Mindat forum 8-10-2017 download
Lake Superior Agate Discussion
Forum thread with responses by Donald Kasper

Possible injection of fluidized sand into vesicles in basalt.

Posted by Larry Maltby

Larry Maltby June 11, 2017 03:36PM

I have puzzled over a group of agates and vesicle fillings that I collected some years ago. A possible explanation has emerged thanks to a professional abstract that Uwe recommended in a previous thread. Here is a photo of one of the agates that I recently posted. I am trying to figure out what the material below the diagonal line is and how it was deposited or injected into the vesicle.

Figure 1.

Agate

Lakeshore traps, Keweenaw Co., Michigan, USA

Response: Incomplete silica migration to the nucleating center, involving host lava exsolution (feldspar and silica separation). The host biotite and feldspar quickly decomposes in supercritical fluid to clay minerals and silica byproducts.

I have shown the entire abstract below and I have highlighted the words that may apply to this specimen. I have at least 20 more specimens like this showing various features that may help with a solution. Much more to follow.

Sequential opening and filling of cavities forming vesicles, amygdales and giant amethyst geodes in lavas from the southern Paraná volcanic province, Brazil and Uruguay
L, A. Hartmann, et-all, Journal: International Geology Review, 2012, Volume 54, Number 1, Page 1

"The opening and filling of cavities in rocks are the major processes related to the generation and sealing of porosity in ore deposits. This study documents three stages of opening and filling of vesicles and geodes in the basalts and rhyodacites of the southern Paraná volcanic province. Each step detailed here is actually part of a sequence of minor hydrothermal events. First, lava degassing at high temperature (1150°C) formed small (<4 cm) vesicles in the crusts of flow units. In sequence, these vesicles were partly to fully filled at low temperature (30-150°C) by hydrothermal minerals, particularly clays and zeolites; this process also sealed the porosity of the lava. ***Second, the injection of fluidized sand generated new cavities, which were partly filled with sand; the newly formed porosity was sealed by the low-temperature fluid.*** Third, intense alteration of the basalt or rhyodacite core into a claystone favoured the opening of small to giant protogeodes (0.1 mm to 4 m) by dissolution; cooling of the fluid led to the precipitation of hydrothermal minerals, particularly the spectacular amethyst, calcite, and gypsum-bearing geodes."

During my research on this subject, I came across references to clastic dykes that are filled with sediments and intruded into other formations. Some of the dykes are filled with basaltic sand. All of the specimens that I will show here were found adjacent to a vertical dyke in the host basalt. Here is a reference: https://en.wikipedia.org/wiki/Clastic_dike

Response: And you found a lot more amygdules not near any dykes. Because the amygdules form everywhere in Keenewah basalt, anything in the lava can be attributed as a causal agent of their formation.

Response: Amygdules on flow bases have captured soil from high temperature contact. Vein agates are broadly open and commonly contain sediments.

Please let me know what you think!
Edited 2 time(s). Last edit at 06/27/2017 12:07AM by Larry Maltby.

Ralph Bottrill June 11, 2017 11:32PM

Interesting Larry. Clastic or sandstone dykes normally form in sedimentary rocks during soft-sediment deformation, usually in semi-consolidated clayey beds which can crack during earth movements, and the crack fill with less consolidated sand falling in from overlying beds. It's a bit more difficult in basalts, but these commonly form strong, deep vertical joints and columns, and you could envisage these opening up during earth movements and allowing unconsolidated sediment to fall in and fill them with dyke like structures. Any unfilled vesicles adjacent to joints could be filled with this sediment. Alternatively, vesicles can fully or partly fill with smectite clays deposited from slow groundwater infiltration along microfractures, and maybe this is what we see, now silicified? But if can can see sandstone dykes in basalts we would love to see the photos?

Response: Soft sediment deformation is not a bit different than basalt, it has nothing whatsoever to do with basalt. Soft sediement deformation forms styolites, v-shaped structures that cut across banding planes. Are these found in your rocks? Never. Okay, soft sediment deformation of rock hard basalt is out.

Response: Voids exposed to the surface fill with dirt. Voids in solid rock near them fill up with nothing at all. There is no teleportation of sediment through solid rock.

Response: There are no microfractures in the host rock and clays are not soluble in water. Any vesicles attached to fractures would all be joined as one silica specimen. These are not found. There are no vein agate-amygdule combination specimens that exist. Bottrill is just making things up.

Jason Bennett June 12, 2017 09:25AM

The other possibility is that these sandy components could be sandstone clasts (possibly poorly consolidated?) that were picked up during eruption...

Response: Of course they were.

In line with Ralph's request for further photos, in-situ textural evidence would be really useful to help distinguish each hypothesis here...are the agates collected in-situ or weathered out somewhere?

Response: Bennett confuses sandstone which does not exist in amygdule agates with volcanic ash and the clays that surround the voids intruded during tectonic implosion events is not sand weathering. It is vesiculation involving zoned mineralization.

Larry Maltby **June 12, 2017 03:17PM**

Ralph, Thanks for your comments.

This geological detail has not been professionally recorded in the Geology of Michigan. I need help to better interpret what we see and I would like to correctly describe these specimens in the Mindat data base.

Unfortunately I do not have a good photo of the vein in-situ. Like most field collectors we get so involved trying to read the terrain looking for a good spot to prospect that we forget we have a camera. Also, I did not realize the significance of these specimens at the time. I do think that I can supply enough photos to define the geology. The issue will likely be, is the material in the vein and in the vesicles sediment or a basaltic intrusion?

Jason, Thanks for your comments also. We look forward to your views on this.

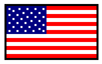
Here are photos of the uncovering of the agate shown above. I was right in line with the vein but the vein was removed during excavation.

Figure 2.

The missing part of the agate was not found.

This is the top of the agate rotated 180 degrees. The jagged edge has been cut away for the photos.

Edited 2 time(s). Last edit at 06/25/2017 01:14PM by Larry Maltby.

Larry Maltby  June 12, 2017 05:12PM

This agate was attached directly to the vein. Other agates with partial filling of intruded material were not observed to be touching the vein but were near to it. Some vesicles were completely filled with the intruded material. Some have tiny micro-agates included in the filling making the analysis more complex. All will eventually be shown here.

Figure 3.

This is an agate attached to an intrusive vein. About half of the vesicle is filled with agate and the other half is filled with the intrusive material.

This is the exterior of an agate attached to an intrusive vein.

Edited 1 time(s). Last edit at 06/25/2017 01:15PM by Larry Maltby.

Response: Since the presumed “intrusive vein” contains zero agate, how did this form the agate amygdule?

Gregg Little **June 12, 2017 06:27PM**

Larry, considering the heat and fluid around in the systems you are describing, this seems quite likely an injection mechanism would be plausible for your location. Is the "injected" portion as granular as it looks in the photo? This could point to it being clastic material. I think the key to this discussion is to determine the composition of the intruded material then the mechanism can be explored.

It appears the system was still very active after the "injection" as there is further agate(?) filling the void space inside the "injected" area. Also note that the agate part and the "injected" part could represent fault reactivation with the fill representing stages of fracture opening.

In the oil exploration field we see similar evidence where gravity-fill is not the sole operator. There are structures like sand dykes and even sand volcanoes. In these cases the sand bed is water saturated and confined above and below causing it to pressure up with compaction (settling, increase overburden, etc). Any fracturing or faulting allows a sudden release of water and sediment into adjacent beds or units either above or below.

Response: Water injected into sand blowing up the sand is not a sand volcano. That is liquefaction.

Response: The discussion is about agate in lava, not sandstone with fluid hydraulics. I was not aware you could inject sand through rock that never has a fracture visible to the naked eye or wide enough to inject one grain, much less tens of thousands.

Larry Maltby **June 13, 2017 03:19PM**

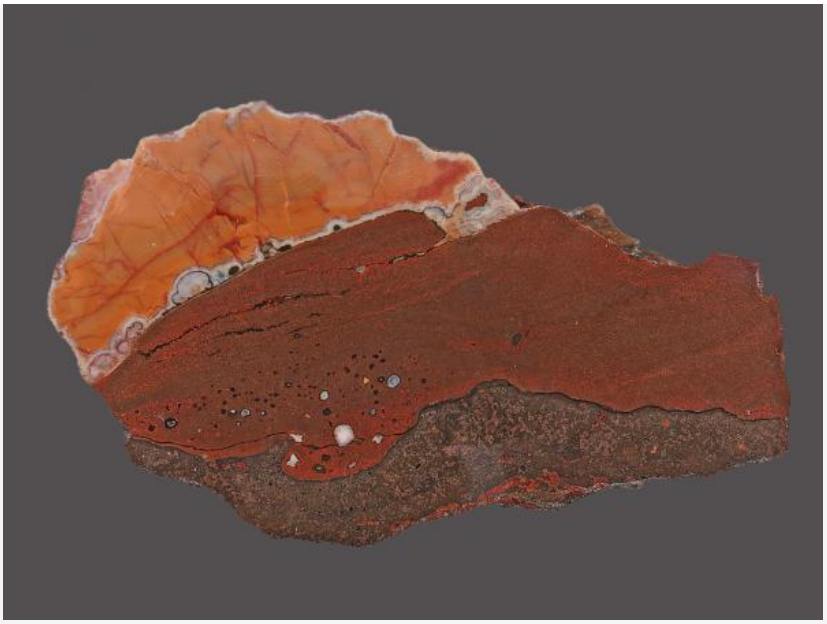
Thanks Gregg,

With your and Ralph's comments I think that we will be able to come up with a reasonable explanation for these specimens. I have attached below a photo of the contact between the intrusive material and the host basalt. As you can see the contrast is significant. I plan to lap the specimen to 1200 grit and take micro-photos of each texture. Photos to follow.

Your comment on how sediment can be fluidized and pressurized probably explains how the vesicles near the vein were infilled. At the time that we were collecting we did not know about this and could have easily missed a feeder vein. Vesicles three or four feet away from the vein were completely filled with agate only. (8.5 x 5.0 x 8.0 cm)

Response: The vesicles were formed by vesiculation. Later fracture cooling created the nearby vein. The vein is not an agate. The vein is attached to one amygdule. It does not matter what the water pressure is, groundwater does not travel through solid rock.

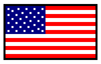
Figure 4.



IMG_1090E2.jpg

Response: Incomplete exsolution of silica and lava. Byproducts settled to the bottom. There was no void stage because there was just fluid and silica and feldspar, but no gas.

Edited 2 time(s). Last edit at 06/25/2017 01:17PM by Larry Maltby.

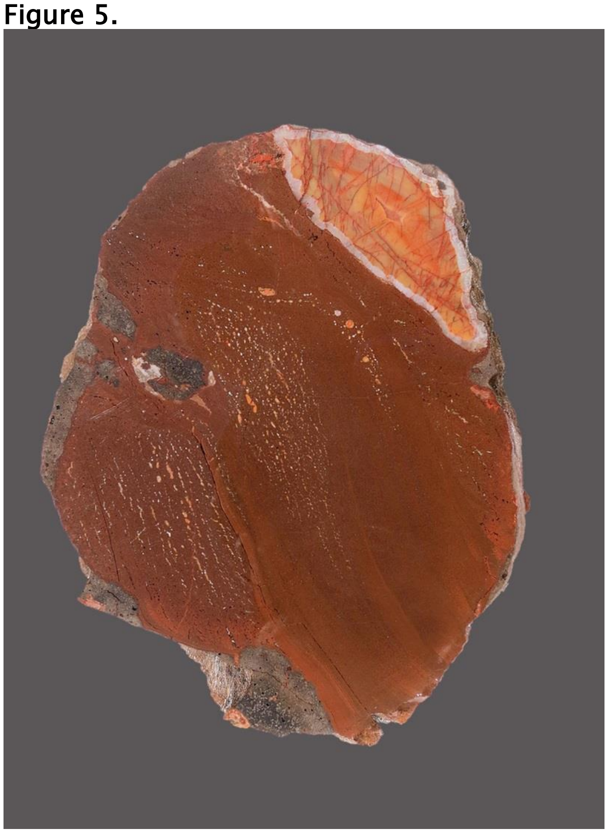
Larry Maltby  June 15, 2017 04:15PM

Here is another specimen of interest. In addition to the agate, the remainder of the vesicle contents in the photo below is likely a fine grained siltstone. The nodule was found associated with what appears to be a clastic dyke with a system of veinlets that distributed sediments including silt, mud and sand into the adjacent empty vesicles in the host basalt.

The best way to see this is to enlarge the bottom portion of the specimen and note the texture and flow lines. There is even some indication of stratification. The porosity is likely the result of liquefaction that aided the transportation of the materials through the vein system. Some of the porosity was later filled with the deposition of quartz.

Response: You don't just transport sediment through solid rock because it is a few feet from a vein or dyke. Also, specimens from many locales are mostly non-agate filled where vein agates are not found (ex, Laguna region, Mexico).

Figure 5.



Siltstone, etc.

Lakeshore traps, Keweenaw Co., Michigan, USA

Edited 1 time(s). Last edit at 06/25/2017 01:20PM by Larry Maltby.

Larry Maltby **June 17, 2017 03:27PM**

Ralph,

Here is a specimen that shows what I now think is a confirmed clastic vein passing right through a filled vesicle in basalt. It appears that when the basalt fractured the crack passed through an empty vesicle offsetting the two halves by about 0.5 cm. The view is of the slightly concave bottom with the left and right ends broken off. The face view of both ends shows the domed shape typical of a gas bubble in a viscus lava. As you can see the material in the vein looks like sand. (9.0 x 9.5 x 3.5 cm) The vein width is about 2.0 cm.

Response: This is a shear structure that formed in host rock, since weathered and broken.

Figure 6.

IMG_1103E5.jpg

The Lake Shore Traps are interbedded with conglomerate, sandstone and mudstone. These formations found on the beach of Lake Superior at one time covered the traps but were eroded away by glacial action on the inland ridges. It looks like a source of sand was available to fill the fracture and the color is similar.

Response: Agates form in lava, not sandstone. At Kramer, CA, agates form in lava over granite basement does not mean you will find granite in your agates. You do not.

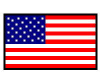
Figure 7.

IMG_0321E5.jpg

Jason,

I forgot to answer your question. Yes, all of the specimens were collected in-situ.

Edited 3 time(s). Last edit at 06/25/2017 01:23PM by Larry Maltby.

Larry Maltby  June 21, 2017 04:51PM

The reference below shows a clastic dyke found in the Late Precambrian, Keweenawan, Osler volcanics that out crop on the northern shore of Lake Superior. It apparently was discussed on a field trip conducted by David Bee, a professor at Penn State University.

http://www.swanson-hysell.org/2012/01/20/featured-field-photo-bifurcating-clastic-dike/

Ralph Bottrill June 23, 2017 11:35PM

Very interesting material Larry. It's always hard doing long range geology, but it may be worth showing the samples to a geologist if you can find one locally?

Paul Brandes June 24, 2017 04:20AM

I've been following this thread with great interest.

Very interesting to say the least, Larry! I have seen the clastic dykes of the Osler Group many years ago and we as a group marveled at how you could get a clastic (sediment) dyke in an igneous rock. The article you provided is one of two ways we postulated as to how you could possibly get this occurrence. One was indeed lava flowing over a wet sediment and boiling the water to steam. Once the steam pressure is high enough (think phreato-magmatic eruption), the slightly cooled lava cracks and sediments infill the fissure. The second way we thought of is a situation similar to sand blows you sometimes see during strong earthquakes whereby saturated sediments due to liquefaction are injected into any crack or fissure it can find in the already cooled basalt, then lithify over time.

As you stated earlier Larry, this is one of the many pieces of Keweenawan geology that has yet to be fully understood. To me, this begs for a research project to be initiated.

Response: Close. 1250 C over wet ground is called supercritical fluid. It is not steam. Cooling cracks are vertical. Why would they not accumulate sediment? This takes effort? It just takes weathering.

Gregg Little June 24, 2017 06:19AM

Larry;

As Ralph says it is difficult doing geology at a distance but I have some overall impressions to share. There appears, as seen in your June 15th post, to be at least two stages of dyke injection defined by the two areas of presence and absence of vesicles. The initial injection was the vesicle bearing sediment evident from formation against the fracture walls and its occurrence as semi-consolidated clasts floating in the vesicle free(?) second stage injection. The angular shape of the floating vesicle-riddled clasts reminds me of shale rip-up clasts in the sedimentary environment. Part of the basalt wall rock also appears to be ripped-up by the second stage injection.

I would also seem plausible that the first injection was more gaseous; higher temperature and greater pressure release (hence vesicles) followed by the second injection being slower(?) and probably lower pressure resulting in little or no vesicles and more of a laminar flow texture. Again this is just speculation from a remote perspective.

Response: Fluid movement alters the vein or dyke rock chemistry of the country rock. Where is this? Right, you have none to show. If high pressure fluid is intruding the country rock is brecciated. Where is this? Right, you have none to show. So the mineralization came from the host rock during vesiculation. We know this because it is not sand. Sand or silt capture only occurs at the flow base in contact with soil. This involves lava slopping onto wet ground and no dyke process of transport. A dyke to just melt through rock is called high temperature metamorphism, not found with agates.

Larry Maltby **June 26, 2017 05:25PM**

Ralph,

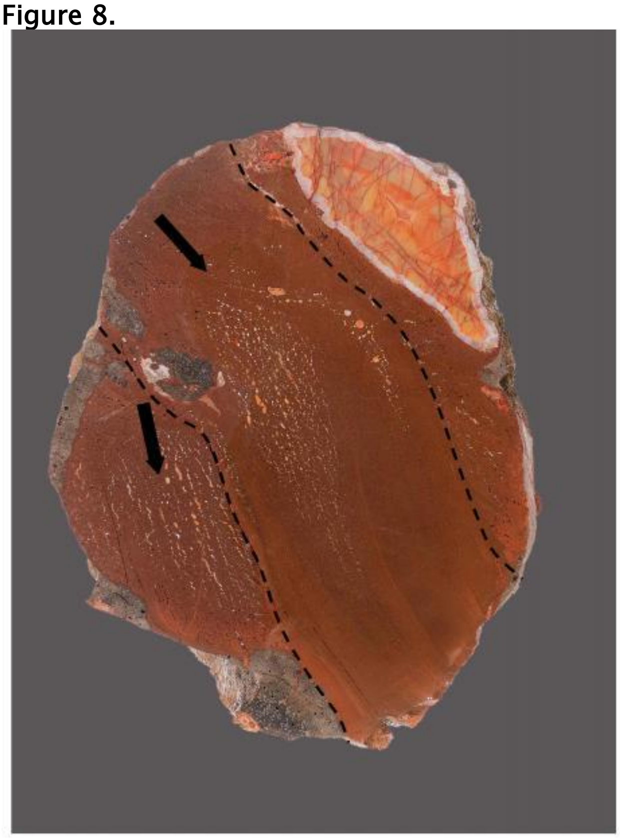
I do hope to review these specimens with several geologists. I have about 30 specimens of this type. They are all very interesting and I will use this thread to show many more photos during this summer. I have added figure numbers to all of the photos to facilitate discussion.

Gregg,

Regarding your comment on figure 5, I see the “flow lines” that I think that you are referring to. I have added the photo below to illustrate some additional information. When I look at the two halves of the specimen, it appears that the fracture (4.5 cm wide) destroyed a preexisting vesicle. The dotted lines depicting the width of the vein can be seen as flow lines in figure 5. I also added my guess as to the direction of flow. (Particles of the host basalt were pulled into the vein.) The space in which the agate formed may have been preserved by compressed air/gas during the intrusion of the sediment.

Response: There was no sediment intrusion. There are no fractures with this sediment around these amygdules. These are minerals captured during vesiculation that typically involve clays that are not soluble in water. To have stream transport, the sediment will be lensatic due to common incomplete fills. You have no lensatic structures. You have no humic acid in this rock showing groundwater flow missing by my study of Lake Superior agates, and all other agates in general.

Figure 8.



Publication2.jpg

Paul,

I agree that more work is needed to define he mineralogy and the geology of the Traps. I have a lot of material that I am trying to get into the Mindat data base. I better hurry, I turned 80 years old this spring.

Jolyon & Katya Ralph June 26, 2017 06:46PM

I think it's important to correct a possible misunderstanding in the title of this thread.

Larry refers to **liquefied sand** which, to me at least, suggests it is molten.

The reference cited refers to **fluidized sand** which to me, at least, suggests sand moving in a fluid-like manner (eg as it does when pouring through an egg-timer)

Response: Molten sand is called molten quartz. That forms solid quartz structures. Liquefied sand is called wet sand, not molten sand.

Larry Maltby June 26, 2017 08:29PM

Thanks Jolyon,
Point taken. Can I edit the title of the thread without messing it up?
Larry,

Jolyon & Katya Ralph June 26, 2017 09:14PM

You can!

Larry Maltby June 27, 2017 03:26PM

I have just uploaded these photos to document the cross-cutting vein.

Figure 9.

This photomicrograph shows the sedimentary content of a vesicle in basalt that is associated with a clastic dyke and vein system. A layer of mudstone can be seen that has subsequently been altered by the orange crystallization of what appears to be laumontite. Micro-quartz is also abundant. The cross-cutting vein indicates that the alteration is secondary to the intrusion of the sediments. At the top center is a segment of the host basalt. The Lake Shore Traps are generally described as Fe-rich olivine tholeiitic basalt.

Response: The orange mudstone is basalt. The gray top core is unoxidized basalt. There are no zeolites in the agates as shown by infrared spectroscopy. Zeolitized host rock with agate in basalt I have yet to observe. It does occur in rhyolitic lava in hydrothermal areas.

Response: If the veinlet on the left fed the silica to the center, presuming all deposition on all surfaces occurred at the same rate, then the feeder veinlet would have filled before the silica structure in the center did. Alternatively, exsolution leading the veinlets and accumulation preferentially at intersecting veinlets means it all grew from silica accumulation at the same time.

The cross-cutting vein indicates that the alteration is secondary to the intrusion of the sediments. Laumontite is the most common zeolite found in the Lake Shore Traps ranging in color from white to orange and a dark brownish red.

Response: The orange in basalt is only from iron oxidation. Zeolites blown through lava makes the lava white, not orange. No laumontite in an agate has ever been found and since zeolites are not soluble in water, if they formed first, they would still be detectable with a method of spectroscopy in the final agate. This does not occur. When zeolites form, they are silica hogs that PREVENT agate from forming. The zeolite formation residual byproduct is crystal quartz.

Edited 2 time(s). Last edit at 06/27/2017 05:02PM by Larry Maltby.

Gregg Little  **June 27, 2017 07:38PM**

Larry; Where you say "The space in which the agate formed may have been preserved by compressed air/gas during the intrusion of the sediment.", I think I might have to clarify my earlier comment on the stages of the fluidized sediment intrusion. I don't think it is necessary to invoke a preservation method for the agate nodule. Stages of formation as follows; 1) emplacement of basalt flow and vesicle formation, 2) agate deposition/solidification in vesicle(s), 3) fracturing and injection of first event fluidized sediment ("frothed" or sediment with abundant gas cavities), and finally for this specimen, 4) fracture reactivation and injection of second event of fluidized sediment (un-frothed or sediment with few or no gas cavities).

The first fluidized sediment injection might be relatively lower in viscosity due to its gassy character and possibly not have a tendency to mechanically include fragments of nodules and wall rock (basalt). The second fluidized sediment injection could be more viscous and with reactivation of the fracture would provide fragments of the previous sediment intrusion and weaken wall rock material to be included mechanically in the flow. I think the flow lines in the second intrusion indicates a slower rate of intrusion (just an impression). It would also be interesting to analyse these flow lines for composition and hence their formation. A cursory examination, to me, indicates a re-absorption of the included (first) fluid sediment injection fragments as there appears to be dark "tails" streaming from the fragments in the down stream direction, as you have indicated in the photo (figure 8).

Response: False. Fluid injection in ore deposits is called hydraulic jacking that causes autobrecciation. You cannot inject high pressure fluid without causing this. It does not trickle in. It has to intrude at supercritical temperature over 374 C. Groundwater does not flow through solid rock. It weathers the contact rock, deepening the weathering over time. These amygdules are not dug out of mud from basalt weathering, they are dug out of solid unweathered basalt. More amygdules are not found at the surface and peter out with depth due for formation from weathering as weathering does not form agates. Only ellipsoidal voids have agates here and most sites, not any void or any fracture found all over basalt flows of the world and the Keenewah, because only the ellipsoidal ones form agate during the eruption. All other voids that are not ellipsoidal and have nothing in them are ignored in this analysis. This is called filtered modeling, a model created by excluding most of the observable data.

Another observation; the gassy sediment fragment with your left-side arrow on it, may not have been transported but by-passed because the fracture wall formed as indicated by your dotted line.

If my ramblings seem a little "out in left field", please remember that fracture geometry is complex (not to mention the material that fills it), we're viewing a 2-D "time-slice" and all this speculation is from a photo.

Gregg Little June 27, 2017 07:54PM

Larry; I just had a small epiphany, if there is such a thing as a small one, from Jolyon's earlier comment. If the first sediment injection was due to gas (steam) then we have fluidization of the sediment. If the second injection was due to liquid water suspension then we have liquefaction of the sediment. That may explain the perceived viscosity difference of the two stages of injection as well as the second eroding the first. May be I am getting carried away here. Lets see what other have to say.

Jolyon; You are such a source of inspiration!

Response: I did not see Joylon contribute anything meaningful to this conversation.

Response: You cannot have liquefaction in amygdules in solid basalt. This is gibberish. Second, agate cannot intrude with water as silica is virtually insoluble in groundwater. Third, calcite is a thousand times more soluble in water than silica, so amygdules should always contain calcite, and not quartz. This is not observed. The amygdules are commonly silica, not calcite.

Edited 1 time(s). Last edit at 06/27/2017 08:09PM by Gregg Little.

Larry Maltby **June 28, 2017 02:06PM**

Gregg,

Yes, when you hold the two halves of the large specimen shown in figure 5 and 8, and look at them in 3-D, it becomes apparent that the fracture pattern is very complicated. To really discuss this one we would need to be seated at the table together. The take away from this specimen for me is that the clastic material looks like lithified silt. In my younger days I was an avid trout fisherman and I studied the aquatic insects that trout feed on. This material looks just like the waterlogged silt that I have dredged up from the back waters of trout streams.

The next group of photos that I plan to show will illustrate what appears to be sandstone in veins and vesicles.

Response: Figure 10 in not an amygdule. It is a lithic stone capture during the eruption. It not a nodule, it is a rock clast.

Larry Maltby June 29, 2017 07:11PM

Figure 10.

This nodule was found near a vertical clastic dyke and shows evidence of clastic veinlets on the surface. The veinlets contain sandstone that completely filled the vesicle in the basalt.

Response: This was originally a septarian nodule.

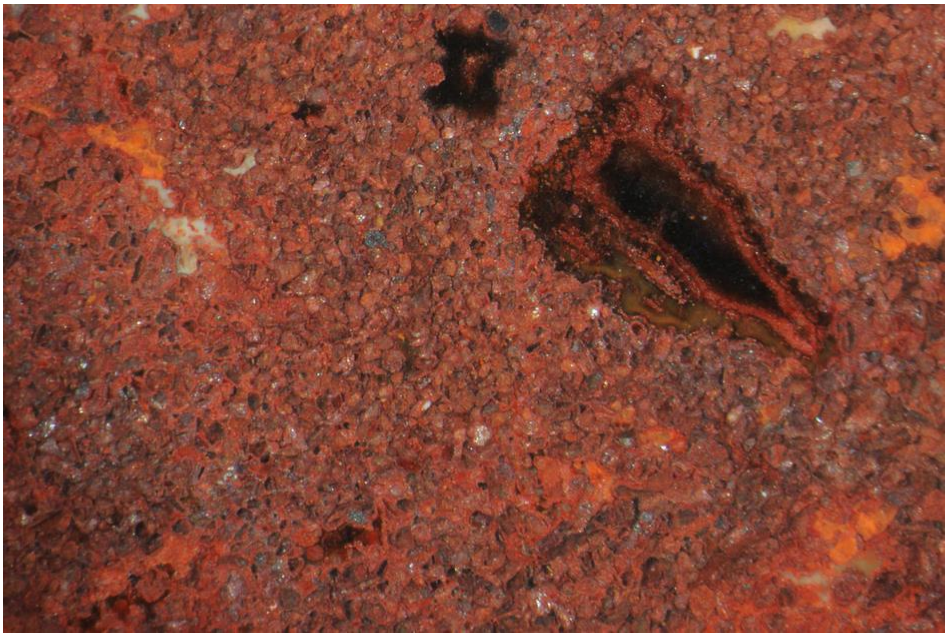
This is a close-up of the sub-angular grains that make up the sandstone in the veinlets. The veinlet is about 2.5 mm wide.

Response: Lava capture of sandstone as it slopped over sandstone basement. Some basement rock was reworked and partially melted. The flow was not hot enough to completely melt and incorporate the sandstone into the lava.

Figure 11

Inside the nodule the sandstone grains are clearly visible and show significant alteration due to silicification including the presence of micro-agates.

Response: This is not a nodule. It is a weathered chunk of vesicular basalt that weathered along joint cooling planes. There is no such thing as vesicular sandstone containing anything much less agates. The "sandstone" are the basalt mineral phenocrysts. The granularity appearance comes from biotite and hematite oxidation.



This is a close-up of the grains that make up the sandstone inside the nodule. The grains appear to be derived from the brownish red rhyolitic pebbles and cobbles that are very common on Keweenaw beaches and as clasts within the Copper Harbor Conglomerate.

Response: This is oxidized basalt.

The photo below shows some of the geological environment. The Lake Shore Traps are interbedded in the Copper Harbor Conglomerate. This photo was taken at the water's edge. You can see the brownish red coloration in the loose gravel and also in pebbles imbedded in the exposed sandstone. The origin of the large clasts of what appears to be felsic amygdaloidal basalt is a mystery. All of the known flows are mafic and dark in color.

Response: The basalt flow was highly vesicular, eroded over a geologic age, and became entrapped in sandstone. This is weathering. The clasts are relicts of the original flow.

Figure 12

IMG_0330E56.jpg

Edited 2 time(s). Last edit at 06/30/2017 12:48AM by Larry Maltby.

Gregg Little June 29, 2017 11:12PM

Larry;

I am not sure what is felsic, the amygdule mineralization or the ground mass of the basaltic clasts? Also these larger clasts don't seem to have much depth but I suppose that could be the wave erosion but if they are thin (when looking "into" the rock face), they could be the first phase of the sediment injection that coats the walls of the fracture, if the fracture orientation is in the plane of the photo, if you catch my drift? The red colour could be alteration from the warm/hot fluids of the second stage injection.

Response: Rocks get reworked all the time, captured in flows, weathered, buried with silt. Red color is from weathering of iron. Basalt is mafic, not felsic.

Larry Maltby June 30, 2017 03:36PM

Gregg,

Here is the definition of felsites/felsic in the Mindat data base. The term felsic is sometimes attached to basalt to refer to silica rich basalt as opposed to (mafic) iron rich basalt.

Response: This is gibberish. Basalt by definition is low in silica. Felsic lava high in silica is a rhyolite.

“Felsites (acid volcanic rocks) tentatively identified as rhyolite, with felsic minerals comprising >20% quartz and alkali feldspar/plagioclase 40-100%” (Ref. Mindat rock data base)

Another name that would fit these large clasts would be “amygdaloidal rhyolite” but I did not find that in the Mindat data base.

Response: Your specimens are amygdaloidal basalt.

By the way this photo was taken on the beach shown in figure 7 above.