The Four Elements of Santorini Architecture
Lessons in Vernacular Sustainability

Thanos N. Stasinopoulos
School of Architecture, NTUAthens, Greece
tns@oikotekton.net

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An ancient philosophical theory:

Four fundamental elements
-Fire, Earth, Air, Water-

generate all natural entities & phenomena through numerous interactions.
The Four Elements connotations

<table>
<thead>
<tr>
<th>Fire</th>
<th>Earth</th>
<th>Air</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>warm - dry</td>
<td>cool - dry</td>
<td>warm - humid</td>
<td>cool - humid</td>
</tr>
<tr>
<td>(summer)</td>
<td>(winter)</td>
<td>(autumn)</td>
<td>(spring)</td>
</tr>
</tbody>
</table>

Greek philosophers linked the Four Elements to the Platonic solids. Aristotle related them to our senses, with further reference to the four seasons.
An obscure **Fifth Element** (‘Ether’?) binds the other four together being the **catalyst of life**.

…thus the **fifth Platonic solid** completes the geometric correlation.
Three additional actors

Nature includes 3 more ‘actors’: man, flora & fauna, all surviving by adapting to the conditions imposed by the Four Elements.

The extra Fifth Element [?] distinguishes living from dead matter.
The Four Elements as an architectural prism

The Four Elements concept offers a handy tool to probe methodically the link between nature & architecture. Vernacular settlements offer splendid examples of that link, developed long before our Machine Age, where electricity and oil substitute ingenuity and prudence.

Case study: Santorini
The island of Santorini

Santorini or Thira: a group of islands around the volcanic bay of ‘Caldera’ 90 km north of Crete.

“The blue drinkable volcano”
• The volcanic cataclysm of 1500 BC
• Is Santorini Plato’s Atlantis?
• Traces of the legend in Akrotiri?
Santorini climate

A sun-scorched, wind-swept, dry land:
- much sun, little rain
- sea mass brings high humidity, mild winters & summers
- exposed to strong [north] winds

1 comfort zone: no extra heating / cooling required
2 thermal mass zone: comfort via heat emitted/absorbed by building mass
3 ventilation influence zone: comfort via convection / sweat evaporation
4 activity influence zone: comfort via metabolic heat
5 mechanical cooling zone: comfort via air conditioning
6 mechanical heating zone: comfort via heating system
The fear of pirates relocated villages far from the shore on steep cliffs or hidden valleys where they were harder to spot or to reach from the sea.
The urban fabric

High density, narrow streets, small buildings due to:

- shortage of safe land
- mutual protection from sun & wind
- security
- family growth
- construction economy
- the highly communal spirit of the old societies.
Major building features

Solid volumes, thick walls, small openings, unifying plaster fused into neighbourhoods via flexible repetition.
Major building features

- organic forms, responding to environmental constraints using local resources, imprinting social evolution
- ergonomic scale similar to ships
- material & space **minimalism** vital for sustainability
- products of necessity rather than choice.
A r-evolution

Neoclassical evolution: an iconoclastic departure from tradition by rich captains.
**EARTH: Building materials**

- Red & black lava stone everywhere
- Timber: an exotic luxury
EARTH: *Theran soil*

‘Theran earth’, a volcanic ash like cement: strong, cheap, local.
An architecture of **compression**: thin vaulted roofs bridging thick sidewalls at any scale.
Vault examples

Cross vaults of a rich mansion

Vaults of various footprints

A cross vault over a small farm storage
Parapets enclosing a layer of pumice transform vaults into a ‘flat roof’ - a fashion for the wealthy.
Luxury had more signs than just ‘flat’ roofs.
EARTH: *Fashion tricks*

in less lavish examples the vault ‘enhancement’ was limited to the front side only...

...but fashion is inverse today:
Frequent tremors necessitate aseismic rules about building geometry & structural elements.
EARTH: *Excavated shelters*

Topography and construction economy led to vaulted caves of various sizes & uses, excavated into soft but coherent volcanic ash. Their masonry fronts may well support a terrace or a footpath above.
**EARTH: Excavated dwellings**

- deep caves are divided in 2-3 rooms by partitions similar to front elevations
- most aseismic structures
- natural heating & cooling due to earth mass
- drawbacks: poor ventilation & daylight.
3-D urban layout with a complex property system.
EARTH: Material recycling

- a major construction difficulty: transport of materials
- the only available means: donkeys & mules
- rule 1: respect ground stability
- rule 2: embed or recycle to lessen transportation burden.
FIRE: Cooling

- A too sunny place
- Excessive insolation creates discomfort by reflections, glare, heat-emitting mass
- Shading devices were too costly or flimsy
- Climbers require precious water and cannot endure winds
- Solar protection is provided by adjacent buildings or free-standing walls
- ‘Meltemi’ offers relief when not too strong
- Only caves comfort in daytime, thanks to low radiant temperature.
FIRE: Heating

- Winter is humid & windy
- Fireplaces did not exist, just small portable stoves - 'mangali'
- Bush branches were the main fuel
- Heavy clothes, metabolic heat, or patience were the alternatives
- Radiant heat from cave walls improved comfort for most of winter
- Small openings reduce heat losses...
- ...but at the same time they decrease daylight to the interior
- Artificial light only from oil lamps & candles.
• annual rainfall <370mm
• no underground water reserves
• plants survive thanks to air moisture
• meagre vegetation offers little firewood
• humidity promotes mould in poorly ventilated caves…
• …and lessens indoor comfort at the end of winter.
WATER: Rainwater collection

- Rainwater collection was absolutely vital, affecting building layout & form.
- The precious liquid was directed from roofs & terraces to cisterns via well-laid routes.
- Limestone was used for disinfecting the cistern and the water route - that had to remain free of droppings.

access hatch

cistern under terrace
Washrooms were away from the main quarters, over a collection tank; its contents were periodically transported to the fields as a man-made fertilizer.

Today tankers bring water to the arid island, supplementing the desalination plant. Thus many old cisterns are converted to septic tanks and swimming pools emerge everywhere.
**Air: Wind**

- totally exposed to the frequent strong winds - local plants know that too well
- extra discomfort by sand-blasting turbulence
- wind protection is vital for outdoor living, more than a ‘nice’ view.
• ventilation & daylight provided into caves only through their façade.
• top clerestory lets warm air to escape; brings daylight deeply.
• vertical ducts through the ground admit extra air & light.
• lack of heating plus limited ventilation trigger condensation & mould growth, assisted by soil moisture.
• bad indoor air, chronic water shortages, co-existence with numerous animals: a smelly rather than idyllic picture of everyday life in the past.
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<tr>
<td><strong>layout</strong></td>
<td>dense fabric for mutual shading</td>
<td></td>
<td>stepped back due to topography</td>
</tr>
<tr>
<td><strong>building types</strong></td>
<td></td>
<td></td>
<td>excavated masonry vaults</td>
</tr>
<tr>
<td><strong>layout features</strong></td>
<td>yards for shade</td>
<td>terraces for rainwater collection</td>
<td>yards for wind protection</td>
</tr>
<tr>
<td><strong>materials</strong></td>
<td>Theran soil for mortar pumice for insulation</td>
<td>no water? no timber!</td>
<td>robustness needed, to withstand wind</td>
</tr>
<tr>
<td><strong>walls</strong></td>
<td>heat capacity dampens temperature swings</td>
<td>no timber? vaults! rainwater collection</td>
<td>wind protection plastered to avoid decay</td>
</tr>
<tr>
<td><strong>roofs</strong></td>
<td>insulated with pumice</td>
<td></td>
<td>heavy to avoid uplift</td>
</tr>
<tr>
<td><strong>windows</strong></td>
<td>small size reduces heat transfer</td>
<td>stone lintels</td>
<td>shutters behind glazing for wind protection</td>
</tr>
<tr>
<td><strong>forms</strong></td>
<td>compact to minimise fabric heat flow</td>
<td>curved structures with compression materials rainwater channelling affects geometry</td>
<td>aerodynamic shapes &amp; details reduce wind effects</td>
</tr>
<tr>
<td><strong>heating</strong></td>
<td>minimal direct gain</td>
<td>no fuel for heating, just for cooking moisture lessens indoor comfort</td>
<td>wind may reduce comfort</td>
</tr>
<tr>
<td><strong>cooling</strong></td>
<td>high reflectivity reduces solar load warm mass emits heat</td>
<td>no timber for shading no climbers for shading moisture enhances indoor comfort</td>
<td>wind may improve comfort strong winds damage shading devices</td>
</tr>
<tr>
<td><strong>ventilation</strong></td>
<td>clerestories expel warm air</td>
<td>dampness &amp; mould due to limited ventilation</td>
<td>clerestories &amp; air ducts enhance air movement</td>
</tr>
<tr>
<td><strong>daylight</strong></td>
<td>small openings sufficient for summer daylight clerestories admit daylight more deeply</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>watering</strong></td>
<td></td>
<td>rainwater collection in cisterns plants surviving on moisture</td>
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Conclusions

The architecture we cherish nowadays as ‘picturesque’ is in fact the outcome of a long struggle for survival in an adverse setting by many generations that have squeezed their means out of the available resources in a truly sustainable manner.

The locals adapted their comfort & needs to the given conditions, merging the Four Elements into an honest & minimalist architectural idiom: a brilliant example of vernacular environmental sustainability.

Perhaps here we should perceive the ‘Fifth Element’ as the spirit and ingenuity of the locals that have created and sustained life through the other Four Elements.