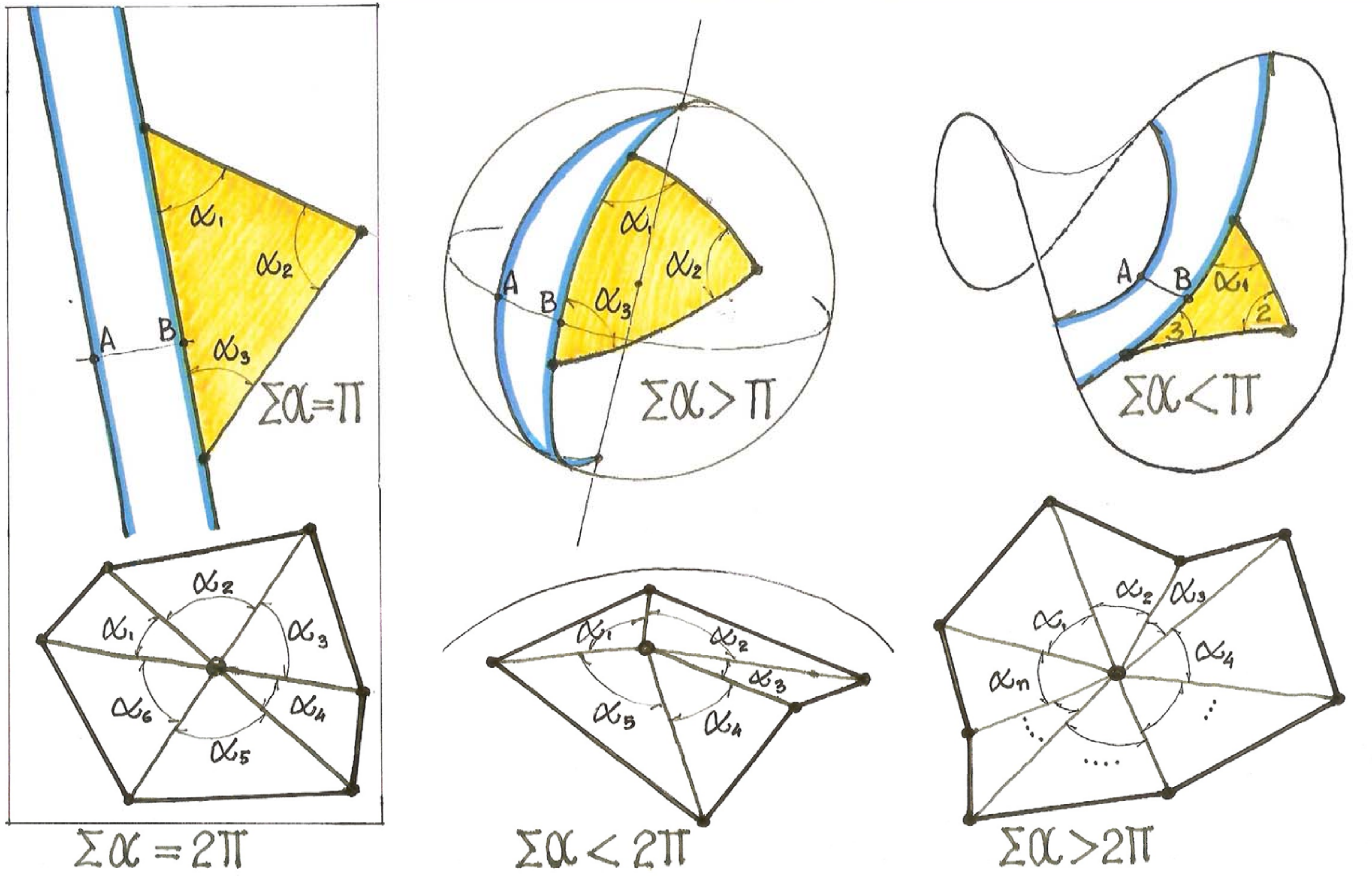
HYPERBOLIC IMAGERY AND STRUCTURL MORPHOLOGY- IT'S APPLICATION TO INNOVATIVE SPACE STRUCTURES.

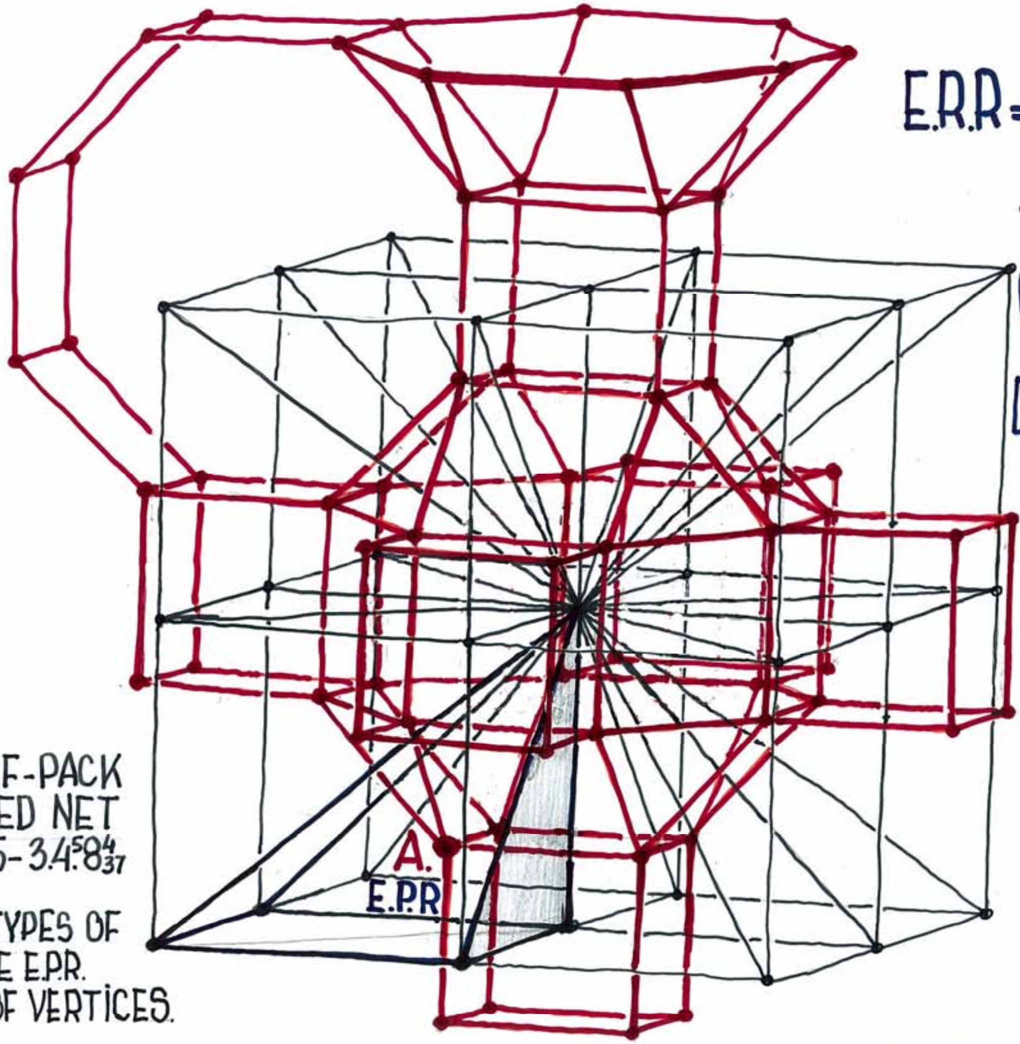
Michael Burt, Arch., D.sc., Prof. Emeritus.
Technion, Israel Institute of Technology.

Hyperbolic geometry is relatively a late comer to the science of mathematics and to the awareness of the structural engineering world. Hyperbolic surface imagery is uniquely related to space partitions with an infinite spread, minimal doubly curved (saddle shaped) surfaces, infinite polyhedra and networks, and could be envisioned and solved as highly periodic and techno-economically efficient space structures.

EUCLIDEAN GEOMETRY | SPHERICAL GEOMETRY | HYPERBOLICAL GEOMETRY



31.01.2013-M.B.



E.R.R = 1/24 OF THE CUBE'S VOLUME.

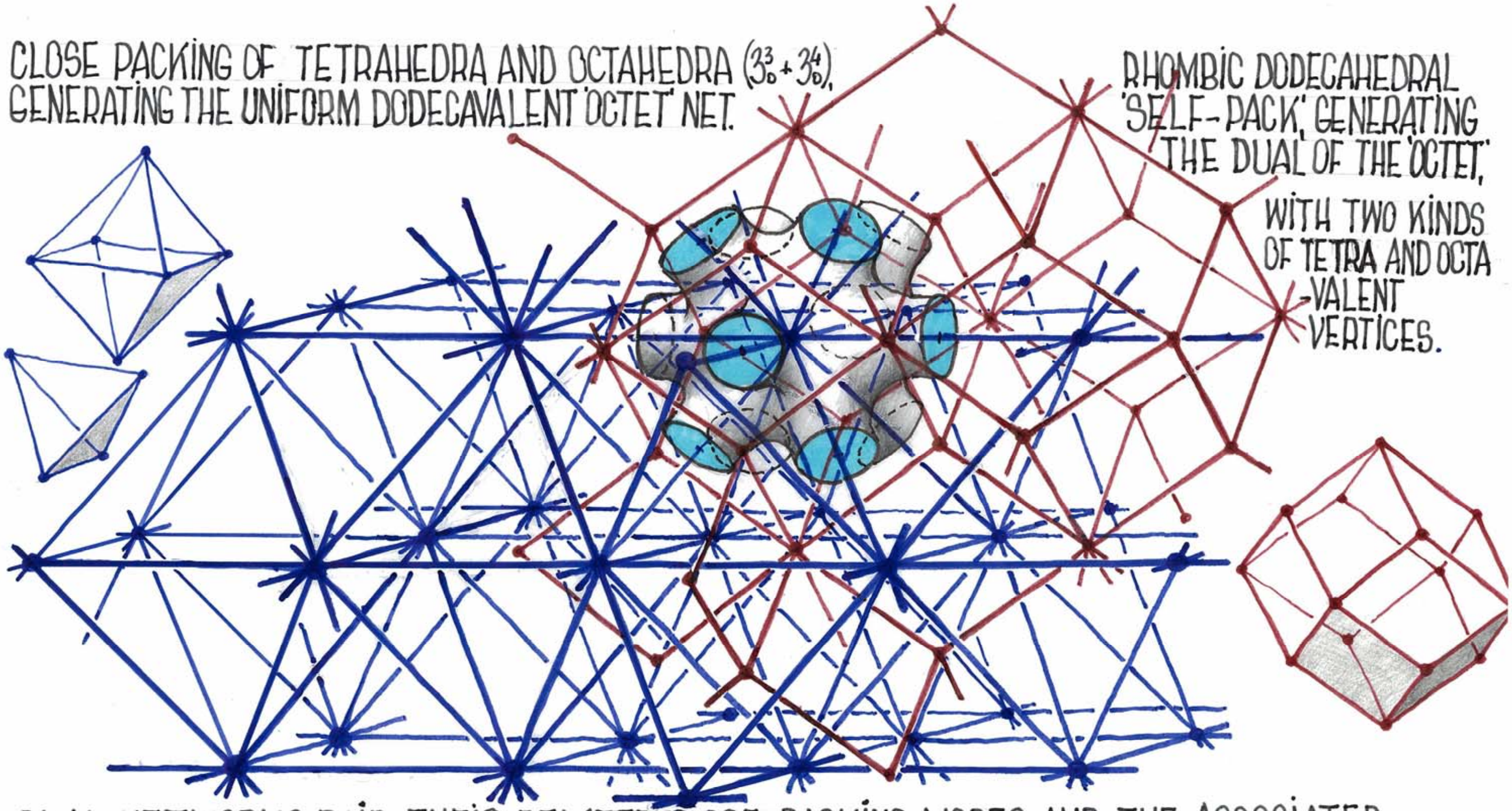
THE NETWORK DESCRIBES CLOSE PACKING OF 4^3_0; 3.4^3_0; $4^2.8_0$

Den. PV.-5-$3.4^5.8^4_{37}$=1.507575951 a/a³

THE E.P.R IS A SELF-PACK AND THE GENERATED NET IS A DUAL OF PV.-5-$3.4^5.8^4_{37}$

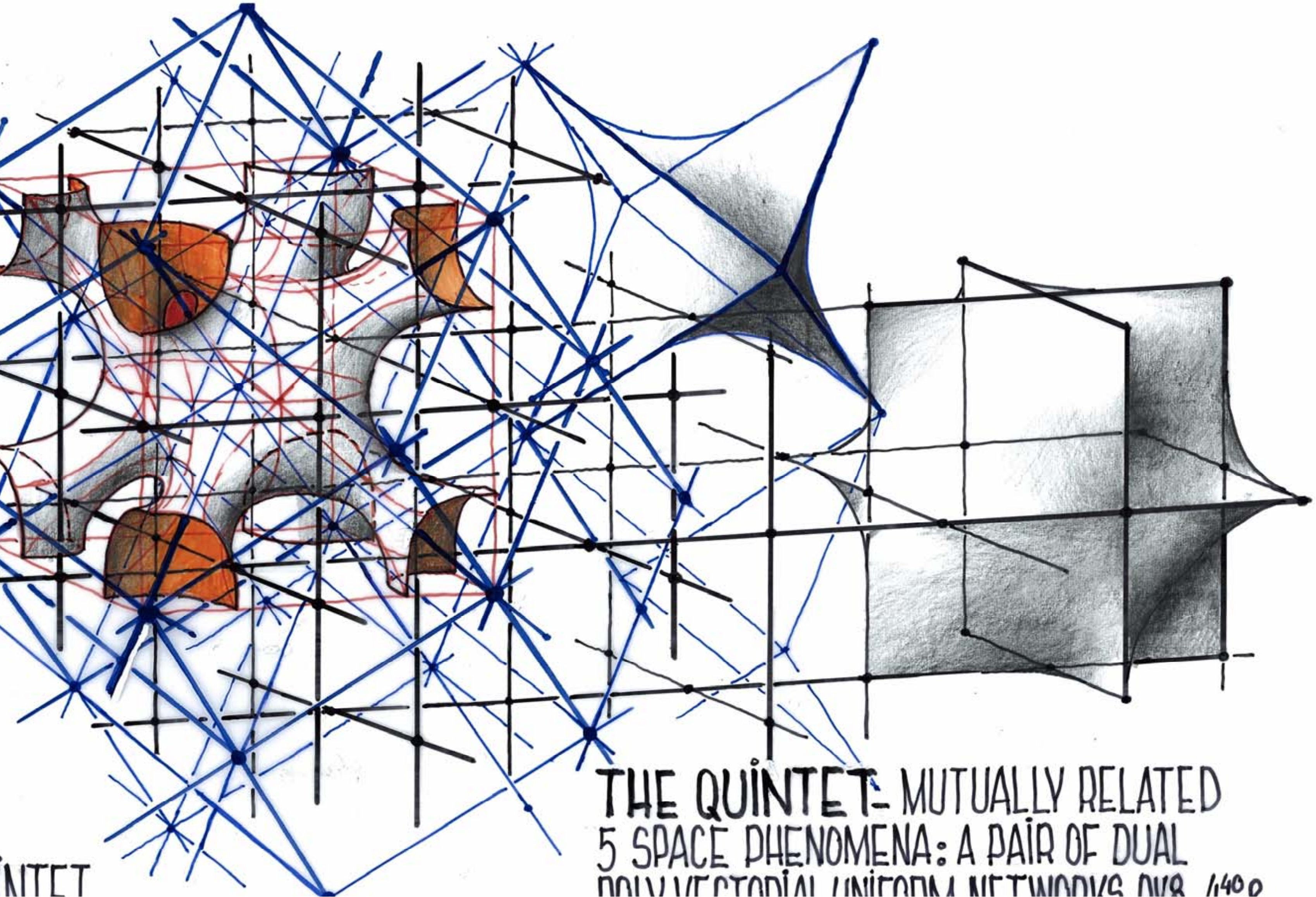
PV.5-$3.4^5.8^4_{37}$ HAS 3 TYPES OF PACKING SOLIDS; THE E.P.R. NET HAS 3 TYPES OF VERTICES.

UNIFORM PENTAVALENT POLI-VECTORIAL P.V.-5-$3.4^5.8^4_{37}$ NETWORK GENERATED BY IN-VOLUME VERTEX-LOCATION OF ITS E.P.R. (A.)



DUAL NETWORKS PAIR, THEIR RELATED CLOSE-PACKING MODES AND THE ASSOCIATED HYPERBOLICAL PARTITION SURFACE, SUBDIVIDING THE SPACE BETWEEN THE TWO.

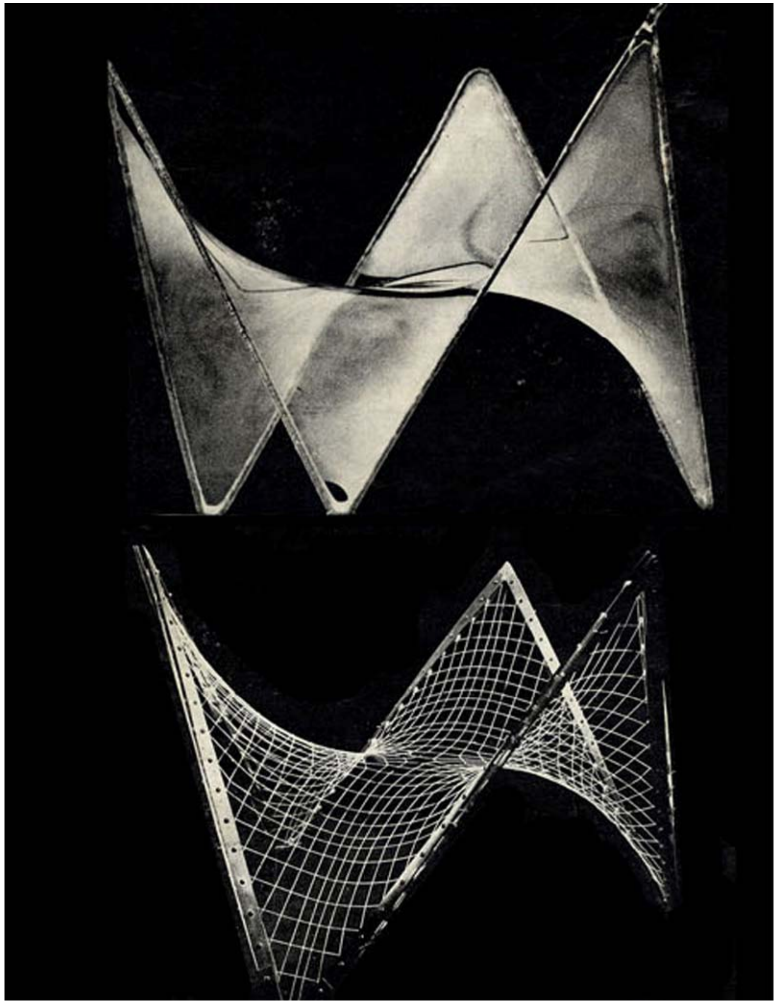
THE 'RECIPROCAL QUINTUPLET' PHENOMENOLOGY OF THE 3-DIMENSIONAL SPACE.
"IF YOU HAVE ONE, YOU HAVE THEM ALL".

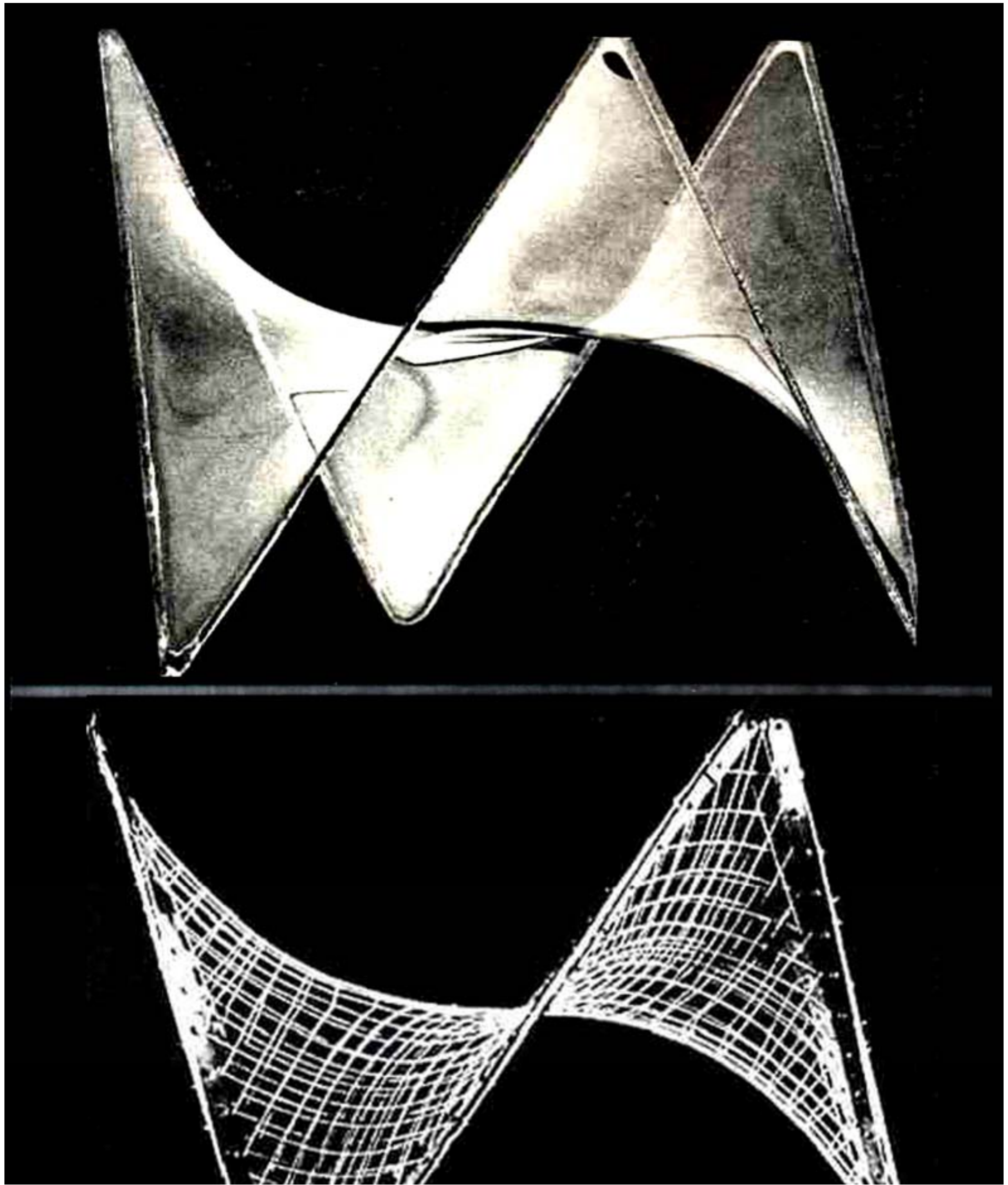


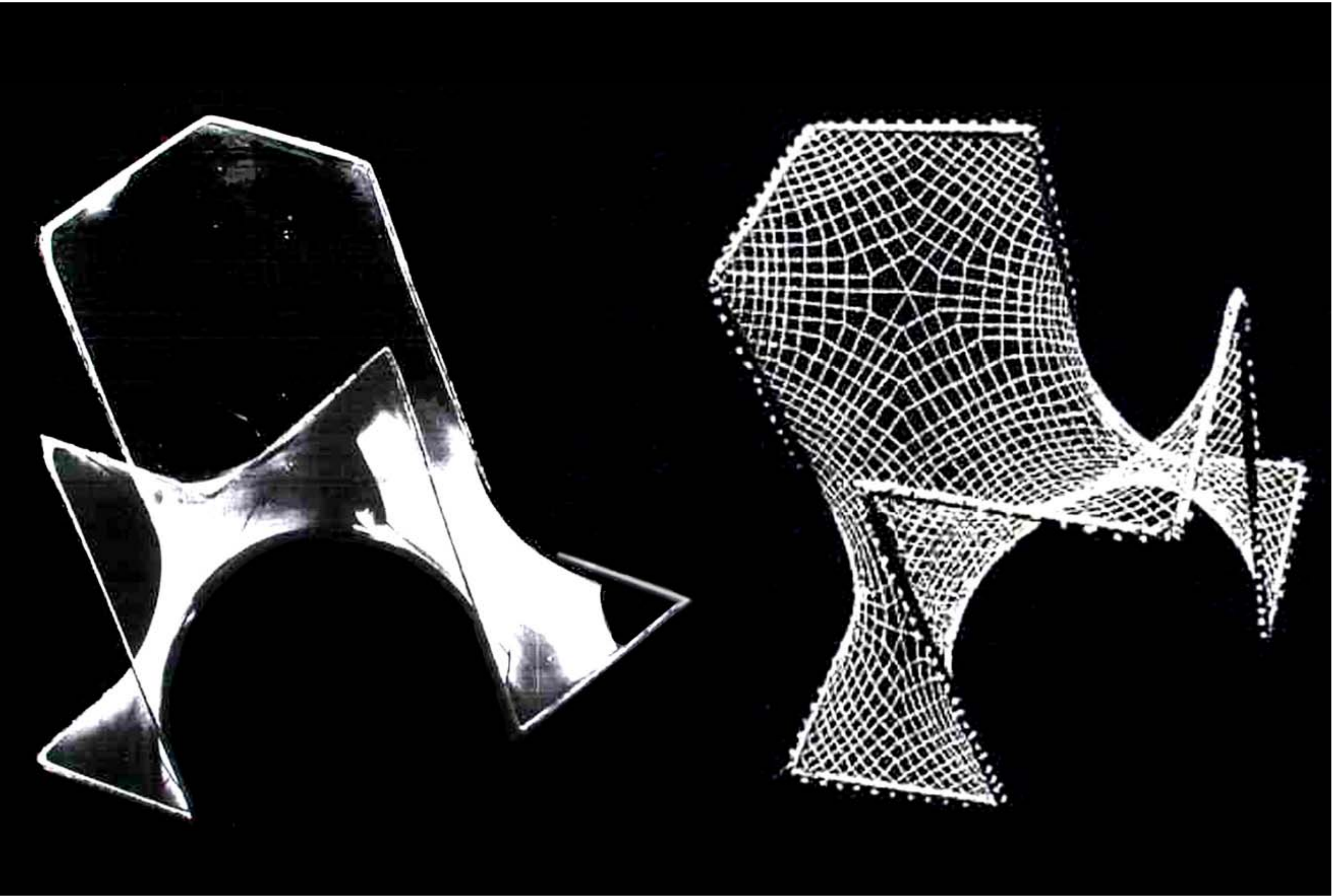
THE QUINTET- MUTUALLY RELATED
5 SPACE PHENOMENA: A PAIR OF DUAL

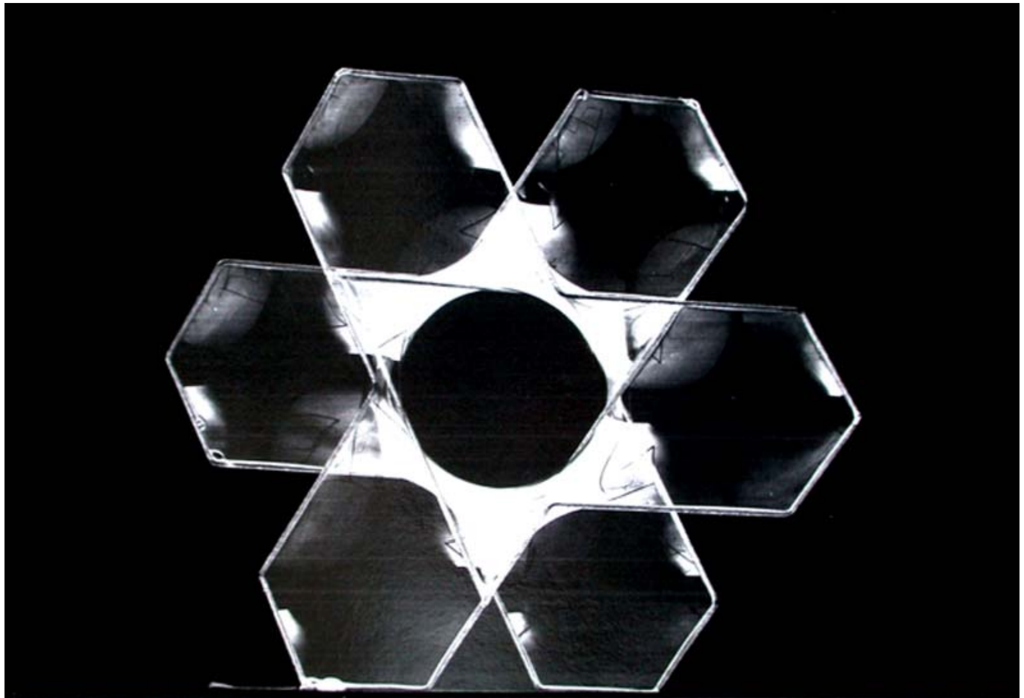
B

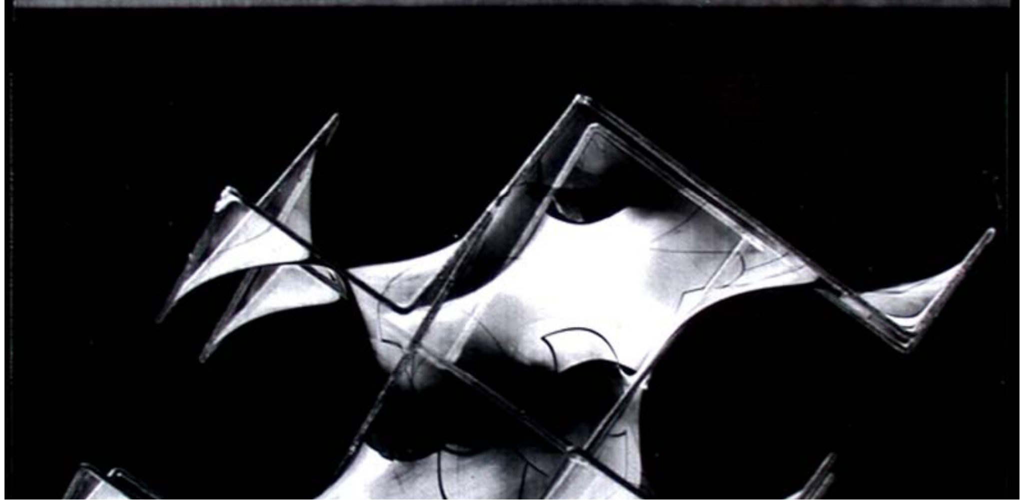
ur study of natural form”, the essence of morphology, part of that wider science of form which deals with the ns assumed by nature under all aspects and ditions, and in a still wider sense, with **forms which theoretically imaginable”…..(**On Growth and Form – rcy Thompson), "Theoretically" to imply that we are ling with causal- rational forms.

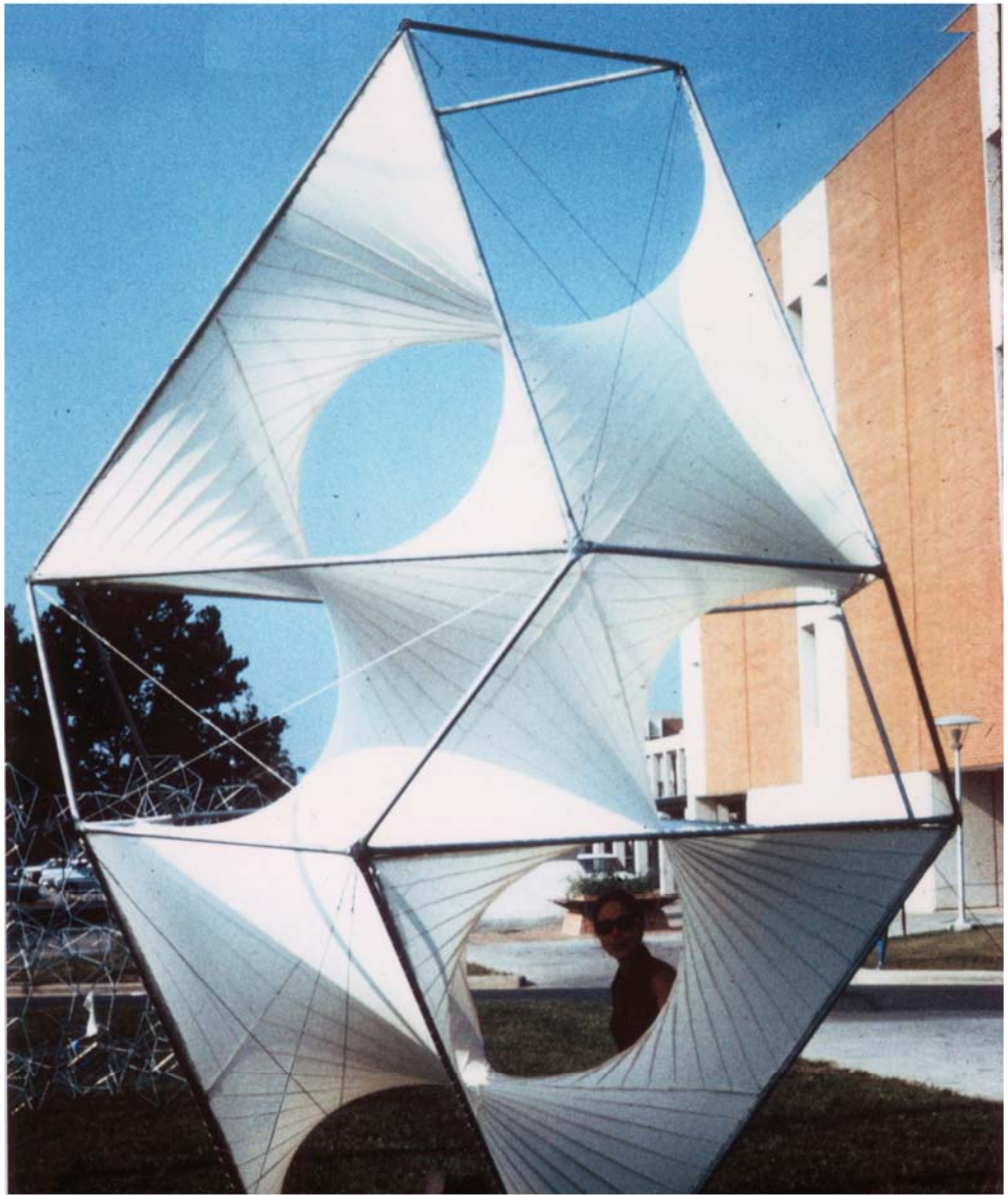


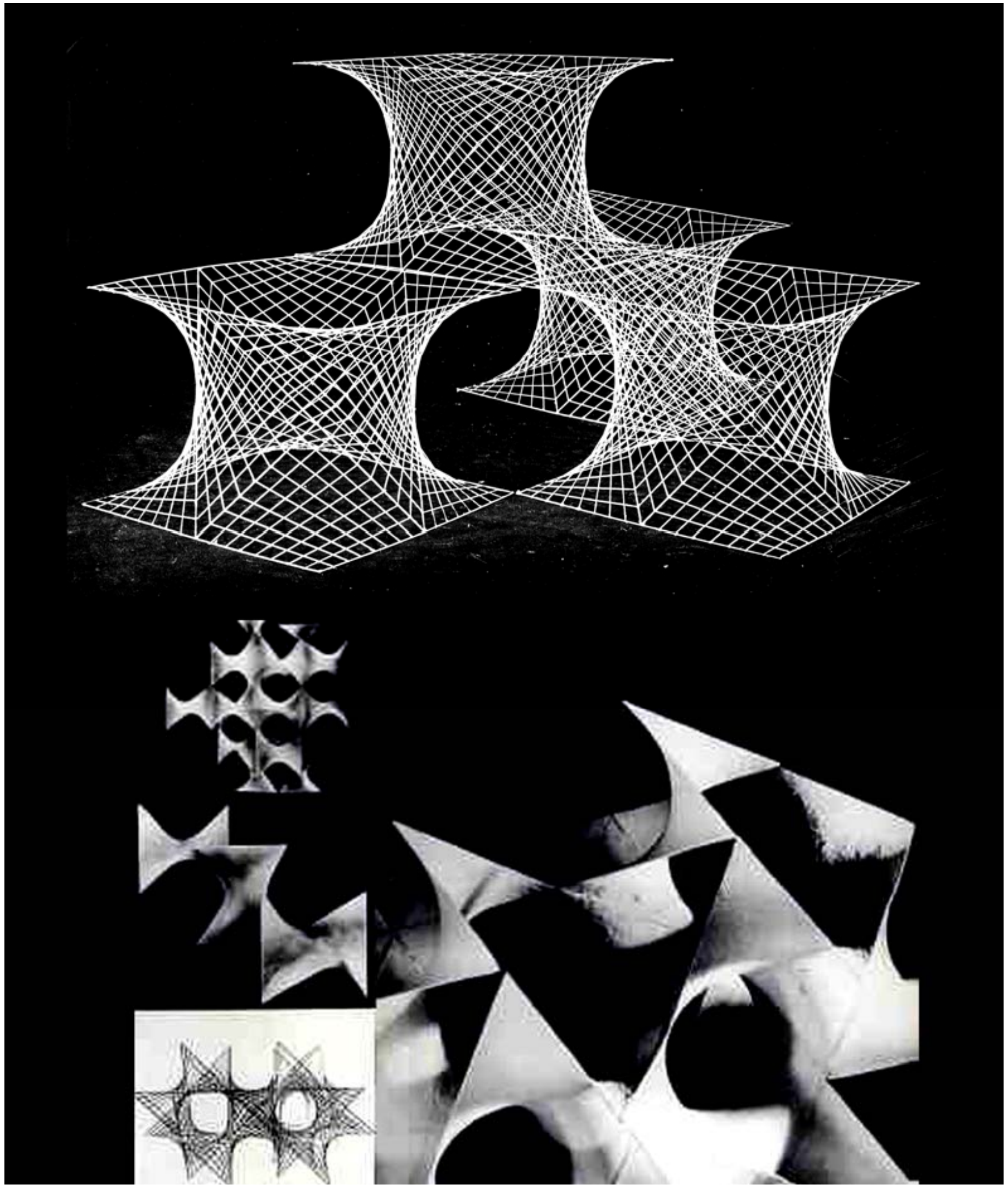


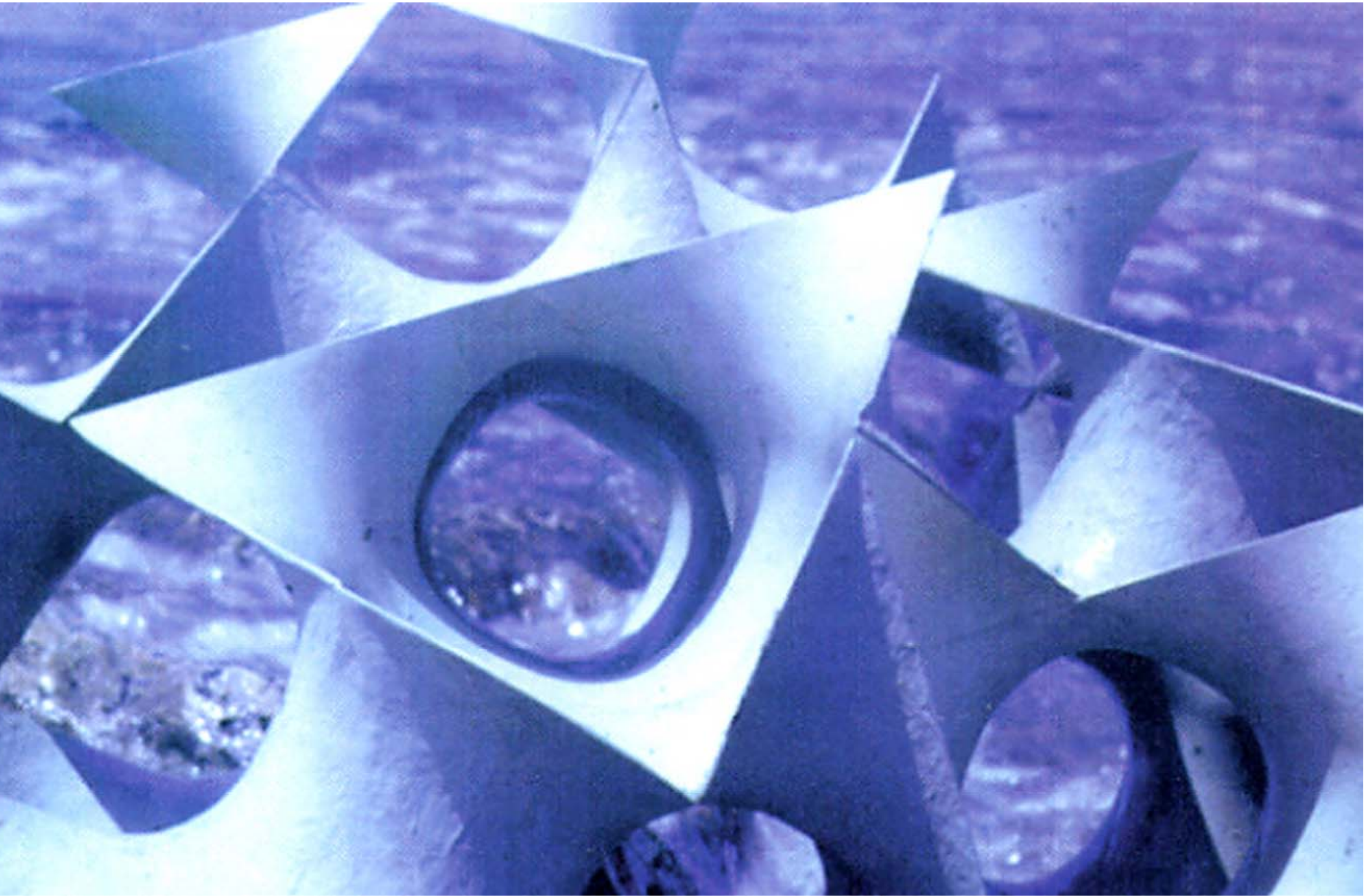


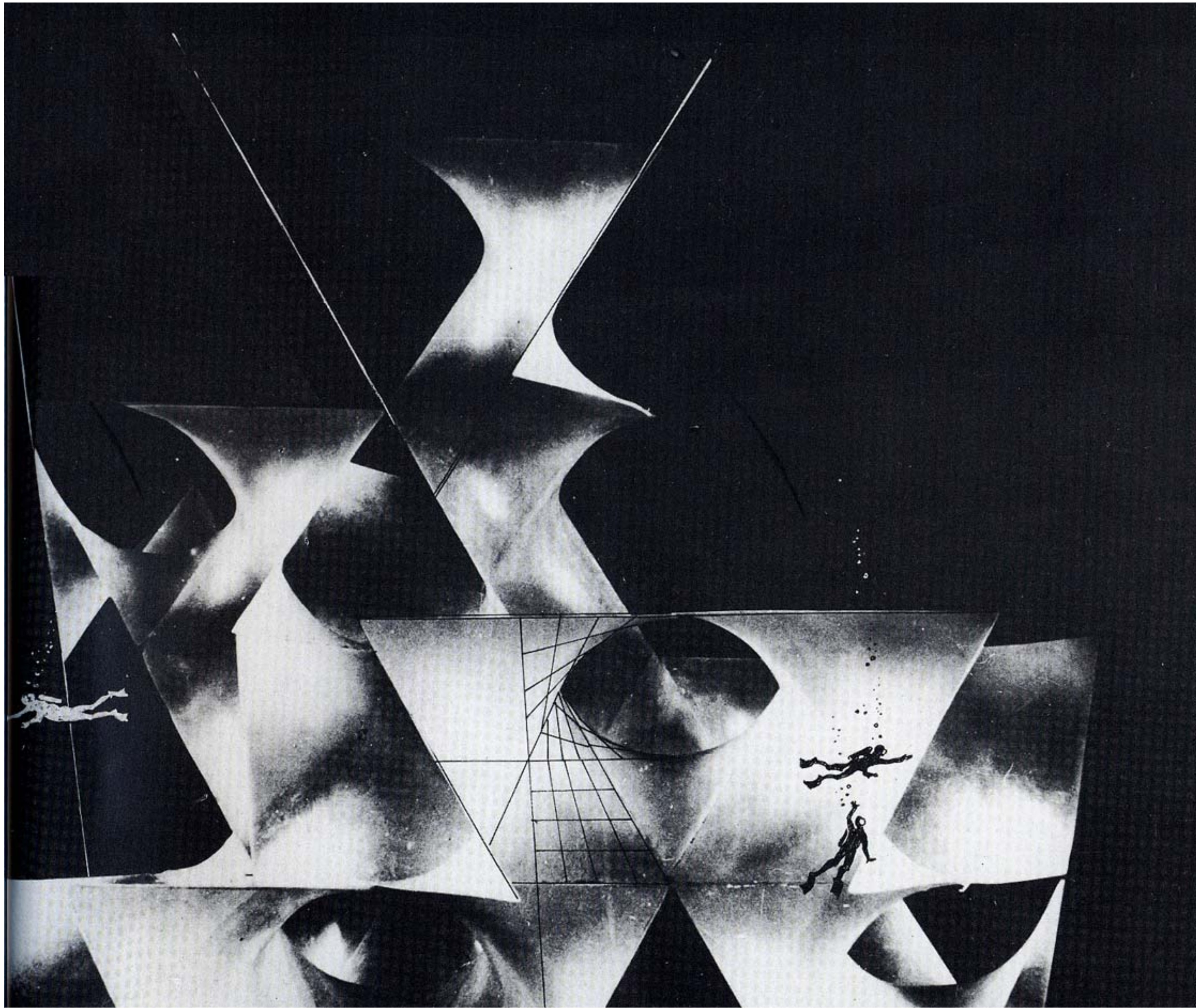


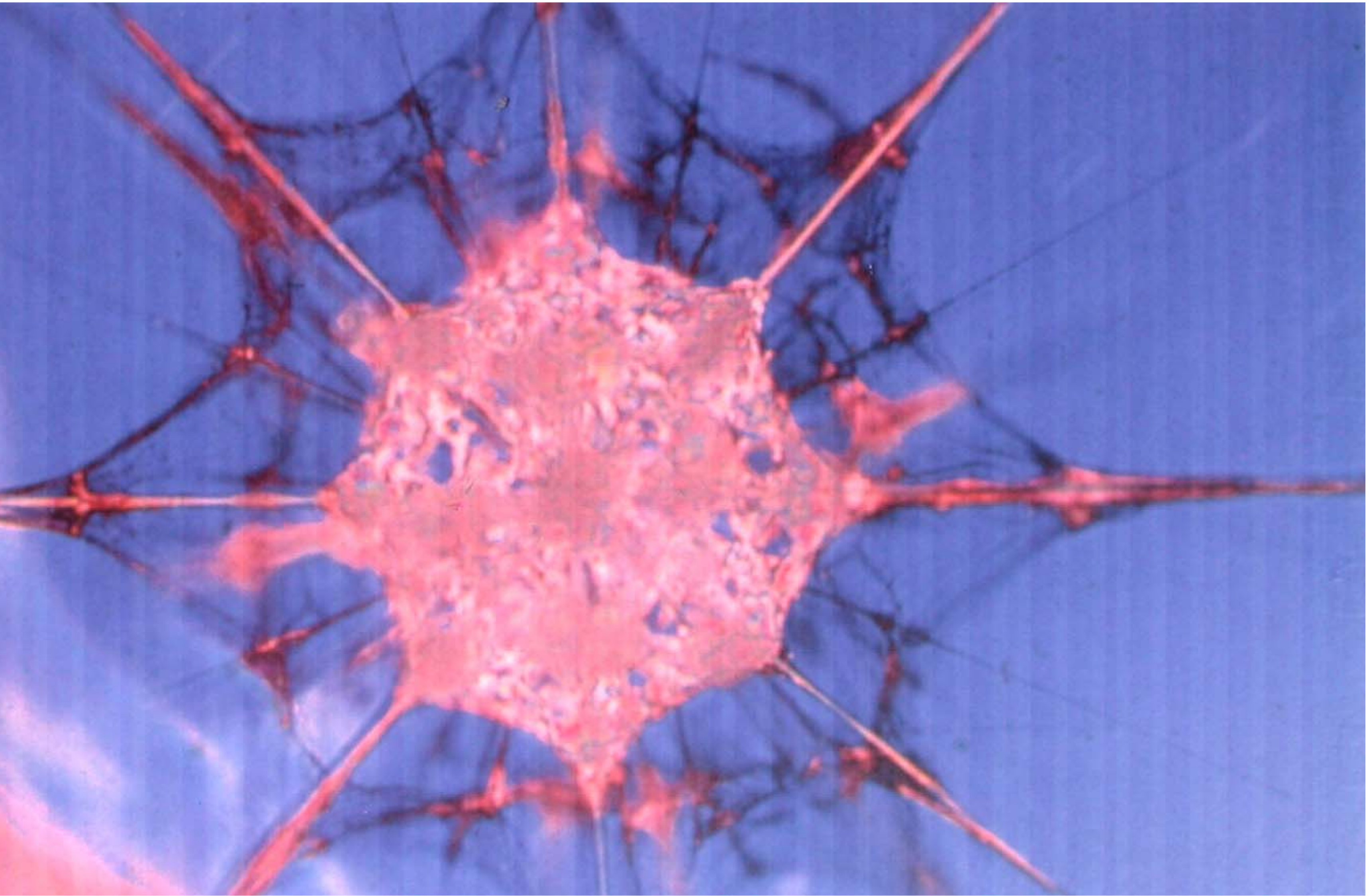


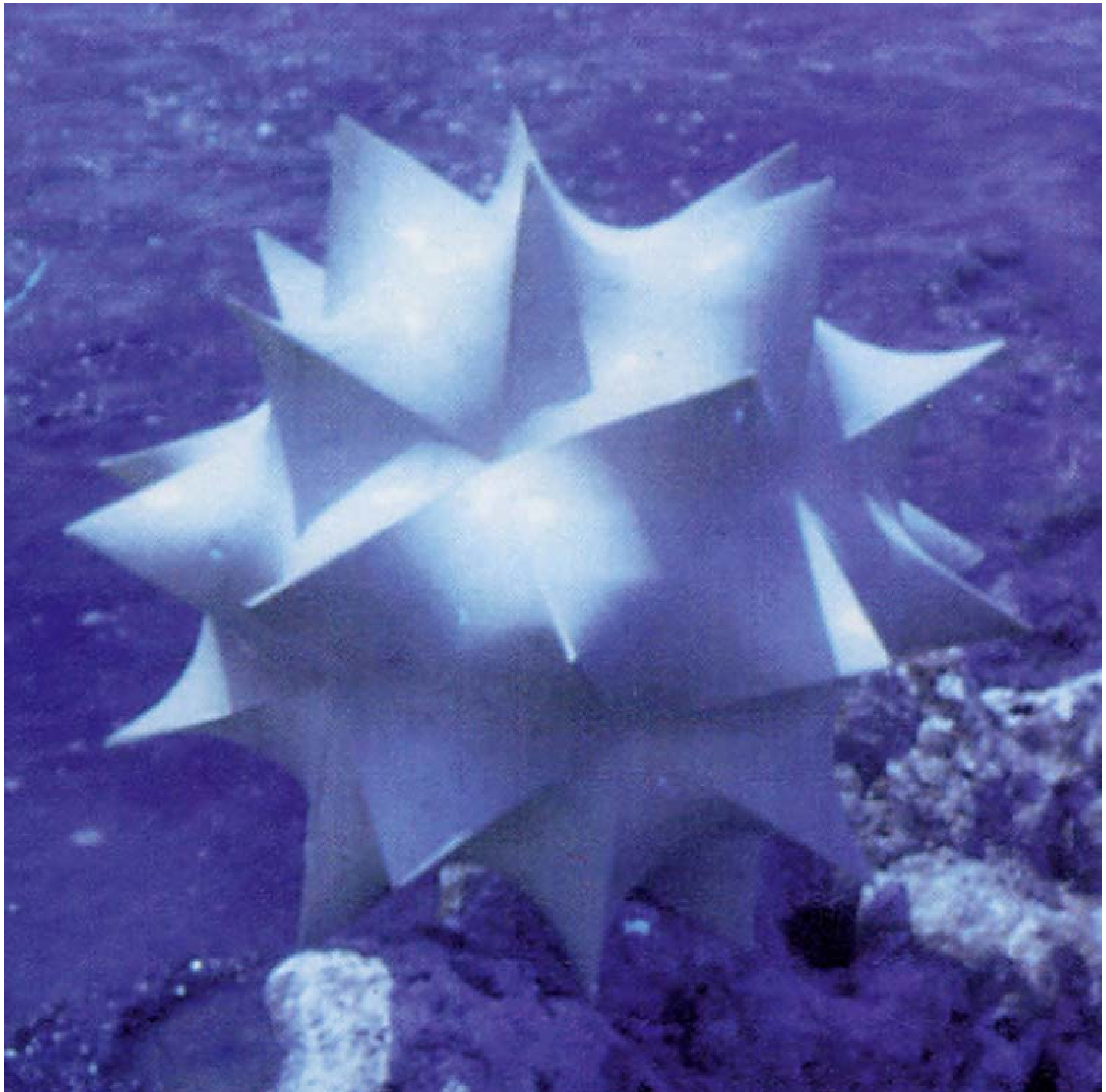


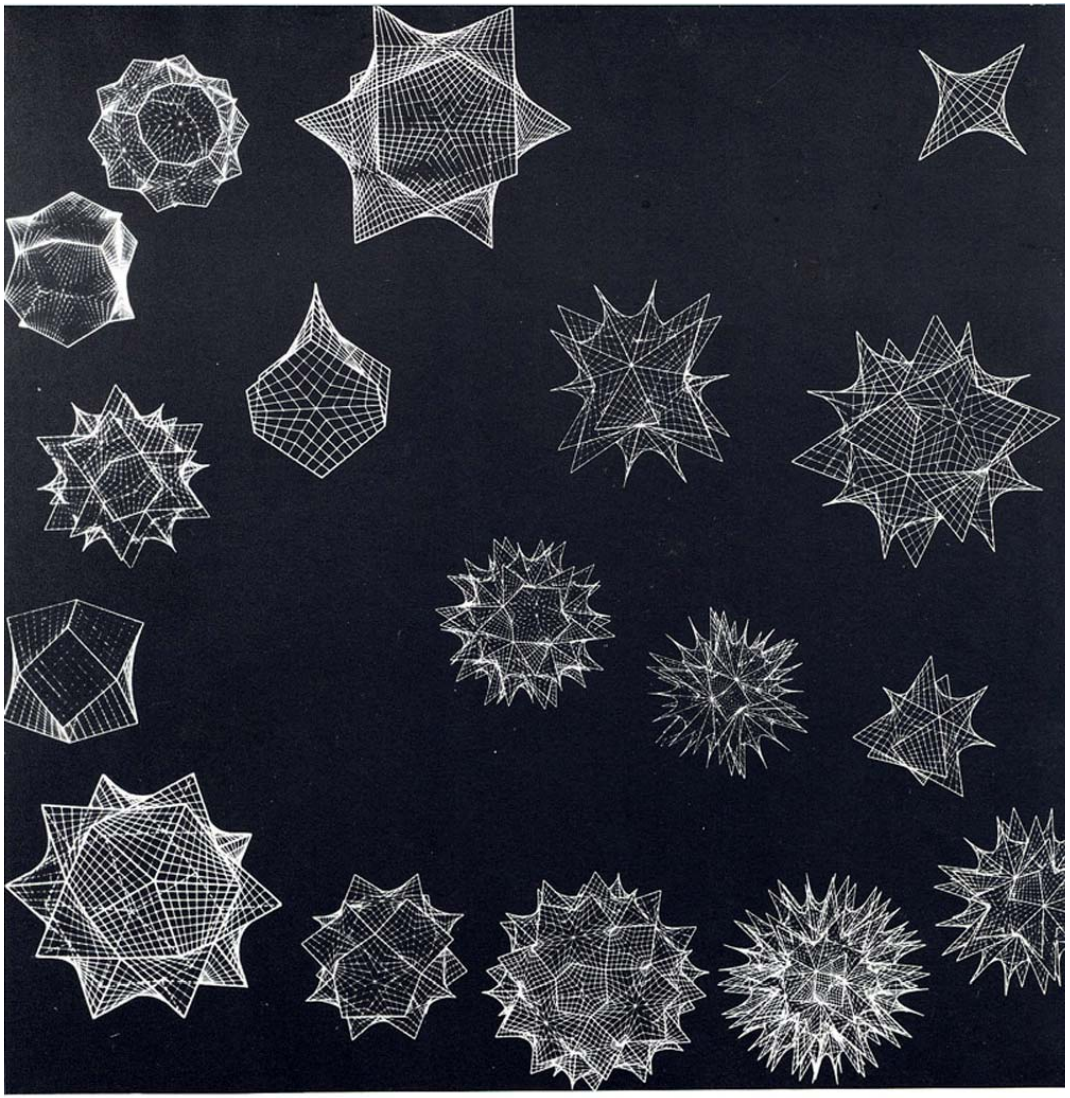


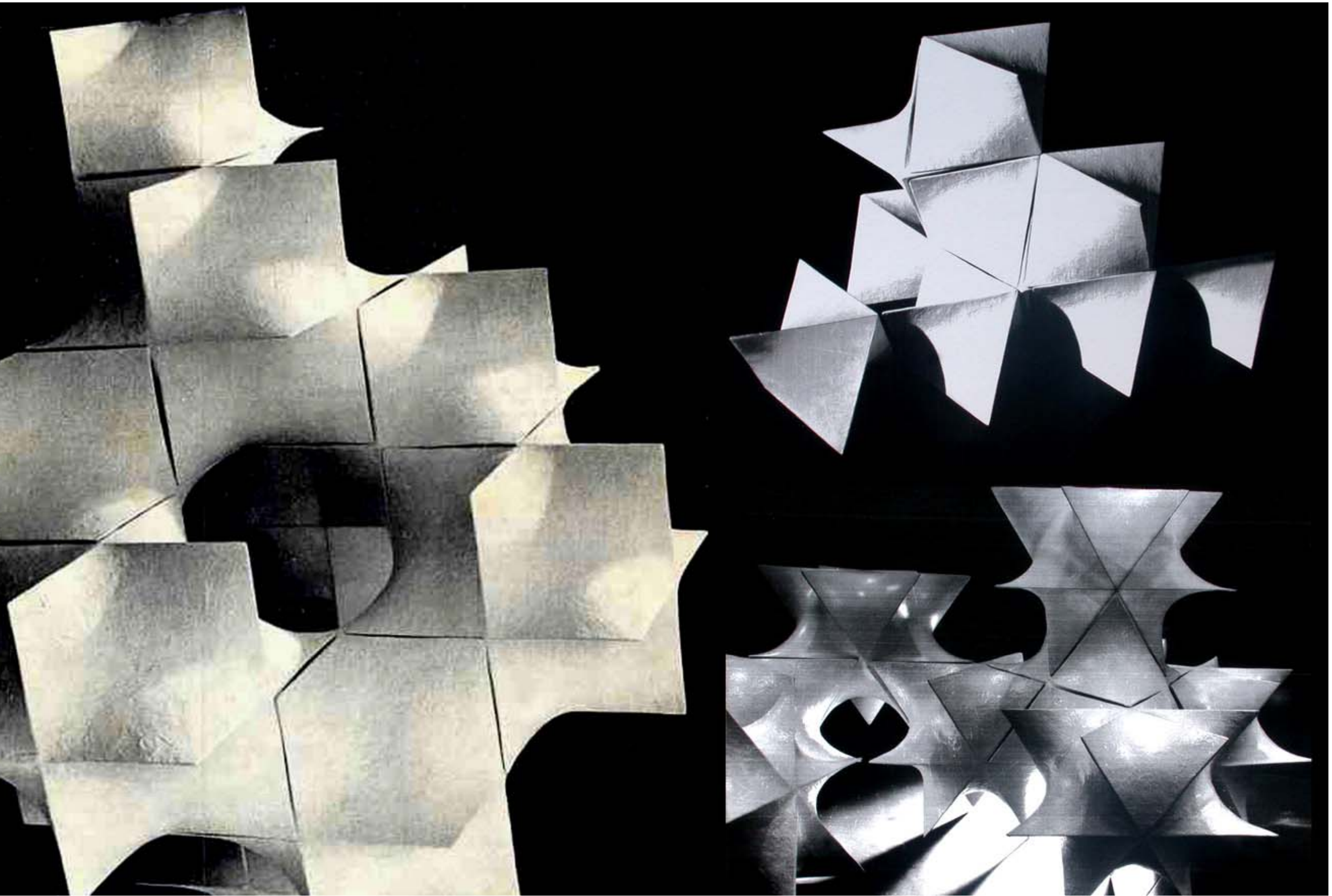


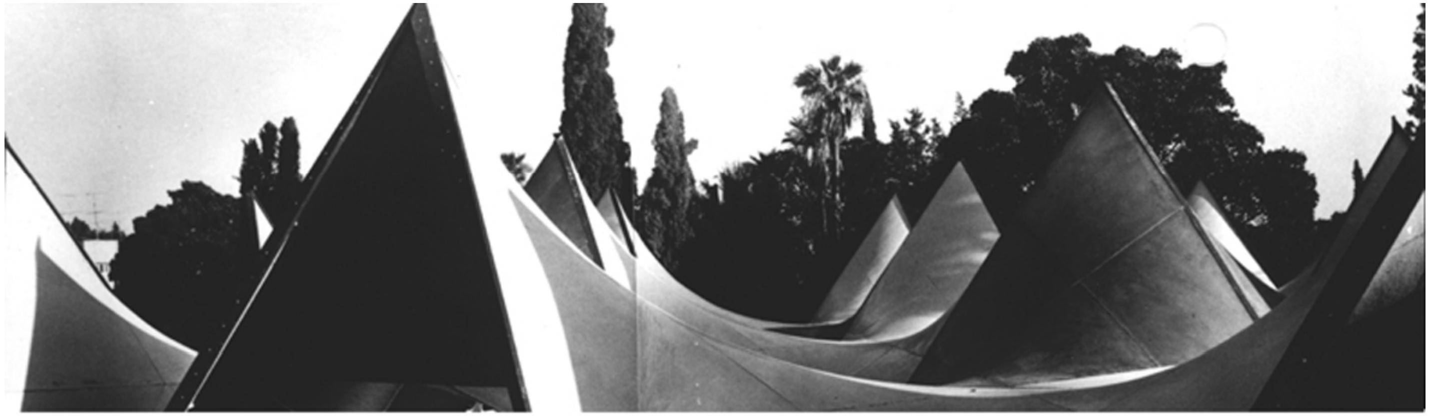


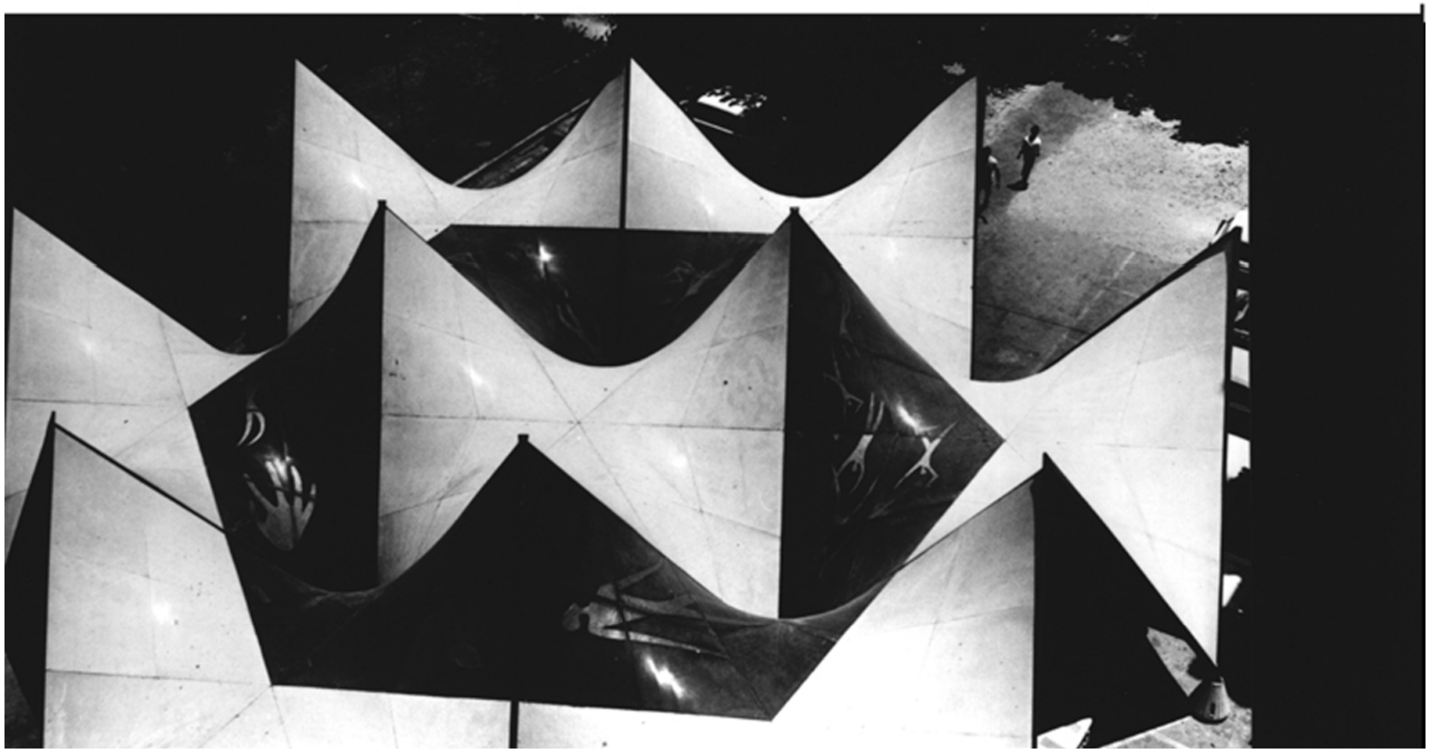


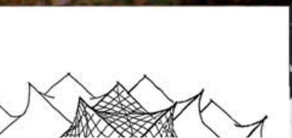


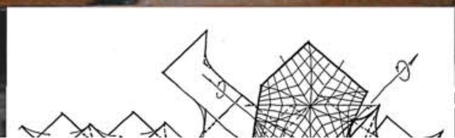


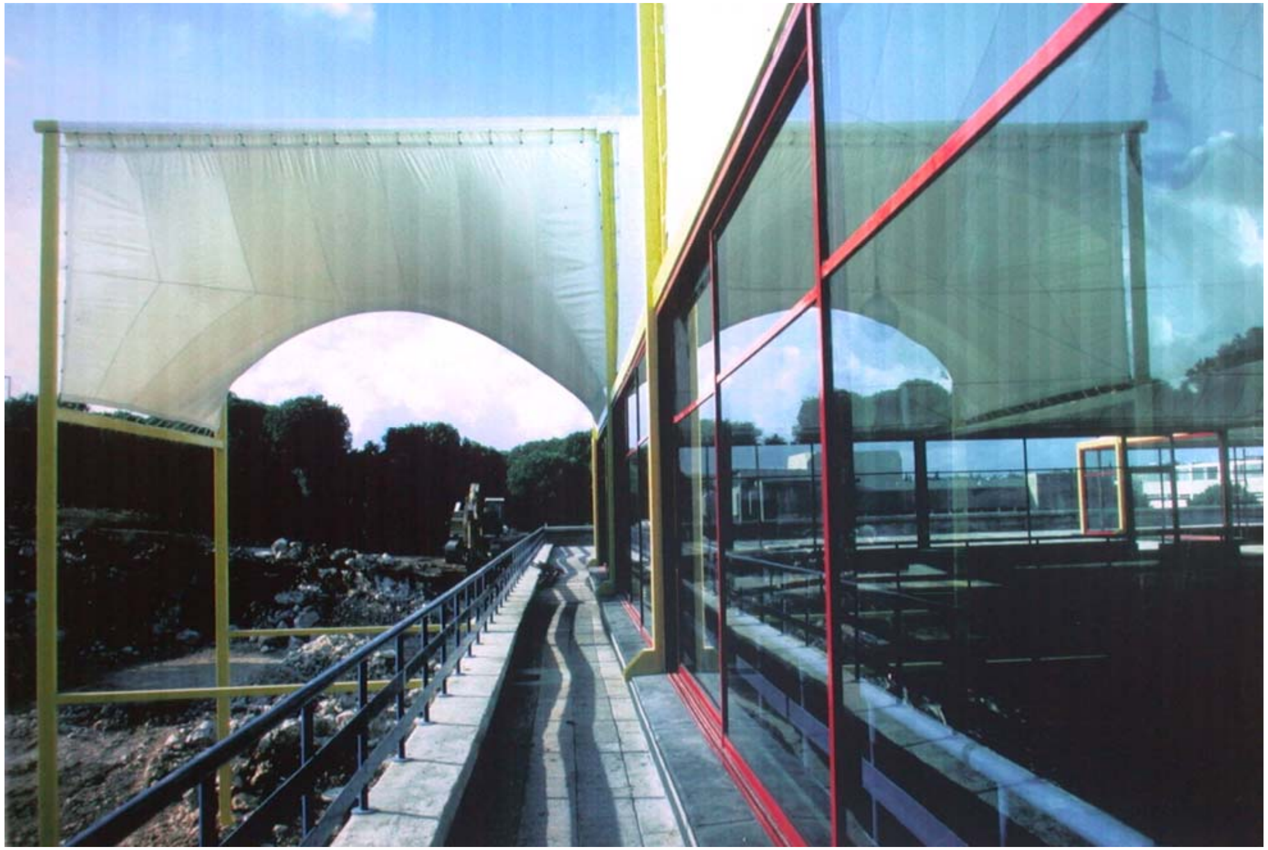








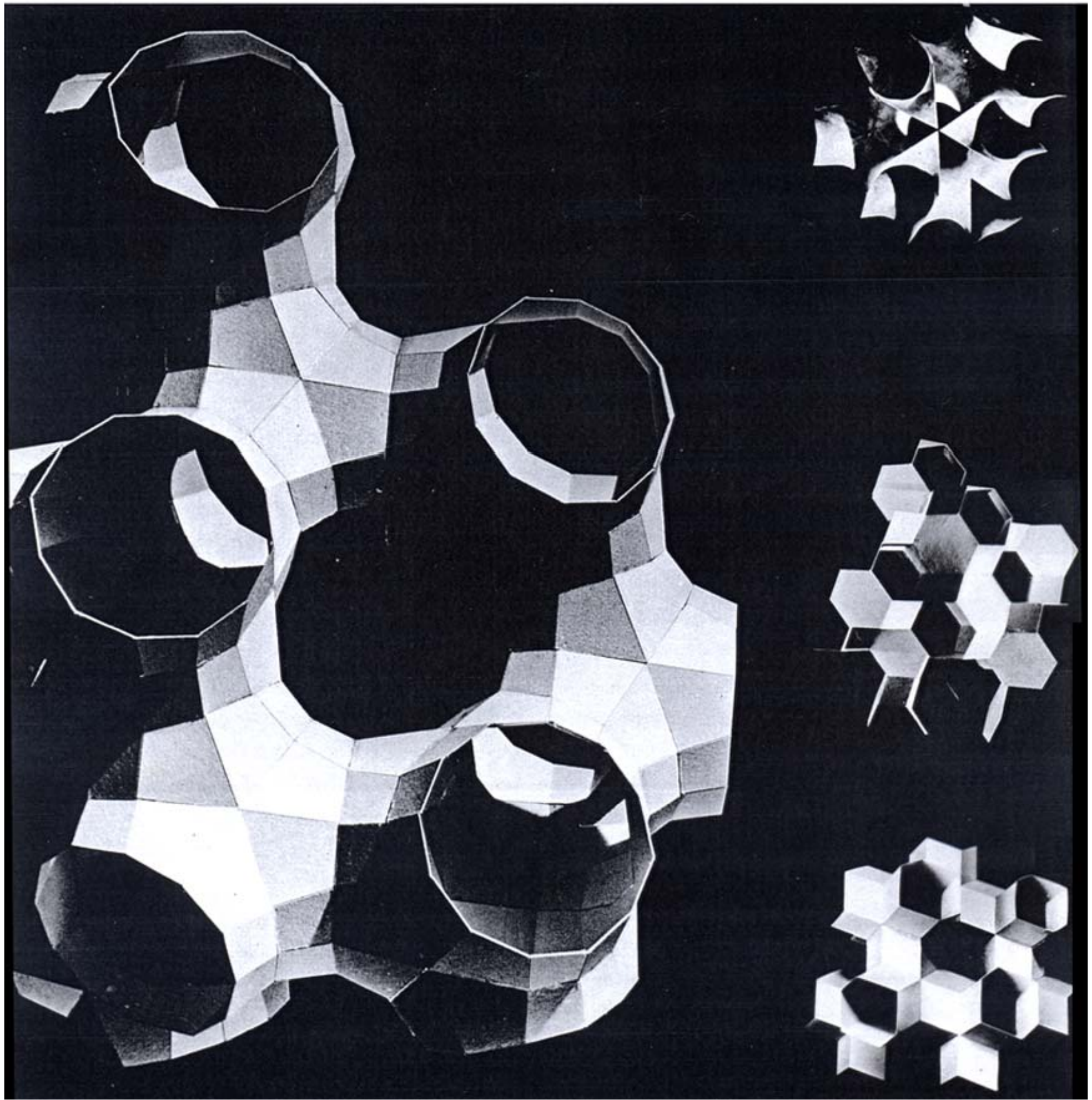



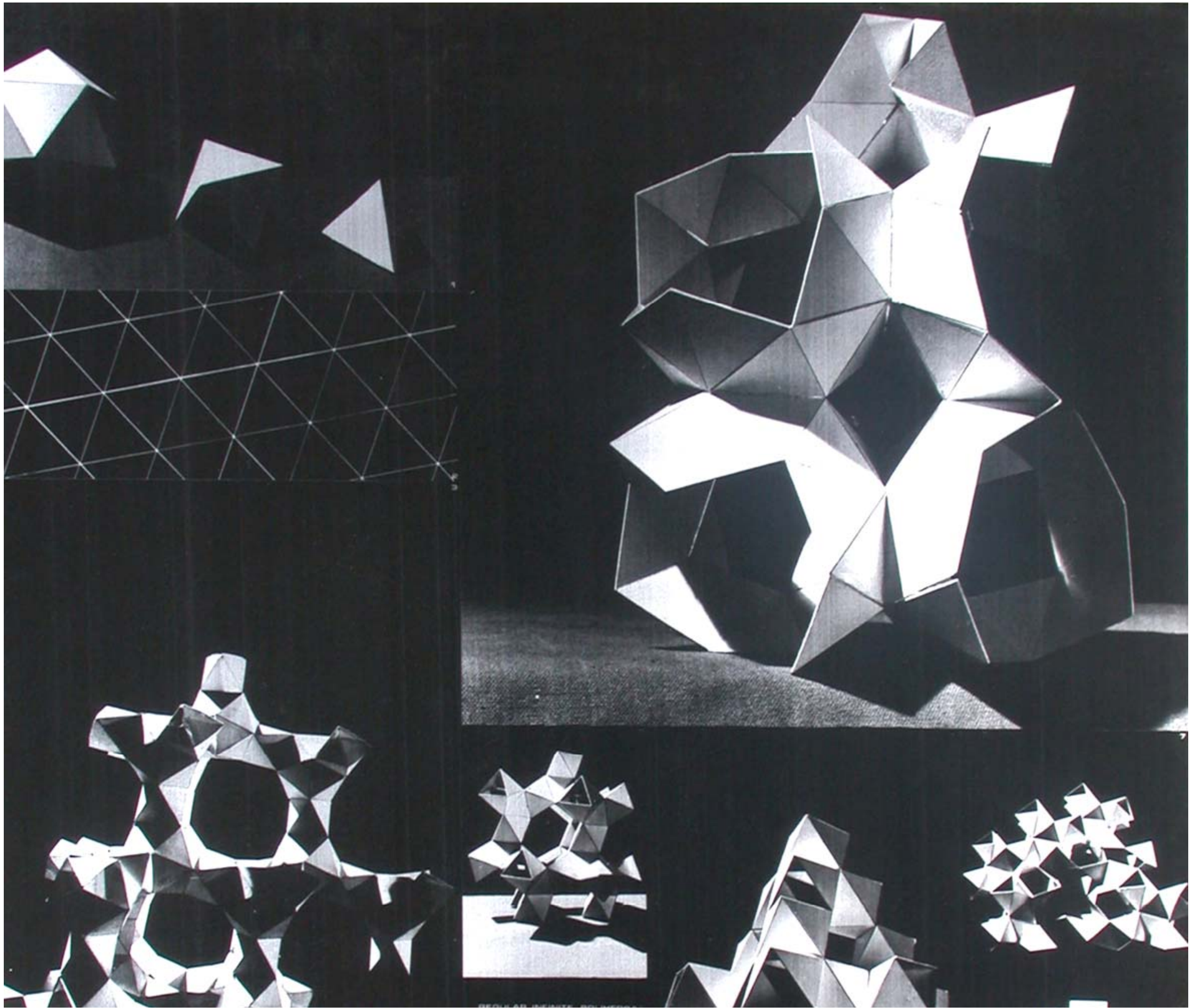
Amado Membrane Structure

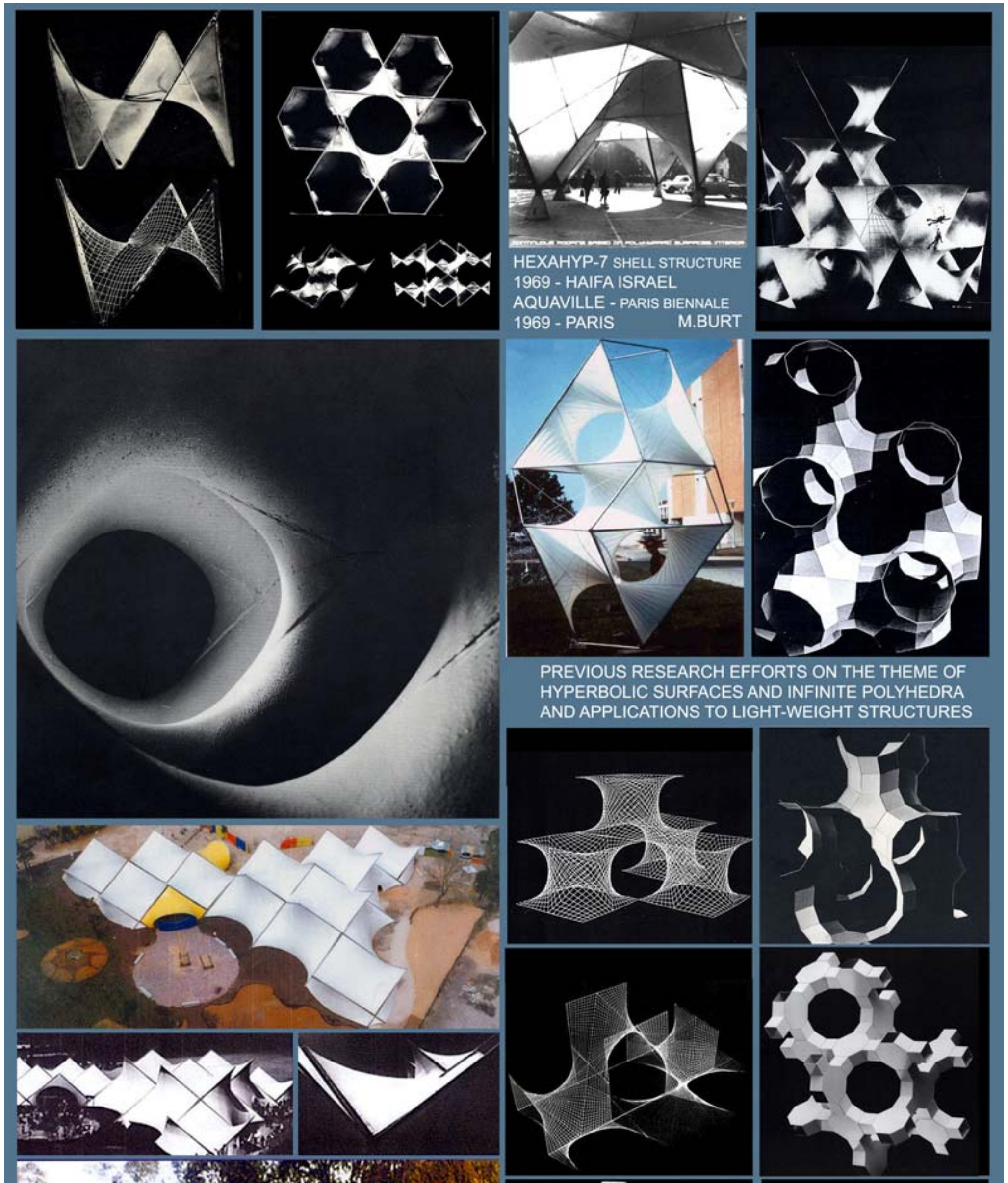
Amado Membrane Structure

Amado Membrane Structure

Amado Membrane Structure






HEXAHYP-7 SHELL STRUCTURE
1969 - HAIFA ISRAEL
AQUAVILLE - PARIS BIENNALE
1969 - PARIS M.BURT
PREVIOUS RESEARCH EFFORTS ON THE THEME OF
HYPERBOLIC SURFACES AND INFINITE POLYHEDRA
AND APPLICATIONS TO LIGHT-WEIGHT STRUCTURES

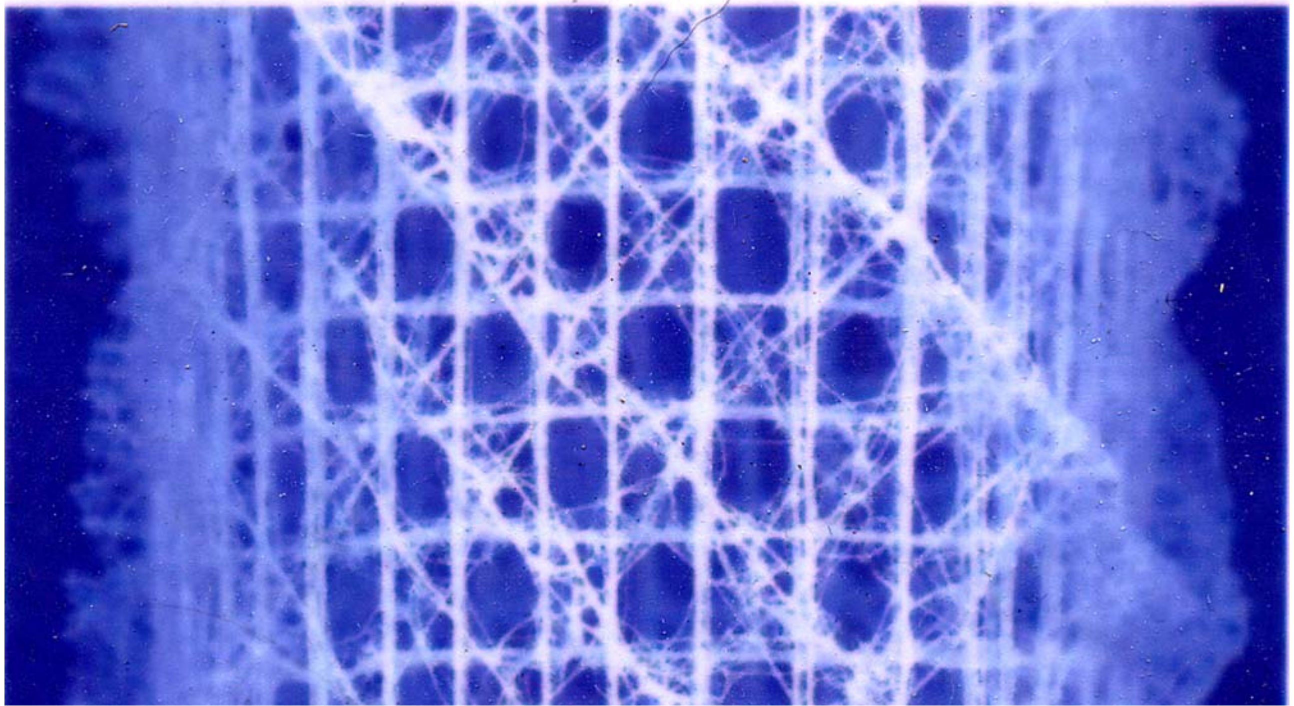
The second category of structures, populating 3D space, describes **polytopal interrelating and interconnected arrays of** (sometimes) energized **point-wise entities which could be represented as diagrams with a network or space lattice characteristics**.

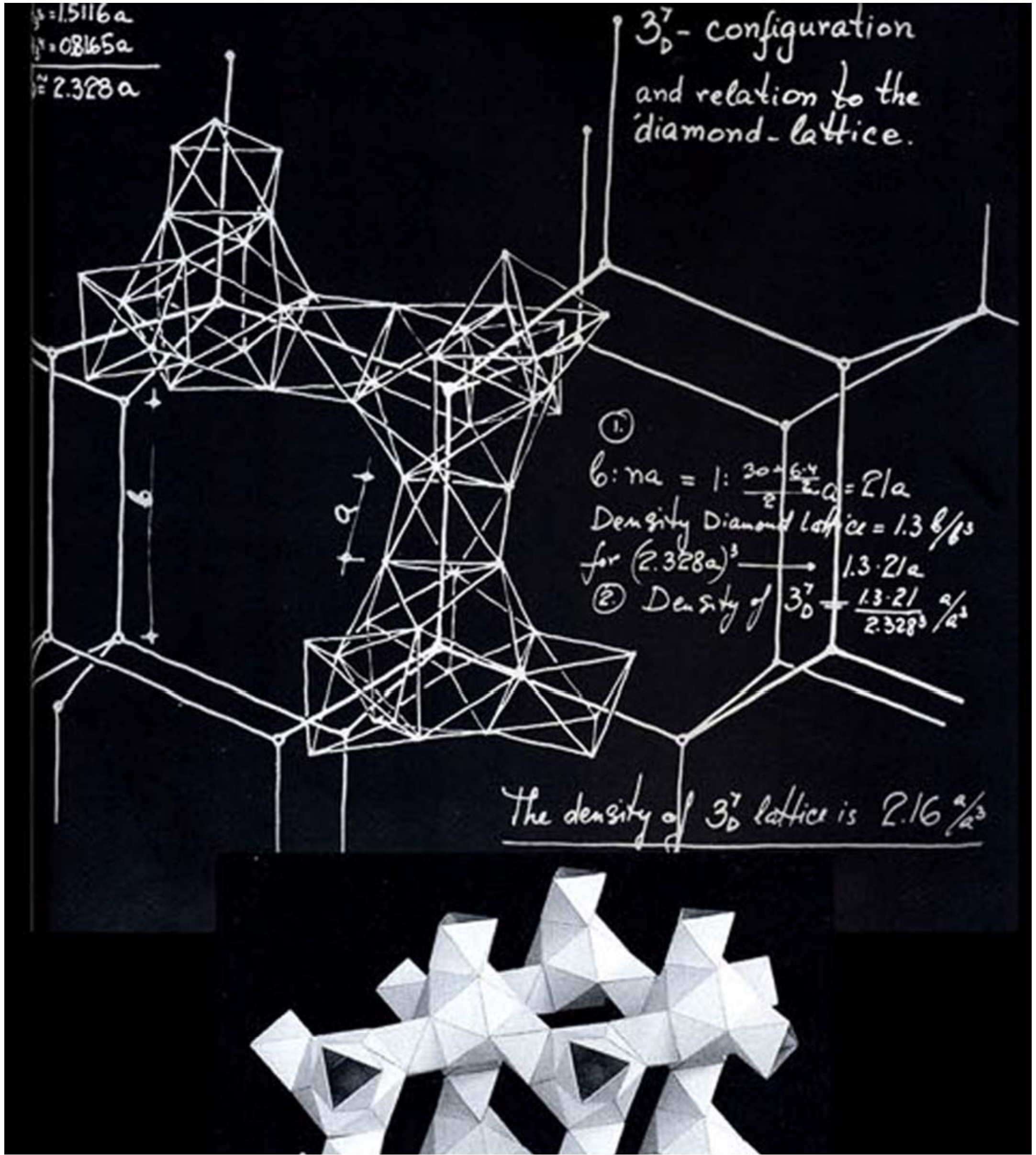
Diagrams of this kind may represent the structure of almost any abstract or physical plurality that may exist, **in the world of phenomena of the biological-physical-material domain, on every possible scale, from the nano-molecular**

"Science Times" July 12/05 p D1

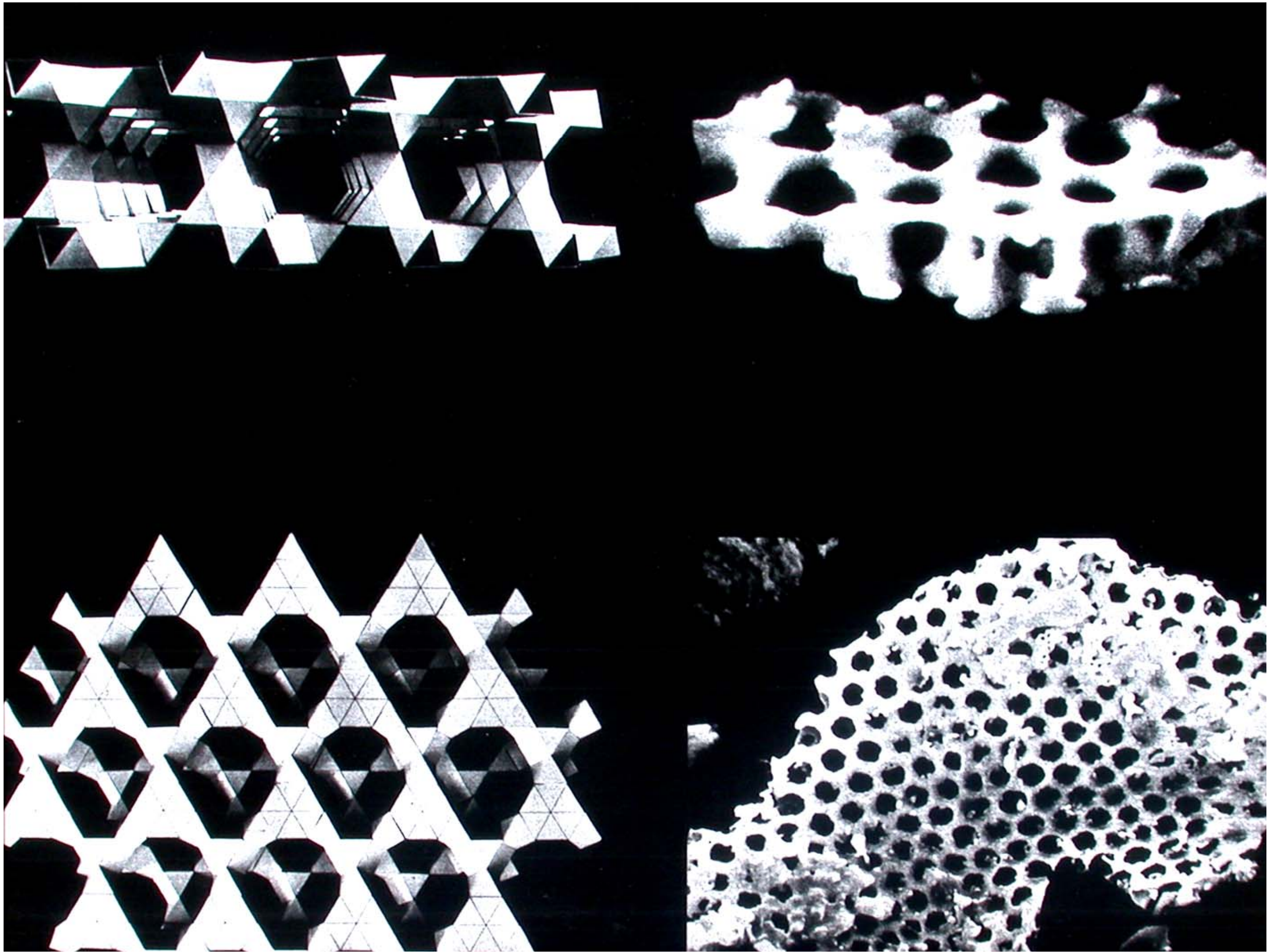
FINDINGS

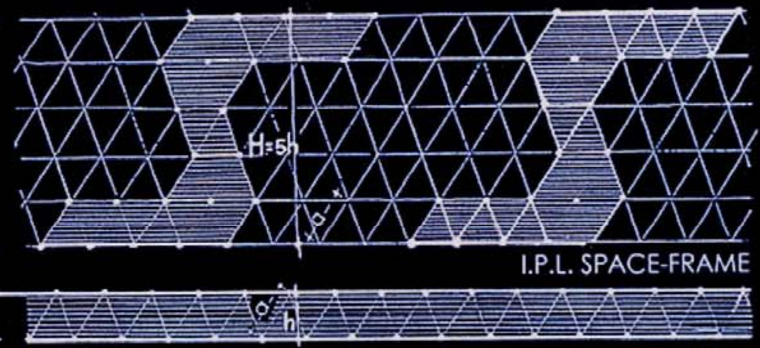
The Glass Menagerie (It's a Sponge)





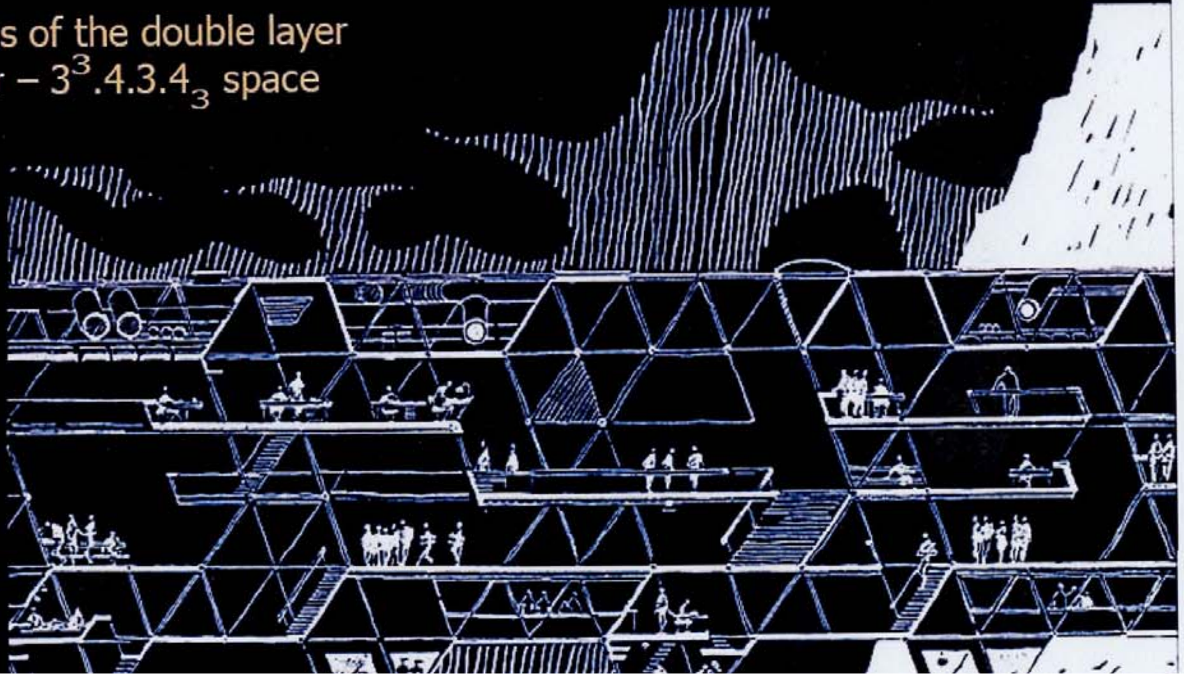
=1.5116a
=0.8165a
= 2.328a
3^7_D- configuration
and relation to the
'diamond-lattice.
1.
Density Diamond lattice = 1.3
for $(2.328a)^3$ → 1.3·21a
2. Density of 3^7_D = $\frac{1.3 \cdot 21}{2.328^3}$
The density of 3^7_D lattice is 2.16

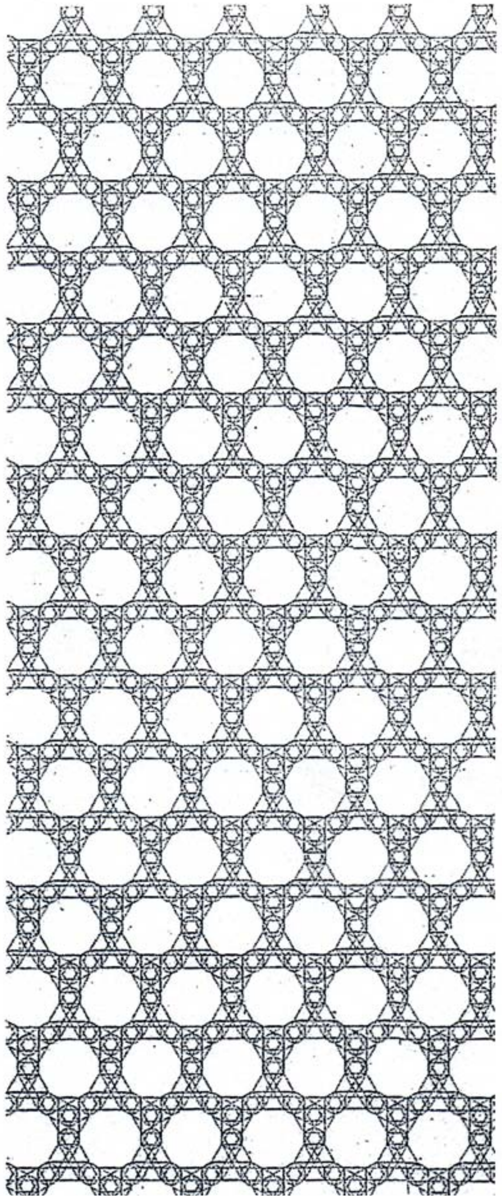




omparative cross sections of the double layer
tatruss and the six layer – $3^3.4.3.4_3$ space
usses.

Interior utilization of the $3^3.4.3.4_3$
I.P.L space truss.



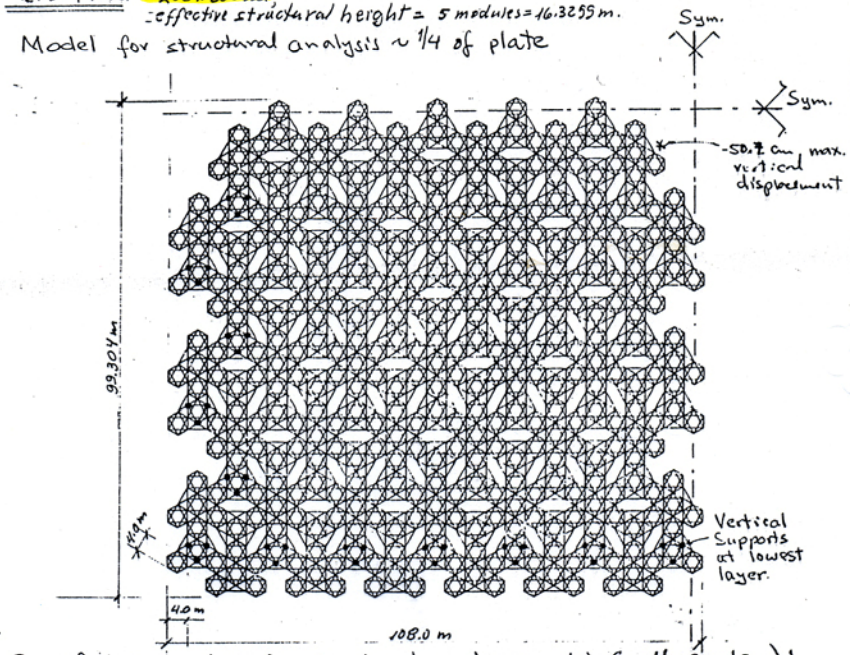


MERO D-8700 Würzburg
Steinachstraße 5
Telefon (0931) 41030

Blatt: I.P.L 200 m x 200 m
ST.B.-Nr.:

IPL- Plate. 200 x 200 m
effective structural height = 5 modules = 16.3255 m.

Model for structural analysis ~ 1/4 of plate



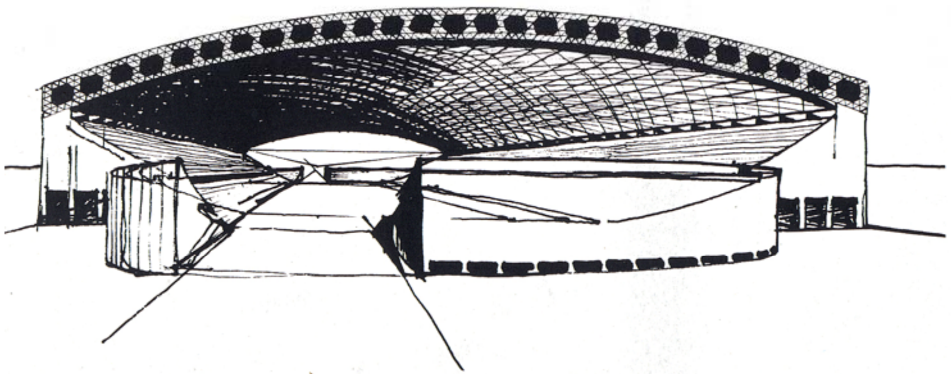
Significant quantities for structural analysis model (~ 1/4 system);

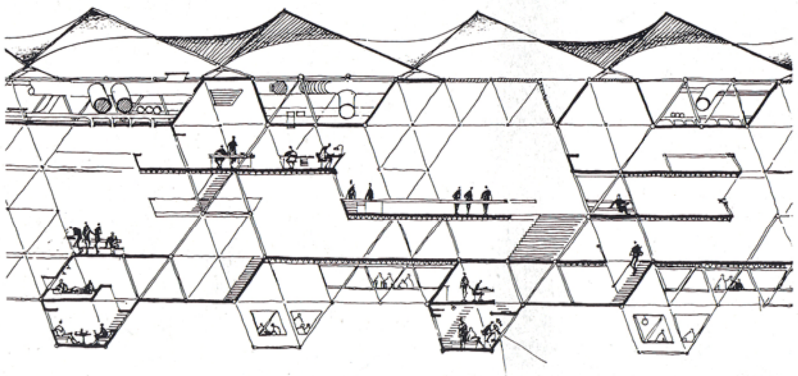
Number of nodes: 2145
Number of members: 7023, 2 lengths: 4.0 m for modules sides and $4 \times \sqrt{2} = 5.6508$ m to diagonalise cuboctahedron-sq
Material properties: of steel
Imposed load: uniform: 1.0 kN/m² (= 100 kg/m²), dead weight of structure include
Supports: vertical, at the sides of plate (+ symmetry constraints at sym. axes).
Maximum vertical displacement = − 50.7 cm at the middle of the plate, e.i. ~ 1/400 of span.
(Additional horizontal displacements up to 10.0 cm)
Maximum forces: − 167 Tons (compression), 130 Tons (Tension)

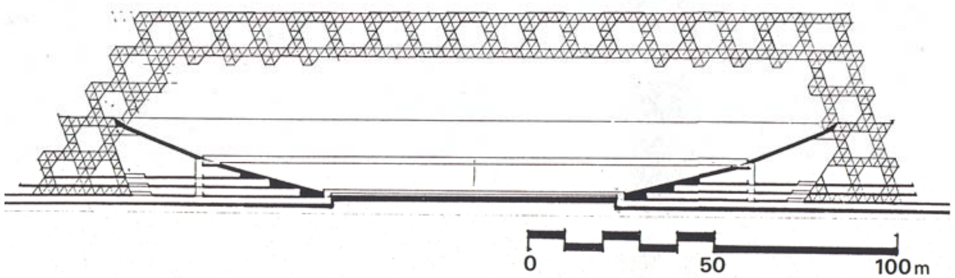
Dimensioning results (for the whole plate with sides 200 m x 200 m = 40 000 m²)
Tubes: 28 092, total length: 119 009.3 m weight = 1343.41 T
Nodes: 8 580, weight = 124.04 T
Σ 1467.45 T → 1500 Tons → 37.5 kg/m²

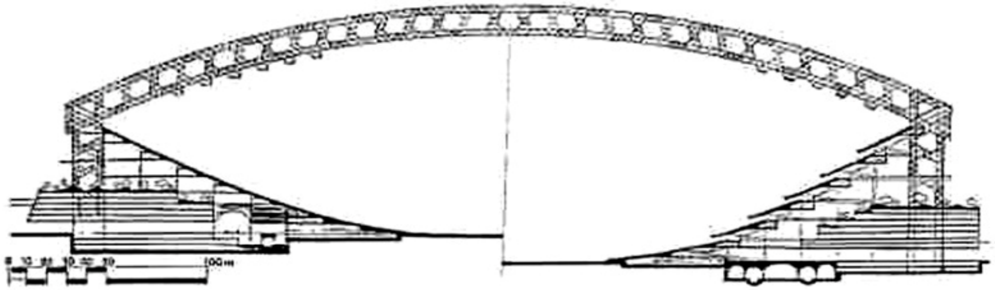
Tube size distribution
ϕ 88.9 x 3.4 | 57%
108. x 3.6 | 17.8%

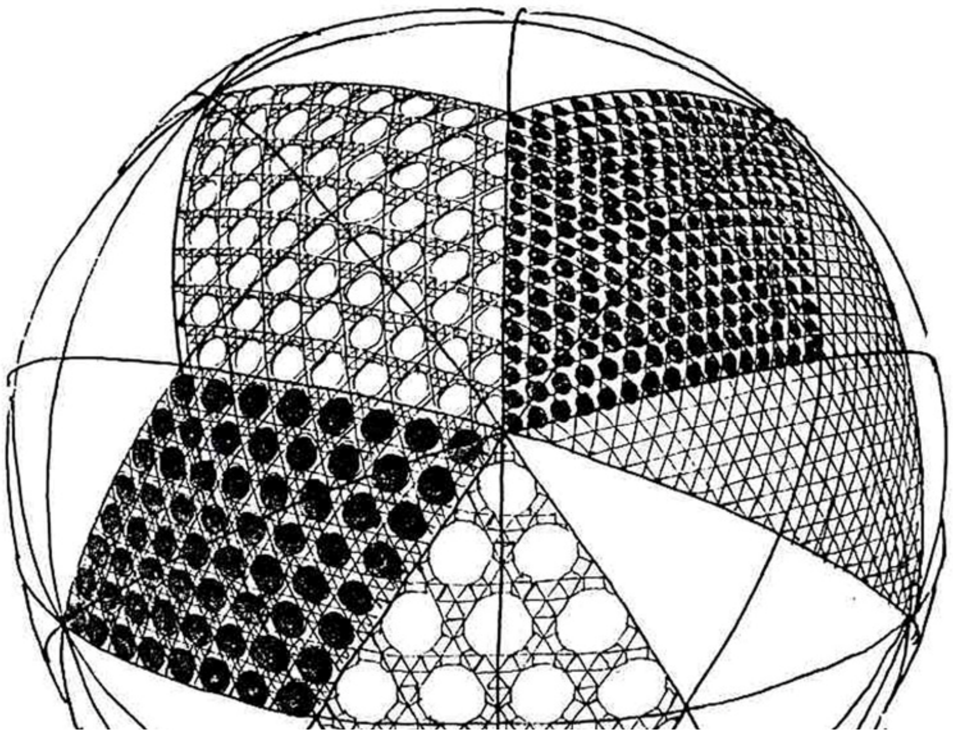
Node size distribution
ϕ 110 (out) / 58 (flats) | 22.5%
132 / 118 | 20.0%

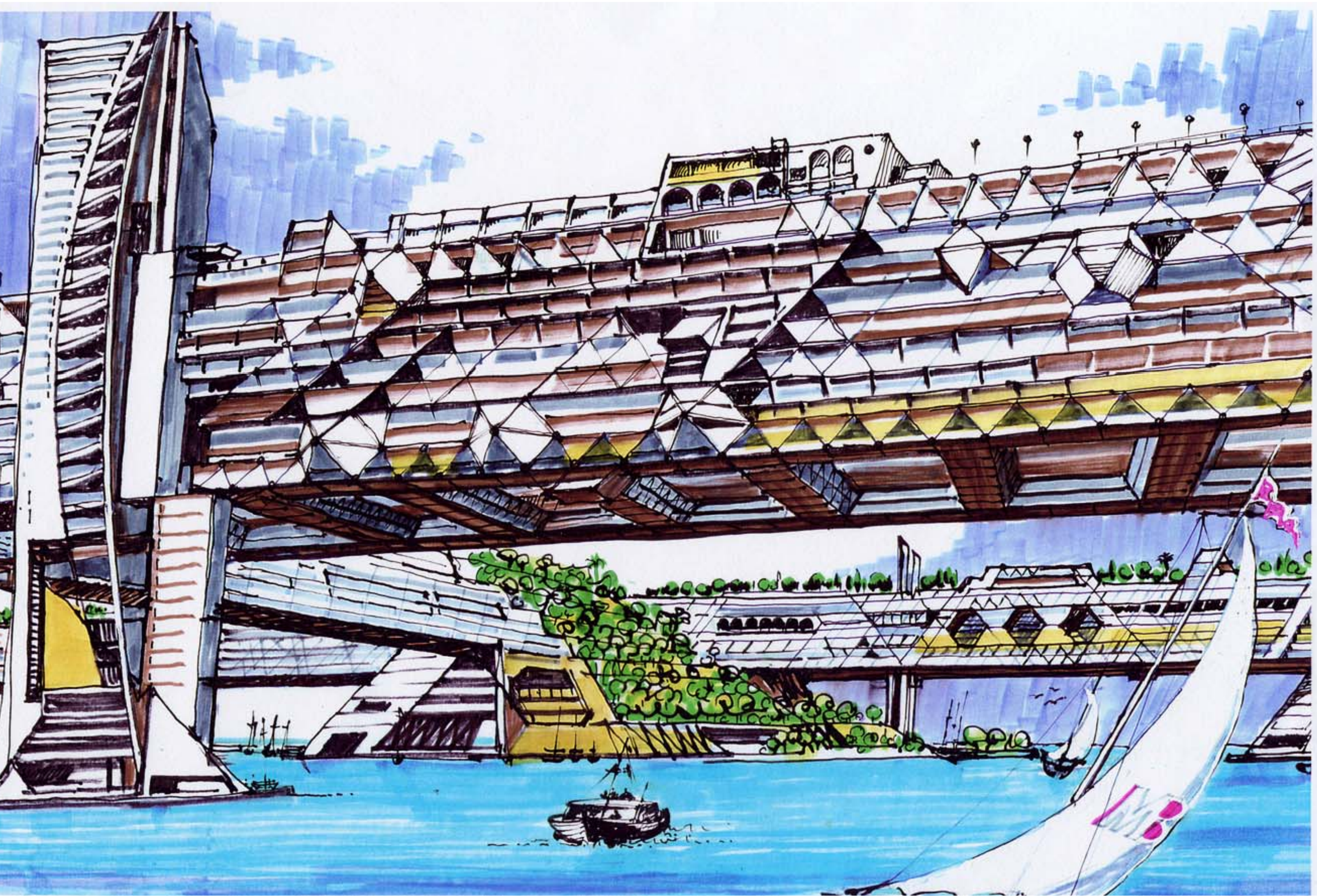


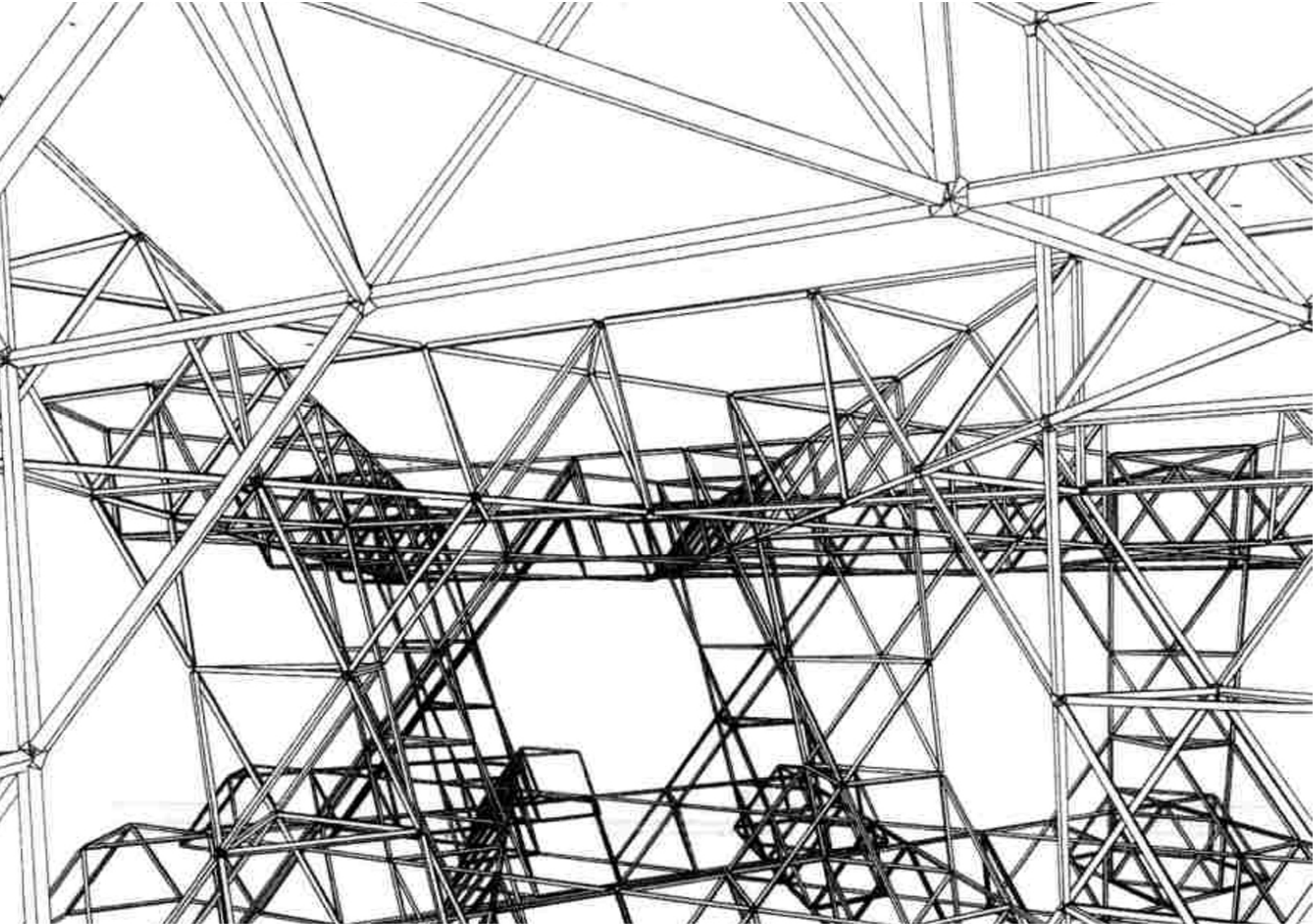


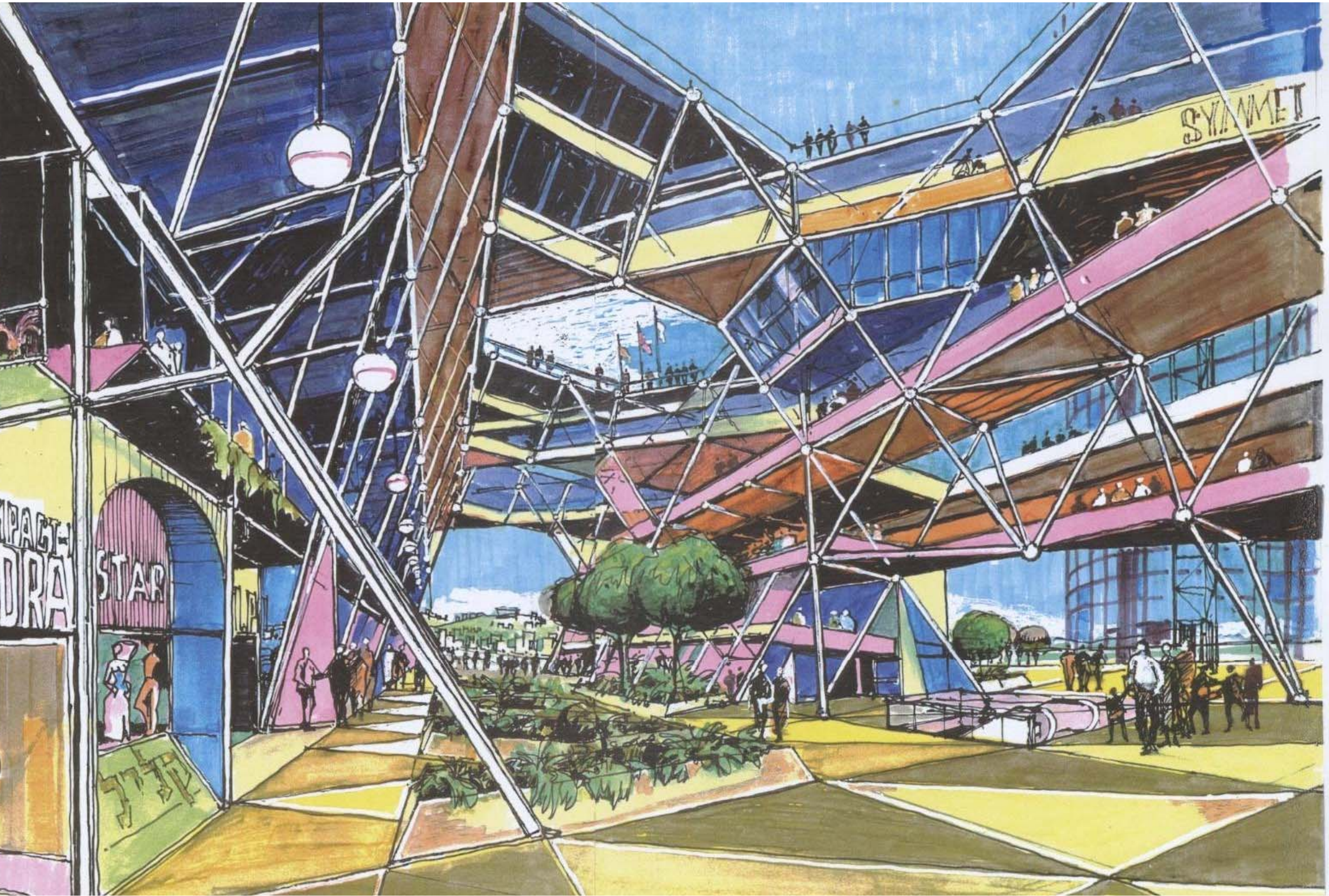

0
50
100 m



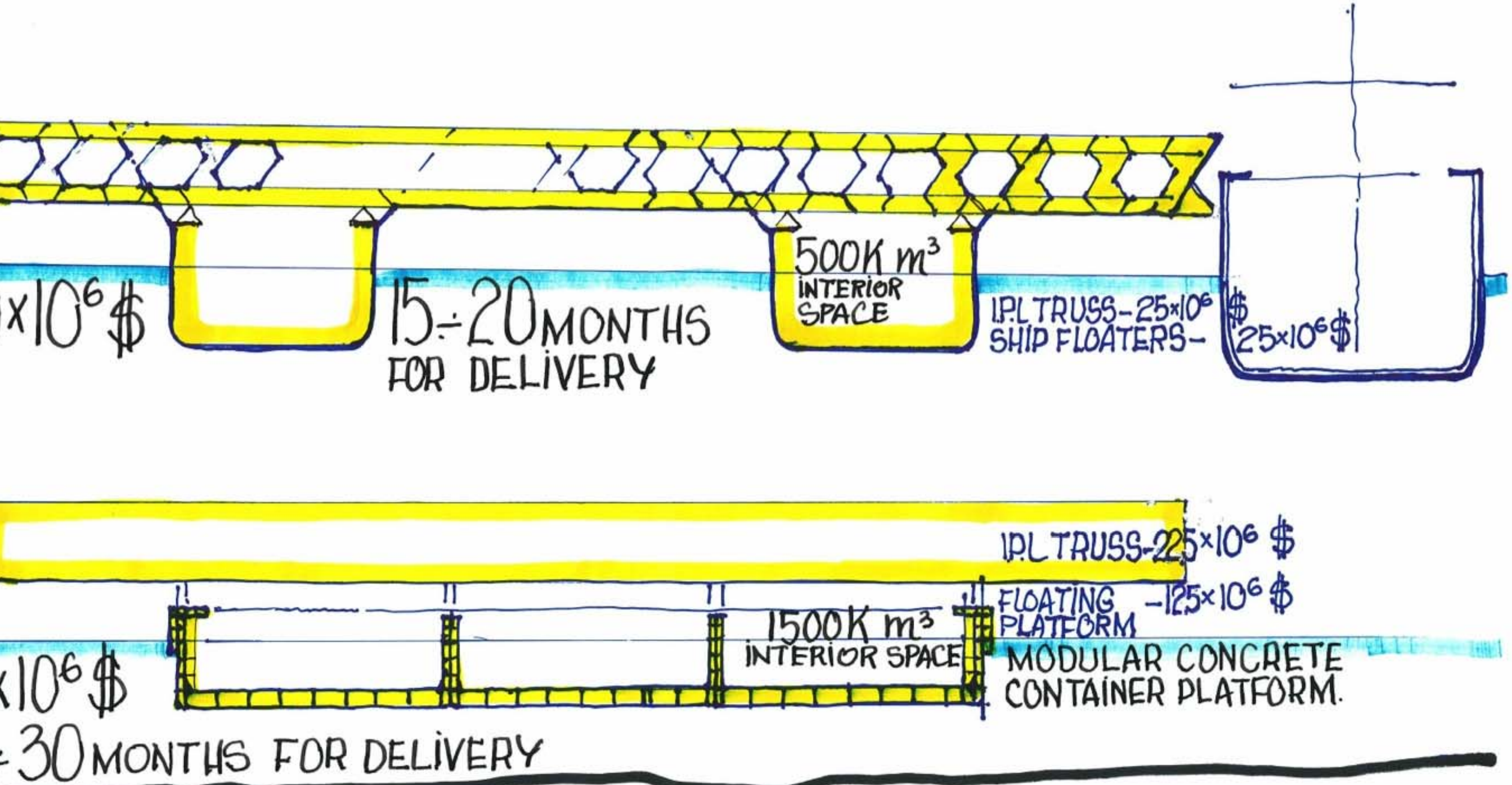






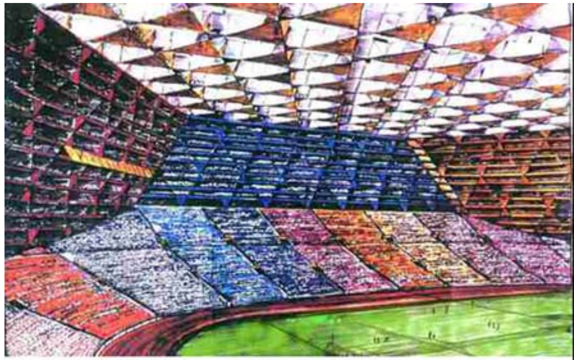


DRA
STAR

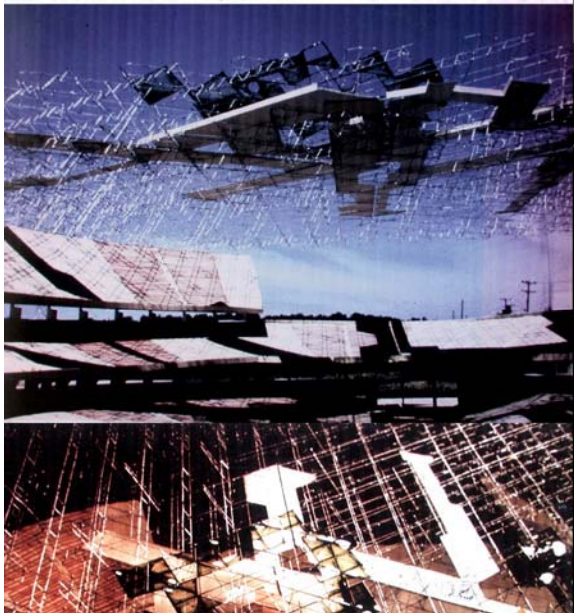


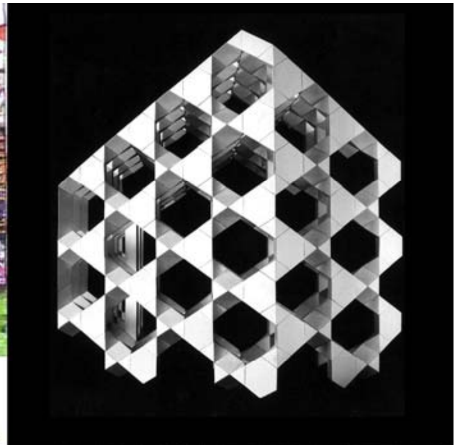
ATING-TRANSPORTABLE PLATFORMS- OF **120.000** SQ.M.

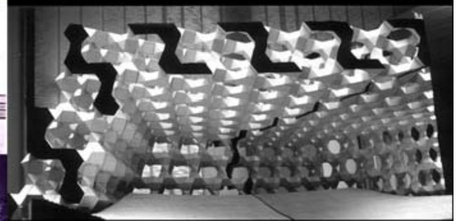
PL SPACE TRUSS ON OBSOLETE SHIP FLOATERS

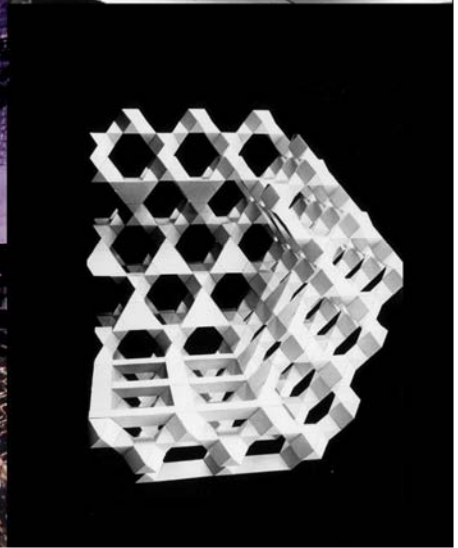



HOSTEL
COMMERCIAL AREA
COMMERCIAL AREA
+40 000 BALCONY SEATS
+60 000 ARENA SEATS
TOTAL 100 000









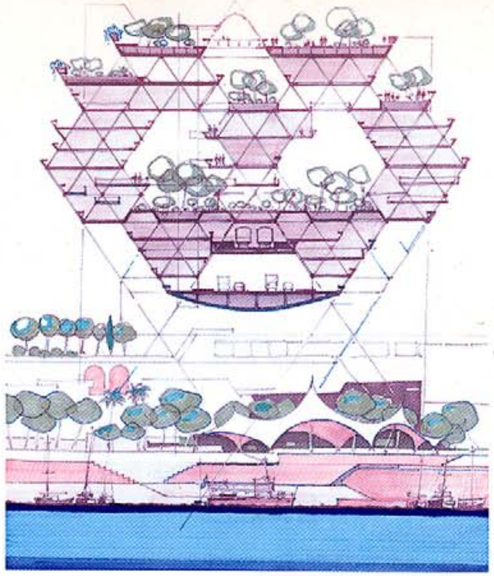
s of Infinite
attice Structures
space trusses:

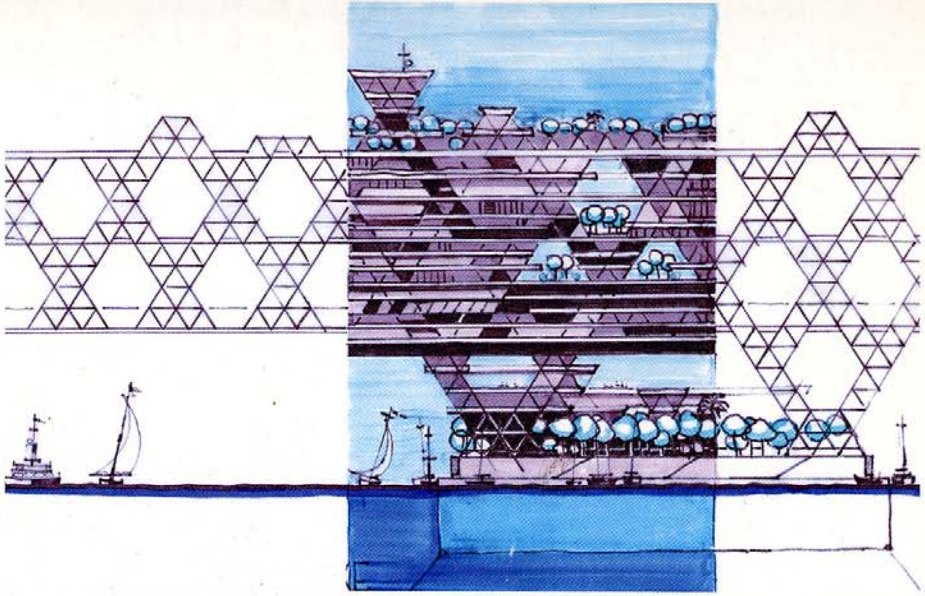
wide span roofs)
enues

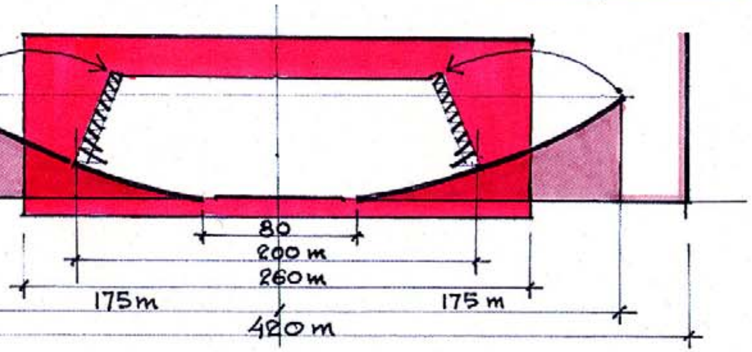
риложение
ктур как
енных конструкций:

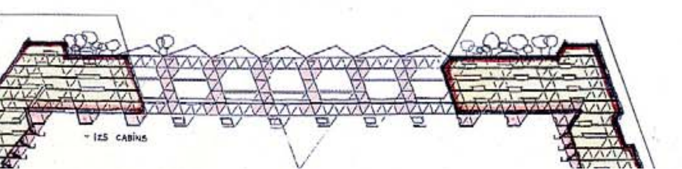
ирокопролетные

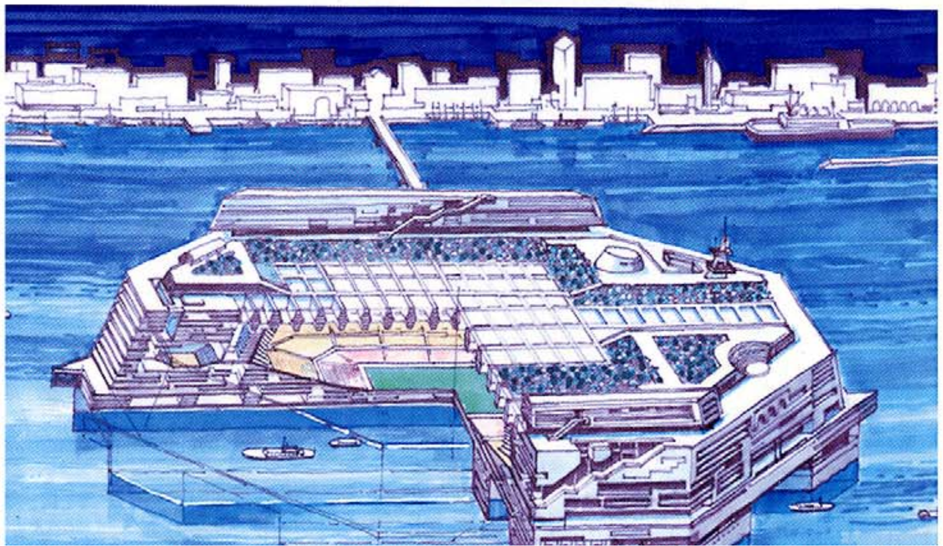
– мосты

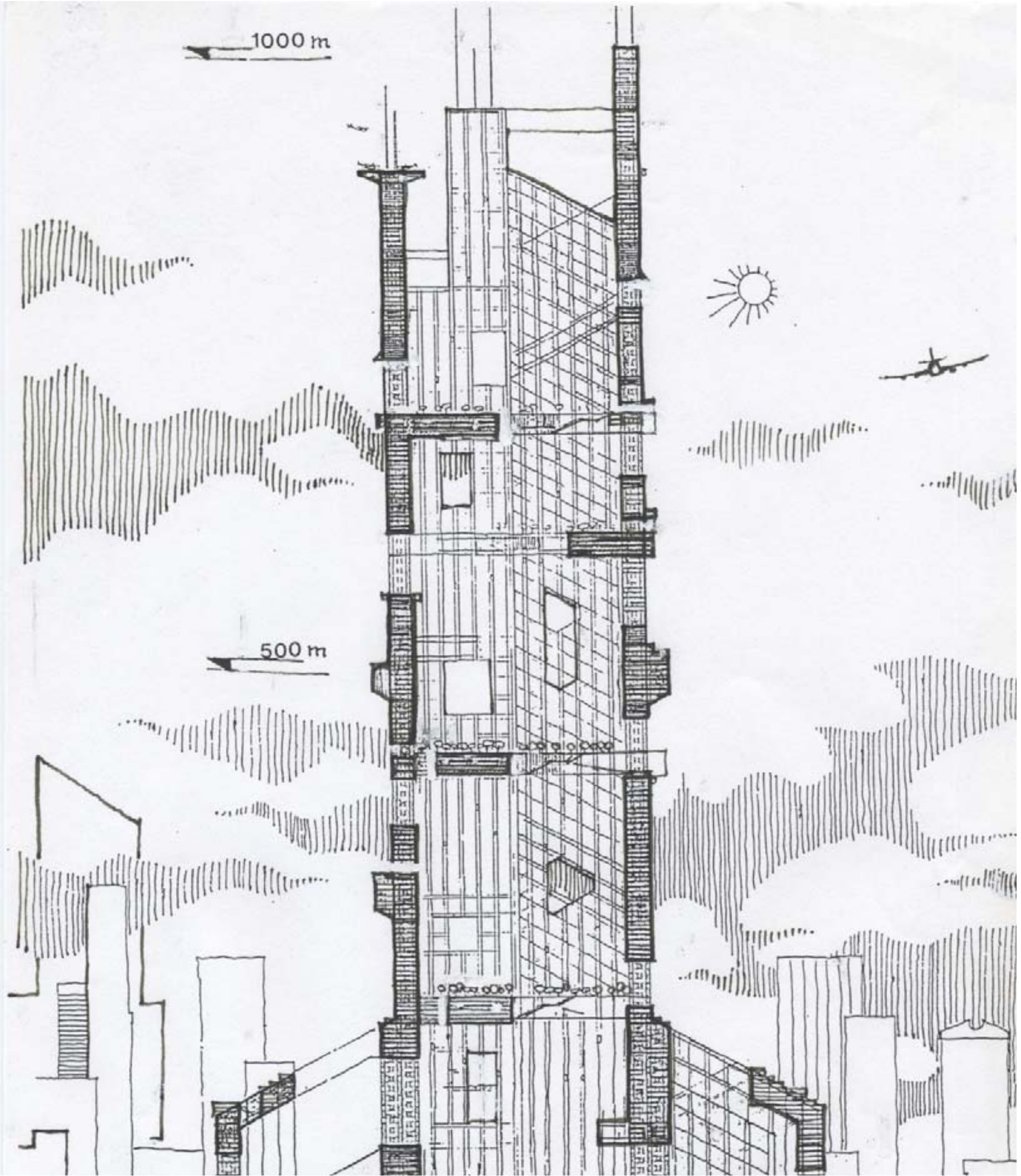




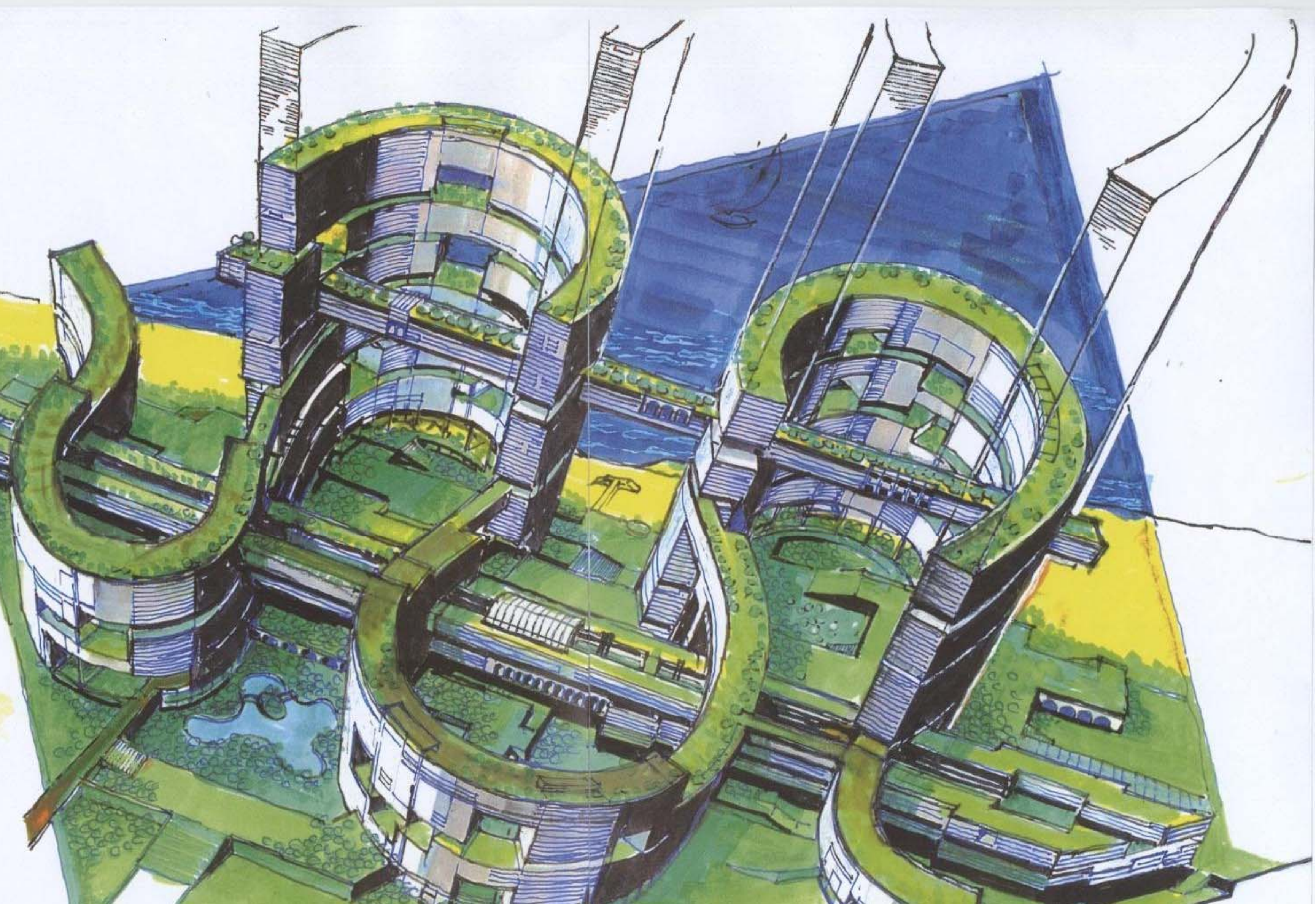


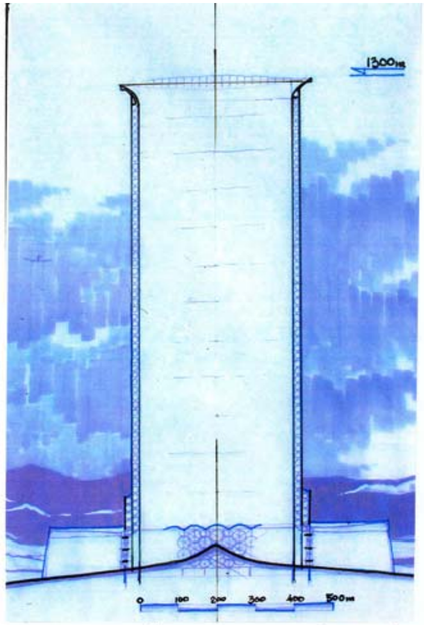




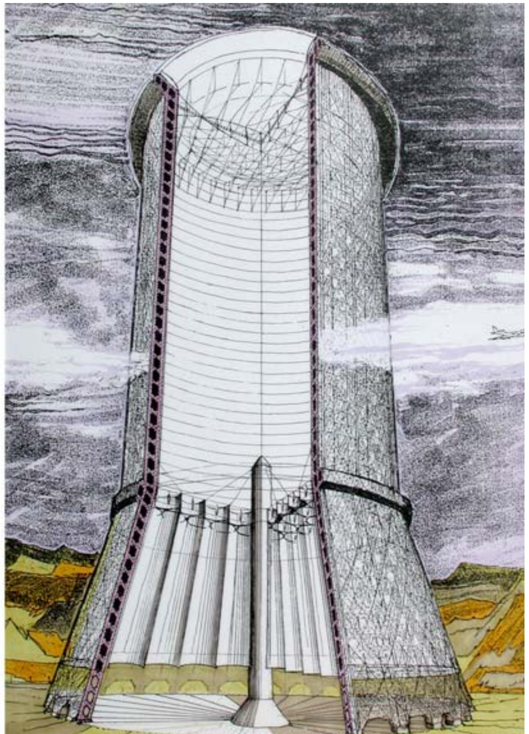


1000 m
500 m

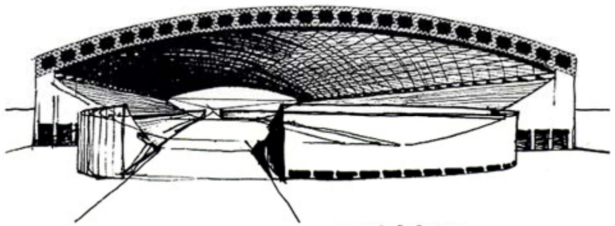




AERO-ELECTRIC POWER STATION, UTILIZING HOT-DRY DESERT AIR (BY DAN ZASLAVSKI), WITH I.P.L STRUCTURE OF 1300m HIGH.



AERO-ELECTRIC POWER STATION I.P.L TOWER



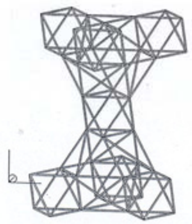
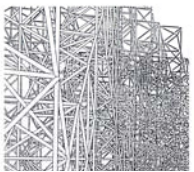
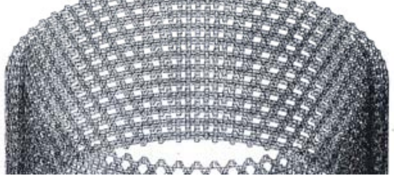
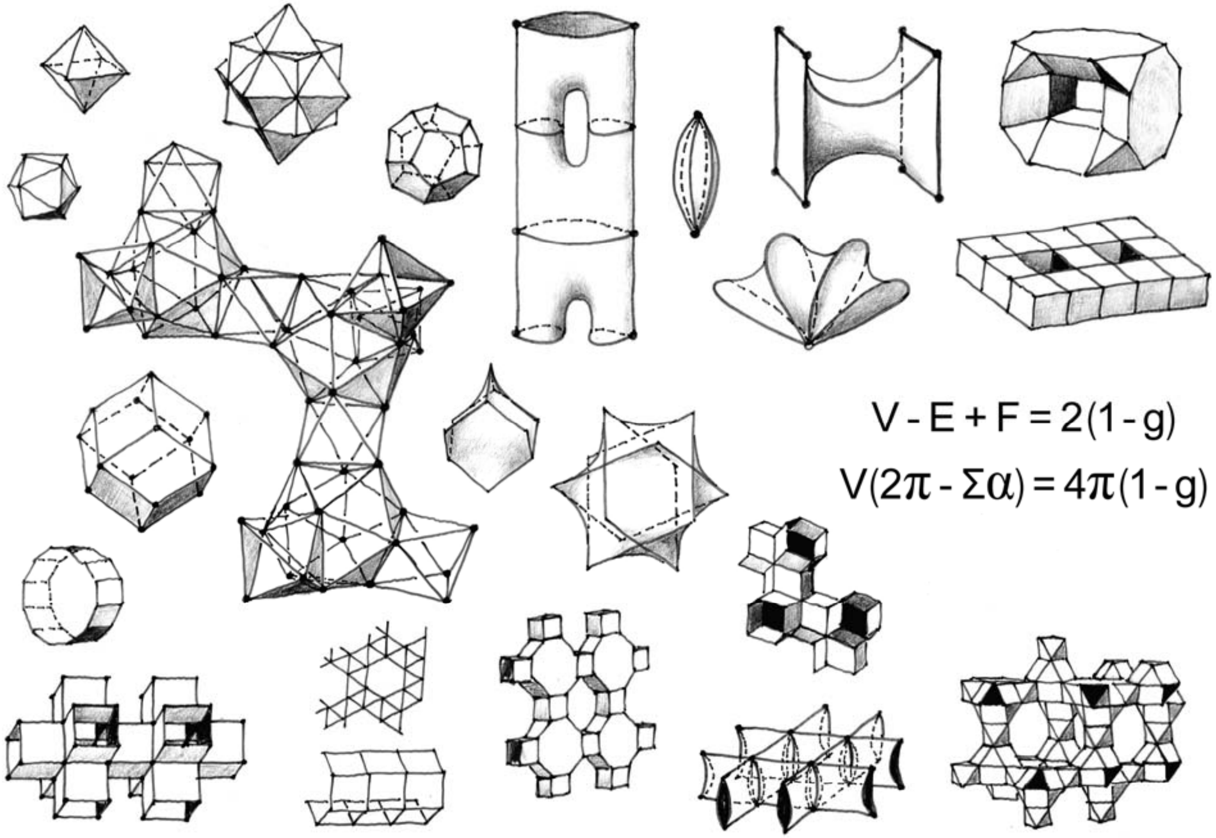


Figure 2. Basic repetitive "column" substructure

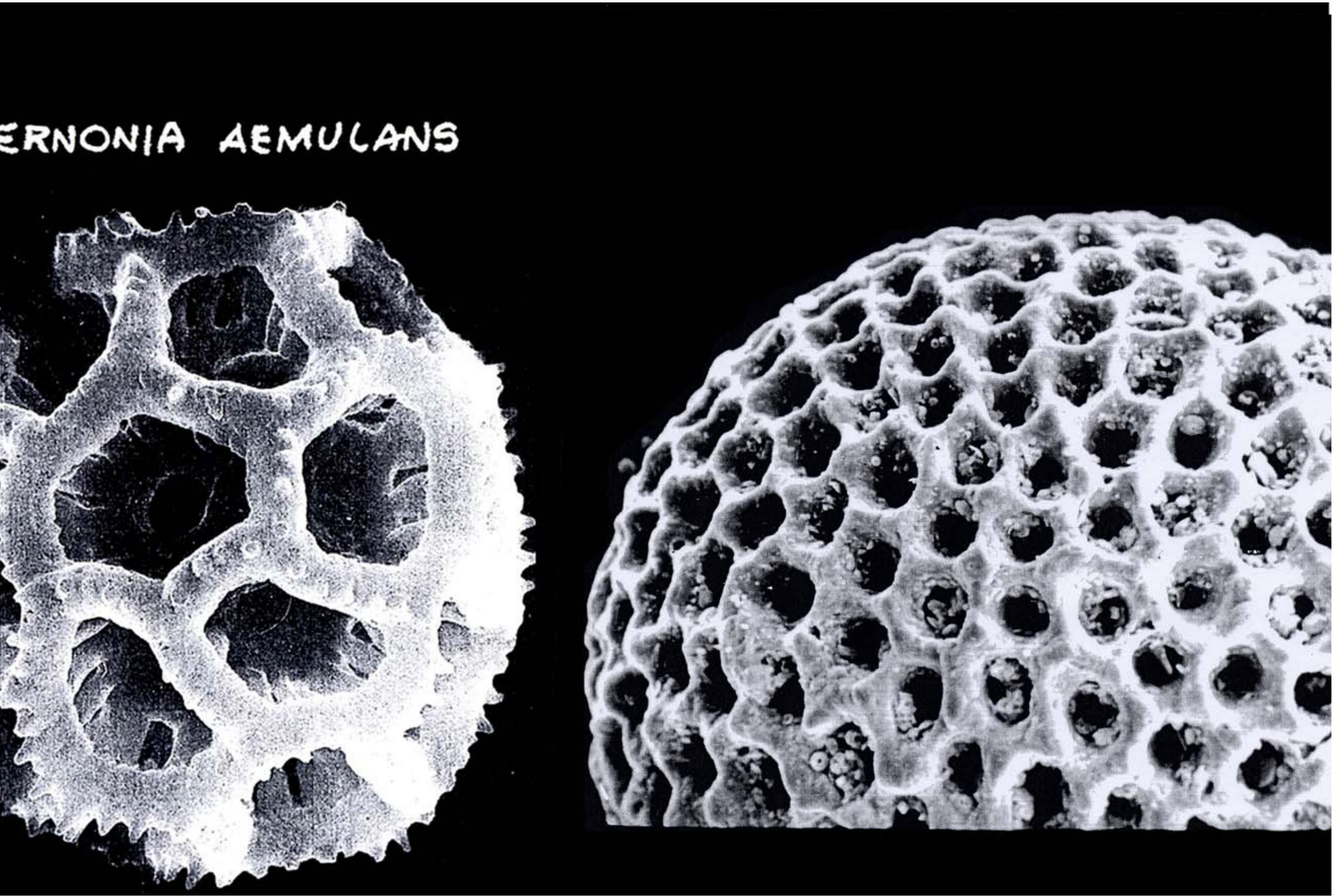






$$V - E + F = 2(1 - g)$$

$$V(2\pi - \Sigma\alpha) = 4\pi(1 - g)$$


ERNONIA AEMULANS

$.4^2.11^2.3^2.11^2.4^2.11.4^2.11^2.3^2.11^2.4^2.11.3.6.4^2.6^2.3^3.6^2.4^2.6_{601}$

$.5) = 601$

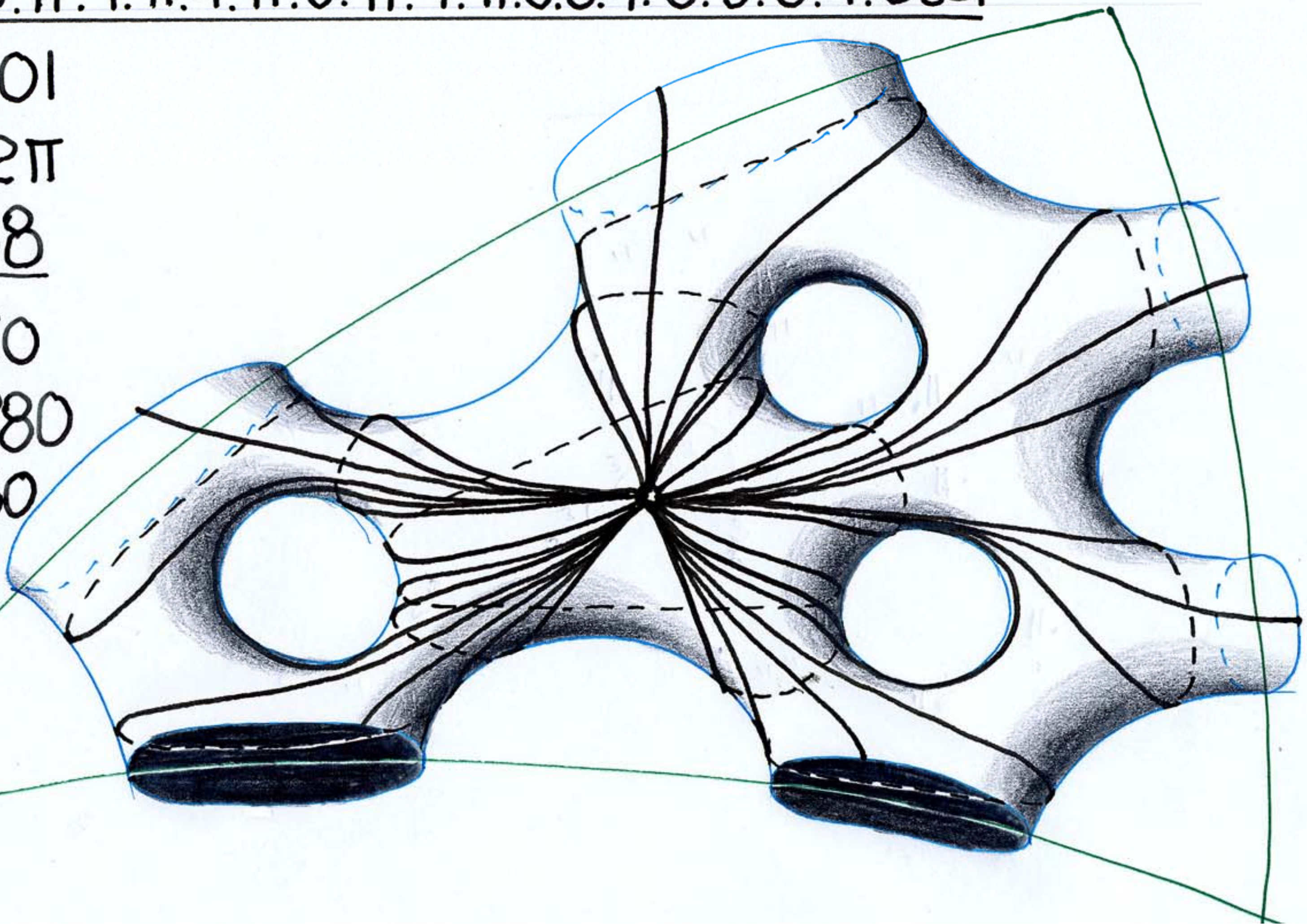
$= 22\pi$

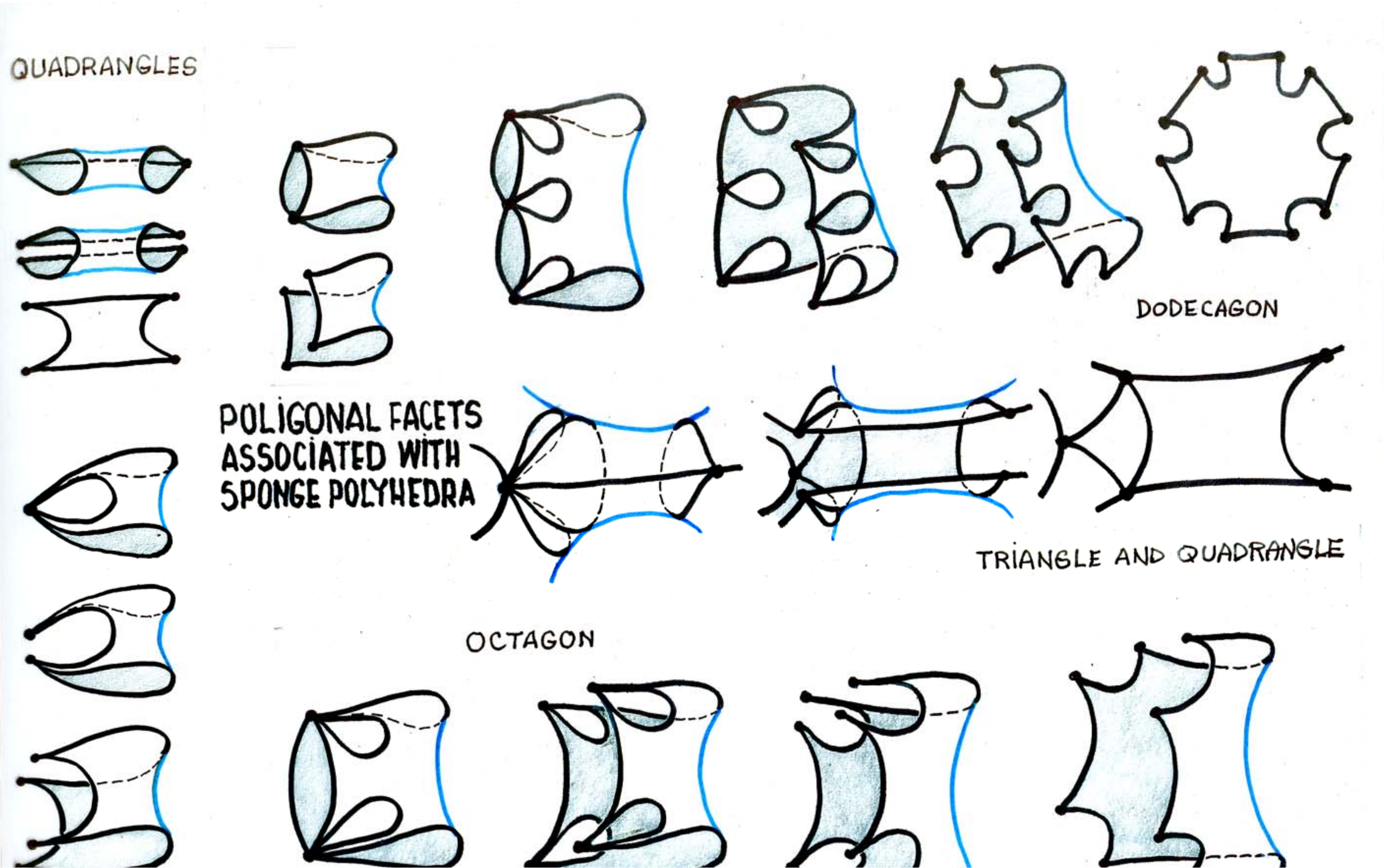
$. = 38$

$= 120$

$= 2280$

$= 960$




QUADRANGLES
DODECAGON
POLIGONAL FACETS
ASSOCIATED WITH
SPONGE POLYHEDRA
TRIANGLE AND QUADRANGLE
OCTAGON

$3.8.6.4^2.6.3.4^2.3.4^2.3.6.8.13.8.6.3.4^2.3.4.3.6.4^2.6.8.3.4^2.3.4^2.3.8.4^2.8.13^2.11.13^2.3.4^2.3.4^2.3.13.4^4.13.11.4^4.11.4^4.11.19.4^4.19.3.4^2.3.4^2.3.19^2.11.19^2.4^{12}.19.3.4^4.3.4^4.3.$
$3.4^4.3.4^4.3.19.3.4^4.3.4^4.3.19.3.4^4.3.4^4.3.19^2.11.19^2.3.4^4.3.4^4.3.19.4^2.19.11.3.4^2.3.4^2.3.11.4^4.11.13.4^4.13.4^4.13^2.11.13^2.8.4^4.8$ 3481

= 3481

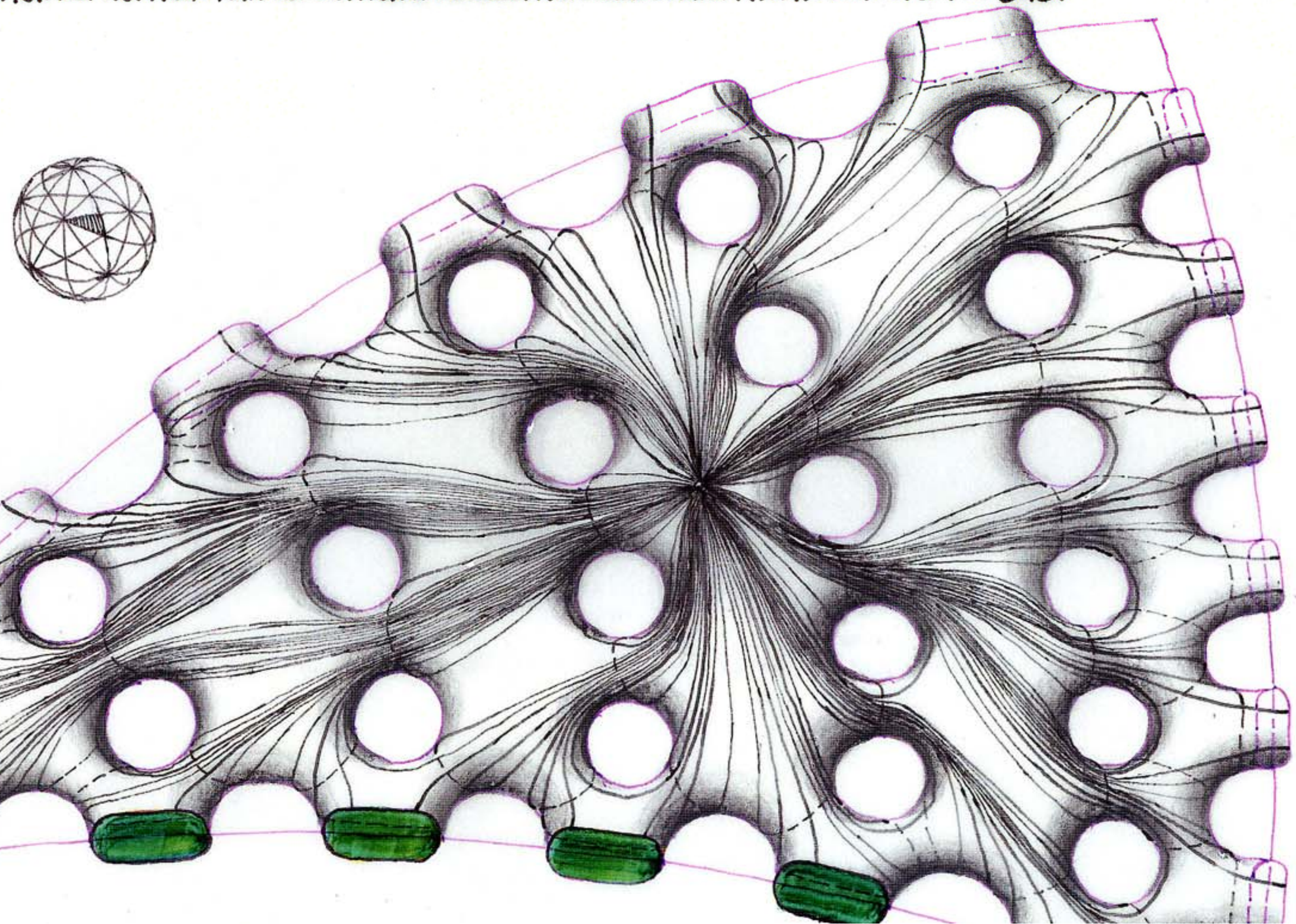
= 118π

= 211

= 120

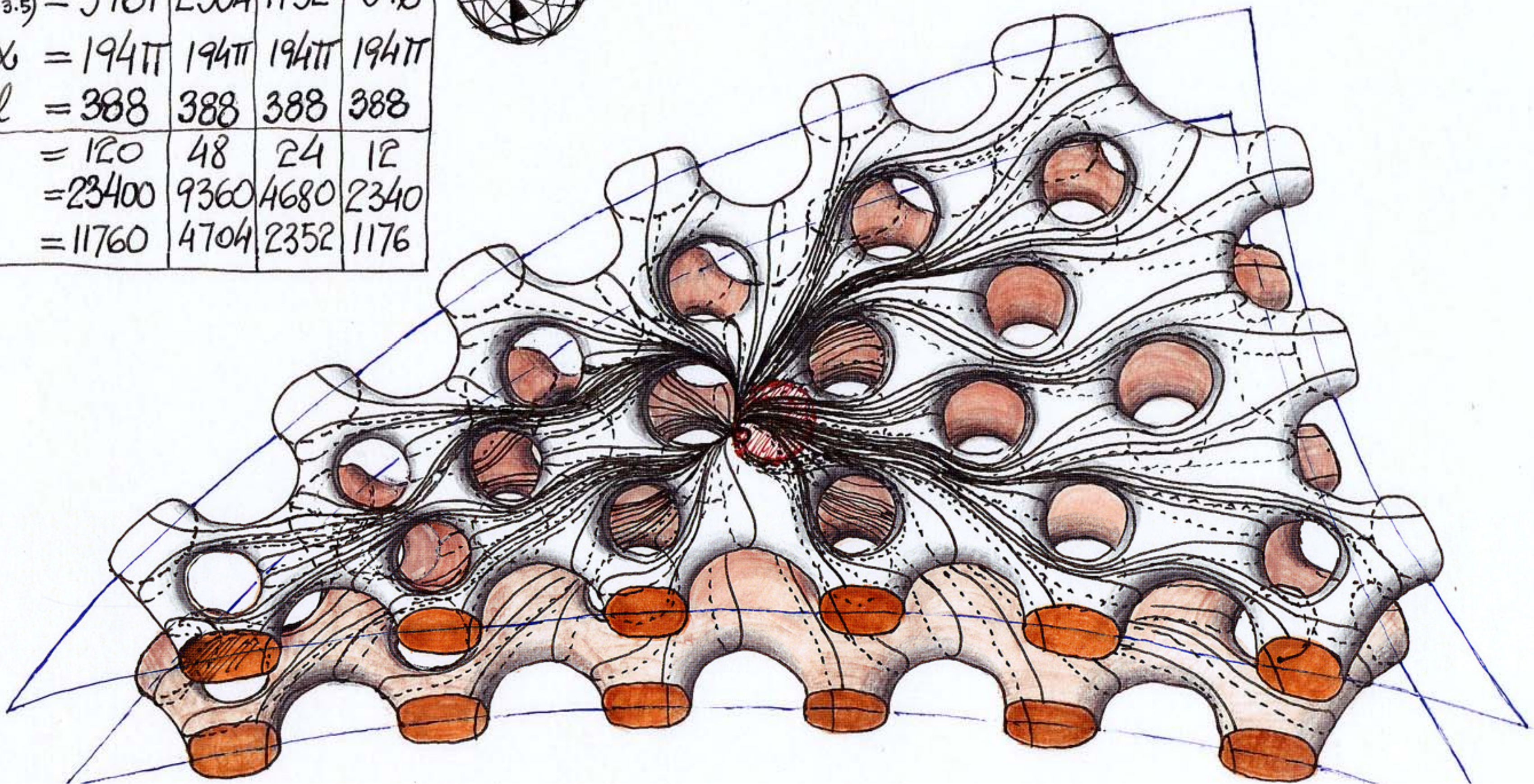
= 12660

= 5580



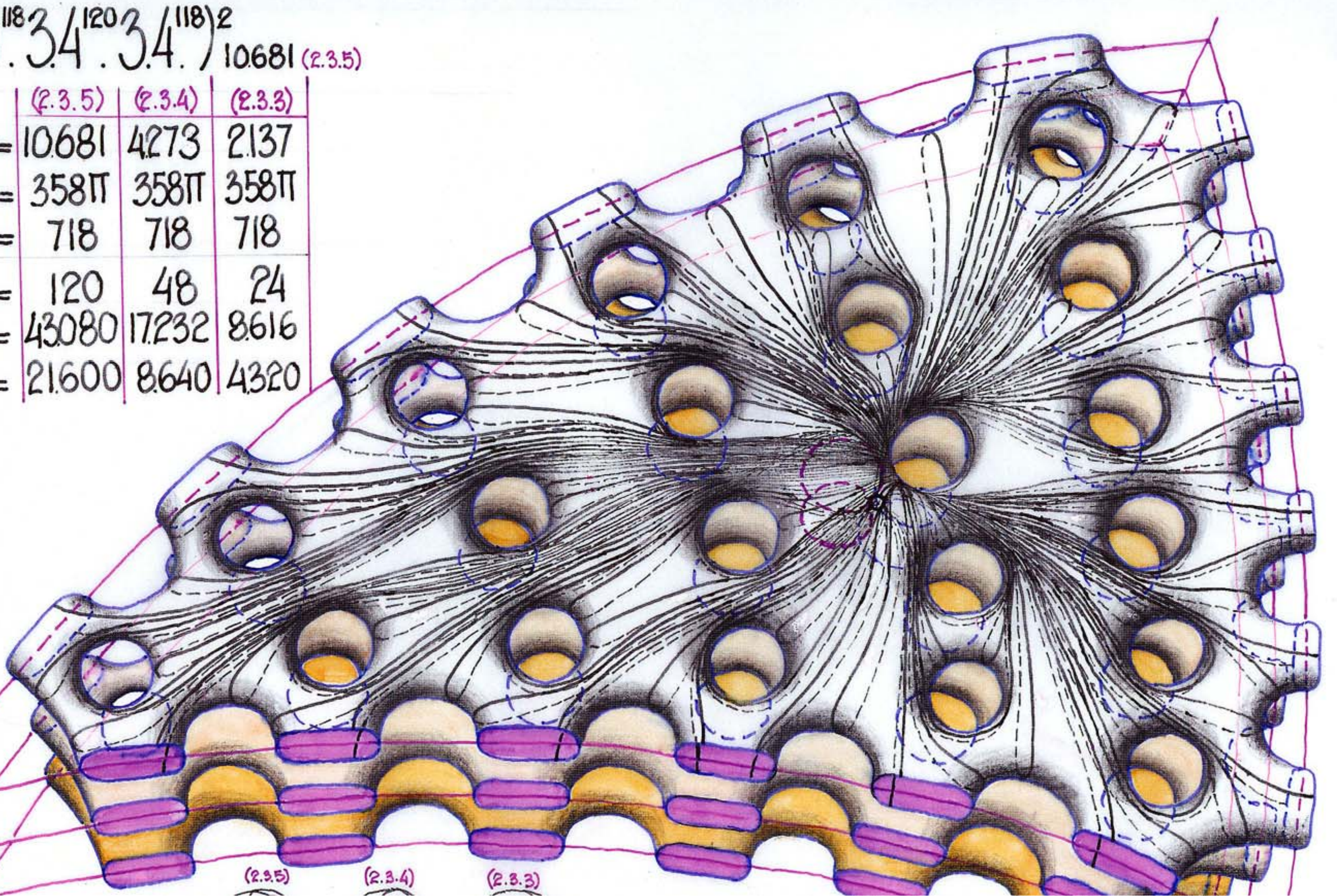
(194)²
)5761 (2.3.5)

	(2.3.5)	(2.3.4)	(2.3.3)	(2.3.2)
(2.3.5)	= 5761	2304	1152	576
α	= 194π	194π	194π	194π
l	= 388	388	388	388
	= 120	48	24	12
	= 23400	9360	4680	2340
	= 11760	4704	2352	1176



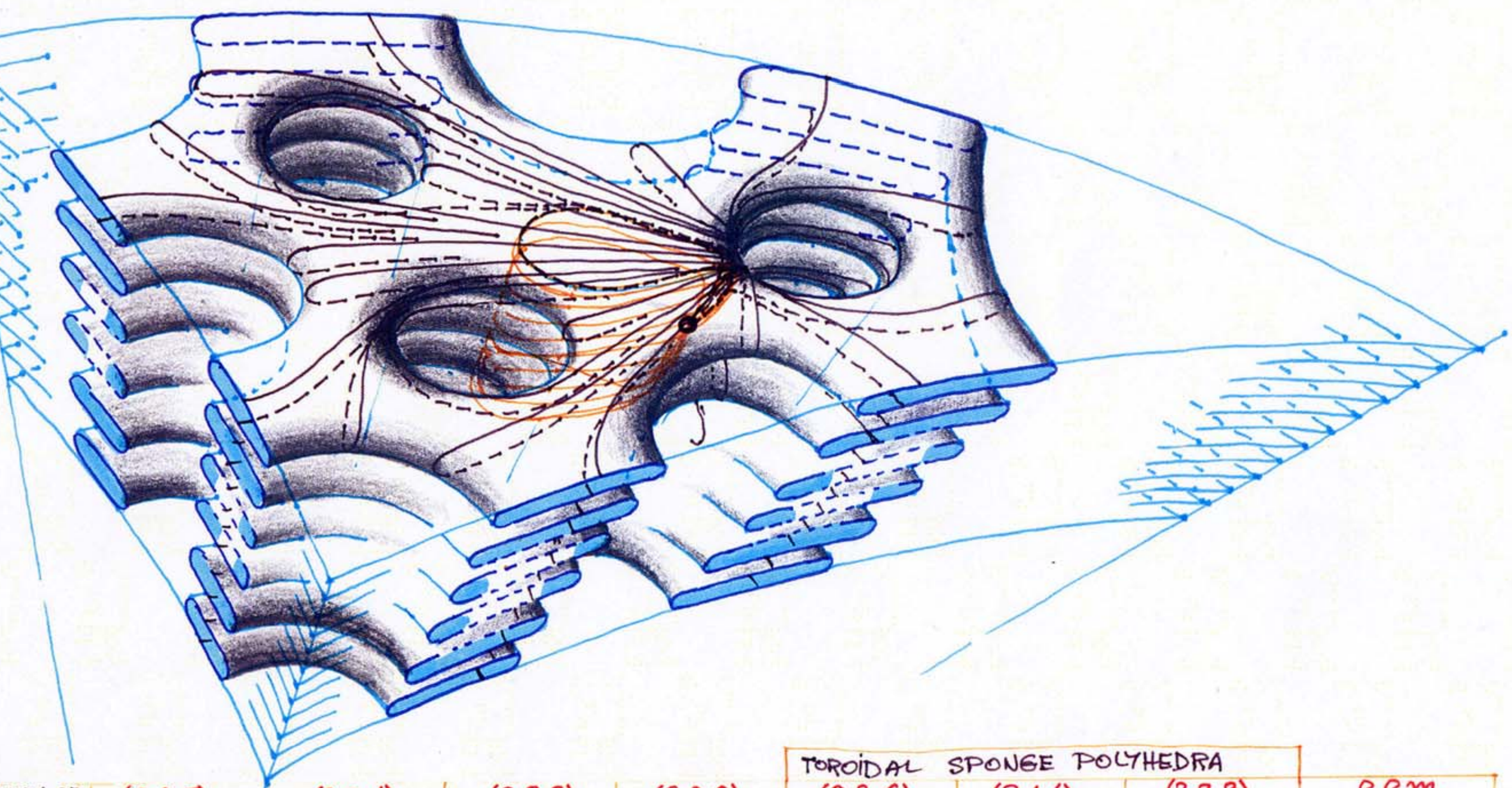
$^{118}.3.4^{120}.3.4^{118})^{2}$ 10681 (2.3.5)

	(2.3.5)	(2.3.4)	(2.3.3)
=	10.681	4.273	2.137
=	358π	358π	358π
=	718	718	718
=	120	48	24
=	43.080	17.232	8.616
=	21.600	8.640	4.320

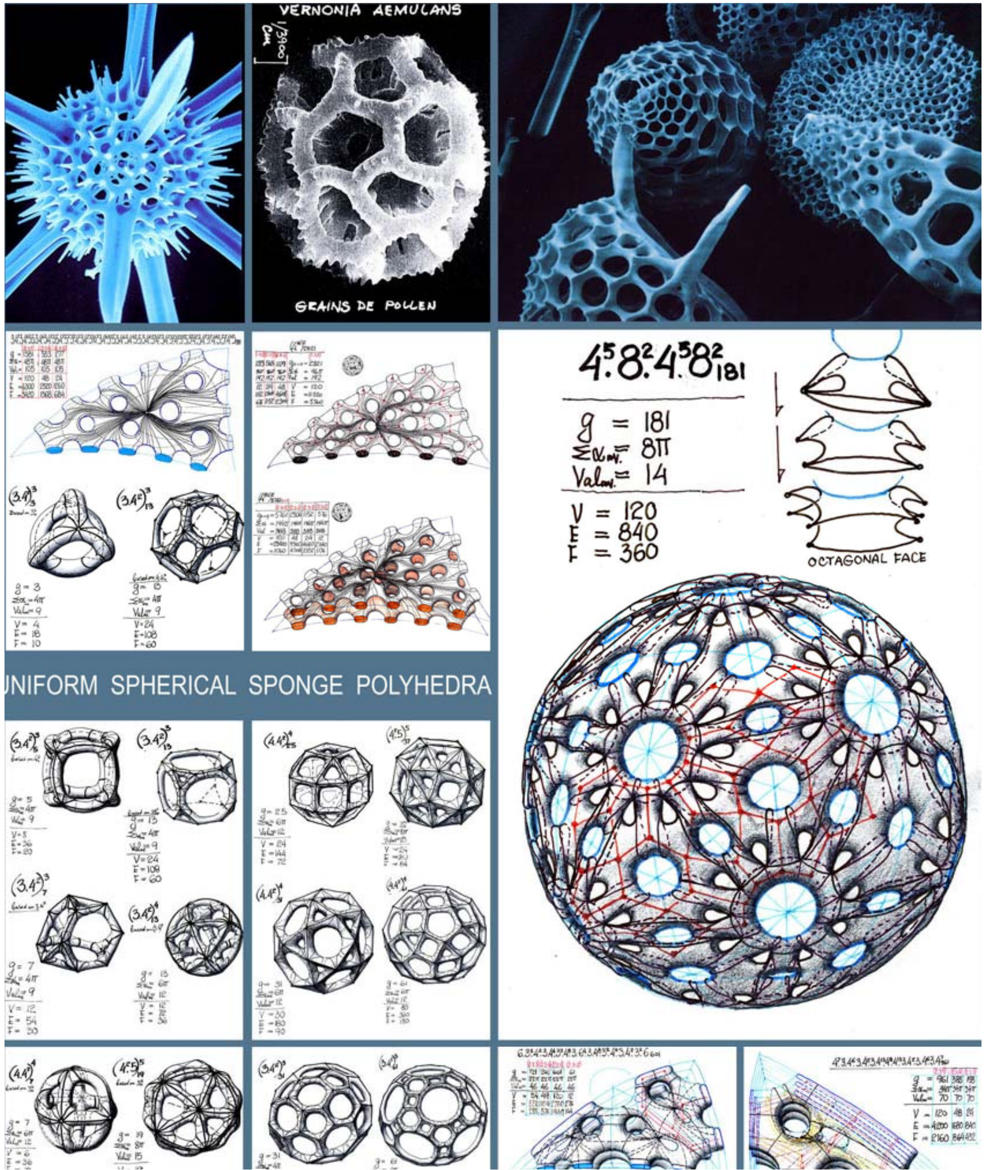


$.4^{11}.4^{11}.3(2.4^{12}.4^{12})^{n-1}.2.3.4^{11}.4^{11})^{2}_{1321+720(n-1)}$;(2.3.5)

$n = 1 \ldots\ldots \infty$

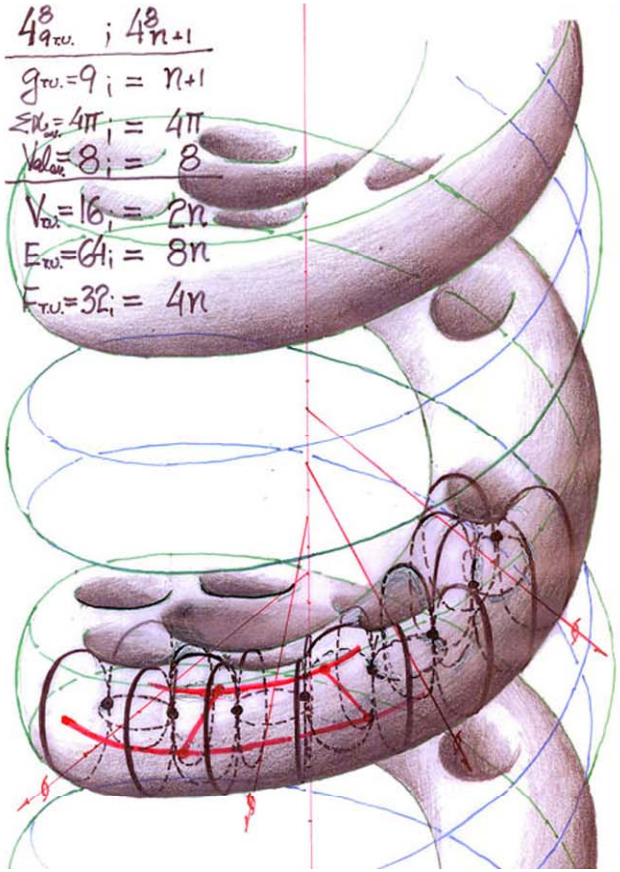


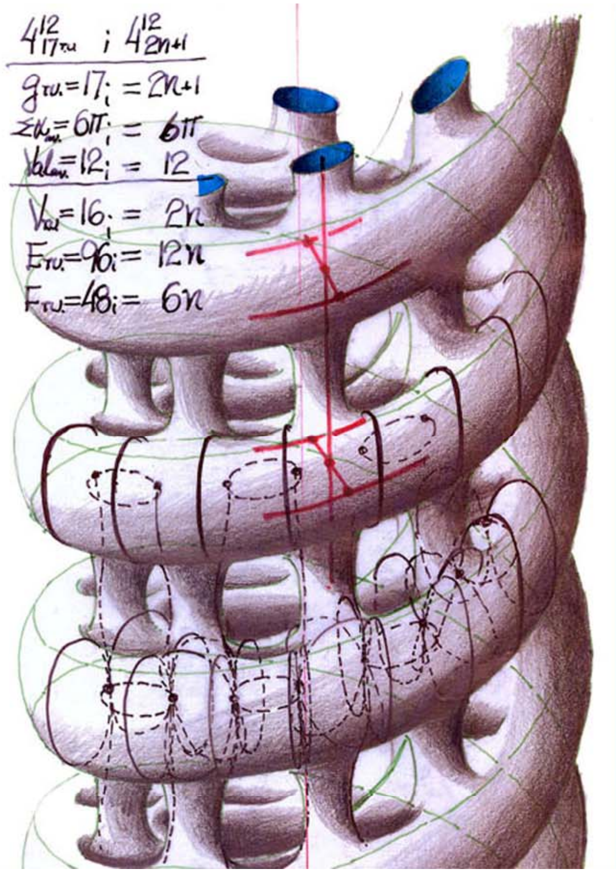
					TOROIDAL SPONGE POLYHEDRA			
YMM. GR.	(2.3.5)	(2.3.4)	(2.3.3)	(2.3.2)	(2.3.6)TU.	(2.4.4)TU.	(3.3.3)TU.	2.2.m
$g_{N,\ldots}$	1321+720(n-1)	529+288(n-1)	265+144(n-1)	133+72(n-1)	133+72(n-1)	89+48(n-1)	67+36(n-1)	(22+12(n-1))m+1
	46π+24π(n-1)	→	→	→	→	→	→	→

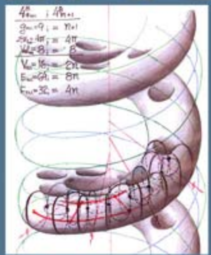

VERNONIA AEMULANS
GRAINS DE POLLEN
4⁵.8².4⁵.8² 181
g = 181
Val = 14
V = 120
E = 840
F = 360
OCTAGONAL FACE
UNIFORM SPHERICAL SPONGE POLYHEDRA

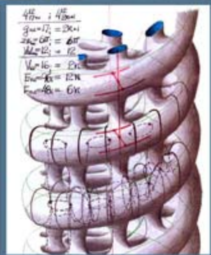
T-1

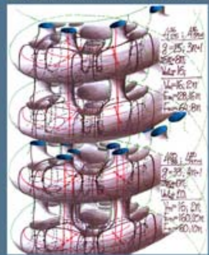
Nature is saturated with sponge structures on every possible scale of physical-biological reality. The term was first adopted in biology: "Sponge: any member of the phylum Porifera, sessile aquatic animals, with single cavity in the body, with numerous pores. The fibrous skeleton of such an animal, remarkable for its power of sucking up water". (Wordsworth dictionary).
Of course the term applied to **'spherical sponges'. It turns out that the key characteristic of porosity is attributable to a much wider morphological phenomenon.**

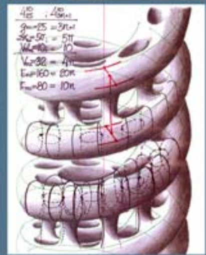

4⁸ 9 T.U. ; 4⁸ n+1
g T.U.=9 ; = n+1
Σ = 4π ; = 4π
Val = 8 ; = 8
V T.U.=16 ; = 2n
E T.U.=64 ; = 8n
F T.U.=32 ; = 4n


4¹² 17 T.U. ; 4¹² 2n+1
g T.U.=17 ; = 2n+1
Σ = 6π ; = 6π
Val = 12 ; = 12
V T.U.=16 ; = 2n
E T.U.=96 ; = 12n
F T.U.=48 ; = 6n

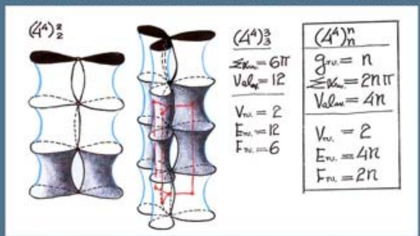


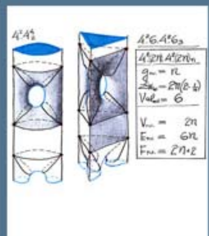


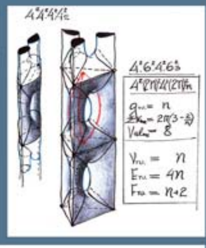


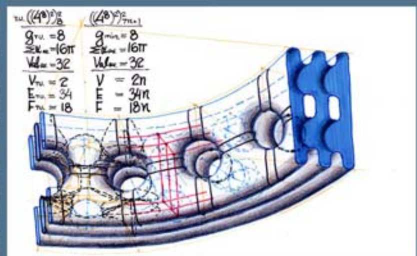


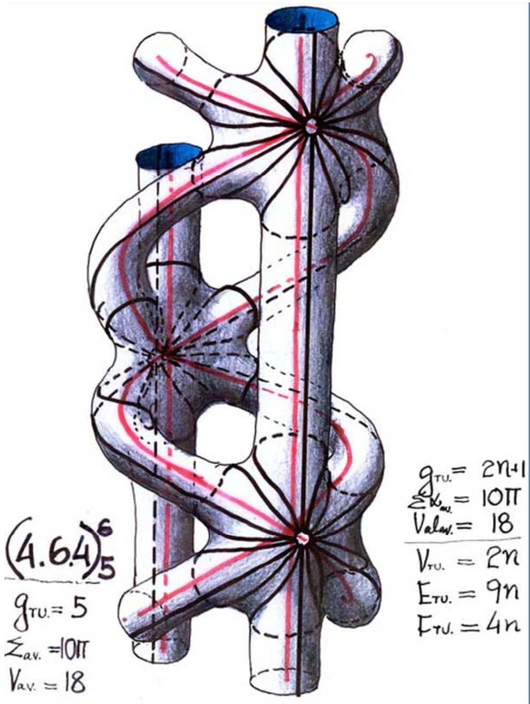
PRIMITIVE UNIFORM SPONGE POLYHEDRA M.BURT

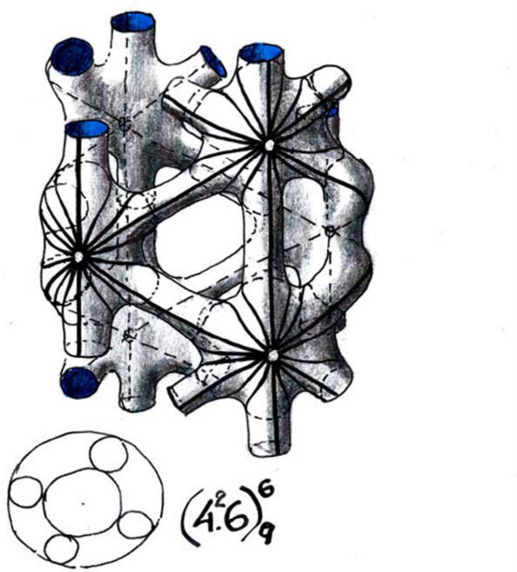












PERIODIC (INFINITE) SPONGE POLYHEDRON – $(4^2.6)^6_9$
OF THE POLYHEDRAL FAMILY: $(4^2.6)^6_{g=2\pi+1}$

$n=2 \quad \left(4.^{2}5\right)^{5}_{19}$

$g = 19 = 9n+1$

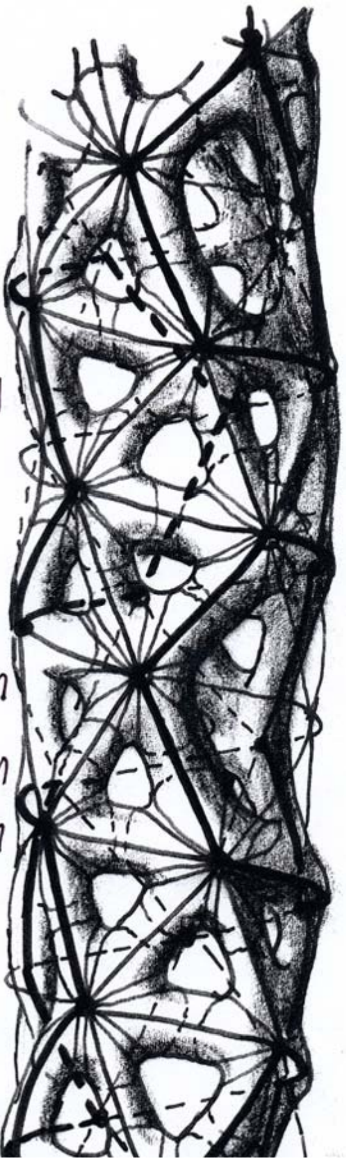
$\sum \alpha_{av.} = 8\pi$

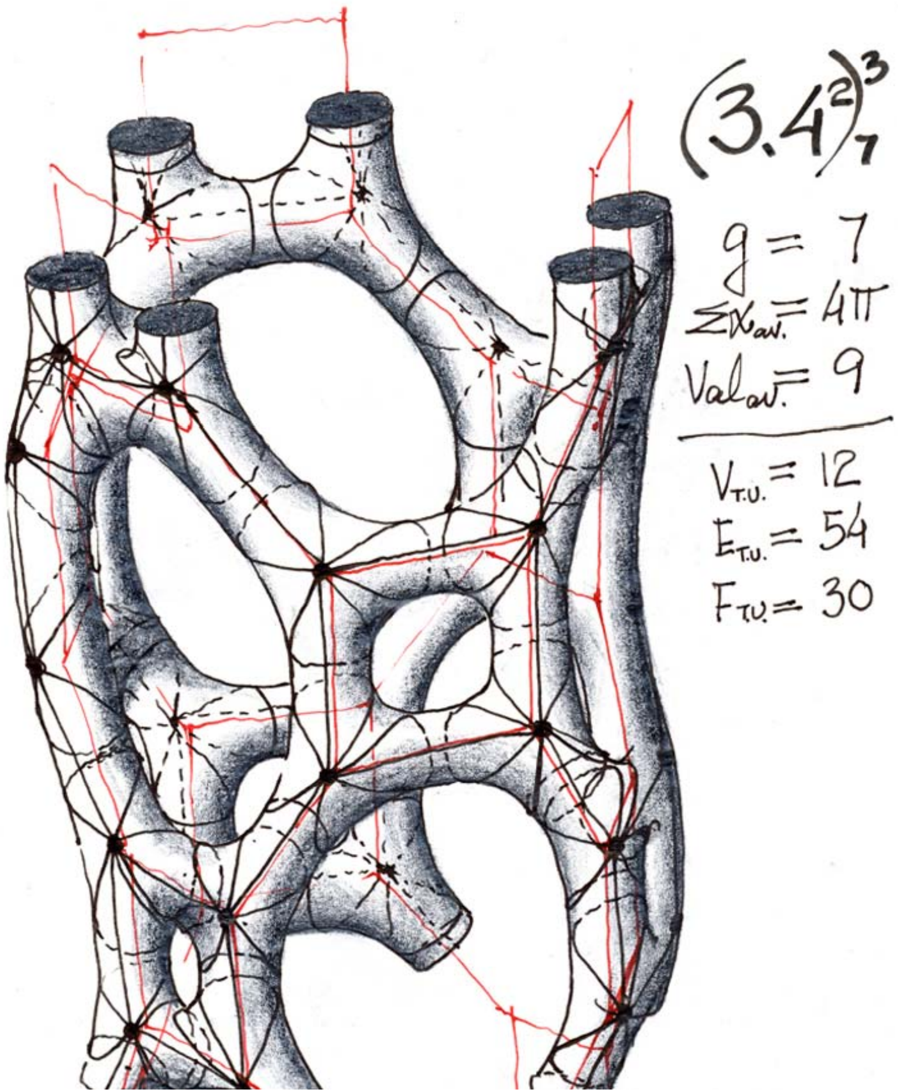
$Val_{av.} = 15$

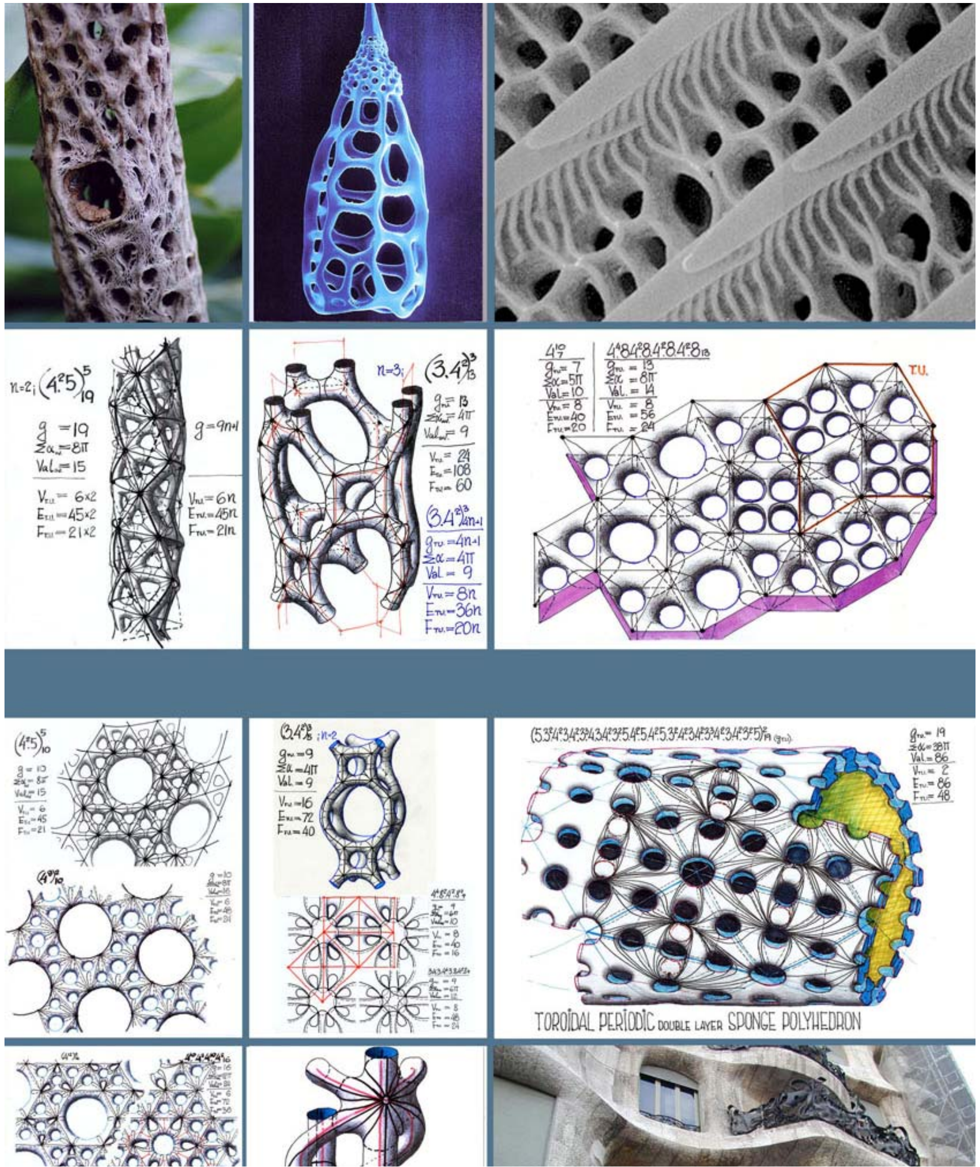
$V_{T.U.} = 6 \times 2 = 6n$

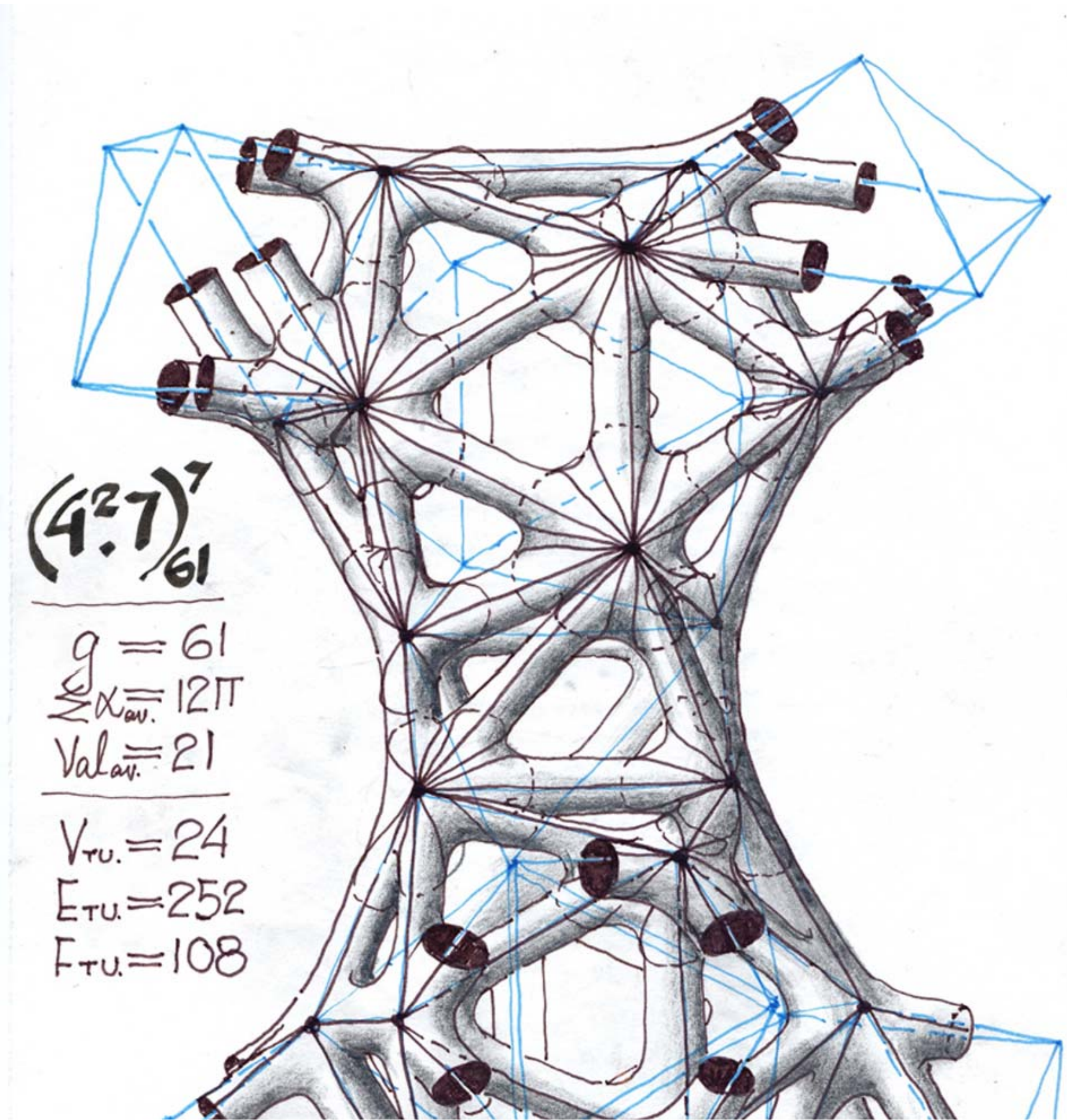
$E_{T.U.} = 45 \times 2 = 45n$

$F_{T.U.} = 21 \times 2 = 21n$




$(3.4^2)^3_7$
$g = 7$
$\Sigma K_{av.} = 4\pi$
$Val_{av.} = 9$
$V_{T.U.} = 12$
$E_{T.U.} = 54$
$F_{T.U.} = 30$


TOROIDAL PERIODIC DOUBLE LAYER SPONGE POLYHEDRON


$(4^2.7)^7_{61}$
$g = 61$
$\sum \alpha_{av.} = 12\pi$
$Val_{av.} = 21$
$V_{TU.} = 24$
$E_{TU.} = 252$
$F_{TU.} = 108$

$(4^6)^2_{97}$

$_{TU.} = 97$

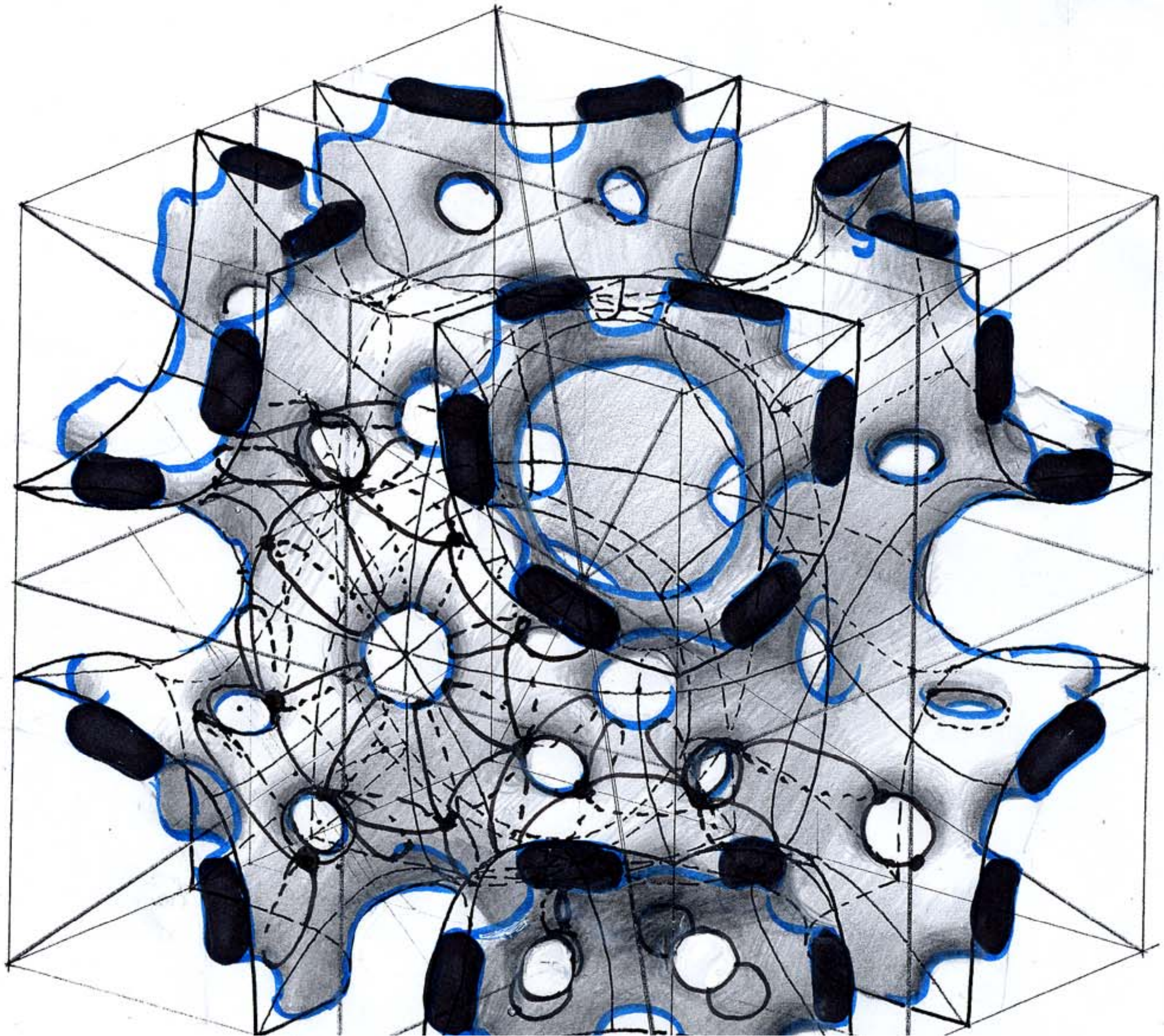
$_{av.} = 6\pi$

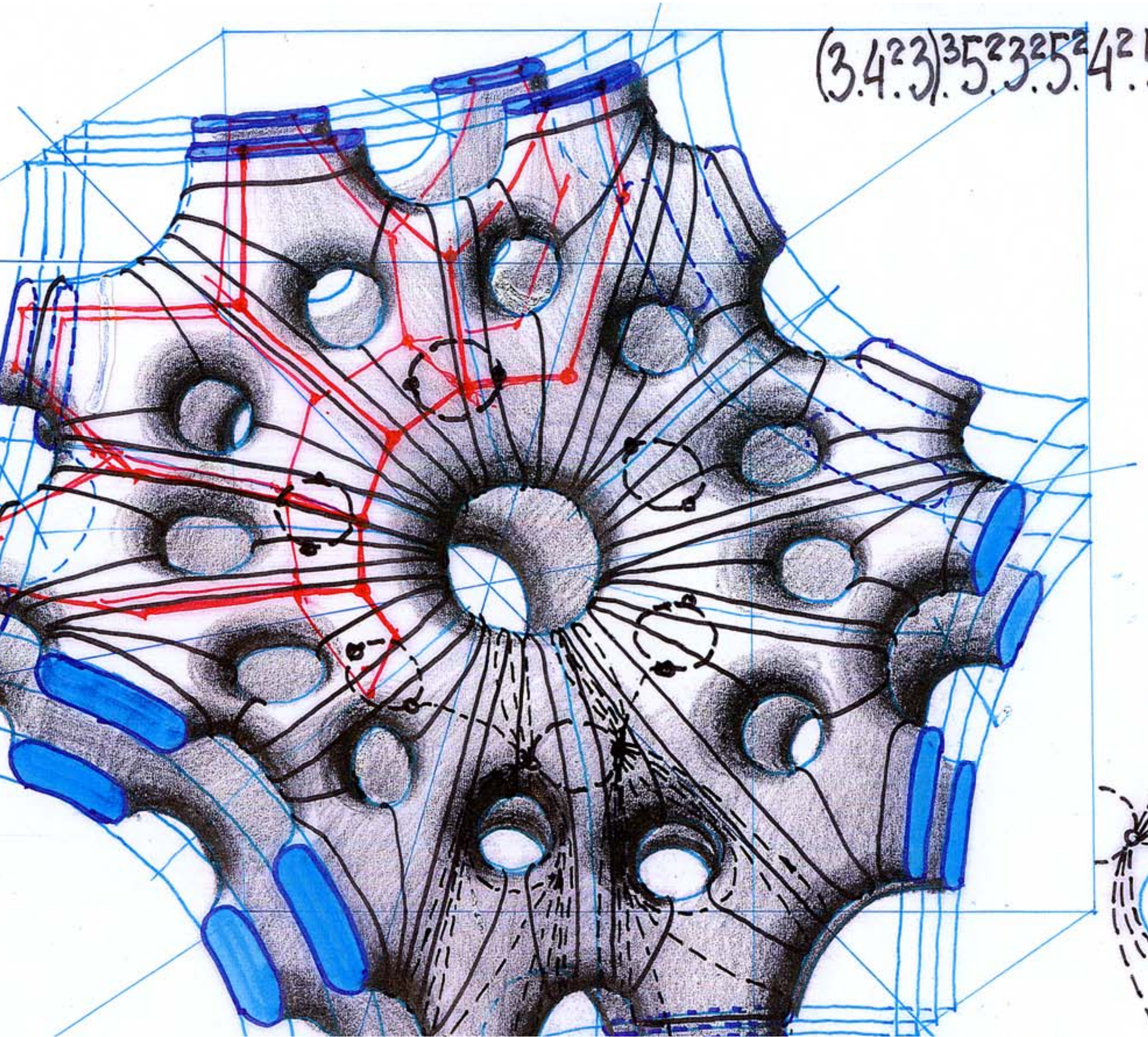
$_{av.} = 12$

$V_{TU.} = 96$

$_{TU.} = 576$

$_{TU.} = 288$





$$(3.4^2.3)^3.5^2.3^2.5^2.4^2.5.3.4^2.3.5.4^2.5^2.3^2.5^2_{337}$$

$g_{TU.} = 337$

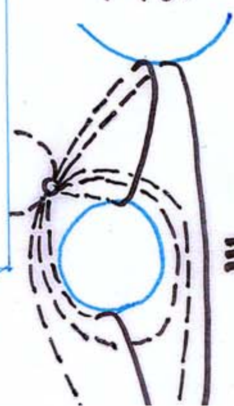
$\sum \alpha_{av.} = 16\pi$

$Val_{av.} = 34$

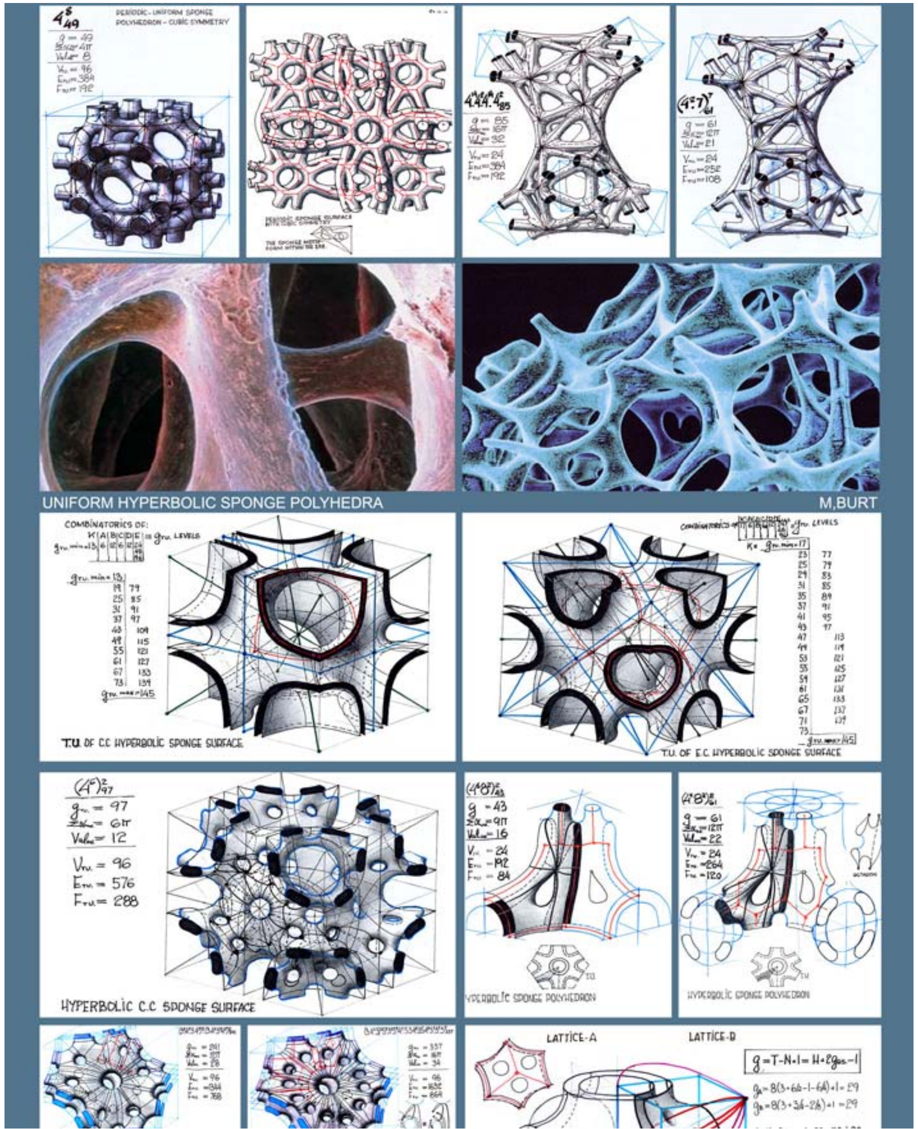
$V_{TU.} = 96$

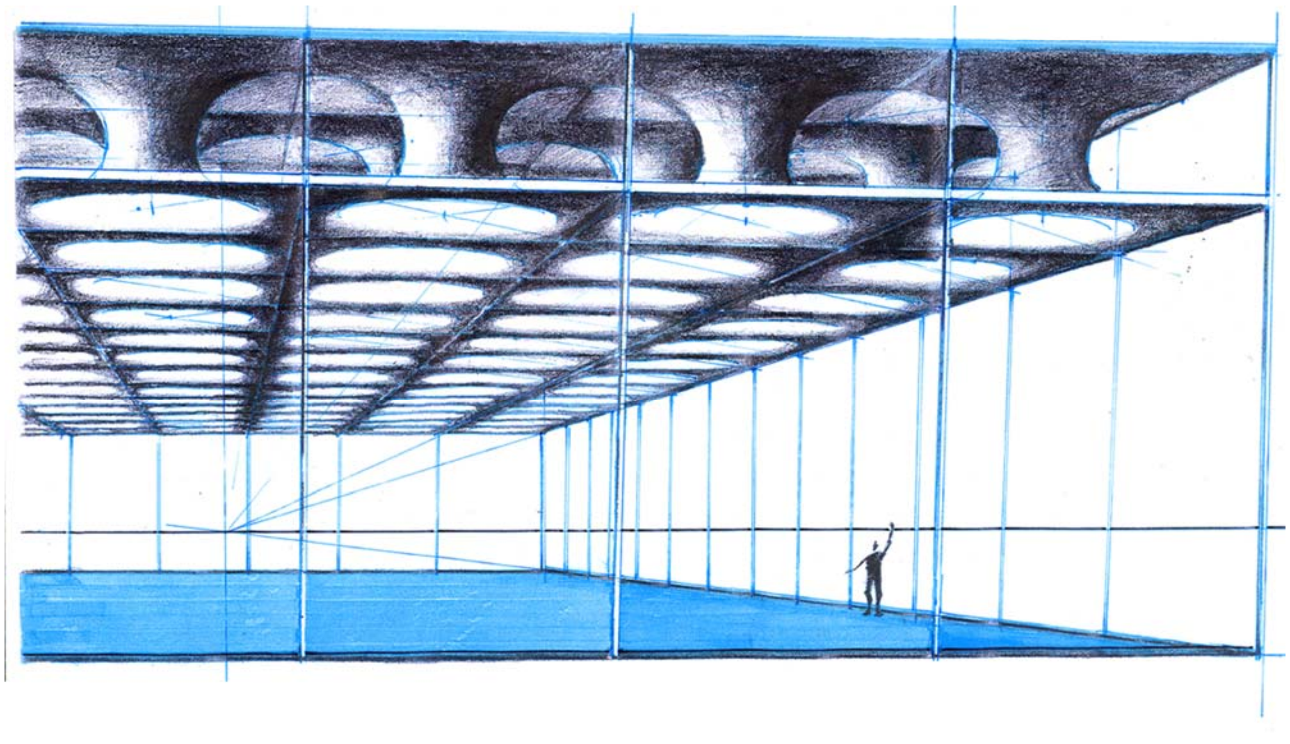
$E_{TU.} = 1632$

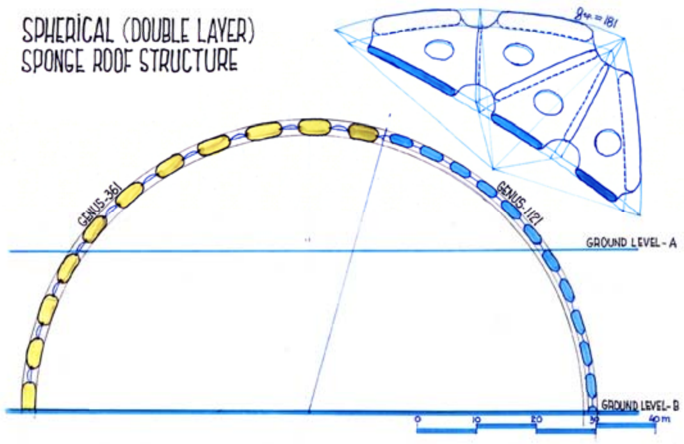
$F_{TU.} = 864$



≡

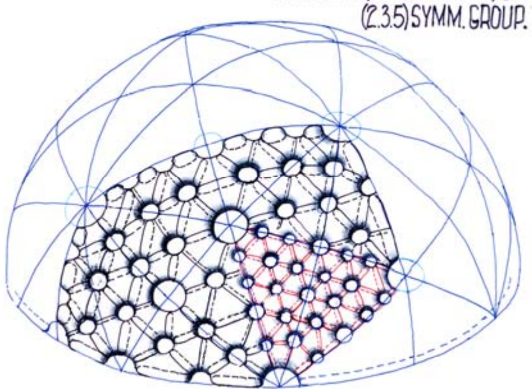

PERIODIC - UNIFORM SPONGE
POLYHEDRON - CUBIC SYMMETRY
PERIODIC SPONGE SURFACE
UNIFORM HYPERBOLIC SPONGE POLYHEDRA
M,BURT
COMBINATORICS OF:
T.U. OF C.C. HYPERBOLIC SPONGE SURFACE
T.U. OF E.C. HYPERBOLIC SPONGE SURFACE
g_{ru} = 97
V_{ru} = 96
E_{ru} = 576
F_{ru} = 288
HYPERBOLIC C.C. SPONGE SURFACE
HYPERBOLIC SPONGE POLYHEDRON
LATTICE-A
LATTICE-B
g = T-N+1 = H+2g_{os}-1

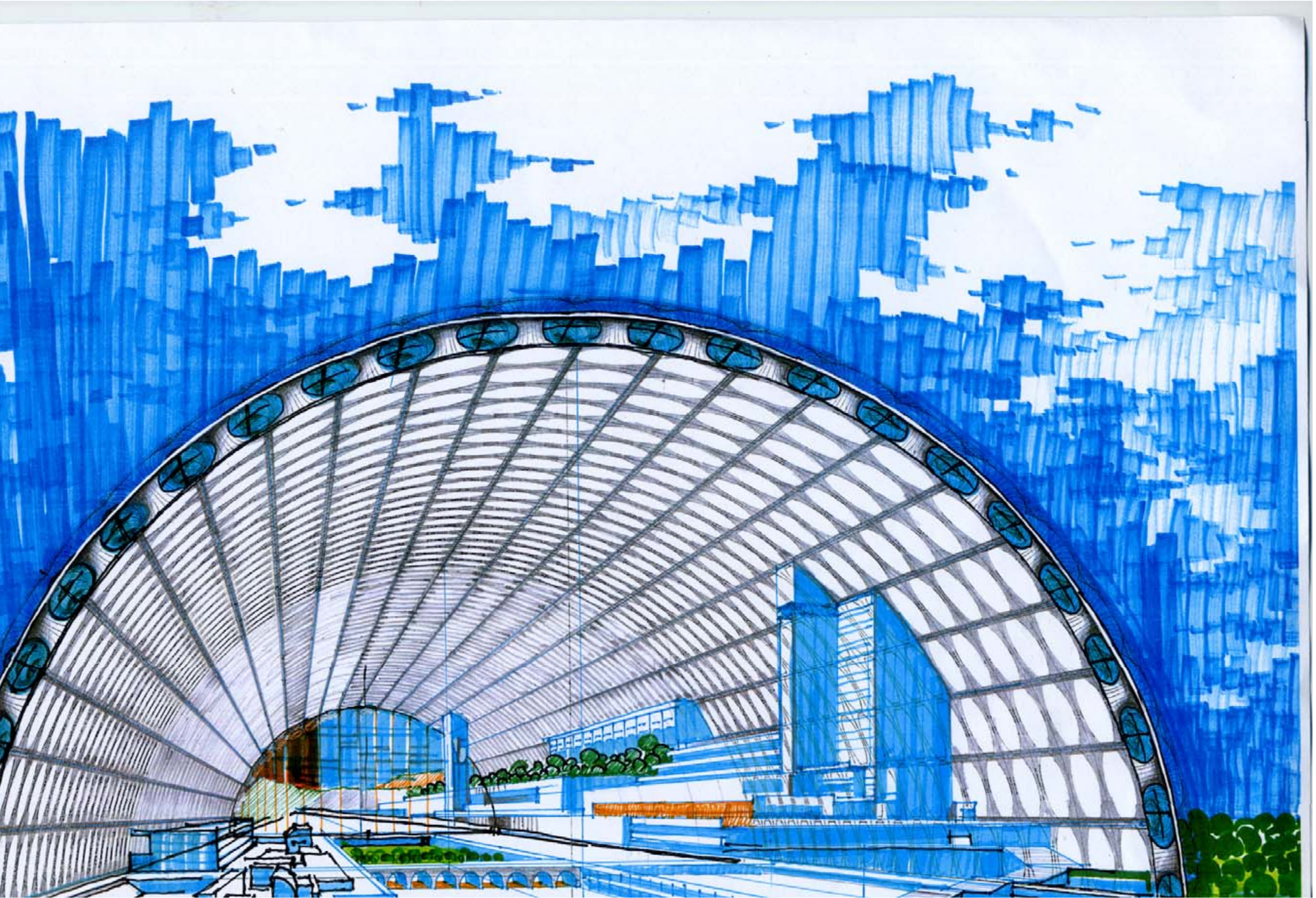


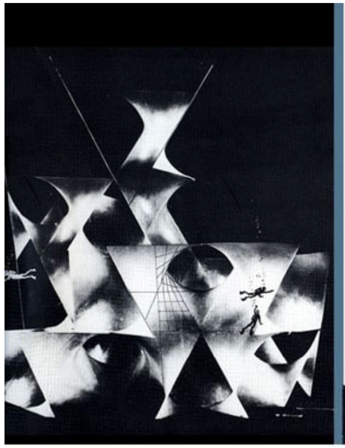

SPHERICAL (DOUBLE LAYER)
SPONGE ROOF STRUCTURE
GENUS-361
GENUS-1121
GROUND LEVEL-A
GROUND LEVEL-B
0
10
20
30
40 m

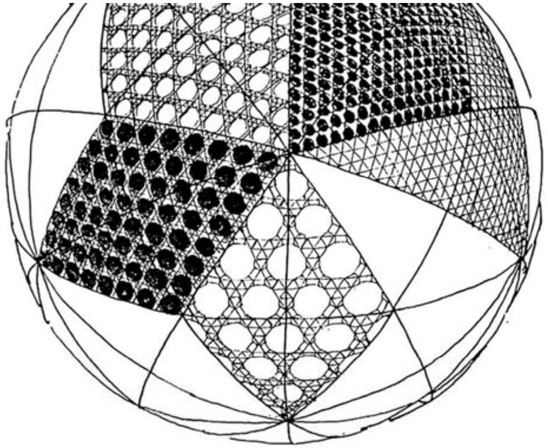
SPHERICA (DOUBLE LAYER) SPONGE STRUCTURE
(2.3.5) SYMM. GROUP. $g_{sp} = 361$

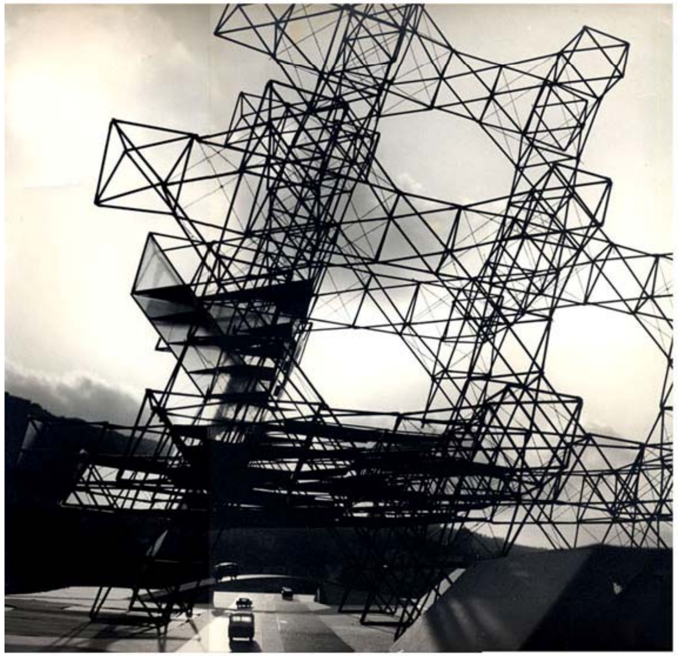
$g_{sp} = 1121$



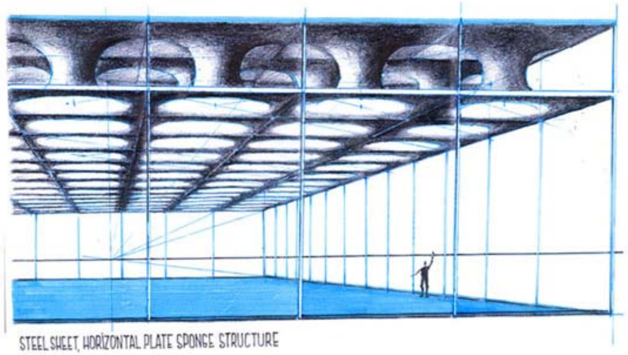




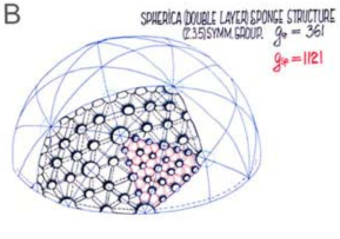




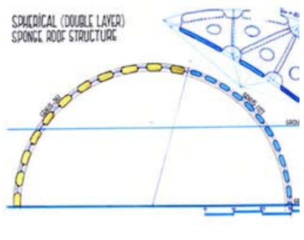
A

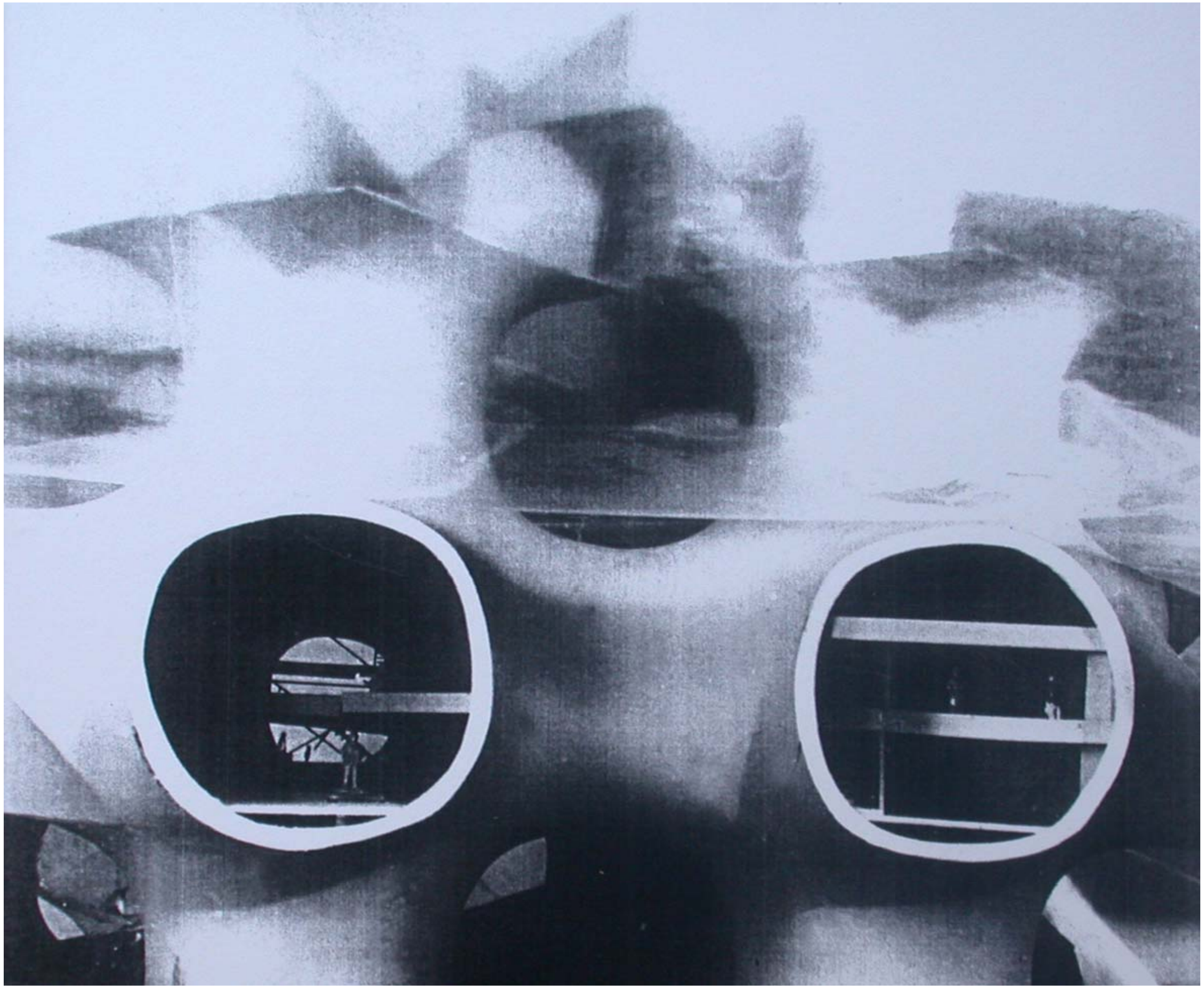

STEEL SHEET, HORIZONTAL PLATE SPONGE STRUCTURE

B

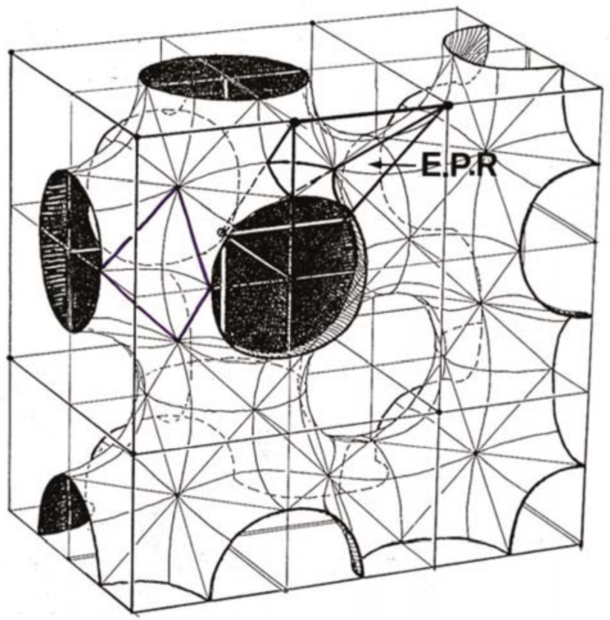

SPHERICA (DOUBLE LAYER) SPONGE STRUCTURE
(2,3,5) SYMM. GROUP. g0 = 361
g0 = 1121

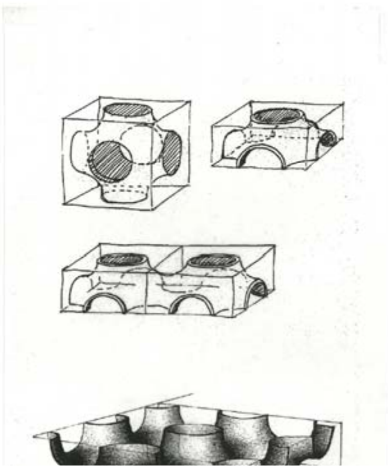
C

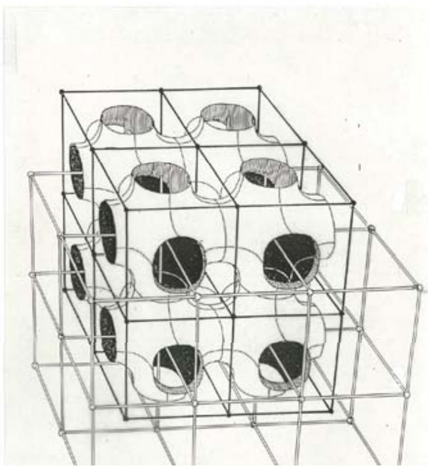

SPHERICAL (DOUBLE LAYER)
SPONGE ROOF STRUCTURE

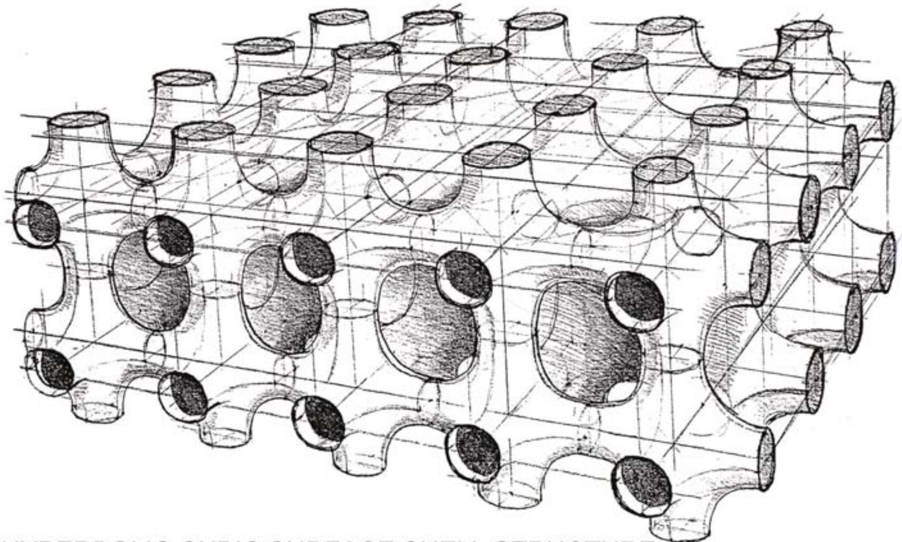


Periodic 2-D manifold
(and related E.P.R.)
subdividing space intc
two identical
subspaces.



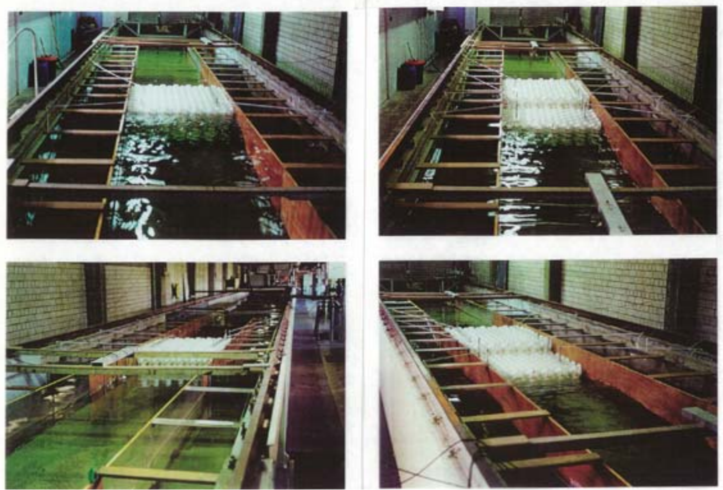




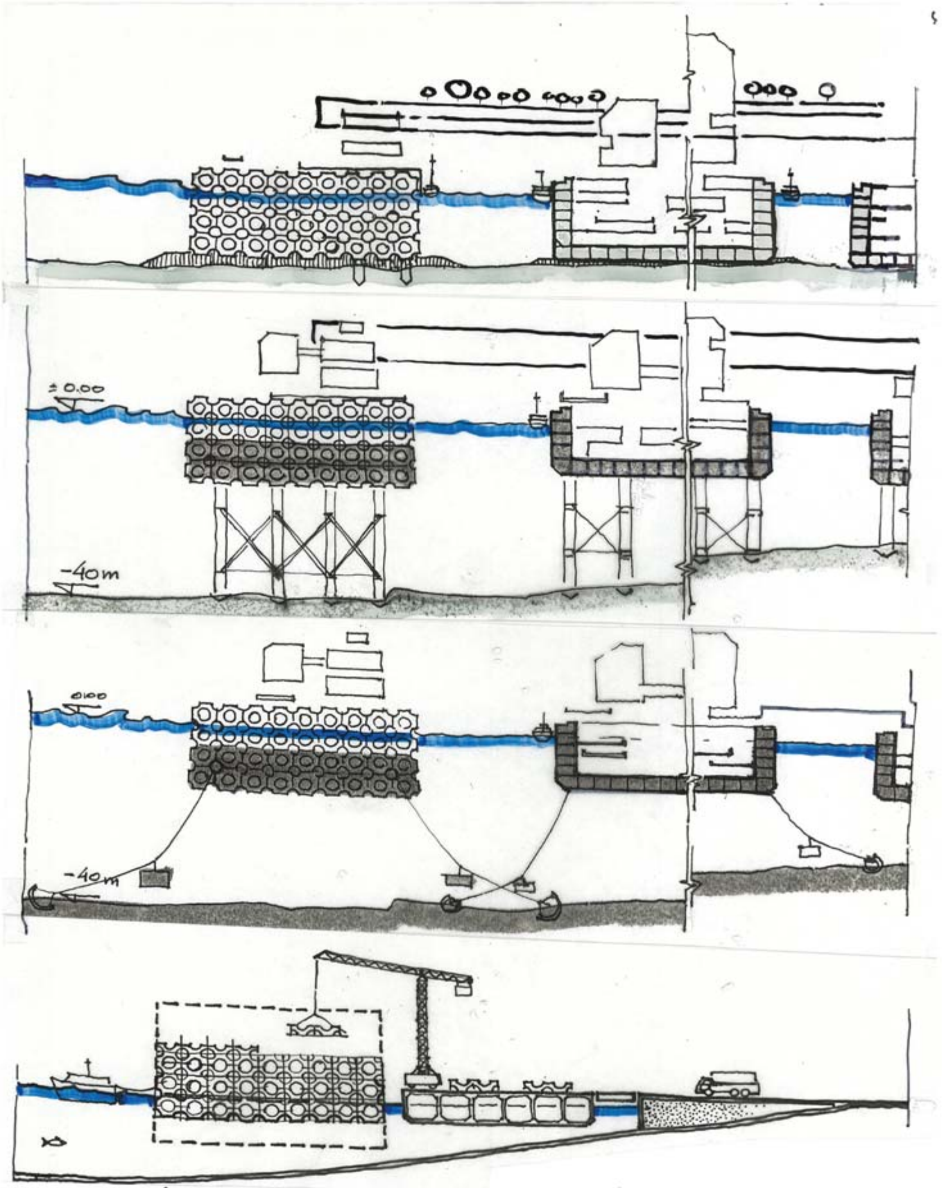


HYPERBOLIC CUBIC SURFACE SHELL STRUCTURE

2.

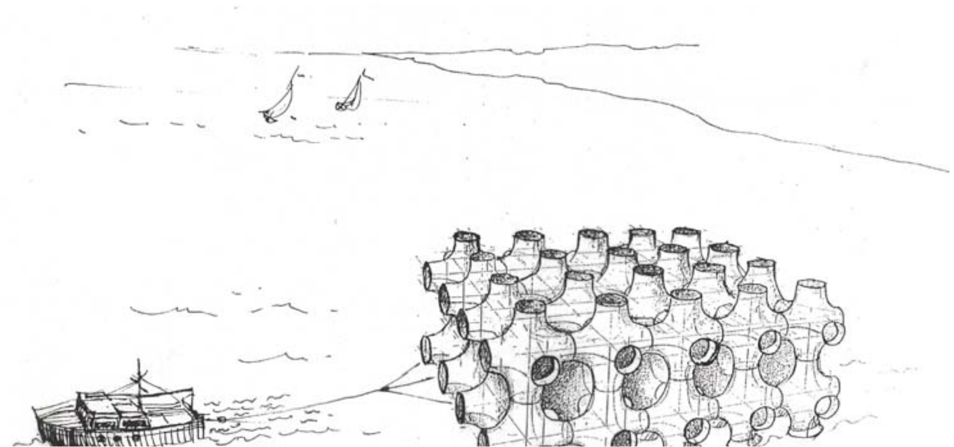


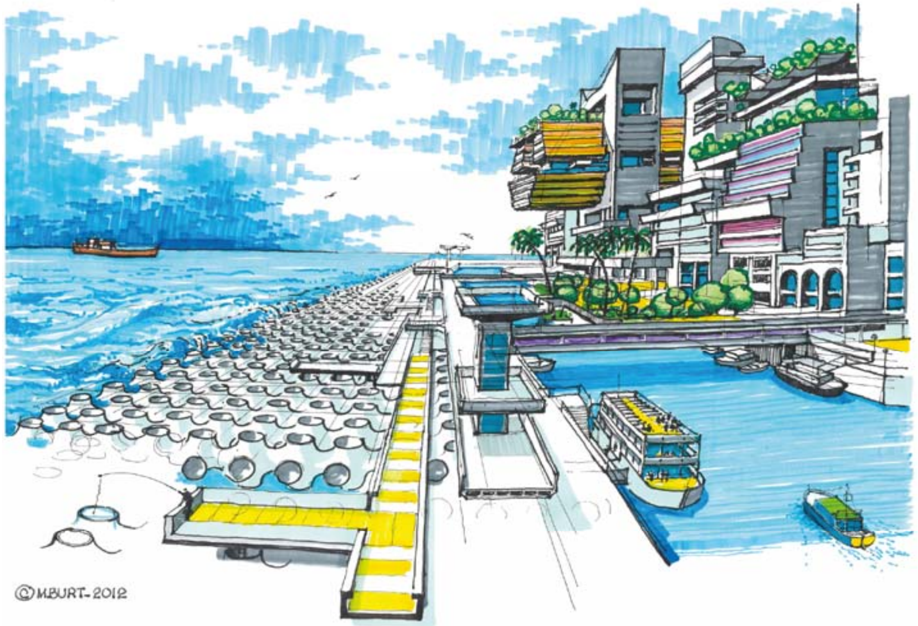
THE TOTAL MATERIAL AMOUNT OF THE SPONGE BREAK-WATER IS ABOUT 3÷5% OF THE AMOUNT REQUIRED TO REALIZE A CONVENTIONAL BREAKWATER UNDER THE SAME CONDITIONS. (CAMERI, TECHNION, I.I.T-1999).



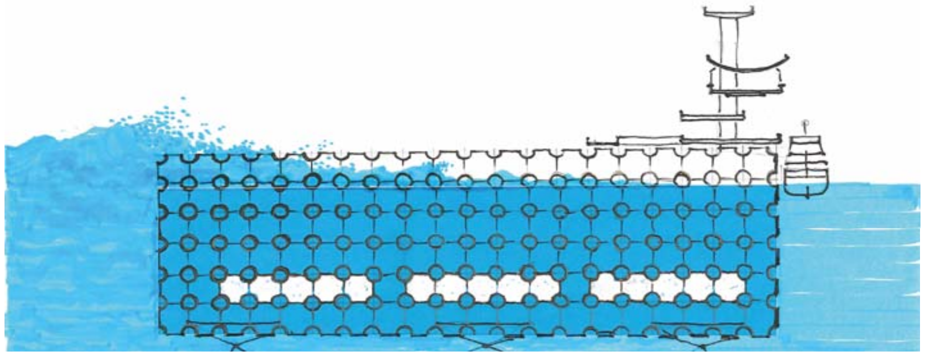
PERMEABLE 'SPONGE BREAKWATERS' AND 'CONTAINER PLATFORMS'

FLOATABLE 'FILL MATERIAL FREE' PRODUCTS, SEA-TRANSPORTED FROM COASTAL FABRICATION PLANT TO THE SITES OF FUNCTION

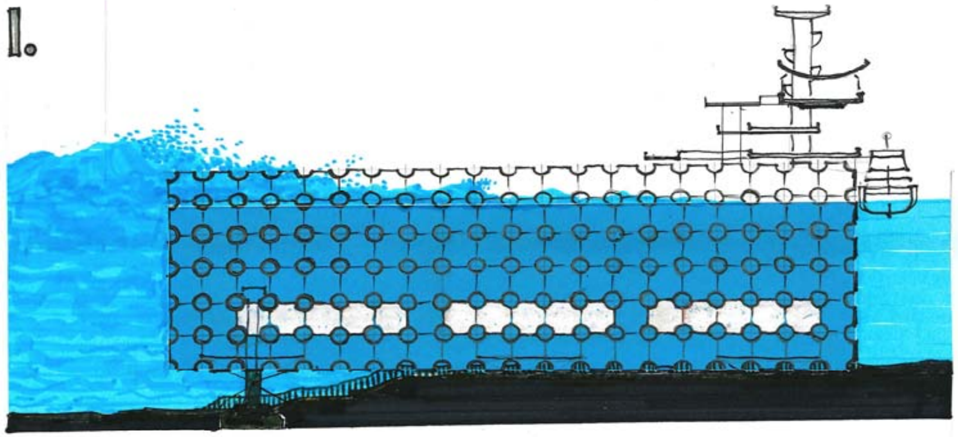




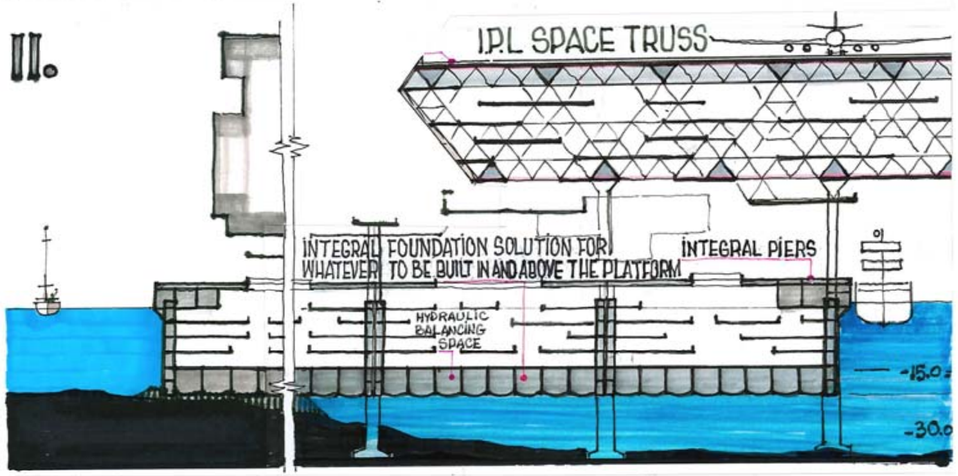
FLOATING PERMEABLE SPONGE BREAKWATER



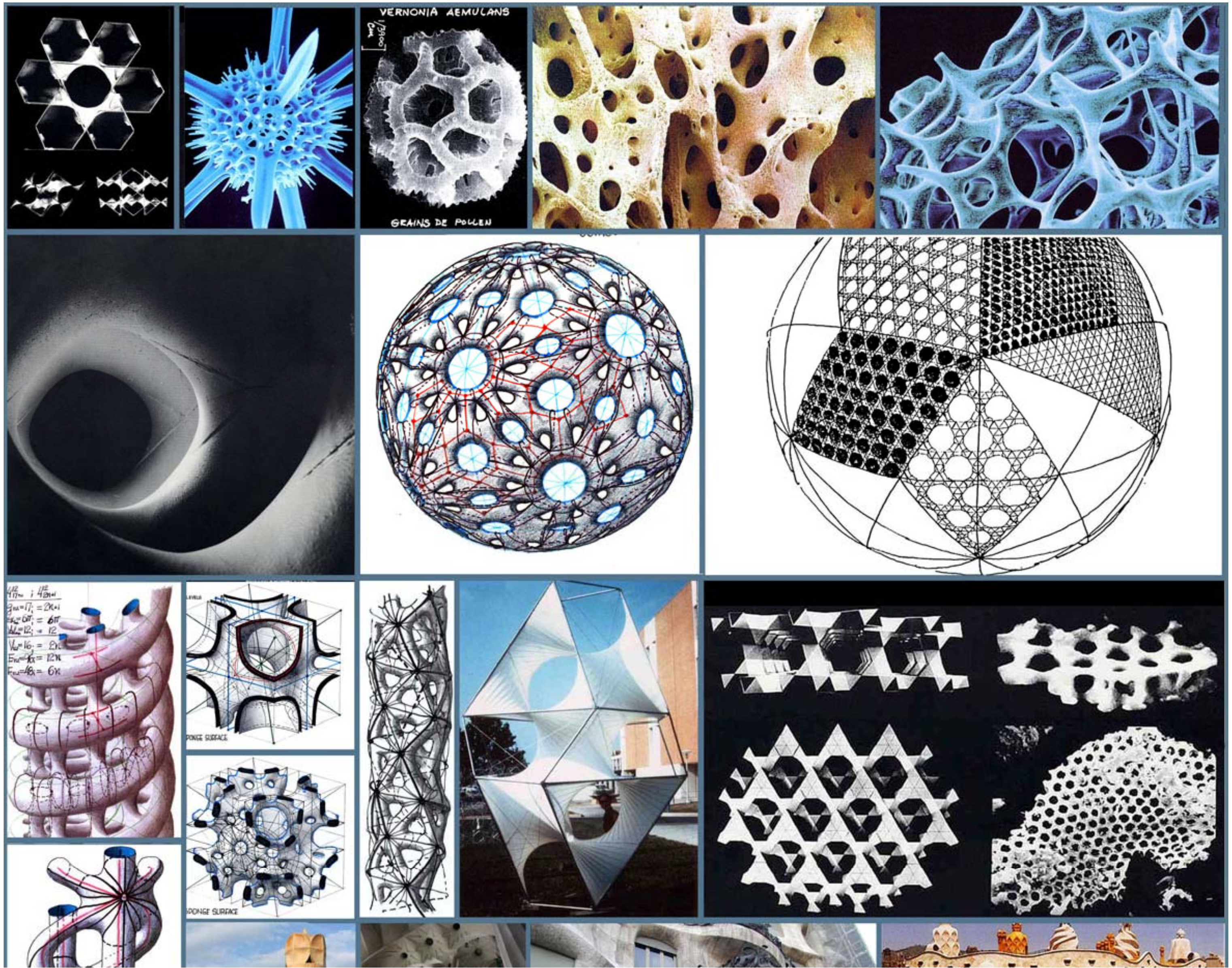
I.



II.


I.P.L SPACE TRUSS
INTEGRAL FOUNDATION SOLUTION FOR
WHATEVER TO BE BUILT IN AND ABOVE THE PLATFORM
INTEGRAL PIERS
HYDRAULIC
BALANCING
SPACE
-15.0
-30.0

III.


VERNONIA AEMULANS
GRAINS DE POLLEN

IN CONCLUSION

Euclidean imagery had provided us with the pyramids and the urban grids around the world.

Spherical imagery had inspired the Pantheon, the Hagia Sophia and the Global Navigation System.

Hyperbolical geometry related structural morphology is still a promise. We are only starting to unveil the potential **space structures to be inspired by the hyperbolic imagery.**

With some extrapolation of the perceiving mind it is right to claim that the sponge phenomenon, with its porosity and permeability characteristics, is central to the physical morphological nature of the human habitat, and represents its defining imagery.