Northwest Micro Mineral Study Group

MICRO PROBE

FALL, 2020

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NO MEETING SCHEDULED

It is still too early to gather together. Hopefully conditions will improve and we can meet again in the Spring.

We miss seeing you all and talking minerals together.

We hope this period gives you all time to go through the rocks that have accumulated over the years and set aside nice things to trade and for the free tables. We can guarantee that when we do manage to meet again, there will be lots of good stuff on those tables.

Meanwhile, having discussed sedimentary environments last Fall and igneous environments last Spring, we now look in this issue at the metamorphic environment, where the other two types of rock interact. This is a realm of very complex chemistry that produces some extremely interesting and colorful minerals. We can only touch on a few example locations. We hope that this will remind you of other areas that deserve examination and discussion. By all means, bring them to our attention. We would love you to take a few minutes and write about them. We welcome your short communications in next year's issues.

So keep working through the minerals that you have, researching and taking pictures, mounting up keepers and things to trade. Be assured that we are eager to put together a time to gather again at the earliest possible date so we can share our finds and enthusiasm with each and every one of you.

Beth and Don

THE MICROPROBE

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IN MEMORY OF GEORGE WILLIAMS

We are sad to have to report the passing of George Williams in June of this year. George was one of the last surviving members of the group of mineral collectors that came together in 1970 to form our Study Group, and he and his wife Laverne served as incorporators a couple of years later.

George was interested in preserving the history of our organization, and to that end he put together an extensive article in the Microprobe, Volume XI #1. In it, he detailed the rationale of the collectors who came together and the focus they emphasized of study and research. We are very glad for the direction that they provided, and for George reminding us of that focus.

George has not been able to attend meetings in recent years, but when I think of him, his ready smile and his softly spoken voice come immediately to mind. He will be missed.

Don Howard



IN MEMORY OF CHARLES SWEANY

Chuck Sweany passed away May 14, 2020. He was living in an assisted care facility with external access so he was surrounded by many generations of family. He was mentally sharp and his jovial self up to the last days. He was a year and a half short of the goal he had set to live to be 100.

Chuck was originally an accomplished jewelry and silversmith. He made beautiful cabs and exquisite inlay work. He was involved in training young people at camps during the summers. Then he got interested in the minerals themselves. Chuck and his wife Evelyn were members of NWMMSG when I first began attending meetings in the 1980's. They were also regulars at the monthly get-togethers that were held at the home of Beulah and Phil Murphy, and they were a part of many of the field trips that Rudy Tschernich organized for our study group.

Chuck was a careful collector with a good eye in the microscope. He accompanied me on several occasions to collect material from finds that would otherwise be ruined by rain and weather, such as the batch of pieces we brought back from the Ritter Quarry that had nice thomsonite and mesolite, so that they could be shared with the group. He was the one who collected much of the filiform pyrite from the site up the Clackamas River, and carefully broke it out and mounted it. He spent many hours breaking down material from Summit Rock looking for the tiny pink zircons, and material from Goble looking for tschernichite and boggsite. That was all material that regularly appeared on the free tables at our meetings.

Chuck continued attending our meetings until he no longer had the energy to last the day out. Even then, he was a regular at the monthly meetings held at the Howard house. He had a good memory and a sharp mind, a warm smile and a chuckle, and he told interesting stories in spite of difficulties speaking due to a strained voice from singing opera. Everyone who knew him treasured him, and he will be deeply missed.

Don Howard

Mineral Environments: Metamorphic

Don Howard

Having talked about igneous and sedimentary rocks in the last two issues, we now come to the middle ground: the metamorphic rocks. The picture here is of a region on sediments that get heated by the intrusion of igneous rock in their vicinity. The sediments are at least partially melted and subsequently recrystallize into new minerals. Clearly, the resulting species are going to greatly depend on the chemistry of the original sediments.

One possibility is that the sediments contain fairly large concentrations of carbonates. This will be likely if they have been derived from sea bottoms, where the shells and skeletal remains of life have enriched them. Calcium carbonate, when heated in air, loses carbon dioxide at about 825°C to become lime (CaO). This reaction is commonly used industrially to manufacture cement. Lime and sand mixed with water forms calcium silicate that bonds the sand grains together into concrete.

But enclosed in surrounding rock, the calcium carbonate cannot rid itself of the CO_2 and instead melts at around 1340°C. Molten CaCO₃ becomes a fairly good solvent of other elements including silicon, which is undoubtedly also present to some extent in the sediment. Upon cooling, the CaCO₃ recrystallizes as the form of calcite called limestone. Other minerals will also crystallize out and be embedded in the limestone. One advantage of collecting the minerals formed in the limestone is the ease of freeing them from their surroundings by dissolving the calcite away using an acid bath.

One group of minerals that form in this way is the garnets, in particular the ones containing calcium. Grossular makes use of the aluminum $(Ca_3Al_2Si_3O_4)$, while and radite incorporates the iron $(Ca_3Fe_2Si_3O_4)$ contained in the original sediments. Since a complete solid solution exists between the two, the garnets found in limestone are often intermediate between the two.

Magnesium is another common ingredient in the sediment. In fairly large concentration, it can lead to dolomite, $CaMg(CO_3)_2$, forming instead of calcite. As a more minor constituent, it often leads to associated diopside, $CaMgSi_2O_6$, often in good sized though intergrown crystals. If iron is more available than magnesium, the



Fig. 1. Andradite in limestone Aneroid Lake, Wallowa Co., Oregon

Fig. 2. Vesuvianite Mono Co., California

corresponding mineral is hedenbergite, $CaFeSi_2O_6$. Since there is also a continuous series between these two, natural crystals are usually intermediate, with light colored material richer in magnesium and darker crystals richer in iron.

Another mineral often associated with the diopside in limestone is vesuvianite, Ca₁₉(Al,Mg,Fe)₁₃Si₁₈O₆₈(O,OH,F)₁₀. It is a tetragonal mineral that often forms in elongated prisms. The terminations can be very complex but are often not seen since the crystals tend to be riddled with transverse cracks. This can be seen in the crystals from the Morris Claim, Benton Range, Mono Co., California illustrated in fig. 2. The prisms are striated longitudinally but are repeatedly cracked across and easily separate into short segments. The reason for this is that the prisms grow at elevated temperature in the molten calcite. As the mass later cools, the thermal expansion coefficient is larger for the vesuvianite than for the calcite, so the prisms attempt to shrink faster than their surroundings, generating forces that try to pull them apart.

Another example of this is given by the ludwigite crystals from Lemhi Co., Idaho shown in fig. 3. Ludwigite, $(Mg,Fe^{++})_2Fe^{+++}O_2(BO_3)$, is an ortho-rhombic mineral that forms elongated prisms. This limestone was rich in boron rather than silicon. The large crystals, often well over an inch long, are similarly fragmented, so that they come apart after being etched out of the calcite. The specimens end up looking like piles of broken sticks, or ragged broken teeth. Other minor associated minerals include magnetite, Fe_3O_4 , spinel, $(Mg,Fe)Al_2O_4$, and forsterite, Mg_2SiO_4 . This is a limestone from sediments containing considerable magnesium and iron.

Another important example of limestone localities is the collection quarries in Riverside Co., California known collectively as Crestmore. This is a magnesium rich limestone that lists over 160

Fig. 4.

Pyrrhotite



Fig. 3..Ludwigite in limestone Bruce Canyon, Lemhi Co., Idaho

identified minerals, including 9 for which this is a type locality. Many of the minerals form as small crystals floating in a bluish crystallized calcite. A fair number are white or cream in color and granular in form, and so are not particularly photogenic.



Geikielite Jensen Quarry, Riverside Co., California

Spinel



Fig. 5. Titanite and epidote in clinichlore Titanite altering to anatase and brookite Hansen Creek, King Co., Washington

Other minerals that commonly are associated with limestones include axinite, $Ca_2(Mg,Fe,Mn)Al_2BO(OH)(Si_2O_7)_2$, as sharply bladed crystals in red and purple, and epidote, $Ca_2(Al,Fe)_3Si_3O_{12}(OH)$, as rich green prisms often thoroughly intergrown. Titanite, CaTiOSiO₄, will form crystals in cream to orange that contrast well with the diopside or epidote in which they are embedded. Subsequent decalcification by ground water can generate the titanium oxide minerals anatase and brookite.

Not all sediments are rich in carbonates, but most have a significate silica component. Ones which feature magnesium and aluminum in addition to the silicon can recrystallize in mica schists. The main mineral here might, for instance, be muscovite, $KAl_3Si_3O_{10}(OH)_2$. Muscovite schist is a glittery silver matrix that makes a popular decorative stone that can easily be split and shaped, so there are numerous quarries devoted to extracting it. The size of the individual crystals can vary from millimeter to centimeter size. Because there may be little calcium present, the garnets that form are often pyrope, $Mg_3Al_2Si_3O_4$, almandine, $Fe_3Al_2Si_3O_4$, or spessartine, $Mn_3Al_2Si_3O_4$. It is also possible that the original



Fig. 6. Axinite New Melones Reservoir, Calaveras Co., California

Fig. 7. Glaucophane in clinozoisite Valley Ford, Sonoma Co., California



Lawsonite both in mica schist Reed Station, Tiberon, Marin Co., California

sediment contained considerable chromium; chrome rich muscovite schist is called fuchsite, is green in color, and the garnets that form therein may be uvarovite, $Ca_3Cr_2Si_3O_4$. Garnets in mica schists often have rather rough surfaces because of bits of the mica included. Biotite schist tends to be a darker, smokey color.

Sediments rich in silica can produce a variety of other types of schist. Actinolite, $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$, forms a green-colored schist where the crystallites are acicular. Chlorite schist, $(Mg,Fe,Al)_6(Si,Al)_4O_{10}(OH)_8$, is also green, often darker, and tends to have a finer granular texture. Garnets commonly occur in each of them.

Several very interesting minerals are to be found in the metamorphic rocks of California. The type locality of the mineral lawsonite, $CaAl_2Si_2O_7(OH)_2H_2O$, is a schist on the Tiberon Peninsula into San Francisco Bay that features both muscovite and actinolite schist. Lawsonite is common in metamorphics throughout the Coast Range mountains of California, often associated with glaucophane schist. Lawsonite forms equant blocky orthorhombic crystals that range from white to light blue.



Fig. 9. Stilpnomelane

Fig. 8. Almandine

Howieite Laytonville Quarry, Mendocino Co., California

Glaucophane, $Na_2(Mg_3Al_2)Si_8O_{22}(OH)_2$, is a dark blue amphibole that grows in long fibers. Occasionally the individual fibers are discernable, but more commonly as a schist they are matted together in such a way as to make a rock that is tough and very difficult to break. I spent many hours as a teen whaling away on boulders of the stuff.

The Laytonville Quarry in Mendocino County, featuring a variety of iron rich schists, is the type locality of several minerals. Deerite, $(Fe,Mn)_6(Fe,Al)_3Si_6O_{20}(OH)_5$ and howieite, $Na_2(Fe,Mg,Al)_{12}(Si_6O_{17})_2(O,OH)_{10}$, are black acicular minerals, while zussmanite, $K(Fe,Mg,Mn)_{13}(Si,Al)_{18}O_{42}(OH)_{14}$, is green and micaceous. Other minerals include glaucophane, lawsonite and stilpnomelane, $K(Fe,Mg)_8(Si,Al)_{12}(O,OH)_{36}$ ²H₂O.

A particularly interesting area is a region in San Benito Co. along the very crest of the coast range in the vicinity of Santa Rita Peak that features a whole host of beautiful minerals in a variety of sites. The andradite garnets range in color from yellow (variety topazolite) to deep black (variety melanite). There is diopside, vesuvianite, and perovskite, $CaTiO_3$. But the most spectacular and famous are the minerals occurring in a natrolite vein cutting across glaucophane schist at what is currently called the California State Gem Mine. The natrolite is solid rather than crystalline, indicating that it was in a molten state and served as a solvent for the other minerals, which grew on the walls of the vein, often to unusually large size. Black crystals of neptunite, $KNa_2Li(Fe,Mn)_2Ti_2Si_8O_{24}$, are often several centimeters long, and the benitoite, $BaTiSi_3O_9$, the state gem of California, are up to a centimeter in diameter. This is also the type locality of several members of the Joaquinite group, $Ba_2Na(Ce,La)_2Fe(Ti,Nb)_2Si_8O_{26}(OH,F)\cdotH_2O$. Since all of these minerals crystallize on the



Fig. 10. Benitoite and neptunite in natrolite (specimen 12 cm across) California State Gem Mine, San Benito Co., California



Fig. 11. Benitoite

Joaquinite California State Gem Mine, San Benito Co., California

glaucophane walls of the vein, it is necessary to etch them out of the natrolite. Etching natrolite is not as quick and easy as etching calcite, but it can be accomplished by treating with dilute hydrochloric acid. Since the process is slow and requires repetition, it is possible to stop before all of the natrolite is gone. The white background is aesthetically more pleasing than the rough, gray-green of the schist.

Jonesite, $Ba_4(K,Na)_2Ti_4Al_2(Si_3O_9)_2(SiO_4)_4O_2GH_2O$, is an even rarer mineral occurring with neptunite and serandite, $NaMn_2Si_3O_8(OH)$, in parts of the vein where there is no benitoite. It forms colorless picket-shaped blades. Another site in the same immediate area has featured some of the finest fresnoite, $Ba_2TiOSi_2O_7$, ever found.

Fresnoite was actually first reported from another contact metamorphic area just east of the city of Fresno. The drainages around Big Creek and Rush Creek have yielded a whole host of new minerals. This is an area of abundant barium, and the primary host mineral seems to be sanbornite, $BaSi_2O_5$, in colorless, clear sheets. Numerous other rare barium minerals are embedded within this matrix. Unfortunately, there is no simple chemical treatment to expose them safely, so they are seen in place.



Fig. 12. Jonesite and serandite California State Gem Mine

Fig. 13. Fresnoite in sanbornite Big Creek, Fresno Co., Calif.



Fig. 14. Sanbornite

Titantaramellite Esquire #1 claim, Rush Creek, Fresno Co., California

Since most of the unusual_minerals are silicates and many are small and light in color, they often do not photograph well. Examples are kampfite, $Ba_{12}(Si_{11}Al_5)O_{31}(CO_3)_8Cl_5$, krauskopfite, $BaSi_2O_5$ '3H₂O, and bigcreekite, $BaSi_2O_5$ '4H₂O. A few, such as bazirite, $BaZrSi_3O_8$, and walstromite, $BaCa_2Si_3O_9$, can be located by their fluorescence. Devitoite, $Ba_6Fe_9(Si_4O_{12})_2(PO_4)_2(CO_3)O_2(OH)_4$, titantaramellite, $Ba_4(Ti,Fe,Mg)_4(B_2Si_8O_{27})O_2Cl_{0-1}$, verplankite, $Ba4Mn_2Si_4O_{12}(OH,H_2O)_3Cl_3$, muirite, $Ba_{10}Ca_2MnTiSi_{10}O_{30}(OH,Cl,F)_{10}$, ferroericssonite, $BaFe_3(Si_2O_7)_2O(OH)$, and traskite, $Ba_{21}Ca(Fe,Mn,Ti)_4(Ti,Fe,Mg)_{12}(Si_{12}O_{36})(Si_2O_7)_6(O,OH)_{30}Cl_6$ '14H₂O, are all dark minerals that are easier to discern, as are the colored minerals such as the red Gillespite, $BaFeSi_4O_{10}$, the bright yellow fresnoite, and dark blue cerchiaraite-(Al), $Ba_4Al_4(Si_4O_{12})O_2(Si_2O_3)(OH)_8Cl_2$. Macdonaldite, $BaCa_4Si_{16}O_{36}(OH)_2$ '10H₂O, forms radiating needles that resemble some zeolites. This is a wonderfully complex region of metamorphisism.



Fig. 15. Gillespite Esquire #8 claim, Big Creek, Fresno Co., California

Fig. 16. Cerchiaraite-(Al) in Kampfite Esquire #1 claim, Rush Creek, Fresno Co., California





Fig. 17. Verplankite Esquire #7 claim, Big Creek Fresno Co., California

Fig. 18. Macdonaldite Esquire #1 claim, Rush Creek, Fresno Co., California

One of the most unusual quarries I visited while in New Zealand was at Arrow Junction near Queensland in the South Island. It featured a schist composed of granular piemontite, $Ca_2Al_2Mn(Si_2O_7)(SiO_4)O(OH)$, pinkish violet in color and very shiny. This was cut by numerous cracks that were filled with milky white quartz in which are regions of fibrous yellow ardennite-(As), $Mn_4Al_4(AlMg)(AsO_4)(SiO_4)_2(Si_3O_{10})(OH)_6$. The stone was easily broken into sheets and had been extracted for decorative purposes.

I hope these examples will convey to you the beauty and range of minerals associated with metamorphism. I have included the chemical formulas with the minerals mentioned to try to get across the complexity and variety of what can be formed. The original sediments are a mixing pot of elements provided by erosion, and the process of melting and recrystallization brings minor concentrations together to form an amazing array of very interesting mineralogy.



Fig. 19. Ardennite-(As) in Quartz in Piemontite Schist Arrow Junction, Central Otago, New Zealand

Etching and Mounting Ferrierite

Don Howard

Ferrierite is a delicate little zeolite that can make attractive micromount specimens. It tends to form on walls of cavities and cracks as small hemispheres formed of blades radiating out from the center of the contact. If the hemispheres remain uncovered, they can be easily mounted in boxes to protect them.

Often, however, the clusters of ferrierite are subsequently covered by other minerals that fill the cracks. When the host rock erodes away, the seams can remain. What is then visible are the small whorls that represent the back side of the hemispheres (fig. 1). While these can be interesting, they lack the delicate beauty of the radiating crystals.

If the filling mineral is quartz, nothing much can be done. If the filling mineral is calcite, however, it can be etched away. Ferrierite is one of the high-silica zeolites, so it is not attacked by hydrochloric acid, and the removal of calcite can be done fairly rapidly.

If the original coating of material is thick, the crust holds together reasonably well after etching and can be mounted in much the same manner as the uncoated specimens. However, if the hemispheres were initially scattered on the crack face, what is left after etching is a host of tiny loose hemispheres and small clusters. Handling these millimeter-sized 'specimens' is not easy, especially since their surface is a mass of tiny blades. It is probably okay if you groove on challenges, but I thought that there had to be a better way.

So here is something I have tried. What if you could mount your specimen *before* doing the etch? That way, you would not risk crushing the tiny crystals by closing on them with your tweezers.



Fig. 1 The back side of ferrierite hemispheres as they appear on the surface of a calcite seam.



Fig. 2 One of the clusters, looking sideways into the side of the piece of calcite seam.

I have been using a hot glue gun recently to fasten specimens to the polyurethane foam inserts that I use in my specimen boxes. It holds very strongly to the specimens, so I thought that it might stick tightly enough not to let go during the etching process, which can take several hours. Would that be sufficiently easy to handle?

I decided that a little more backing was in order. I use ½" diameter plexiglass rod to make knobs for my little drawers, and there were a bunch of ends too short to use for knobs, so I selected one about 3 mm long and smoothed the two faces. I covered the back of a small chunk of the calcite seam with the hot glue and pressed the little disk of plastic rod into the glue. Once it had cooled, I had the piece you see in fig. 3.

Next, the whole thing went into a beaker containing diluted HCl. Bubbles immediately began to rise. Now I noticed something odd: the sample insisted on remaining down with the plastic disk on top. This is because the specific gravity of the calcite is 2.71, while that of the plastic is only 1.19. The calcite is much better at sinking! In fact, the density of the plastic is so low that, once the calcite has finished dissolving and has become calcium chloride in the solution, the density of the solution is greater than 1.19 and the plastic disk floats. However, it sinks nicely in the pure water rinse that follows.

Once washed and dried, the sample appears as in fig. 5. The slice of plastic rod proved to be a very convenient 'handle' to do the transferring and later mounting. The little clusters of crystals stay stuck tightly to the glue layer, which provides a good background for viewing and photography.

Materials for doing all this are inexpensive and readily available. The glue gun and sticks of glue came from a craft store. The HCl can be found at a paint or hardware store, where under the name *Muratic Acid* it is used to clean concrete. The rod came from a plastics store.



Fig. 3 A small piece of a calcite seam with a piece of plastic rod hot-glued to it.



Fig. 4 Into the etch, with the denser calcite on the bottom.



Fig. 5 The finished specimen, washed and dried and ready to be boxed.



Here are two pictures taken from the completed mount. The bladed hemispheres are undamaged. In fact, the etching process disclosed the presence of another mineral, heulandite, visible in the lower photograph as the honey-brown blocks on the upper right. The white powdery stuff seems to be a remnant of the wall of rock that had eroded away. All of the pictures shown are of material from the North side of Raymond Peak, Alpine Co., California.



Crumbling Foundations

By Al Pribula (Reprinted from The Conglomerate, September, 2020, Newsletter of the Baltimore Mineral Society)

A little knowledge of minerals and mineral chemistry can go a long way. When the foundations of a large number of houses in parts of Connecticut and Massachusetts began to crack and crumble, homeowners and state officials began to wonder why. A failing foundation is an obvious problem for a homeowner, since it has a very distinct negative impact on the resale value of a house, and lifting a house and replacing the foundation is a pretty expensive process. Because of this, many homeowners were defaulting on their mortgages and abandoning their houses.

What does this have to do with minerals? It has been determined that the primary cause of this problem is <u>pyrrhotite</u>. Huh? What does pyrrhotite have to do with house foundations? Well, it was discovered that the crushed stone (aggregate) used in the preparation of the concrete used to make these foundations contained a relatively high percentage of pyrrhotite. So? What does that have to do with crumbling foundations?

Well, it's because pyrrhotite (chemical formula $Fe_{1-x}S$, meaning that there is slightly less than one iron for every sulfur on average, but I'll use the chemical formula FeS to represent it this to keep it a bit simpler) reacts with water (H₂O) and elemental oxygen (O₂) from the air to form sulfuric acid (H₂SO₄) and an iron-containing product (it could be a number of possible products, but I'll use the chemical formula for limonite (FeO(OH) to represent this):

$$4 \text{ FeS} + 6 \text{ H}_2\text{O} + 9 \text{ O}_2 \rightarrow 4 \text{ FeO}(\text{OH}) + 4 \text{ H}_2\text{SO}_4$$

If the rock is at least partially limestone (which is primarily calcite (CaCO₃)), the sulfuric acid can then react to form secondary minerals such as gypsum (CaSO₄•2H₂O):

 $CaCO_3 + H_2SO_4 + H_2O \rightarrow CaSO_4 \cdot 2H_2O + CO_2$

This will obviously degrade the aggregate, weakening the concrete. But, even worse than that, the products of this set of chemical reactions have a larger volume than the starting materials, causing the concrete to expand and crack, weakening the concrete even further and causing it to crumble. The related iron sulfide minerals pyrite and marcasite (chemical formula for both is FeS₂) undergo a similar set of reactions to produce the same products and the same resulting problem. Pyrite is much more common than pyrrhotite, but it reacts much more slowly, so it is less of a problem. Marcasite reacts even faster than does pyrrhotite, but is much less common than pyrrhotite and is more commonly found in sedimentary rock, which is not frequently used as aggregate in concrete.

How did the pyrrhotite get into these rocks in the first place? Iron is the fourth-most abundant element in the earth's crust (oxygen, silicon, and aluminum are the most common



three), so iron minerals are fairly abundant in many rocks. Sulfur, however, is much lower in abundance (less than 1/100 the concentration of iron), so it is what a chemist would call the "limiting reactant"— that is, it limits the amount of the sulfide minerals which can form, rather than metallic elements like iron, copper, zinc, or lead. When metal ores are deposited (probably from processes similar to the "black smoker" formations found near tectonic plate boundaries), they very often are in the form of sulfides (such as galena, sphalerite, or chalcopyrite). When these weather, the sulfur is released and can be mobilized to form other minerals. Also, sulfur can be introduced into rocks by bacterial action in sediments which contain little or no oxygen. This is especially true in sediments in marine and estuarine locations. Given enough time, these sediments can form sedimentary rock deposits. In sedimentary rocks, pyrite and marcasite are the predominant iron sulfide minerals.

As these sedimentary rocks get buried deeper and deeper under younger sediments, heat and pressure build up, causing the rock to metamorphose. During this metamorphosis, sulfur is driven out of the sediment, causing the marcasite and pyrite to alter into pyrrhotite. Metamorphosis of primary sulfide ore deposits formed from "black smokers" produces pyrrhotite by a similar process.

As a result of all of this, the United States Geological Survey (USGS) undertook a study to determine the localities across the US most likely to have high concentrations of pyrrhotite in the rock strata. They used their own Mineral Resources Data Base, a compilation of state geologic maps, and the Mindat database to produce a map of the US where pyrrhotite was likely to be found. The distribution of these rocks was not uniform across the country. In the East, the rocks underlying the core of the Appalachian Mountains formed a belt of high pyrrhotite concentration, while the central part of the country had relatively little, since the rocks in that part of the country are predominantly sedimentary. In the West, there were pockets of these deposits, but these did not form a significant belt of deposits because of the very complex geology of that region.

Because of this, you would think that a standard would have been put forward specifying the maximum sulfur or pyrrhotite content of aggregate for concrete, and you'd be partially correct. The European standard is that the sulfur content of the rock must be less than 0.1% sulfur by weight if pyrrhotite occurs in the rock, and the Canadian standard is essentially that it should be less than 0.15% sulfur by weight (but higher concentrations, up to 1%, are allowable if the material passes certain other tests). However, while ASTM International (formerly the American Society for Testing and Materials, the standards group for the US) acknowledges that iron sulfide minerals in the aggregate cause brown staining and volume increase in concrete, and thus can cause the problem described above, no standard for sulfur or pyrrhotite content has been set by them for concrete aggregate used in the US.

Most of the above information was taken from USGS fact sheet 2020-3017 (March 2020), accessible online at https://doi.org/10.3133/fs20203017.