressful jolt back through arm tissues.

Repetitively swinging a hammer at wood, steel or rock, or swinging a tennis racket, are very recent events. Swinging an object to strike another object brings a jolt to the arm on impact that throwing does not. Tying that rock (later, iron or steel) to a handle in order to magnify the swing transmits and magnifies the jolt-stress to the tissues of the arm system. Technological evolution, our braininess, has gotten well beyond the evolution of our physiology in many ways.

But body and brain do learn to cope. The tool becomes an extension of the arm and hand, part of the body as full body/mind integrity develops – conscious at first, then unconscious, instinctive; the same as it is with musicians - body, mind and tool working in balanced harmony. And there is music to hammer sound. An individual cathedral stone-carver can be identified by the rhythm of his hammer taps. It has been recorded that in African smithies a bellows boy develops a unique sound known all over the village, and that the smith can harmonize by his hammering.

Think of shaping rock at your banker, as Tomas mentions below, a sea of stone chips at your feet, each representing a hammer blow,



ADAPTIVE INTELLIGENCE

DRY STONE WALLS OF MALLORCA

by Miguel Ramis

Mallorca is the largest island (1,405 square miles, slightly larger than Rhode Island) of the Balearic archipelago. Due to its strategic location in the western Mediterranean it has been densely populated throughout its long and colorful history. The successful agriculture-based economy that evolved there made territory an important cultural issue.

The flatlands were obviously the most desirable areas and these were possessed by the most important families, the descendants of the noblemen with King James I who defeated the Moors and took control of the island in 1229.

The forests were slowly transformed into cultivated land by the landed gentry and the religious orders, especially the very organized Cistercians. Trees were cut, water channels, mills and cisterns built and the forests physically adapted to suit economic ends. The mountainous areas, with hardly any soil, remained wild. The poor people, called *roters*, (ro-TAIRS) started to establish agreements with the landlords: for the right to inhabit and cultivate a section of hilly terrain they would give the landlord half of what they were able to make the land produce—the practice known elsewhere as sharecropping. The wealthy landlords had nothing to lose, and the poorest people had the opportunity to make a living.

Thus, the hills began to change. Retaining walls, called *marges*, tamed the stony landscape step by built step. Erosion was checked and the soil was held in cultivable terraces on which crops like olives, grapes and onions were grown, produce that had been exported since Roman times. The Sierra Tramuntana is a mountain range in the northwest quadrant of the island; in this area alone over 10,000 linear miles of *marges* were built over time.

After generations of hardscrabble life the most resourceful and hard working *roters* had been able to earn the means to buy the land and the territory started to change from large estates to small farms or *fincas*. Social revolution was the by-product of the transformation of the natural landscape.

Once the erosion was controlled, agriculture in the mountains became possible. Vineyards, olive trees and other plants brought a green carpet to the mountains. Greenery attracts rain, and rain abets the development of a successful agricultural economy.

The dry walls are a home for many creatures: snakes, insects, and especially *caracoles*, or snails, which were an important source of protein in the meager diet of the poor folk and are a delicacy still in Mediterranean cuisine.

The last decades have witnessed an increasing trend for tight stone fitting. This was never traditional in the past. It is nothing a *marger* could not do, but simply illogical in terms of efficiency. Furthermore, smaller joints mean the snails would not be able to house in the *marges*, thus blocking the possibility of gathering them.

To clarify, we are talking here about countryside agricultural terrace walls. There are tight fitting walls dating from 19th century, civil works, such as the roadway walls ordered by Queen Isabel II. These civil works started a trend towards tight fitting that is basically urban.

THE EVOLUTION OF SKILL

Agriculture has always been the proving ground of the art of the stonemason. The ingrained habit of using stone to build non-mortared walls evolved into a traditional building art form, the principles and aesthetics of which were passed from generation to generation of craftsmen capable of conceiving of and executing more demanding and technical stonemasonry designs such as roadways, bridges, water channels and reservoirs, flooring, pavements and, ultimately, sculpture.

DISTINCT FEATURES OF A MALLORCAN WALL

Dry Stone Walls, Polygonality and Arches

In general Mallorcan walls, are comprised of pentagonal and/or hexagonal shaped stones. In rural walls stones are usually placed in the wall as they are found, with little or no shaping, so they tend to be only rudimentary pentagons or hexagons. In more urban or formal settings the stones tend to be tailored polygonal shapes.

As indicated in the detail of the photograph of Mestre Biel and as can be seen in the other photographs, the Mallorcan *marge* is a complex mesh of many interwoven arches. In a well-built *marge*, most stones are surmounted by an irregular arch of other stones—and are themselves elements in one or more other arches.

With rectangular coursed stonemasonry, if a stone is taken out of the wall, a natural corbelled arch is formed by the stones in the courses above it. With polygonal masonry, what you get is a true arch formed by 3 or more stones. The wall would not even notice the missing stone since the arch will be in tension. Because the ground under a wall tends to subside here and there over time, especially after heavy rains, the arches embodied in the wall enter into tension. Hence a polygonal wall can withstand these movements better than a rectilinear wall due to its inherent tensile strength.

A scene from the Stone Foundation's dry stone walling workshop last summer in the village of Deia, Mallorca: Mestre (master) Biel Estela, 76 years old, is assisted by workshop instructor Lluc Mir as Michel Giannesini works nearby and Donna Hasbrouck looks on. Mestre Biel has been working with stone since he was 13 years old. Building such walls has become second nature with him and he is probably not conscious of the interlocking series of arches that he is incorporating into the structure of this one (see detail). Note the rudimentary but effective Mallorcan scaffolding which can be easily removed and repositioned: two planks resting on two stout pieces of rebar inserted into crevices in the wall (the soda can is a safety measure.)

The arch is one of the strongest and most efficient building forms of all times, so it is no surprise to discover that they are integral to this walling system.

Non-Horizontal Coursed Wall

The stones are placed vertically instead of horizontally. In the event of the foundation sinking, the stones adjust, find new positions, obey gravity, work like wedges; tensile strength is not lost. In a horizontally coursed wall, a subsiding foundation immediately causes a loss of tensile strength that can never be regained.

It is no wonder that in Japan and Peru, areas subject to earthquake, a polygonal wall system evolved. The Mediterranean historically is also a seismic zone, so the technique could well be a universal anti-seismic solution.

Paret en sec versus Paret en verd

In Mallorca there is a clear distinction between the *paret en verd*, a horizontally coursed house wall built with lime and earth mortar, and designed to take top-to-bottom bearing weight, and the *marge*, a dry wall with non-horizontal courses, designed to withstand the lateral pressure of the earthen terrace behind it.

Capginyes

The *capginya* (see photo next page, top) is a vertical column of sizable stones placed at regular intervals within the *marge*. This simple and effective design is, in fact, an integral pilaster or in-built corner that, in the event of a collapse on one side, limits the damage and sustains the other side until the repair is made.

A BRIDGE TO FREEDOM

by Tomas Lipps

SEVERE ECONOMIC DISTRESS troubled England in the first half of the 19th century. Work was scarce, particularly in the building trades. Sir John Summerson, the notable English architectural historian, said that "State expenditure on buildings was absolutely withdrawn, except for those of military or naval purpose." Private enterprise was similarly affected. It is reported that one stonemason/artist at that time, walking the roads through thirty-four counties for six months, managed to find employment for only three weeks.

leg irons

In desperation, many people resorted to criminal behavior, from petty theft to highway robbery. There were more convicted criminals than the prisons could contain and sailing ships that were no longer seaworthy were refitted as floating gaols. The need for labor in the new colonies and the lack of space in the prisons resulted in thousands of criminals being transported to Australia and the neighboring islands. For stealing an overcoat or a piece of lace a man or woman could be imprisoned and transported to a life of servitude in the new colonies.

In the British penal colony of Van Damien's Land (later named Tasmania after the Dutch sea captain, Abel Tasman, who first encountered it in 1642) the most important road was the Midland Highway, connecting the administrative center in Hobart Town in the south and Launceston, the island's second largest municipality, in the north. The road crossed the Macquarie River at the township of Ross.

It was necessary to ford the river there until 1822 when the first bridge was built, a rough affair comprised of dry stone piers spanned by logs on which dirt was piled. Six years later it was in such a ruinous state that the Lieutenant Governor, George Arthur, in response to the entreaties of townspeople and settlers living in and around Ross, directed the Royal Staff Corps to commence repair of the bridge. A party of six convict laborers in the charge of an army lieutenant was dispatched to Ross, but because the winter of 1829 was just beginning there was little to do.

They were but loosely supervised and left largely to their own devices. "They rose in the morning and went openly to work for the settlers like any free men, and spent their evenings at the Angel or the Sherwood Castle (pubs) more freely than most men. They were, in many ways, model citizens; they earned their money and spent it promptly on the spot. But they did not repair the bridge, which became more dilapidated each week."[1] Finally, on the 20th of March 1831, it collapsed.

Response was immediate, or nearly so. In May a contractor was dispatched from Hobart with a crew of forty men. Within two days the bridge was repaired enough to use again and the men were put to work setting up a brick kiln, transporting wood to fire it and cutting stone from the quarries close to the town for a new bridge—a bridge about which no decision had yet been made—either where it would be sited or of what material it would be constructed.

STONEWORK, BONDING, PRINCIPLES OF

by Joe Kenlan

THE ORIGIN OF STONEMASONRY

and, arguably, of architecture, is in the prehistoric development of bonded stonework. This allowed for the construction of free-standing walls of sufficient height and an economical width so that houses and other buildings with load-bearing walls and openings for doors and windows became practical. Think of a lintel as a stone spanning a very wide joint.

Over time, bonded stonework seems to have evolved into two separate styles or systems. At the recent Symposium and in his introduction to the article on Mallorcan dry stone walling, Tomas Lipps has described these as 'static' and 'dynamic.' The static system is principally employed in load-bearing structures. The dynamic system is most useful when there are lateral forces to be resisted (in retaining walls, for instance).

In more dynamic styles of masonry, tension in the wall is dispersed in all directions, causing the composite wall to act as a unit. One example of this is the 'honeycomb' style done so beautifully in Japan and elsewhere. In these walls massive battered corners are laid up and the body of the wall between them filled with six sided stones very carefully set 'on their points' in a honeycomb pattern. Due to the interlocking nature of the pattern pressure is exerted in many directions within the wall, enabling it to accommodate gravity and use it to resist its enemies: the lateral force of the mass held in place behind the wall, hydrostatic pressure, the settling of the earth under the wall and unsettling seismic tremors.

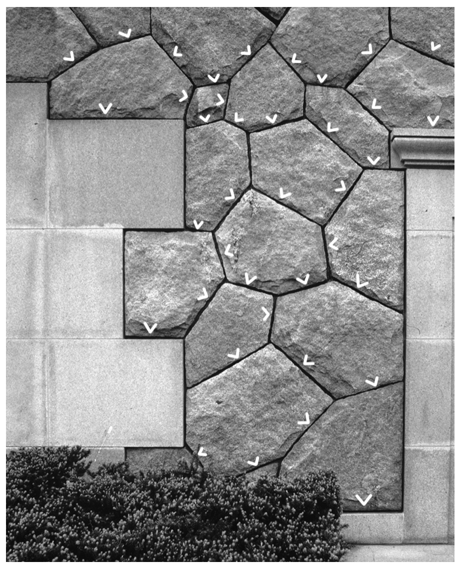
In addition, the weight of the heavy, sloping corners actually bears on the body of the wall (and the backfill), placing the whole structure in compression—the greater the pressure, the stronger the wall becomes. The result is an intuitive response to the stresses expected in a seismically active area.

The static form works on the assumption that gravity always acts perpendicular to the earth. Accordingly, it is designed to resist this by means of a horizontally oriented structure. Its mass, and the integrity of that mass, are all it has to resist lateral or uneven pressures, so care has to be taken in the way it is footed. Much of the world's formal architecture from the pyramids to the great cathedrals is static in nature, although static systems often incorporate dynamic forms: the arch and extensions of the arch—the vault and the dome for example.

Since this level and plumb style of work is what is built and taught in my country, I'll concentrate on that.

The reason I'm bringing it up at all is that a curious thing appears to be happening in recent years in stonemasonry. Apparently, the way in which stonework is bonded has come to be widely regarded as a matter of minor importance, a mere reflection of personal taste. I say this based on the amount of work I see that seems to pay no attention to the principles of bonding, not only in my area of North Carolina and elsewhere, but 'gracing' the pages (and even the covers) of a number of popular 'how to' books and magazines.

This is a common syndrome among apprentice masons and workshop students whose eagerness to get on with the fun of putting stones together causes them to lose sight of the fact that what they are really



Left: Washington, D.C. Polygonal wall showing diagonal forces at work. Photo: T L

Below: Park College, Parkville, Missouri
A section of well-bonded, static style, quadrilateral stonemasonry. Notice that the three rules mentioned in the article have been respected: (1) every vertical (and diagonal) joint between two stones has been covered, (2) with adequate overlap by the stone above and (3) every vertical (and diagonal) joint has a single stone on one side. The horizontal bed joints are broken and the courses tied together by the taller 'jumpers.' The diagonal vertical joints give liveliness to what would be less interesting if every stone were a rectangle. All of the weight of the wall is bearing directly down, but from any one of a number of points—in this case the large stone marked with a dot at the top of the photo—it tends to spread in a roughly triangular pattern. Photo: T L