A “mare” - pronounced MAHray - [the Latin (ancient Roman) word for “sea” is an appropriate term because the Maria (plural for Mare and pronounced MAHria) were formed by floods of liquid lava, and are economically the best places to start settlements on the Moon.

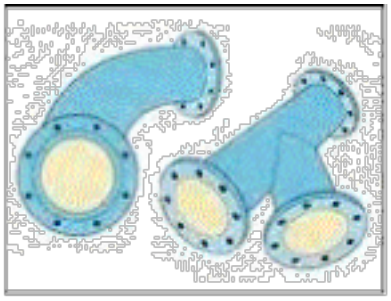
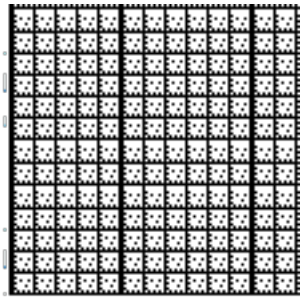
These lava floods are almost pure basalt in composition.

Basalt https://en.wikipedia.org/wiki/Basalt

“**Basalt** is a common extrusive igneous (volcanic) rock formed from the rapid cooling of **basaltic** lava exposed at or very near the surface of a planet or moon. These lava flows, like all other liquids flows downhill, and thus **it fills basins.** The lunar “seas” were filled with lava floods some 3.9 billion years ago. The rarity of craters on these basaltic plains, in comparison to the relatively “saturation-bombed” highlands, gives us a good idea of the dramatic drop-off in frequency of impacts that occurred before these maria-filling outflows of magma.”

In contrast to the moon dust of the Moon’s highlands, there is a lot you can do with basalt, as we have learned here on Earth from the various basaltic flows on this planet. By the way, neither the North or South pole areas of the Moon are basaltic.

CAST BASALT: An Industry Perfect for a Startup Lunar Outpost

Basalt pipes   **Basalt tiles**

Number 1, hands down, is that cast basalt pipes, tubes, and chutes - are the only pipes that abrasive moondust powder will not etch away until they leak.

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

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

There is a growing, newly reinvented cast basalt industry in Germany, Spain, Great Britain, the United States, and Viet Nam that is producing two or more types of products that will be very useful in the early lunar settlements: **abrasion-resistant pipes** & **regolith-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 don't wear down. The factory representative gave me take a sample, which some years later, at a science-faction event, disappeared as I was packing up to go home.

Basalt! There is plenty of it on the Moon. The great flat lava flow sheets that fill the mare (pronounced "MAH ray") basins are essentially basalt. The regolith (moon dust) 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. 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, **the product performance of cost basalt products is at the top - triple "A"**.

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. But we did get to crawl through a small lava tube near Bend, Oregon. An unforgetable experience!

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**."

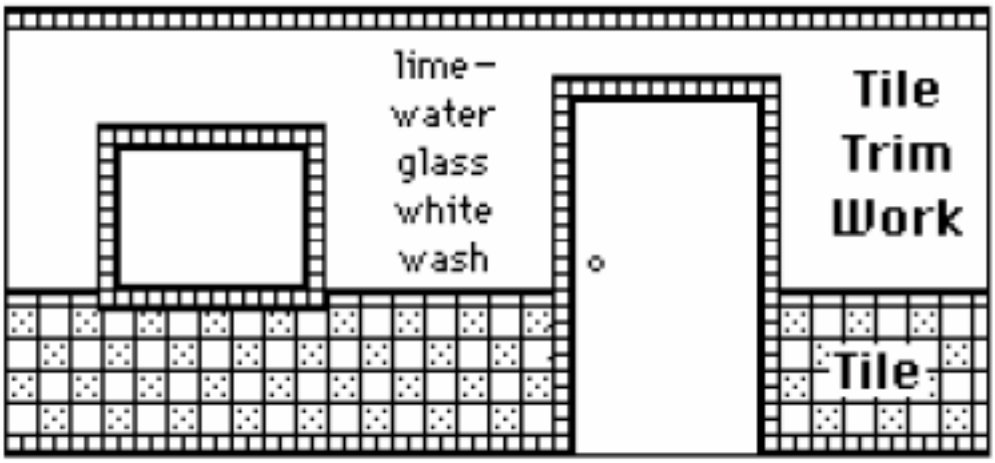
• Antidesgast, S.A. Barcelona, Spain http://www.antidesgast.com/english/castbasalt.htm

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. 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.**



Above: a wall with basalt tiles for window and door trim and for wainscoting.

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, to produce iron and steel, to produce aluminum, to produce ceramics, to produce glass, as well as to provide a 5 yard/meter blanket for our habitats - allowing us to keep our thus-covered habitats at room temperature through dayspan heat and nightspan cold.

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 option does not seem"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 (and wall) Tiles

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, the 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. A sample tile from a West Virginia plant that produces tiles for floors in factories where they can take a beating, was a good half inch thick.

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.

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."

Tile in contrasting sizes, and coordinated colors and patterns, would make a good companion wall finish, as would simple whitewash. 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 glaze

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 & 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, the exposed top layer of which has been 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**: SiO3), **olivines** (iron and magnesium silicates Si2O4), **ilmenite** FeTiO3, **spinels** and **plagioclase** CaAl2Si2O8.

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% TiO2 to 13 wt% TiO2. 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 bricks**

- **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)

- **Clothing from T-shirts to shirts and work pants and more**
- **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

Basalt Fibers - www.fibre2fashion.com/industry-article/3/256/new-reinforced- material1.asp

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

Above: Left, a lamp base carved out of basalt. Right: a helmet made of basalt fibers

• **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**

Properties of basalt -- http://www.islandone.org/MMSG/aasm/AASM5C.html

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

Basalt Products Continued

√ **Cast Basalt Pipes:** With unequalled abrasion-resistance, **cast basalt 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**

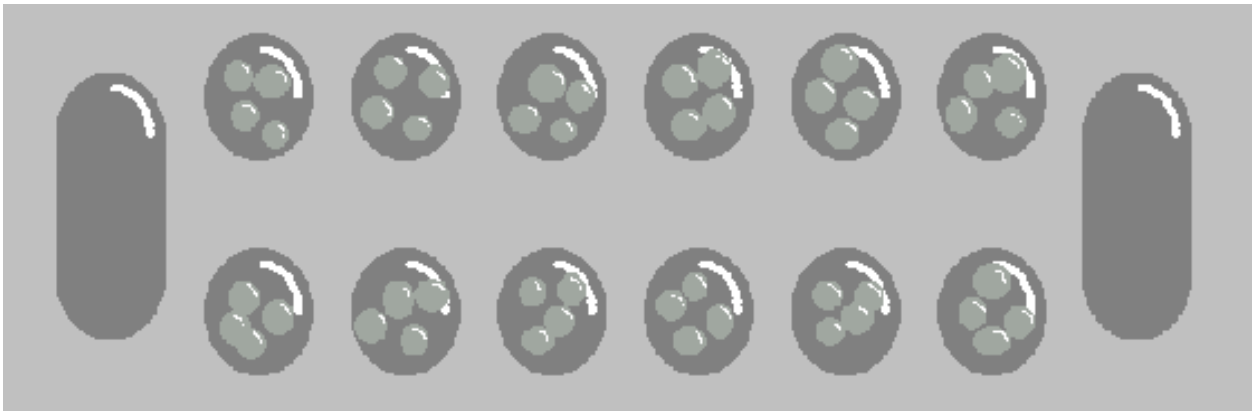
Beaides individually crafted items, production items may include pipes and tiles of various kinds.

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 a basaltic Mare location? Now, the Moon's "Farside" is mostly highlands, with very few maria, as are both the Moon's poles, North and South. ##

CARVED BASALT

- **Carving blocks for sculpture statues, other artifacts: lamp bases, planters, etc.**
- **Fountains, bowls, table pedestals, vases,• Statues, plaques, beads, bracelets,**
  lamp bases [example above], planters [example above], napkin holders, an….endless list

- **Game boards for Oware alias Mancala, a game played world wide for centuries.**
  [Photo of Mancala board below]



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 the settlers 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 settlement 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.

Lunar Prospector found harvestable water-ice preserves in craters above 60° North latitude - conveniently just north of the shores of the 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 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 as well as Electrical Power Plants.

This area is also rich in KREEP deposits. [an acronym built from the letters **K** (the atomic symbol for potassium), **REE** (rare-earth elements) **and P** (for phosphorus)**,** is a geochemical component of some lunar impact breccia and basaltic rocks.]

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.

* We must still bite the bullet and **learn to store enough power generated during 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.**

NOTE: Artists here on Earth who have used basalt as a carving medium could send along with the settler volunteers, a wide selection of carved basalt items to inspire their own creativity.

CAST BASALT INDUSTRIES ON EARTH

There is a growing, newly reinvented cast basalt industry in Germany, Spain, Britain, the United States, and Vietnam 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 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. T**he walls of Mars enormous Valles Marineris canyon are probably basaltic also.**]

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. In addition to cast basalt products pipes and tiles, there will be plenty of things needing for 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**, 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 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 2.9g/cm3.

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, Studs**, **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,**
- **Filters/partial plugs, Blocks** for **shielding retainer walls**
- "**Porch" slabs** for **airlock approaches, external paths and walks**
- **Thermal insulation • Electrical insulation • Acoustic insulation**
- **"Case goods" furniture** as we might use wood composites such as OSB, MDF, etc.





Above and below: abrasion resistant cast basalt pipes and fittings

Various forms of abrasion-resistant cast basal pipes, for handling moondust

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, planters, statues,** 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. Both Cast and Carved lunar basalt items will become a significant source of export income.**

Basalt-starved Highlanders will be customer #2 after South Pole ice miners: "LOL!"

Cast basalt tiles will be used as decorative **flooring**, and **counter tops and wall trim** in homes and commercial areas.

Basalt tiles are now being used extensively by architects and designers for use both as a industrial floor covering in heavy industry and 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," yet retain their appearance, with little maintenance.

Above and right: objects carved out of basalt chunks

Theses nonporous “industrial strength” tiles are **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, as well as in public places.** These tiles are available in standard squares, Florentine, Charlotte, hex and other shapes, and in several sizes to allow a great diversity of floor and patio patterns.

Floor Tiles in Lunar Settlements

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 composites, could rest on metal, concrete, or glass composite joists. The thick cast basalt tiles could then be set into the grid without mortar. 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, and at EVA airlocks, personalizing such entrances and helping curb import of dust into the interior. One can think of many more 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.

(**above, a "dome" covered with basalt fabric:** This dome is a product of basalt fibers: **great for shielded structures** housing many otherwise unshielded habitats, but also for factories and sports arenas)

BASALT Fiber, Fabrics, and Clothing ideal for use outdoors and fiberglass batts ("heat resistant") on the Moon

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

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.)

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 fiber is now being used in India to make rebar to hold concrete slabs together (it does not rust) **Perhaps one day basalt products made on the Moon might be used to build the frameworks of orbiting platforms in Geosynchronous Earth Orbit.**

(**Chapter Project:** For that use [GEO platforms] which would work better: ( ) basalt rebar, ( ) glass/glass composites - both from the Moon - or ( ) steel from Earth?)

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

Note: There are no basaltic Maria nearer either of the Moon's poles than Mare Frigoris is 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 also looms at the top of the list as there are "partially ice-filled craters just to the North all along the highlands above this long east to west mare.

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

The many important uses of basalt: tiles

Cast 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, home and retail settings. The skillful **16-21 hr annealing process** brings out the natural beauty that gives the tiles **a unique appeal and a natural shine without glazing**.

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 they retain their appearance, require little maintenance.

This nonporous "industrial strength" tile is also **nearly indestructible.** 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 Basalt Tiles in Lunar Settlements

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 jamb, casing, baseboard, ceiling cove moldings, even wainscoting. We suggest the use of "ceramic" tiles for these applications:

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 companion wall finish, as would simple whitewash or waterglass-based paint. ###

"heat resistant") BASALT Fiber, Fabrics, & Clothing ideal for use "outvac"
https://www.basalt.guru/basalt-fabric-wearable-heat-protective-clothing/

**(Sample basalt fiber cloth sample packs $12 and up - Get some for your chapter!
I just ordered 4 sample packs for the Milwaukee Lunar Reclamation Society NSS Chapter)**
https://www.basalt.guru/basalt-samples-online-store/

Above: a jacket made of Basalt Fibers: Basalt fiber T-shirts, pants, and many other apparel items are now available in Basalt fiber fabrics. (probably non flammable, as well as long-wearing)

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

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, by all tests, and that it is rust proof is the "slam dunk" consideration. Oops! One more deal sealer. It takes only 1/20th the fuel to bring things made on the Moon down to GEO than it does to bring items produced on Earth the much shorter distance up to LEO. ##

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 packaging)

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

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

Our "okay, but" suggestion is to fill a properly shaped basalt fiber bag (zippered pillow cases, or cushions) **with small rigid pea-sized foam "pebbles" - the smaller the "foam pebbles/pea" 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

Why do I ask? The more we can "colorize" homestead interiors, the more subtly we can boost pioneer morale and enthuse potential pioneer immigrants.

√ That's quite a family of basalt based industries that we can launch here on Earth with which to convince others that we can settle the Moon and that the Moon is not just "pie in the sky."

A considerable effort to expand its line of basalt products has been made in Viet Nam, in HoChiMin 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 off-set 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 products made from it, already has a winning feature. **It is not flamable**!

On the Moon, in case of fire, 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!

Otherwise **house plants - including floral - will carry much of the color load along with colored basalt tiles.**

REPORTS: Basalt Fibers: Alternative To Glass? : CompositesWorld

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

Glass wool, commonly 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.**

Can we make similar products out of basalt fibers? Most likely, yes.

Basalt Fiber Properties, Advantages and Disadvantages

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

"**Basalt fiber** is a relative newcomer to fiber reinforced polymers (FRPs) and structural composites. It has a similar chemical composition as glass fiber but has **better strength** characteristics, and unlike most glass fibers is **highly resistant to alkaline, acidic and salt attack** making it a good candidate for concrete, bridge and shoreline structures."

"Compared to carbon and aramid fiber, it has the features of **wider application temperature range** -452° F to 1,200° F (-269° C to +650° C), **higher oxidation resistance**, **higher radiation resistance**, **higher compression strength**, and **higher shear strength**. (Note that application temperatures of FRPs are limited by the glass transition temperature of the matrix, which is lower than the application temperature of the fibers.)

"The price of fibers made from basalt is higher than those made of E-glass, but less than S-glass, aramid or carbon fiber and as worldwide production increases, its cost of production should reduce further." ##

Back to Mare Frigoris and neighboring craters with ice deposits

There are a number of other craters, North of the 60° latitude line, 30° south of the Moon's North Pole in which there are permanently shaded areas on their southern slopes where ice is likely to have accumulated over the eons. No other area on the Moon is so blessed and has so many plusses as a place to begin settlement of the Moon. The closest mare area to the Moon's South Pole is "nowhere near."

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.)

There is no 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."

A conveniently located "mare" ("sea") - (NOT either pole, N or S) - 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 products promise to be on the short list of cornerstone lunar industries.

Once more: how much basalt is there "at" either of the Moon's poles???

ZILCH!! NADA!! ZERO!!

To Outbound Readers including members of the Moon Society

The above is a "peek" into my first book - "A Pioneer's Guide to the Moon"
It will be long, most likely divided into two volumes

Next comes "**A Pioneer's Guide to Mars**" - much shorter - followed by
"**Beyond Moon and Mars, a Pioneer's Guide to the rest of the Solar System**"
(the moons of Jupiter, Saturn, Uranus, and Neptune, Pluto-Charon,
And *surprise! surprise!* Mercury and Venus. ##