**Inorganic Soil Components Part 1**

**What is Inorganic Material?**
The inorganic component in soils comprises anything that was never alive. In most soils, it is composed of different varieties of clays, quartz, and lithic fragments of other rocks. The overwhelming bulk of most natural soils is inorganic. On average, natural soils are made up of about 45% inorganic components, 25% water, 25% air, and 5% organic matter. The role of inorganic material in natural soils is to maintain an open, oxygen-rich structure and to add stability as the organic components break down.

Sometimes a question comes up about whether clay is organic or inorganic. Clay minerals are definitely inorganic, but the soil in which they are found is strongly influenced by organic processes. Organic compounds of one sort or another are common and associated with the clays. Sometimes clay minerals can even form complexes with organic compounds. Think of the clays as part of the habitat of organisms which live in the soil in symbiosis with the plants that live there as well. The organic matter interacts with the inorganic material in the substrate both physically and chemically.

**What is Organic Matter?**
We think of organic matter as the plant and animal residues we incorporate into the soil. We see a pile of leaves, manure, or plant parts and think, "Wow! I’m adding a lot of organic matter to the soil." This stuff is actually organic material, not organic matter.

What’s the difference between organic material and organic matter? Organic material is anything that was alive and is now in or on the soil. For it to become organic matter, it must be decomposed into humus by microbial activity. Organic material is unstable in the soil, changing form and mass readily as it decomposes. As much as 90 percent of it disappears quickly because of decomposition. Organic matter is stable in the soil. It has been decomposed until it is resistant to further decomposition. Usually, only about 5 percent of the organic material is converted to organic matter.
What Is the Role of Organic Matter in Soils?

Nutrient Supply
Organic matter is a reservoir of nutrients that can be released to the soil. Each percent of organic matter in the soil releases nitrogen, phosphate and sulfur. The nutrient release occurs predominantly in the spring and summer, so summer crops benefit more from organic-matter mineralization than winter crops. If you don’t include organic matter in your soil mix it is fine, but you will have to be responsible for the nutrient supply. This may seem like a drawback, but as you become more advanced in bonsai you’ll find that withholding nutrients is an important technique that you’ll want to implement as your trees become more developed.

Water-Holding Capacity
Organic matter behaves somewhat like a sponge, with the ability to absorb and hold up to 90 percent of its weight in water. A great advantage of the water-holding capacity of organic matter is that the matter will release most of the water that it absorbs to plants. In contrast, clay holds great quantities of water, but much of it is unavailable to plants. If you don’t include organic matter in your soil mix, your plants will likely require more watering than you are used to, but the factors that control water-holding capacity in soil will be discussed in a companion document.

“Given only the health of the soil, nothing that dies is dead for very long.”

-Wendell Berry, The Unsettling of America, 1977
Inorganic Soil Components Part 2

Akadama
Akadama is a volcanic soil - it is composed of partially to completely altered tephra deposits of volcanic ash and pumice. It’s parent material was derived from arc volcanics, probably andesitic in composition like those in the Cascades. Remnant pumice grains are apparent in several bags I’ve bought, but generally the pumice and ash are nearly completely altered.

The pictures you may have seen of the akadama mined in Japan there are layers - a dark organic-rich layer on top, then the red akadama layer, then the yellow kanuma layer. The boundaries between these layers are called soil horizons. These kind of volcanic soils are called andosols. An- is japanese for "dark" and -do meaning soil. The dark reference refers to the black, humic rich upper layer of the soil. This layer is part of the definition of an andosol - it must occur within the upper 15cm of the ground surface. So you should think of akadama as a soil, not a volcanic tephra deposit. It used to be many years ago, but that is mostly all gone now and replaced by clay minerals.
The alteration is interesting - with a lot of water, the ash breaks down to form allophane and imogolite, smectitic clay minerals that commonly occur together in an andosol. In fact, their occurrence is nearly diagnostic - andosols are pretty much the only kind of soil in which they are found. Allophane is the primary clay mineral phase in akadama (http://onlinelibrary.wiley.com/doi/10.1111/j.1747-0765.2006.032_6.x/abstract).

There is an interesting pH control on the allophane-imogolite association, however. As pH changes, aluminum can combine with the humic acid that leaches from the surface forming Al-humus complexes that can substitute for the allophane-imogolite clay minerals. At a certain pH, one becomes dominant over the other (http://www.isric.org/isric/webdocs/docs/ISM_SM2.pdf). So in a typical andosol, horizons form as a response to changing pH in the subsurface. This is what I suspect the akadama-kanuma horizon is.

**Akadama is dominated by allophane-imogolite clay minerals with subsidiary Al-humus complexes whereas kanuma is dominated by Al-humus complexes with subsidiary clay minerals.**

I made this bold to get your attention - these organic complexes found within the clay are not found in any of the other soil components we use. I’m not saying its better or worse, but it’s certainly different.

So where can you find this magic substance? To replicate the conditions in Japan, you need 1) volcanoes, 2) a lot of rainfall, 3) a lot of organics, and 4) time. It occurs in volcanic regions all over the world! Important deposits are found around the Pacific rim: on the west coast of South America, in Central America, the Rocky Mountains, Alaska, Japan, the Philippine Archipelago, Indonesia, Papua New Guinea, and New Zealand. They are also prominent on many islands in the Pacific: Fiji, Vanuatu, New Hebrides, New Caledonia, Samoa, and Hawaii. In Africa, major occurrences of andosols are found along the Rift Valley, in Kenya, Rwanda and Ethiopia as well as Madagascar. In Europe, andosols occur in Italy, France, Germany, and Iceland. In total, there are some 110 million hectares of the earth's surface that is covered with andosols. More than
1/2 of this is in the tropics. In a word, they’re common. On the left is a map of their distribution in the US.

In production of akadama, the clay first is cleaned, kibbled and sieved in three different grains sizes: 1. small grain (1-5mm), 2. middle grain (5-10mm ), 3. large grain (10-25mm ). Later, it is kiln dried at temperatures around 300° C. Some akadama is fired at higher temperatures which gives the grains increased stability. Four brands are commonly available, Akadama Jirushi, Akadama Ibaraki, Akadama Tokoname.

Here’s a map of the distribution of allophonic and non-allophonic soils in Japan along with a map of where akadama is mined.

Akadama Ibaraki is the the most commonly available brand. A few years ago it was called Double Red Line, but the factory that manufactured it changed its owner and it has since improved its quality, especially the cleaning process. It does not come with root remnants in the bag as it used to when it was known as Double Red Line. This is a kiln dried (low-fired akadama). Akadama Jirushi is similar to Ibaraki, but perhaps a bit harder granule. However, it is not as well sieved and the bag contains a higher percentage of granules less than 2mm.
Yaki Akadama and Akadama Tokoname are high-fired making the granules harder so they last longer in the pot without breaking down.

As a result of the natural variability and processing there is some variability in granular hardness. But it’s not sintered or calcined to increase hardness like some of the other soil components in common use. So it’s softer and will break down over time. How rapidly is dependent on the temperature at which it is fired, your climate, your watering habits and numerous other factors. Here in Houston it’s damp and humid. It rains a lot and can get quite hot. But it rarely freezes. I water 2-3 times a day in the growing season and use Akadama Ibaraki. I believe that the akadama will break down over time, but I’ve not found that to be a problem on time-scales of at least 4-5 years under the growing conditions in my garden. Here’s a picture of soil components that had been in a pot for 4-5 years.
Pumice & Scoria

What the heck is pumice? And what the heck is lava rock, for that matter? Let’s focus on those two soil components.

Pumice and lava rock (I'll henceforth refer to this as scoria) are original volcanic materials. They are not an alteration product like akadama nor are they manufactured like haydite or surface. Pumice and scoria are vesiculated (filled with gas bubbles) volcanic glass - the vesicles form as the lava is quenched to glass giving it it’s characteristic high porosity and low density. When volcanoes erupt, a rush of gas blows out the vent. This gas was once dissolved in the magma below and released as it ascended. The escaping gas carries with it small pieces of lava that solidify as they fly through the air. This action can produce a ground cover of scoria or pumice all around the vent. Here’s a side-by-side comparison of pumice and scoria:

Scoria is almost always black or dark gray to reddish brown and it forms from basaltic lava. This kind of lava tends to be richer in iron and magnesium. The basaltic lava starts out as black, but oxidation of iron during eruption and emplacement of the scoria turns it red. So what’s the difference between red scoria and black scoria? Well the red stuff is a bit rusted. That’s it.

Pumice is typically white to light gray to light tan. It forms from felsic magmas which are typically high in silicon, aluminum, sodium, and potassium and low in iron, magnesium and calcium. Rhyolitic magmas usually contain more gas. Because of this, pumice tends to have a much higher concentration of trapped bubbles - so many that the walls between them are very thin. The vesicles in pumice contain enough air that the rock will float on water whereas the thick walls of scoria make it heavy enough to sink. In Japan, white pumice is sold as “Hyuga”. As far as I know (minus subtle differences in color – hyuga tends toward tan and grey whereas US pumice tends toward white), it is exactly the same stuff as the white pumice widely available in the US.
Over time (millions of years), they both will alter into various clay minerals and quartz. The exact alteration pathway depends on the composition of the parent material, the water composition, temperature, pH, and microbial activity. But typically, it breaks down to form various smectitic clays - most often montmorillonite but saponite is common as well (i.e, http://claymin.geoscienceworld.org/content/48/3/423). If it is in contact with alkaline waters and depending on the composition, zeolites can also form (i.e., http://pac.iupac.org/publications/pac/pdf/1980/pdf/5209x2115.pdf).

Both pumice and scoria are extremely durable and mechanically stable in the pot. They will not break down. The density of both pumice and scoria are low because of the vesicles - pumice can be literally filled with them as in the picture to the right. All of those holes were bubbles that evolved from the lava as it ascended through the earth. Just like taking the top off a soda can! When the lava was erupted into the air it was rapidly quenched, freezing those bubbles into place. If the lava was really gassy, it can have a lot of bubbles making it high porosity and low density. If the lava was not gassy, it can have fewer (or none) making it lower porosity and lower density.
Haydite

Haydite is also known as LECA (lightweight expanded clay aggregate) or exclay (expanded clay). Haydite and its daughter products (Gravelite, Perlite, Rocklite) were made in the USA, LECA was manufactured in Europe.

Haydite is a manufactured product. It was invented and patented by Stephen Hayde in the 1900’s in Kansas City, Missouri. His product was a structural grade lightweight aggregate. The process uses a rotary kiln to flash heat clay, shale or slate at temperatures of over 2200° F. In the process, water in the shale flashes to steam and the material expands producing air pockets in the grains. The heat also sinters the rock making it quite hard. It’s essentially a ceramic. The end product is a strong and durable lightweight aggregate used in numerous types of construction throughout the world. The first significant use of “Haydite” was in the construction of the hulls of several liberty ships in World War I. This application was very successful and was continued in the second World War.

The manufacturer recommends using as a soil amendment at a rate of no more than 15% by volume.

So what do you need to know? Haydite is:
1. Like a ceramic - it’s chemically inert
2. Has some microporosity due to the manufacturing process
3. Is incredibly strong and hard - it won’t break down over time
4. Is pretty light weight - it won’t add a lot of weight to your pot
5. Can be a bit variable in texture depending on the starting material - it can be manufactured from clay, slate or shale
6. Comes in a wide range of sizes
7. It’s cheap and readily available.
Turface

Turface is a brand name for a calcined clay. Calcined clay is another manufactured product like Haydite. However, the process of calcining is different than the process of sintering. Both processes involve heating a sample to a specific temperature, but with calcination, the goal is almost always to affect a phase change. In other words - one mineral goes in, a different mineral goes out. Sintering generally means heating to make a substance hard and dense, but there's no phase change.

To make calcined clay they start with a clay mineral called Kaolinite which is a common clay mineral on the earth's surface. It's a very pure clay mineral having a chemistry of 1 part Al₂O₃ and 2 parts SiO₂. But the mineral is hydrated, having 12% crystal bound water. They take an ultrafine natural sample and heat it to temperatures of 1300° F in a rotating kiln. At these temperatures the kaolin is completely dehydrated (all the hydroxyl ions are boiled away) forming a poorly crystalline metakaolin. This process changes the properties and alters the size and shape of the kaolin particles. That's how calcined clay is made - very similar to Haydite except it's fired at a lower temperature, heated more slowly and starts with a different starting material. Seramis, discussed below, is also made out of a kaolinite clay, but it has very different properties due to the differences in the manufacturing process.

Turface:
1. Is akin to a pottery - it's chemically inert
2. Has some microporosity due to the manufacturing process
3. Is very strong and hard - it won't break down over time
4. Pretty light weight
5. Is angular to subangular (the grains aren't rounded in texture)
6. Comes only in fairly fine grain sizes
7. Is cheap and readily available.
Inorganic Soil Components Part 3

Perlite

Perlite is made from a naturally occurring volcanic glass called obsidian. Obsidian is a glassy volcanic rock with a vitreous, pearly luster and a characteristic concentric fracture. Interestingly, it can have between two and six percent water in its structure depending on its source. It’s made up of mainly silicon and oxygen which are the primary ingredients in regular glass, quartz and many other minerals and products. The type of obsidian used to make perlite has a lot of water in its structure. This special kind of obsidian is found all over the world with the largest production in and around Turkey. In the United States, New Mexico produces the largest amounts of perlite.

The obsidian is rapidly heated to over 1,600° F (671° C), the water expands forming tiny trapped bubbles in the perlite. The trapped water flashes to steam causing the obsidian to expand 7-20 times its original volume depending on the original water content of the source of rock. The rock has to be rapidly heated - if it is heated slowly, the water will escape and not expand the glass. The resulting expanded particles —actually clusters of minute glass bubbles—are spherical in shape, usually fluffy or frothy, highly porous due to a foam-like cellular internal structure, and have a very low density. This changes the way light is reflected and gives it a whitish color (originally before it was expanded it was black or gray but can also be green, brown, blue or red). Perlite is chemically inert and has a neutral pH.

In a sense - perlite is kind of a man-made pumice. The expansion and bubbles are what gives perlite its white color and extremely light weight. Expanded perlite can be manufactured to weigh as little as 2 pounds per cubic foot (32 kg/m3) making it adaptable for numerous applications. The product is then kibbled and split into different size fractions. - it may be very coarse or very fine-grained.
**Decomposed Granite**

Decomposed granite, also known as DG, is rock that is derived from granite via its weathering. An accumulation of coarse angular fragments of DG is often referred to as grus. As it weathers, the granite breaks down to the point that the parent material readily fractures into smaller pieces of weaker rock. Further weathering yields material that easily crumbles into a mixtures of gravel-sized particles, that in turn may break down to produce a mixture of clay and silica sand or silt particles. Its uses include its incorporation into paving and driveway materials, residential gardening materials, as well as various types of walkways and heavy-use paths in parks. Different colors of DG are available, deriving from the natural range of granite colors from different quarry sources, and admixture of other natural and synthetic materials can extend the range of DG properties.

It has a distinctly different appearance and texture to grit. Grit is also made from granite, but manufactured from unweathered granite. Because of the different texture, it likely has different physical and chemical properties than DG. But grit is also easy to obtain already sieved whereas DG will require some work on your part to sieve it into the necessary size fraction. It’s extremely important to sieve the dust out of DG - you’ll end up with a pretty impermeable soil if you do not. Grit, on the other hand, has very little dust and you can buy it different size fractions (get it at your local feed store - the small stuff is called chicken grit and the large stuff is called turkey grit).

In terms of it’s properties, granite has almost zero microporosity. It tends to have a fairly low porosity, overall, but very high air-filled porosity and low water-holding capacity. It’s quite heavy and can add a lot of weight to your soil if it’s a significant part of your soil mix. In terms of the appearance, grit has kind of a stark white appearance while DG is more of a buff color. Grus has a nicer appearance in the pot, in my opinion.
Other Japanese Soils You'll Hear About

Kiryu
Kiryu (on the left) is sometimes referred to as "river sand". I don't know much about it except that it is used as the "grit" component in soils. Japanese growers increase the fraction of this component in soil for plants that require more drainage (read higher AFP) such as conifers.

Hyuga
Hyuga (on the right above) is just pumice from Japanese volcanoes. As far as I know it's exactly the same as pumice found here in the US. It tends to be a bit more tan or grey in color.

Kanuma
As discussed above, Kanuma is mined right there with akadama. There is the dark, humus-rich top soil, then the red akadama, then the yellow kanuma. It's another alteration product of volcanic tuff. It is partly to completely altered. You can find remnant pumice grains in it just like you can sometimes see with akadama. It tends to be more water retentive and has a quite high microporosity. In Japan, azaleas are commonly potted in straight kanuma. I believe that the color difference is related to the clay type - rather than the allophane-imogolite clays in akadama, I think that kanuma may have more of the Al-humus complexes in it.

Keto
Keto is an organic soil. This is a sticky clayey peat soil imported from Japan for use in rock or slab plantings, tray landscapes and forest groups in shallow pots or on trays. It is mixed with water to create "muck" and then rolled in a ball before application.
Still More Soils You’ll Hear About

Diatomaceous earth

Diatomaceous earth, often referred to as DE, is an off white, talc-like powder that is the fossilized remains of marine phytoplankton. Don’t use DE straight up as part of your soil mix. It’s far too fine grained for that. However, kibbled and sieved, it may be used as a soil amendment. In Europe, there is a kitty litter made from DE. It was once branded ‘Tescos Low Dust Lightweight Catlitter’, but this product is not available in the US. This is often a source of confusion for new US bonsai growers who read that cat litter can be used as bonsai soil - what folks are referring to specifically is the DE brand above and not the kind of kitty litter generally available in the US. Some have found a DE based oil absorbent branded by Napa Auto Parts ‘Napa Oil-Dri #8822’ to be a suitable substitute, but be aware that this product fairly fine-grained. There are coarser grained DE soil products sold as soil amendments that may be found at your local hydroponics store.

Zeolite

Zeolites are microporous, aluminosilicate minerals commonly used as absorbents and catalysts. Although zeolites occur naturally, they are produced industrially on a massive scale. There are 40 naturally occurring zeolite frameworks and over 200 are manufactured. Their special ability to selectively sort molecules results from their very regular pore structure. The size of the ionic species that can enter the pore space is controlled by the dimensions of the molecular channels. So zeolites are commonly used as part of commercial water purification, as catalysis and sorbents. It’s commonly used as a soil amendment for sports fields, parks and lawns. If one can find it in the appropriate size range it likely can be used successfully as a bonsai soil component. You may be able to find this class of products at your local hydroponics store or available online.
Seramis is an orange baked clay granule. It looks like crushed brick but is far more lightweight and has more microporosity. The grains tend to be elongate, rather than spherical, and rounded, rather than angular. It is manufactured in Germany from a high quality clay found only in the Westerwald region of Germany. This area has been famous for its pottery since the 16th century. The clay is mined from an Eo-Oligocene deposit consisting primarily of kaolinite, illite and quartz. In the production of seramis, the clay is diluted with water and then undergoes a special process to achieve a final pore volume of over 80%. The clay is then dried, kibbled, sieved and fired. The clay assumes its reddish-brown color in the firing process due to oxidation of the iron it contains and is then cleaned of dust. The resulting product has a very high porosity, a high AFP and a high water holding capacity. For a time this product was available in the US, but unfortunately, has become quite difficult to find. If you see it, pick some up - it's a great product.
Costs

Costs for these materials can be somewhat deceiving. Oftentimes folks will look at the price of a bag and judge costs based on just what they lay out of pocket for the bag. But you’ll recognize at some point that some size fractions are too small to be useful while other size fractions are too large. Because of this, the costs of the soil are really quite dependent on the size fractions in the bag and that varies from product to product and supplier to supplier. Examine some examples in the table below:

Akadama, at $3.47/liter (Double red line brand from Wee Tree), has the highest gross cost - nearly 10 times the price of Turface. However, if you’re interested in using the 3/8”-1/4” size fraction, it’s important to recognize that only 4% of a bag of Turface falls into that size range whereas 43% of the Akadama does. You’re paying nearly $9.50/liter for that size fraction with Turface and significantly less for Akadama. The most cost effective for that size range was Seramis - not because it had the lowest gross cost, but because it had the highest fraction of the bag in that size range. Bummer that you can’t get Seramis in the US any longer. Waste also is a consideration. In my garden, I do not use anything finer than ⅛” in my soil mix. The least waste was Seramis in which only 1% of the bag of fell into this size fraction. The most was Turface in which nearly 45% of the bag did.

<table>
<thead>
<tr>
<th></th>
<th>Gross Cost</th>
<th>1/2”-3/8”</th>
<th>3/8”-1/4”</th>
<th>1/4”-1/8”</th>
<th>&lt;1/8”</th>
<th>Net Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumice (domestic - Wee Tree)</td>
<td>$2.00/liter</td>
<td>29%</td>
<td>33%</td>
<td>27%</td>
<td>11%</td>
<td>$6.06/liter</td>
</tr>
<tr>
<td>Seramis</td>
<td>$2.10/liter</td>
<td>0%</td>
<td>67%</td>
<td>32%</td>
<td>1%</td>
<td>$3.13/liter</td>
</tr>
<tr>
<td>Turface (MVP - Ewing)</td>
<td>$0.38/liter</td>
<td>0%</td>
<td>4%</td>
<td>51%</td>
<td>45%</td>
<td>$9.50/liter</td>
</tr>
<tr>
<td>Akadama (double red line - Wee Tree)</td>
<td>$3.47/liter</td>
<td>9%</td>
<td>43%</td>
<td>40%</td>
<td>8%</td>
<td>$8.06/liter</td>
</tr>
</tbody>
</table>

Resources

If you’re lucky enough to live on the west coast, soil components are easy to obtain. I used to go to T. E. Walrath Trucking in South Tacoma when I lived in Seattle because they carried bulk pumice. You set up an appointment, then show up with a shovel! But elsewhere in the US the least expensive way to purchase soil components by far are in bulk. The costs you will incur purchasing in bulk can be ¼-⅓ the
price of purchasing the same item by the bag. So get some friends, split a pallet and have it shipped in bulk - it’s really easy. Here are some places that might do it:

<table>
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<tr>
<th>Name</th>
<th>Location</th>
<th>Site</th>
<th>Available</th>
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</thead>
<tbody>
<tr>
<td>Bonsai Tonight</td>
<td>Alameda, CA</td>
<td><a href="https://store.bonsaitonight.com/collections/bonsai-soil">https://store.bonsaitonight.com/collections/bonsai-soil</a></td>
<td>Akadama, Clay King, Pumice, Kanuma</td>
</tr>
<tr>
<td>T. E. Walrath Trucking</td>
<td>Tacoma, WA</td>
<td><a href="http://tewalrath.com">http://tewalrath.com</a></td>
<td>Pumice</td>
</tr>
</tbody>
</table>

As of this writing, prices (excluding shipping) are generally $7-$8 per 40lb bag or $350-$400 range for a pallet (50 40lb bags) of pumice or scoria. Akadama is pricier - generally $20-$25 per 14L bag or about $1000-$1250 per pallet for bulk purchases. Purchasing by the bag is higher material and shipping cost. Shipping to Houston is about $300 per pallet. So for example if you split three pallets of (1 each of pumice, scoria, and akadama) with four friends you’ll end up with 26 40 lb bags (one 40lb bag is about 1 cubic foot) of pumice and scoria and 13 14 liter bags of akadama (a 14L bag is about ½ a cubic foot). That is about 240 gallons of bulk soil and your total costs will be about $650 total - so somewhere in the $2.50 - $3.00/gallon range is your price point for bulk soil purchases. So make friends and buy in bulk. Or do it through your club or study group. You can save a ton of money that way.
But sometimes you just need that one extra bag. And you need it tomorrow, not on a pallet next month. In that case, it's good to have some local resources. So, if you live in the Houston area, here you go:

<table>
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<tr>
<th>Name</th>
<th>Location</th>
<th>Site</th>
<th>Available</th>
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</thead>
<tbody>
<tr>
<td>Timeless Trees</td>
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<td><a href="http://timeless-trees.com">http://timeless-trees.com</a></td>
<td>Akadama, Pumice, Lava Rock</td>
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<td>Quality Feed and Garden Company</td>
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</tr>
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<td>Maas Nursery</td>
<td>Seabrook, TX</td>
<td><a href="http://www.maasnursery.com">http://www.maasnursery.com</a></td>
<td>Expanded Shale</td>
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<td><a href="https://www.ewingirrigation.com">https://www.ewingirrigation.com</a></td>
<td>Calcined Clay</td>
</tr>
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<td>Southwest Fertilizer</td>
<td>Houston, TX</td>
<td><a href="http://www.southwestfertilizer.com">http://www.southwestfertilizer.com</a></td>
<td>Lava Rock</td>
</tr>
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