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The Anecdote of Liuite

—In View of the Progress of Modern Technology, There Might Be No More New Minerals to Be Found on the Earth after another Half a Century

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Abstract

Liuite ($FeTiO_3$ with an orthorhombic perovskite structure) is a new mineral approved by the Commission on New Minerals, Nomenclature and Classification (CNMNC) of the International Mineralogical Association (IMA) in November 2018. It was named after my family name, Liu, because I am the first person who synthesized/identified this new material in my laboratory in 1975 at the Research School of Earth Sciences, Australian National University. Since 1991, however, liuite has been proposed or suggested to name for other minerals by various Earth scientists from various countries. The scenario of the intriguing story is presented here.

Keywords

Liuite, Lingunite, Earth Mantle, Most Abundant Mineral

1. Introduction

Mineralogy is one of the oldest branches of science. Yet there were no unique and strict rules how a mineral was named until the IMA was founded in 1958. The IMA is now consisted of 38 national mineralogical societies or groups and is affiliated to the International Union of Geological Science (IUGS). The CNMNC of IMA is the organization that accepts the proposals of a new mineral and approves, after strict examinations, the name of a new mineral. The CNMNC was, however, formed by a merger between the Commission on New Minerals and Mineral Names (CNMMN) and the Commission on Classification of Minerals (CCM) in July 2006.

There are many thousands of minerals (5000 - 6000) known to exist on the Earth in the pre-IMA era; some with a mineral name(s) and some not. It is rather common that a mineral is named after the place where it was found or named according to its major chemical composition. Inevitably, the same mineral may have many names because it is likely to be found in different places and under different cultures, or the same name may apply to a few different minerals or even rocks. Post-WWII, however, there is a tendency to name a new mineral after a person's name.

The CNMNC adopted a criterion that only the first person(s) who finds a new mineral in nature can propose and apply for a new mineral name and that if a person's name is to be used for a new mineral, the person(s) who first found the new mineral in nature must be excluded. In addition, it must be accepted by a person whose name is used for the new mineral if the person is alive.

Among minerals, there is a special group called high-pressure minerals. They are thermodynamically stable under high pressures (e.g., more than some tens of kilobar) with or without high temperatures. Yet, they are able to exist metastably at the ambient conditions on the Earth. The most noticeable examples of this group of minerals are diamond and jadeite.

In the early 20th Century, the Harvard pioneer, P. W. Bridgman conducted most extensive high-pressure research on various elements, alloys and compounds and was the first American Nobel laureate in physics since WWII in 1946. T. Hall successfully synthesized diamond at high pressures and high temperatures in 1954. I worked at Hall's high pressure laboratory at the Department of Chemistry, Brigham Young University, Provo, Utah for the whole summer in 1971. Jadeite was first experimentally demonstrated to be a high-pressure mineral at a Harvard laboratory (Birch & LeComte, 1960).

2. Exploration to the Unknowns

In addition to synthesizing the already known high-pressure mineral like diamond, the high-pressure research also extended to explore new materials which were not known to humans at the time. In 1952, the famous Harvard geophysicist F. Birch predicted that quartz (SiO_2), one of the most common minerals on the Earth's surface, may adopt a rutile-type crystalline structure at high pressures and temperatures in the Earth's lower mantle (Birch, 1952). Utilizing SiO_2 as the starting material, L. Coes synthesized a high-pressure material in 1953. The new material, however, does not have a rutile-type structure. Instead, it possesses a unique crystal structure that is not known to any other existing crystalline materials (Coes Jr., 1953). A new mineral name, coesite, after the last name of its synthesizer, was assigned to the new material in the next year even though coesite was not found in nature at the time (Sosman, 1954). The detailed crystalline structure of coesite was later determined (Ramsdell, 1955; Zoltai & Buerger, 1959) and the nature occurrence of coesite was found at Meteor Crater, Arizona, USA (Chao et al., 1960).

Birch's prediction of a rutile-type SiO_2 was synthesized at still higher pressures at the Institute of High-Pressure Physics in Moscow (Stishov & Popova, 1961). The nature occurrence of a rutile-type SiO_2 was found at Meteor Crater, Arizona, USA and was named as stishovite (Chao et al., 1962).

It is well known that conventional SiO_2 polymorphs and all silicate minerals that exist on the Earth's surface possess the SiO_4^{4+} tetrahedral configuration. Stishovite is the first known compound to contain silicon in six-fold coordination.

3. Encyclopedia Britannica

In this connection, we may quote an article from the *Encyclopedia Britannic*a to start our story of liuite. After a lengthy discussion of human's motivation, history, activities and detailed experimental techniques in the field of high-pressure research, the article was concluded by applications achieved in this field. It listed only two achievements in the application: Diamond-making and Earth science.

Diamond-making implies the general new materials made under high pressure and/or high temperature. Of special significance to Earth science were the high-pressure syntheses of two new forms of silicates. The synthesis of stishovite elucidated earlier is the first significant event to Earth science according to the *Britannic*a article. Then, "*In* 1974 *a second high-pressure discovery revolutionized geologists' understanding of deep-earth mineralogy when Lin-gun Liu of the Australian National University used a diamond-anvil cell to synthesize silicate perovskite*, *a dense form of the common mineral enstatite*, $MgSiO_3$ (Liu, 1974, 1975a). *Subsequent studies by Liu revealed that many of the minerals believed to constitute the deep interior of the Earth transform to the perovskite structure at lower mantle conditions—an observation that led him to propose that silicate perovskite is the Earth's most abundant mineral* (Liu, 1982), *perhaps accounting for more than half of the planet's volume.*" (The italics are from Britannica.)

It is obvious, from what is stated in *Britannica*, that silicate perovskite is an extremely important constituent of the Earth and the other planets as well. In other words, silicate perovskite is likely to be the most abundant mineral of which the Earth is made up.

4. Liusite vs Liuite

Because of the importance of silicate perovskite to the Earth, as a Chinese Earth scientist, it is essential to introduce this new material to the Chinese community. In order to translate what silicate perovskite really stands for in Chinese, E. Huang at the Institute of Earth Sciences, Academia Sinica in Taipei found that there is really no easy way out except to create a new mineral name for silicate perovskite. On the basis that all the high-pressure minerals were previously named after the last name of a person who first synthesized/identified that new material (e.g., coesite, stishovite, ...), Huang suggested to name silicate perovskite as liuite. However, direct translation of liuite into Chinese (劉石) becomes extremely confusion because there must be thousands of Chinese males that have the same name. After a thorough discussion, Huang decided to use liusite (Liu's rock), instead of liuite, to name (Mg, Fe)SiO_3-perovskite and published a short Chinese note, stating his recommendations, in *Science Monthly* (Huang, 1991). The direct translation of liusite into Chinese (劉氏石) becomes much clearer and meaningful. Of course, liusite was not endorsed by the IMA simply because it was not yet found in nature at the time.

5. Akimotoite vs Liuite

In July 1997, American scientists Sharp et al. published a paper in the renowned journal *Science* which describes their discovery of an ilmenite-type (Mg, Fe)SiO_3 new mineral in a shocked L chondrite (Sharp et al., 1997). One month later in the same journal, two Japanese scientists also published a paper describing their discovery of an ilmenite-type (Mg, Fe)SiO_3 new mineral in the Tenham meteorite (Tomioka & Fujino, 1997).

In September 1997, Tom Sharp wrote me a letter stating that he was going to apply to the CNMMN to name the ilmenite-type (Mg, Fe)SiO_3 new mineral as liuite in honour of my first synthesis/identification of $MgSiO_3$-ilmenite (Liu, 1976, 1977). I had accepted Tom's invitation. As a matter of fact, however, in my 1976 paper I had pointed out that a hexagonal $MgSiO_3$ synthesized at 500 kbar (Kawai et al., 1974) might be in reality the same $MgSiO_3$-ilmenite that I synthesized in 1976, but I had first identified the structure of $MgSiO_3$-ilmenite and my synthesis was at a much lower pressure of 200 kbar.

Before I heard any news concerning Tom's application for a mineral name of liuite for ilmenite-type (Mg, Fe)SiO_3, this new mineral had been named as akimotoite after the Tokyo University geophysicist S. Akimoto by the IMA in late 1997. It was obvious that it had to be due to the result of a motion by Tomioka and Fujino to the IMA for the new mineral name akimotoite. I have never asked Tom about the story behind his proposal to name this new mineral as liuite, and Tom has never told me the story either. I can understand if the ilmenite-type (Mg, Fe)SiO_3 were to be named kawaiite or after any of the other co-authors in their 1974 paper. S. Akimoto is a famous high-pressure researcher, but he definitely had nothing to do with $MgSiO_3$-ilmenite.

After reading an early version of the present article, N. Tomioka wrote me a letter in December 2021. He pointed out that the proposal to name $MgSiO_3$-ilmenite as akimotoite was recommended by the 1997 US-Japan High-Pressure Geophysics Conference and approved by the IMA in the same year. This is probably why Tom Sharp has never told me the story.

Towards the end of the 20th Century, there was a tendency in the Earth Science community to name a new mineral after a person who did not have much to do with the new mineral except that the named person was famous and/or influential. Quite often the named person was the head of an organization associated with the person who first found the mineral in nature.

6. Lingunite vs Liuite

In 2000, Gillet et al. published a paper in *Science*, which claimed to be the first discovery of a hollandite-type (Na,Ca)$AlSi_3O_8$ in the shocked Sixiangkou meteorite (Gillet et al., 2000). In the same year, Tomioka and Fujino also published a paper describes their discovery of a hollandite-type (Na, Ca)$AlSi_3O_8$ new mineral in the Tenham meteorite. After 2000, the occurrence of the same new mineral in various meteorites has been reported in various literature. In reality, however, a hollandite-type (Na, Ca)$AlSi_3O_8$ was first found in a meteorite by the Japanese scientist, Mori, in 1990. Unfortunately, Mori's discovery was published in Japanese in a short abstract at the Annual Meeting of the Japanese Mineralogical Association which was not widely read, including even by Japanese scientists.

In 2003 the German scientist El Gorsey, who is the last author of the paper published by Gillet et al., wrote me a letter stating that he would urge the first author Gillet to apply to the IMA for a new mineral name in honour of my first synthesis/identification of $NaAlSi_3O_8$-hollandite (Liu, 1978). I accepted his kind invitation. Nothing happened even after more than one year was elapsed, however.

I met N. Tomioka (not for the first time) in Kobe in June-July 2004 during the IMA General Meeting, which is held every 3 to 4 years. Without knowing El Gorsey's proposal, Tomioka proposed to me in person to apply to the IMA for a new mineral liuite in honour of my work. I declined Tomioka's kind offer with thanks because I had already accepted El Gorsey's proposal. If I were to accept Tomioka's invitation instead, there would have been no lingunite (see below).

Since, after more than one year, Gillet did not take any action about the application for a new mineral, El Gorsey decided to do it himself. In one of our correspondences in August-September 2004, El Gorsey stated that he would not follow the tradition to adopt my last name, and hence propose liuite for the new mineral because there are too many Lius in China. Instead, he would propose to use my given name Lin-gun, to name the new mineral as lingunite, if it is acceptable to me. I accepted his proposal and (Na, Ca)$AlSi_3O_8$-hollandite was named lingunite by the IMA in late 2004.

7. Bridgmanite vs Liuite

As mentioned earlier, silicate perovskites are the most important minerals within the Earth due to their abundance in the Earth's lower mantle. I synthesized/identified all sorts of silicate perovskite at the Australian National University during 1974-76 before anyone else ever laid their hands on these new high-pressure materials. The discoveries of natural silicate perovskites were first claimed by Sharp et al. and Tomioka and Fujino in their 1997 papers in the same meteorites as described earlier in their discoveries of natural (Mg, Fe)SiO_3-ilmenite (or now akimotoite). Unfortunately, the samples of natural silicate perovskite in their studies were damaged after their studies.

In 2014, however, scientists at Caltech employed the same meteorite (Tenham) previously used by Tomioka and Fujino and confirmed the existence of a natural (Mg, Fe)SiO_3-perovskite (Tschauner et al., 2014). When these authors at Caltech decided to apply to the IMA for a new mineral name for (Mg, Fe)SiO_3-

perovskite, the use of liuite was an option for the obvious reasons that these materials were first synthesized and first proposed to be the Earth's most abundant mineral by Liu in 1974 and 1982, respectively, just as what has been said in the Encyclopedia Britannica. The suggestion to name the new mineral as liuite, however, was dismissed by some American colleagues simply because lingunite has already been named after Lin-gun Liu. Instead, these colleagues strongly proposed naming the new mineral as bridgmanite after P. W. Bridgman, the Harvard pioneer in high-pressure research, as described earlier. The name of bridgmanite was thus approved by the IMA for (Mg, Fe)SiO_3-perovskite in 2014.

I have always wondered if P. W. Bridgman would not feel honoured by the use of his name for the new mineral. One may even be curious to question why no contemporary American scientists contested against this mineral name? To my understanding, there were quite a few such candidates. Unfortunately, it appears that none of them would like to see any other colleagues' pirate this mineral name either. In addition, just in case, if one of them would have won the competition, one would still have to face the criticisms from the contemporary scientific community worldwide. A dead man would have said nothing.

8. Liuite

In April 2017, C. Ma from Caltech told me that he had identified a perovskite-type $FeTiO_3$ in a shergottite meteorite and that he would like to invite me to accept his proposal to name this new mineral as liuite because I had first synthesized/identified a perovskite-type (Fe, Mg)TiO_3 (Liu, 1975b). The new mineral name of liuite was then approved by the IMA in Nov. 2018 (Ma et al., 2021), regardless of the fact that lingunite has already been named after my given name. The latter event demonstrates that there is really nothing wrong with the suggestion to use liuite (although I would have preferred liusite or 劉氏石 instead) to name the (Mg, Fe)SiO_3-perovskite in 2014.

Since C. Ma commenced working in the electronic microscope laboratory at Caltech, his group has found some 40 new high-pressure minerals in various meteorites. The discovery of new minerals at Caltech's laboratory provides some prominent figures in the American high-pressure research field with the opportunity to acquire new mineral names, even though these prominent figures have really made no contribution what-so-ever to the new minerals. Ever since the first high pressure mineral coesite named after L. Coes in 1954 (not endorsed by the IMA at the time), there was no high-pressure mineral named after an American scientist until the discoveries at Caltech's laboratory in the early 21st Century.

Because of the chemical composition of liuite, the equivalent Chinese name of liuite should be 劉鈦鐵礦 according to the Chinese mineralogical nomenclature.

Throughout my research career, I have made more than 50 new high-pressure materials. So far, five of them have been found in nature and approved by the

IMA as new minerals; akimotoite in 1997, lingunite in 2004, bridgmanite in 2014, liuite in 2017 and davemaoite in 2020. In either case, the total number of new materials I made or the number of new mineral names endorsed by the IMA is likely to be a record. It is one of the very rare examples, if not the first and/or only one, that both the last and given names of a person were endorsed by the IMA for new minerals.

I did not know and had no acquaintance with Tom Sharp, A. El Goresy and Chi Ma until they wrote me an invitation to accept their proposals to name the new minerals.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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