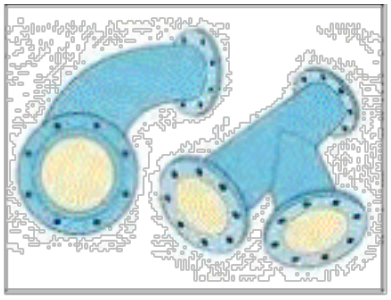
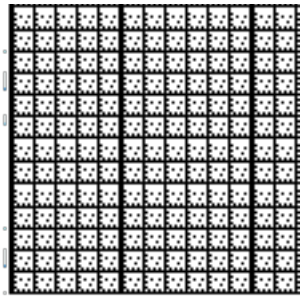
Issue #5 May2, 2918

Many of our members may wonder what the heck we can make out of moon dust. That's a good question. There are two major types of moon dust, that of the lighter rugged "highlands" and that in a darker smoother **mare** (pronounce MAH ray, the Latin ancient Roman word for a "sea.")

Well I'm not sure about Highand moon dust, but what makes up the dark "seas" or **maria** (plural od mare, pronounced MAH ria) is lava flows, sometimes many layers of the stuff.

And lava is basaltic, bingo! You can make a heck of a lot of things out of basalt.

CAST BASALT: An Industry Perfect for a Startup Lunar Outpost

Basalt pipes   **Basalt tiles Plus**

Carved basalt: lamp bases, statues, planters, pots, pans of various sizes and shapes, chair or bench seats, table tops, and more - **perhaps even bath tubs**.

Note that surface basalt is pretty much "powdery sand." Larger "intact" chunks will be found as we go down a few meters (as we will have to do to set housing units down a few meters, then cover them with thermal and radiation -proofing regolith.

Large chunks may well be found in abundance in lava tubes as well, having fallen off the sides and ceiling., a process called "spallation."

Perhaps **most importantly, pipes, tubes and chutes made of cast basalt can handle abrasive moondust fines while metal chutes and tubes would soon wear through.**

There is a growing, newly reinvented cast basalt industry in Germany, Spain, Britain, India, Viet Nam, and the United States that is producing two types of products that will be very useful in the early lunar settlements: **abrasion-resistant pipes** & **regolith (moondust)-handling equipment** as well as **countertops**, & **decorative wear-resistant floor and wall tiles**.

More than a decade ago, I read a one-liner in an encyclopedia about a "cast-basalt industry in central Europe." Immediately the need of early Lunan settlements to hit the ground running with appropriate-technology industries came to mind. Then I found a firm in West Virginia that makes cast basal tiles, mostly for industrial settings, because they worn down. The factory let me take a sample, which some years later, at a science-faction event in Minneapolis/St. Paul, it disappeared.

Basalt! There is plenty of it on the Moon. The great flat lava flow sheets that fill the Maria basins are essentially basalt. The regolith surface of these "Seas" is but meteorite impact-pulverized basalt.

Melted and cast basalt can be given the mold-transfered look of crosscut sawed wood, of bark, leaves, or other "nature textures". In a world where wood won't be available (until we have planted trees inside our living places), **carved and cast basalt will be a primary material for artists and craftsmen and suppliers of home goods.**

If we start homesteading in Mare Frigoris, carved and cast basalt art forms will be a primary way of making ourselves at home. And they might also be **a primary form of export to space stations and space hotels in Earth orbit.**

The idea of just melting the stuff with a solar concentrator furnace and then pouring it into molds to make useful products seemed a no-brainer. Even if cast basalt had (an assumption) low performance characteristics, there would be plenty of things needing to be made in both Moon and Mars settlements for which high performance would not be necessary. Table tops, planters, tiles paving slabs and much more. That said, their performance is at the tops.

A few years ago years ago, I asked friends in the basalt-rich Pacific Northwest (members of the Portland, Oregon chapter of the National Space Society), if they knew of any such industry in their area. This did not turn up any new leads. Meanwhile they took me through a lava tube near Bend, Oregon.

Today we have the Internet, and I finally returned to the issue and did a simple web search. Voilà! There is a thriving cast basalt industry here on Earth, and like most "materials" industries these days, it is vigorously reinventing itself. "And the envelope, please!"

Cast Basalt's Abrasion Resistance

Casting basalt in itself is not something new. People began to experiment with it in the 18th century. Industrial manufacturing with this material began in the 1920s when **Cast Basalt Pipes** began to be used as an "Abrasion-resistant, Chemical-resistant" lining. The material is crushed, and heated until it becomes molten at 1250°C [2280°F], then cast in molds (e.g. tiles), or centrifuged into pipe shapes. The cast items are then heat treated so that the material crystallizes to take on extreme hardness (720 on the Vickers scale where mild steel is 110; 8-9 on the Mohs scale where diamond is 10). The density is 2.9 g/cm3.

Items for use in material handling (think of handling abrasive regolith moondust on the Moon!): pipes, pipe fittings, cyclones, conveyor parts -- the list of applications is quite long. Two companies ship worldwide.

- Kalenborn Kalprotect, Vettelschoss, Germany

http://www.bulk-online.com/YD/Data/Co/09254.htm

This company's trade name for its cast basalt product is ABRESIST "one of the most tried-and-true materials for wear protection. It is high sliding, has a low coefficient of friction, good impact

resistance, and very good chemical-resistance. More than 1 million meters of pipe have been lined by Kalenborn with **fused cast basalt**."

• Antidesgast, S.A. Barcelona, Spain http://www.antidesgast.com/english/castbasalt.htm

This company makes a similar line of products under the trade name of Basramite, "the world standard for ash slurry pipework at fossil fuel power stations". An all round cost effective, adaptable lining material, extending the life of equipment subject to erosion."

Abrasion-Resistant Materials on the Moon

One of the strongest misgivings frequently expressed about the feasibility of industrial operations on the Moon is the very abrasive and "hard to handle" nature of regolith or moondust. But the answer is right there: Cast basalt as a material up to the job of handling moving regolith in industrial and construction operations seems **a "lunar" solution made in heaven.**

Are there any qualifications? The chemical analysis of the basalt used by Kalenborn includes the expected aluminum, silicon, iron, and titanium oxides, but **a higher than typical percentage** (on the Moon) **of manganese, sodium, and potassium oxides. These elements are found on the Moon, however, in parts per thousand, not in parts per hundred.**

What we need is a lab test of the performance characteristics of a similarly melted, cast, and annealed small samples of real lunar mare basalt regolith. *This research would make a great thesis for a student majoring in inorganic materials.*

An early lunar cast basalt industry producing abrasion-resistant pipes, troughs, and other parts of sundry regolith-handling equipment would seem to take priority over everything else. Why? **We have to handle regolith to produce** √ oxygen, √ iron and steel, √ aluminum, √ ceramics, √ glass, as well as to provide a √ 5 yard/meter blanket for our habitats - which will also allow us to keep our thus-covered habitats at room temperature.

Basaltic regolith-handling equipment will also be necessary √ to emplace shielding, √ to excavate, √ to build roads and √ to handle regolith being heated to harvest its gas load of hydrogen, helium, nitrogen.

Yes, we could use imported items for this purpose. Yes, we could use nonresistant items and keep replacing them as they break down and wear out. But given the above, that does not seem to be "logical." **If we are to diversify lunar industry in a logical progression, cast basalt is the place to start, with an in situ demonstration as task # one.**

Cast Basalt Flooring Tiles

Besides the company cited above in West Virginia, two companies, one in Britain, one in the U.S., use cast basalt to make "durable but decorative" flooring tiles in a variety of shapes.

• Greenbank Terotech Ltd., Derby, UK http://www.greenbanktl.demon.co.uk/

• Decorative Cast Basalt Sales "DCBS, Inc. Webster Springs, WV http://www.decorativebasalt.com/

Both Greenbank Terotech and DCBS import Czech basalt to produce "Volceram [**vol**canic **ceram**ic] Flooring Tiles" of "natural beauty and practicality."

Cast Basalt is now being used extensively by architects and designers for use both as a **industrial floor covering in heavy industry** and as **decorative flooring in commercial, and home settings.** The skillful 16-21 hr annealing **process brings out all the natural beauty that gives the tiles** a unique appeal and a natural shine without added glazing.

For commercial and industrial use, their hardness ("**four times harder than rock**) and **imperviousness to acid and chemical attack** make the 25 mm (1") thick tiles very attractive. They "take a beating," retain their appearance, and require little maintenance.

These nonporous "**industrial strength**" tiles are nearly nearly indestructible, and **chemical-resistant**. Yet in the annealing process they acquires **a natural beauty** that rivals more common ceramic tiles that have to be glazed. This makes them equally **perfect for kitchens, bathrooms, halls, patios,** etc.

Tiles are produced in standard squares, florentine, charlotte, hex and other shapes, and in several sizes to allow a great diversity of floor and patio patterns.

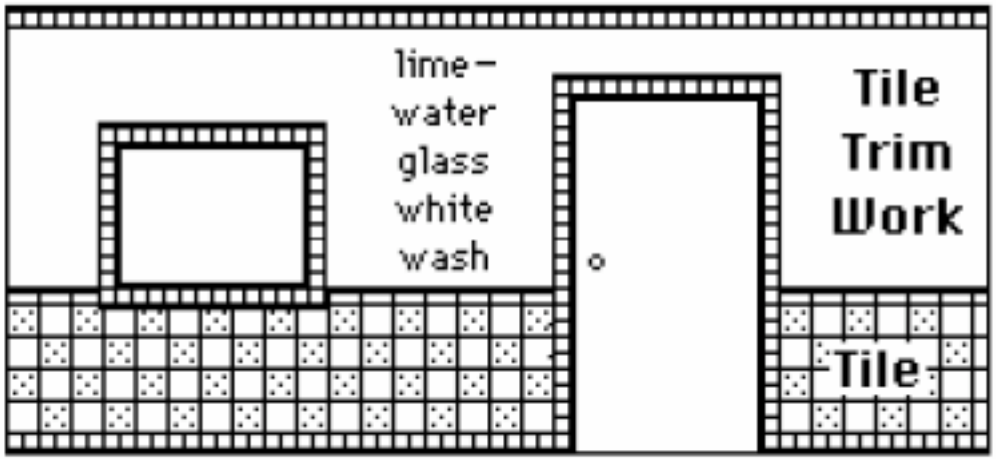
Role of Tiles in Lunar Settlements

Modular habitat structures, will have to have circular vertical cross-sections to distribute the stresses of pressurization and the weight of shielding moon dust equitably, whether their overall shape be that of a sphere, cylinder, or torus. This means that **a flat grid will have to be constructed over the bottom cavity, and the tiles set in the grid**. The dead space below the grid could be **used for storage, water reservoirs, utilities, and utility runs**, etc. -- an efficiently compacted "basement".

An open-spaced flanged-grid subfloor, of some no rust alloy or of glass composite, could rest on metal, concrete, or glass composite joists. The thick cast basalt tiles could then be set into the grid without mortar. (Below: cast basalt tiles applied to a wall - just one of many wall-tiling options.)

Larger cast basalt tiles could be used for **floors of factories, commercial enterprises, schools,** etc. And why not **also outside, set upon a graded and compacted bed of sieved regolith, to serve as a sort of porch or deck at EVA airlocks**, both to personalize such entrances and to help curb import of moon dust into the interior. One can think of many uses!

The floor tile possibilities and applications seem endless. But **cast basalt tiles could be used for more than flooring.** Without the availability of wood for the customary "**woodwork**," plain, textured, and/or decorative tiles could be used, in the role of **jamb, casing, baseboard, ceiling cove moldings, even wainscoting.**



Tiles could also be made to apply with a vertical overlap, "shingle style."

Cast basalt then seems to be the right material with which to kick-start diversified lunar industries as well as forms of art. On the Moon, where the regolith particles are quite sharply angular because they've never been subject to water- or wind-weathering, we will need a family of abrasion-resistant regolith handling items before we launch our lunar concrete, ceramics, metal alloy, glass, and glass composite industries.

- **Cast Basalt looms as a cornerstone of lunar industrialization. The more products needed in Lunar Settlement that we can make out of basalt, the smaller the list of items that we will need to import from Earth.**

Once we have advanced to the processing and manufacturing of these other building materials, we will be able to start providing habitat expansion space from made-on-the Moon materials. Then once again, cast basalt, this time molded into durable and decorative tiles, will help in furnishing the interior spaces of these new "elbow room" modules. Cast basalt will be a key trailblazing cornerstone lunar industry.

Lunar Basalt

What, Where, and How: its Critical Role for Lunar Industrialization and Settlement Construction

[From MMM #234 - April 2010] By David Dietzler with contributions from Peter Kokh

Technical Terms and Chemical Description of "Basalt," "Gabbro," "Lava," "Magma" **Basalt** is hardened surface **lava**. Hardened subsurface lava is called **gabbro**. Molten surface rock is called **lava** and molten subsurface rock is called **magma**.

The lunar mare areas are covered with basalt which pulverized into a fine powder by eons of meteoric bombardment is called regolith. **This material will be relatively easy to mine with power shovels.**

The regolith consists of pyroxenes (iron, magnesium, and calcium silicates: SiO_3), olivines (iron and magnesium silicates Si_2O_4), ilmenite $FeTiO_3$, spinels and plagioclase $CaAl_2Si_2O_8$.

Lunar basalts are classified as high, low and very-low titanium basalts depending on ilmenite and Ti bearing spinel content. **They differ from their terrestrial counterparts principally in their high iron contents**, which range from about 17 to 22 wt% FeO. They also exhibit **a range of titanium concentrations** from less than 1 wt% TiO_2 to 13 wt% TiO_2. A continuum of Ti concentrations exists with the highest Ti concentrations being least abundant.

Lunar basalts differ from terrestrial basalts in that they show **lots of shock metamorphism**, are **not as oxidized** and **lack hydration** completely.

See: http://en.wikipedia.org/wiki/Basalt

"Coastal" vs. "mid-mare" basalts

Olivine contents range from 0% to 20%. Basalts from the mare edges or "coasts" probably contain more plagioclase, the mineral that makes up most of highland soils, than basalts closer to the center of the mare.

Types of Processed Basalt

• Cast Basalt: Basalt can be melted in solar furnaces, cast into many forms, and heated again and allowed to cool slowly (annealing) to recrystallize and strengthen the cast items. It can be cast in iron molds and possibly in simple sand molds dug into the surface of the Moon.

Iron could be obtained by harvesting meteoric Fe-Ni (iron/Nickel) fines that compose up to 0.5% of the regolith with rovers equipped with magnetic extractors. Iron molds could be cast in high alumina cement molds.

The high alumina cement could be obtained by roasting highland regolith in furnaces at 1800-2000 K to drive off silica and enrich CaO content. This could be hydrated in inflatable chambers with condensers to recover any water vapor. It might also be cost effective to "upport" [import from Earth] iron molds to the Moon since they would have a very long lifetime.

• **Sintered basalt** is not fully melted. It is placed in molds, pressed, and heated with microwaves or solar heat just long enough for the edges of the particles to fuse. This requires less energy than casting. Sintered Basalt can be **used for low-performance external building blocks, pavers,** and other uses.

• **Drawn basalt fibers** are made by melting basalt and extruding it through platinum bushings. • **Hewn basalt is quarried from bedrock, road cuts, or lava tube walls.** It can be cut with diamond wire saws.

2) Uses of Basalt: source: http://en.wikisource.org/wiki/Advanced_Automation_for_Space_Missions/Chapter_4.2.2

Table 4.16 Lunar Factory Applications of Processed Basalt

Cast Basalt – Industrial uses

• Abrasion-resistant Pipes and conduits

• Abrasion-resistant Conveyor material (pneumatic, hydraulic, sliding)

• Abrasion-resistant Linings for ball, tube or pug mills, flue ducts, ventilators, cyclers, drains, mixers, tanks, electrolyzers, and mineral dressing equipment

- **Abrasion-resistant floor tiles and brick**s
- **Furnace lining for resources extraction operations**
- Machine base supports (lathes, milling machines)
- Large tool beds
- Crusher jaws
- Sidings
- Expendable ablative hull material (possibly composited with spun basalt)
- Track rails reinforced with iron prestressed in tension
- Railroad ties using prestressed internal rods made from iron
- Pylons reinforced with iron mesh and bars
- Heavy duty containers (planters) for "agricultural" use
- Radar dish or mirror frames
- Thermal rods or heat pipes housings
- Supports and backing for solar collectors
- Cold forming of Metal fabrication with heat shrink outer shell rolling surfaces
- Tubs for raising fish.

Basalt Fiber – Uses (in place of glass fibers)

• Cloth and bedding, pads and matts

• Resilient shock absorbing pads

• Acoustic insulation

- **Thermal insulation**

• Strainers or filters for industrial or agricultural use

• Electrical wire insulation - taking the place if "romex"

- **Ropes for cables** (with coatings)

• Insulator for prevention of cold welding of metals
• Filler in sintered "soil" cement
• Packing material

[In Gujarat, India at M .S. Univ., Kalabhavan, Baroda, basalt fibers are used as **a reinforcing material for fabrics, having better physical-mechanical properties than fiberglass, but significantly cheaper than carbon fiber.**] www.fibre2fashion.com/industry-article/3/256/new-reinforced- material1.asp

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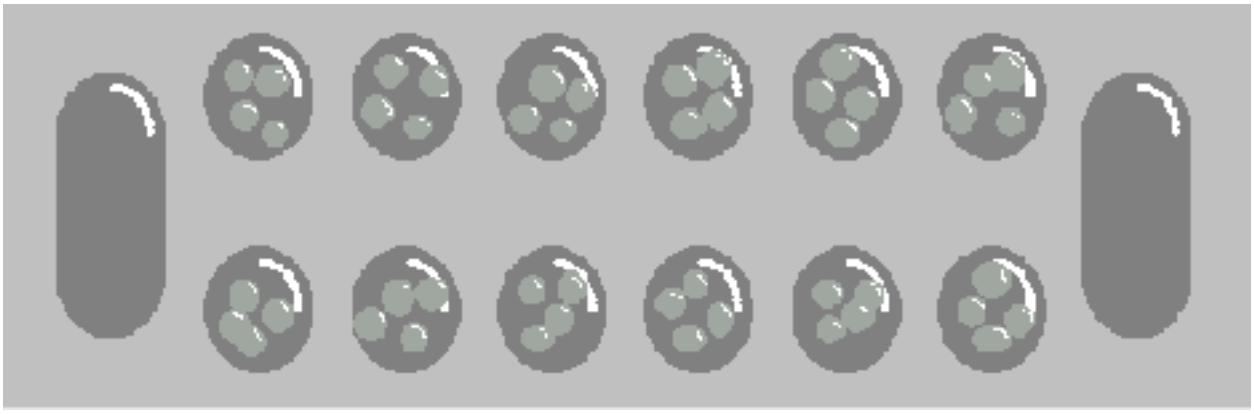
• **basalt brake pads**? (no asbestos on the Moon)
http://www.technobasalt.com/news/?id=14
http://www.basalt-tech.ru/en/prospects

•**Hewn Basalt (MMM's list)**
• Heavy duty **Building blocks**
• **Road paving slabs**
• **Heavy duty floor slabs**
•**Architectural pillars, headers, arches**
Carved Basalt Items
• **Carving blocks for sculpture statues, other artifacts: lamp bases, planters, etc.**
• **Fountains, bowls, table pedestals, vases,** etc.
•**Statues, plaques, beads, bracelets**,
•endless list

• **Game boards for Oware alias Mancala, a game played world wide for centuries.** (below)



3) Properties of basalt From-- http://www.islandone.org/MMSG/aasm/AASM5C.html
Table 5.9.- Some Properties Of Cast Basalt

- Resistivity of melt @ 1500 K 1.0X10-4 ohm-m (author's note--this is of importance to magma
- Thermal conductivity,... melt @ 1500 K 0.4-1.3 W/m K... solid @ STP 1.7-2.5 W/m K
- Magnetic susceptibility 0.1-4.0X10-8 V/kg Crystal growth rate 0.02-6X10-9 m/sec Shear strength ~108 N/m2

4) Gallery of Basalt Products

Cast Basalt Pipes:

With unequalled abrasion-resistance, such pipes and chutes will be prerequisite for all moon dust handling industries, even for oxygen production.

Cast Basalt tiles (Czech Republic); **blocks:** the author has a carved scarab (made in Egypt); Cast basalt planters, Bathtubs, shower drain floors

Beaides individually crafted items, production items may include pipes and tiles of various kinds.

Note: with this manifold and diverse list of uses, how could one even think of setting up shop in the Lunar Highlands as opposed to in a basaltic Mare. Now, the Moon's "Farside" is mostly highlands, with very few maria, as are both the Moon's poles, North and South.

Basalt: What Does All This Mean?
The Mare Frigoris North coast" is the best place to start

By Peter Kokh and Dave Dietzler

The cute things such as what you can carve out of solid basalt, aside, the essential message is in **the abrasion resistance of cast basalt pipes and fittings vs. the very abrasive nature of Moon dust out of which we are going to have to make as much as possible is a perfect match.**

The name of the game is to produce locally on the Moon as much as possible of local frontier needs, and to develop export markets for those things,
1) to defray imports on the one hand, and 2) to earn credits to import what they cannot produce on the other hand.

Our Thesis: **A lunar basalt industry** is a **pre-requisite to any other lunar materials industry**. Unless we prefer to bring from Earth, all items needed to handle abrasive material such as moon dust, **Lunar industrial settlements must have access to basalt**

We believe that we must start in the maria, preferably along a mare/highland coast with access to both major suites of lunar material.

Note: The Lunar North Pole is some 600 miles from the nearest such coast – the north shore of Mare Frigoris.

Note: The Lunar South Pole is more than twice as far removed from the nearest such coast, the southern shores of Mare Humorum or Mare Australis.

Despite the advantage of more hours of sunlight, and eventually recoverable water ice, **starting at either North or South pole** [instead of in Mare Frigoris] **would be an industrial dead end.**

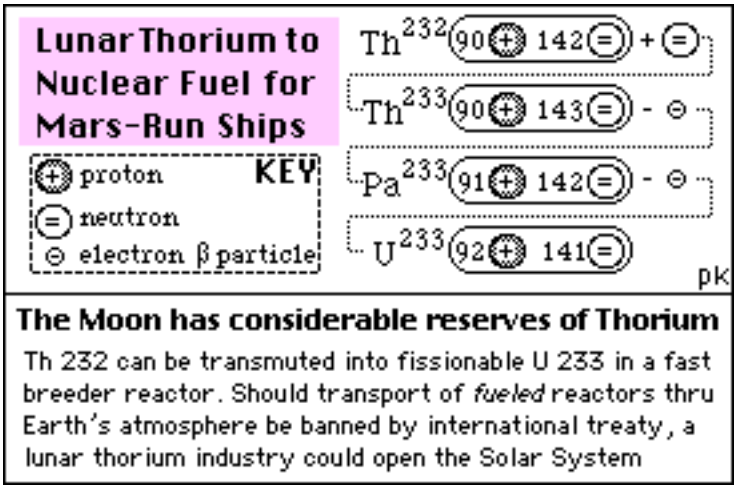
Yes, access to water is essential, but most of us interested in lunar settlement, before the possibility of finding water ice at the pole became a common hope, were determined to launch lunar settlement anyway. **But Bingo!: harvestable water-ice preserves are to be found in North craters above 60° North latitude - conveniently just north of the shores of a 100°-wide Mare Frigoris.**

- We could/would harvest solar wind protons from the moondust and combine them in fuel cells with oxygen coaxed from the same soil, to make water and extra power.

Having to do this, despite the now-confirmed reserves of water ice at both poles, may be a good thing, as it **will prevent the "rape of water-ice" for the production of rocket fuel, and thereby preserve ciecum-polar ice for future lunar settlement needs such as agriculture and biosphere.**

Yes Liquid Hydrogen and Liquid Oxygen are the most powerful fuels now in use. But
1) **We don't need that much Isp to rocket off the Moon**, or to hop from here to there on the Moon's surface, and

2) **We should be more concerned with developing more powerful fuels anyway, including nuclear fuels. [Thorium-rich highland deposits lie just to the South of Mare Frigoris, in the Mare Imbrium "splashout.]" This Thorium can be turned into a fuel for nuclear powered rockets: U-233.**



Polar water ice is at cryogenic temperatures, and extremely hard to saw, cut, or drill.

***Harvesting ice in darkness at the bottom of steep crater walls will not be easy, and unless done entirely robotically, could be a very risky occupation.**

***That polar ice will be easy to harvest is myth #2.**

***Myth #1 is that the sunlight at the poles is eternal.** Honest estimates are that sunlight at any one spot is available only 76% of the time at the South Pole, and possibly 86% of the time at the North Pole. That means for 52% "of the nightspan" at the South Pole and 72% at the North Pole.

* We must still bite the bullet and **learn to store power generated in the dayspan** for 100% of the nightspan. Then we can go anywhere, including places on the Moon - such as a "shore" between highlands and a mare where a more complete suite of mineral assets are available, including possible gas deposits elsewhere: The critical role of basalt is so fundamental to success that we must rethink our destinations. **Mare Frigoris alone fills the bill.** DDz/PK

Basalt- based Industries

There is a growing, newly reinvented cast basalt industry in Germany, Spain, Britain, Vietnam, and the United States that is producing two types of products that will be very useful in the early lunar settlements: **abrasion-resistant pipes** & **material handling** (think regolith/moon dust-handling) **equipment** as well as **countertops, and decorative wear-resistant floor and wall tiles** These talents make a cast basalt industry a top priority.)

Some time ago [late 1980s], I read a one-liner in an encyclopedia about a "cast-basalt industry in central Europe." Immediately the need of early Lunan settlements to hit the ground running with appropriate-technology industries came to mind.

Basalt! There is plenty of it on the Moon. The great flat lava flow sheets that fill the maria basins are essentially basalt. The regolith surface of these "Seas" is but meteorite impact- pulverized basalt. There is much much less basaltic mare areas on the Moon's Farside.

[There is plenty of basalt on Mars as well. The whole Tharsis Uplift area (Arsia Mons, Ascraeus Mons, and Pavonis Mons) is basaltic, as is Olympus Mons. And there are other lava sheet and shield volcano areas on Mars, all rich in basalt.]

The idea of just melting the stuff with a solar concentrator furnace and then pouring it into molds to make useful products seemed a no-brainer. Even if cast basalt had low performance characteristics (an assumption that turns out to be false), there would be plenty of things needing to be made in the Moon settlements for which high performance would not be an issue. **Table tops, planters, lamp bases, statues, bathtubs, and paving slabs** came to mind.

But for years, I could find nothing more than that teasing one liner. In the mid 1980s, I asked friends in the basalt-rich Pacific Northwest (members of the Oregon L5 Society) if they knew of any such industry in their area. This did not turn up any new leads. That was then. Today we have the Internet, and I finally returned to the issue and did a simple web search. Voilà! **There is a thriving cast basalt industry here on Earth in the United States, central Europe, India, and Vietnam**, and like most "materials" industries these days, it is vigorously reinventing itself. "And the envelope, please!"

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Think of it! Were it not for these basaltic seas (maria) on the Moon, much of our moondust-handling equipment would be quickly worn out because moondust is so abrasive.

Cast Basalt – commercial, agricultural, & residential uses

- Large diameter (**3"+**) **pipe for water mains, toilet and sewer drainage, systems**
- **Floor tiles can also be used for Countertops, tabletops, back splashes**
- **Planters, flower pots and tubs of all sizes**
- **Contoured seating surfaces** (contoured seats lessen the need for resilient padding, cushions)
- **Lamp bases, Nozzles** and rigid **Tubing, Wire-drawing dies, Stud**s, **Furniture**
- **Ball bearings and wheels, Low torque fasteners, Utensils, Low load axles**
- **Scientific equipment, frames and yokes, Pump housings**
- Light tools snd Light duty **containers and flasks** for laboratory use
- lightweight light-duty **crates and boxes,**
- **Acoustic insulation**
- **Filters/partial plugs, Blocks** for **shielding retainer wall**s
- "**Porch" slabs** for **airlock approaches, external paths and walks**
- **Thermal insulation • Electrical insulation**
- **"Case goods" furniture** as we might use wood composites such as OSB, MDF, etc.

(page above: Various forms of abrasion-resistant CAST basal pipes, for handling moondust)

EXAMPLES OF CARVED BASALT

In a number of past articles through the years, we have talked about **art forms that might be available for Lunan Pioneers, supportable by materials processed locally on the Moon.**

Note: The Moon will **NOT be a source of granite, marble, soapstone, sandstone** or other materials favored through the ages by sculptors on Earth. Without an economical source, **copper, brass, bronze, and pewter will not be available media either.**

But Lunan sculptors could work with **concrete, glass, and various metals.** Art du Jour temporary sculptures could be created by children from various garden stuffs (e.g. wood, fruit, vegetables, etc.). More recently, we introduced **AAC, autoclaved aerated concrete**, as a possible medium. It is "carvable" but fragile.

All this time we were ignoring an obvious sculpting material abundant on the Moon: basalt. **Basalt has been carved into objects small and large throughout the ages by many peoples.** Basalt carving continues today, with newer tools such as titanium tipped chisels and various abrasives.

Now we had indeed written about "cast basalt" as a hard durable material that could be shaped into all sorts of useful and decorative items. But **casting and carving are two different things.**

The lunar maria ("seas") consist of congealed lava flows: basalt. But **all available surface basalt has been pre-pulverized to several meters below the surface by repeated meteoritic bombardment.** That is why the use of basalt as as a carving material never occurred to us; we thought only of casting it.

But **significant quantities of non-pulverized, non-fragmented basalt** should be available for quarrying from **the walls of the numerous lava tubes** to be found below the surfaces of the various maria. e.g; in **Lava tubes**, a natural feature formed by the way the lava sheets flowed across the lunar surface, filling the major nearside impact basins.

Another source may be "road cuts." To see for ourselves what promise this material holds, we ordered a 3" Scarab of basalt carved in Egypt, for about $30 plus shipping. This item is on display at Lunar Reclamation Society events.

Carved Basalt: lamp bases, bath tubs, countertops and much much more!

We did a Google Image search for carved basalt and on basalt carving products and carving methods and tools. **Basalt is indeed a promising carving medium for future pioneers, on Mars as on the Moon, that will yield many decorative objects as well as useful items for frontier homesteads.**

Carved lunar basalt items could become a significant source of export income for the settlements. Highlanders will be customer #1. When pioneers reach Mars, basalt and a similar kaleidoscope of basalt products will be available there too, in the flanks of great shield Volcanos, and within the lava tubes which lace their interiors.

Google images of carved basalt items

Basalt tiles are now being used extensively by architects and designers for use both as a industrial floor covering in heavy industry and as decorative flooring in commercial and home uses. **For commercial and industrial use, their hardness ("four times harder than rock, one of the hardest ceramic materials known") and imperviousness to acid and chemical attack make the 25 mm (1") thick tiles very attractive. They "take a beating," while retaining their appearance, with little maintenance.**

This nonporous "industrial strength" tile is **nearly indestructible, and chemical- resistant.** Yet in the annealing process they acquires a natural beauty that rivals more common ceramic tiles that have to be glazed. This makes them **equally perfect for kitchens, bathrooms, halls, patios**, etc. Tiles are produced in standard squares, Florentine, Charlotte, hex and other shapes, and in several sizes to allow a great diversity of floor and patio patterns.

Above: a dome made of basalt fibers
Left: a coat made of basalt fibers

Role of Tiles in Lunar Settlements

Above: this dome is a product of basalt fibers: great for shielded structures housing many otherwise unshielded habitats, but also for factories and sports arenas.

Modular habitat structures, will have to have circular vertical cross-sections to distribute the stresses of pressurization equitably, whether their overall shape be that of a sphere, cylinder, or torus. This means a flat floor will have to be constructed over a bottom cavity. (this dead space could be used for storage, water reservoirs, utilities, and utility runs, etc. -- an efficiently compacted "base" "ment".

An open-spaced flanged-grid subfloor, of some no rust alloy or of glass composite, could rest on metal, concrete, or glass composite joists. The thick cast basalt tiles could then be set into the grid without mortar, as illustrated below.

Larger cast basalt tiles could be used for floors of factories, commercial enterprises, schools, etc. And why not also "outside", set upon a graded and compacted bed of sieved regolith, to serve as a sort of porch or deck at EVA airlocks, both personalizing such entrances and helping curb import of dust into the interior. One can think of many uses!

Cast Basalt Tiles for Walls and More

The floor tile possibilities and applications seem endless. But cast basalt tiles could be used for more than flooring. Without wood for the customary "woodwork", plain, textured, and/ or decorative tiles could be used, in the role of "woodwork" i.e. jamb, casing, baseboard, ceiling cove moldings, even wainscoting. We suggest the use of "ceramic" tiles for these applications:

Ceramic tiles are used to provide trim borders. While the seemingly endless variety in color, pattern, and glazing now available on Earth could not easily be produced on the Moon, a variety of hues from the lunar palette (regolith grays, oxide colors, stained glass colors) should be available either unglazed or in soft satin glazes. Tile in contrasting sizes, and coordinated colors and patterns, would make a good wall finish, as would simple whitewash.

BASALT Fiber, Fabrics, and Clothing ideal for use outdoors

("heat resistant") on the Moon

https://www.basalt.guru/basalt-fabric-wearable-heat-protective-clothing/ and fiberglass batts

Basalt fibers are great for shielded structures housing many otherwise unshielded habitats, but also for factories (see Dome, previous page)

And for many types of clothing. (see previous page)

https://www.basalt.guru/basalt-samples-online-store/

(Sample packs $12 and up - Get some for your chapter!)

Basalt fabrics could be used to make "bags of moon dust" to pile up as removable "**roofing**", **retaining walls** (think of "overlooks" along cliff-hugging trails, etc.)

Basalt fiber is now being used in India to make rebar to hold concrete slabs together (it does not rust) - and **perhaps to build the frameworks of orbiting platforms in Geosynchronous Earth Orbit.**

QUESTION? For that use (GEO platforms) which would work better: basalt rebar, glass/ glass composites, or steel? **This test would be an interesting chapter project.**)

Basalt fabric is also used in wearable heat protective fire proof clothing, including fire-proof gloves, as well as some fiber-reinforced plastics.

Basalt is the key to opening the Moon

Basalt then seems to be the right material with which to kick-start a diversified group of lunar industries, and new settlements

>> (before we launch our lunar concrete, ceramics, and metal alloys, glass, and glass composite ("**Lunaglax**") industries will be flowering

Note: There are no basaltic areas (maria) at or around either of the Moon's poles any closer than in Mare Frigoris (to the Moon's North Pole.)

Cast Basalt building materials and fabrics loom as a cornerstone of lunar industrialization. And that indicates that a conveniently located "mare" ("sea") - NOT either pole, north or south - is the place to start.

Mare Frigoris looms at the top of the list. Why? There are "partially ice-filled craters just to the North all along the highlands above this very wide mare.

And cast basalt, carved basalt, and basalt fiber products promise to be on the short list of cornerstone lunar industries.

"Heat resistant") BASALT Fiber, Fabrics, & Clothing ideal for use "outvac" ("heat resistant") on the Moon

https://www.basalt.guru/basalt-fabric-wearable-heat-protective-clothing/

https://www.basalt.guru/basalt-samples-online-store/

"homes built with concrete and basalt reinforcement are the way to go!"

(**Sample packs $12 and up - Get some for your chapter!**)

Basalt fabrics could be used to make **"bags of basalt dust" to pile up as "roofing" and retaining walls (think of "overlooks"** along cliff-hugging trails, etc.)

On the Moon, where the regolith particles are quite sharply angular (never exposed to water- or wind-weathering) we will need a family of abrasion-resistant regolith handling items.

Basalt wire can can even be used to make **rebar to hold concrete slabs together** - and **perhaps to build the frameworks** of orbiting platforms in Geosynchronous Earth Orbit. Basalt rebar is superior to metal rebar

Which would work better: basalt rebar, glass/glass composites, or steel?

(**This test would be an interesting chapter project.**)

Expanding Basalt Products in New Directions
To significantly minimize ex$pensive "upports" from Earth

Two Questions

√ **Can we produce a basalt spongy "foam"?**

Think Mattresses, pillows, and Upholstered Furniture! Such a mare-(Frigoris)-based industry could serve outposts elsewhere on the Moon as well, and would make the establishment of new outposts much easier, and less expensive, as well as "much sooner."

The answer is both **yes, and no**.

Yes for rigid foam (used in packageing)

https://www.youtube.com/watch?v=OpmVtHkzD6s

But "**no" for spongy foam**.

Our '"okay, but" suggestion **is to fill a properly shaped bag** (zippered pillow cases, or cushions) **with small rigid foam "pebbles" - the smaller the "foam pebbles" the better the pillow, or cushion, or mattress will shape itself to whatever object is placed upon it.**

("Mike, the Pillow Guy" from Minnesota might be interested!)

Can we "color" basalt products?

Some restricted coloring is available

http://calvinfabrics.com/cerros-basalt/

http://www.sitonit.net/textiles_mainpage/textilesearch/details26-0010534-1006.html

The more we can "colorize" homestead interiors, the more subtly we could boost pioneer morale and enthuse potential pioneer immigrants.

√ Both of these industries, if we could start them up here on Earth, would help convince people that the Moon is not just "pie in the sky."

Considerable effort to expand its line of basalt products has been made in Vietnam, in Ho ChiMin City (formerly "Saigon")-

http://pic.stonecontact.com/picture201511/20178/137575/slab-racks-stone-display-stands-p559019-1b.jpg

It looks like subtle "graying" is easier than other colors of the spectrum. Gray shades are easier on the eye, and accessory plants and flowers and other items will help.

If colorization is limited, the gray-black tones of basalt products can be offset by accessory planters (green foliage, and the many colors of flowers), aquariums with gold fish etc. - not to forget colored spotlights and lamp bulbs.

Basalt and producers made from it, already has a winning feature. It is inflamed! On the Moon, we can not just open a window or a door and run outside, however we are dressed. The more completely everything in our lunar homesteads is fireproof, the better;.

Of course, if we can grow cotton (indoors on the Moon, that will open many doors for variety of products and dye colors. —-If!

House plants - including floral - will carry much of the color load.

REPORTS: Basalt Fibers: Alternative To Glass? : CompositesWorld

https://www.compositesworld.com/articles/basalt-fibers-alternative-to-glass

Glass wool, one product called "**fiberglass,**" is a material used as thermal building insulation. Why not in lunar surface vehicles as well, both against the extreme cold of the lunar nightspot and against the extreme heat of the lunar day span.

Glass fiber when used as a thermal insulating material, is specially manufactured with a bonding agent to trap many small air cells, resulting in the Characteristically air-filled low-density "glass wool" family of products.

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although **not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites.**

Basalt Fiber Properties, Advantages and Disadvantages

www.build-on-prince.com/basalt-fiber.html

Basalt is an invaluable key to Opening the Moon

Basalt seems to be the right material with which to kick-start quite diversified lunar industries, and new settlements >> before we launch our lunar concrete, ceramics, metal alloy, glass, and glass composite ("Glax") industries.)

We do not expect to find basalt at or around either of the Moon's poles.

Cast Basalt building materials and Basalt fiber fabrics promise to be a "Cornerstone of lunar industrialization." And that indicates that a conveniently located "mare" ("sea") - NOT to be found at 17either pole, north or south - is the place to start.

Basalt filled Mare Frigoris looms at the top of the list because there are "partially ice-filled" craters to the North of its "coast" all along.

Cast basalt, carved basalt, and basalt fabrics promise to be on the short list of cornerstone lunar industries.

In India they are making rebar (the steel rods you -put in concrete slabs to hold them together) out of basalt fibers. Since basalt doesn't rust. This is a superior product.

Frequent MMM contributor, Dave Dietzler, is confident that you can make cylindrical habitats for settlers.

Back to the issue of Settling the Moon. There is no basalt near either of the Moon's. Poles. But we need water too! Yes, and Lunar Prospector found craters partially filled

with ice as far as 30° from both poles, that is, north of 60° North Latitude and south of 60° South Latitude.

So the question is, how close to either of these polar areas are any Maria? Well, we can cross off the Moon's southern hemisphere - there are no Maria anywhere near.

But we strike gold in the Northern Hemisphere, where the "North shore" of the very wide Mare Frigoris is within reach of a half dozen craters partially filled with ice.

What's Next?

Well you will have to wait until my first book comes out.

"A Pioneer's Guide to the Moon"

I had hoped to have the manuscript ready to show publishers attending the upcoming International Space Development Conference which opens in a few weeks. But it looks like I will only have a partial manuscript ready in time. When it does come out, it will probably be in two books or "tomes:" The main script in the first book, many supporting articles in the second.

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In the meantime, I sent to a basalt fiber company a request for samples of basalt fabric and they have just arrived. I'll be bringing them to the ISDC. Who would have thought you could make clothing out of the stuff? Who would have thought you could make much of anything out of moon dust?

Next question

What can you make out of highlands type moon dust? In comparison, not much. But there is one highland area, and whoopee! Its **immediately south of Mare Frigoris**, where the highlands are loaded with **Thorium** (from which you can make **nuclear U233 fuel for rockets going to Mars (in a much faster ride)**, and also with **KREEP** deposits (Potassium, Rare Earth Elements, and Phosphorus) not to be found elsewhere on the Moon in any appreciable amount.

So Mare Frigoris rich in its own moondust, is further enriched in being close enough south of highland craters with appreciable amount of water ice, and bordered to the south with Thorium and KREEP rich highlands.

Now we've all talked about lunar sourcing of building materials to make solar power satellites, and, more urgently, giant platforms one to each allotted space in **the already over-crowded Geosynchronous Earth orbit**, each of which could hold a hundred or more satellites, that way keeping them from bumping into each other, and with robot mechanics on each of these platforms to make repairs, relocate satellites etc. **Basalt products will have a role in this effort, as will Moon-derived glass/glass fiber composites.**

What does Mars have to contribute to all this?

Anything made on Phobos and/or Deimos, Mars' two mini moons, could be shipping cost competitive with similar Moon-made products, but the shipping windows are many many months apart. But **products made on the Moon may have a very big impact in opening Mars —— provided we open the Moon first.** #

Peter Kokh, - editor and principal author of Moon Miners' Manifesto #s 1-301, 1986-2018 *and counting,* Milwaukee, Wisconsin (on a Great Lake of "Mare Michigansis")

NOTE: Next Month's Outbound - #6, will be focused on Mars