
CMS News

A Publication of The Clay Minerals Society

August 1992

Philip Low elected to National Academy of Sciences

Philip F. Low, professor of soil chemistry in the agronomy department of Purdue University, and the CMS 1992 Distinguished Member, has been elected to the National Academy of Sciences.

Low was one of 59 new members voted in during the academy's annual meeting on April 28. Election to membership in the academy is considered one of the highest honors that can be accorded an American scientist or engineer. The academy serves as a "hall of fame" of science. There are 1,651 active academy members.

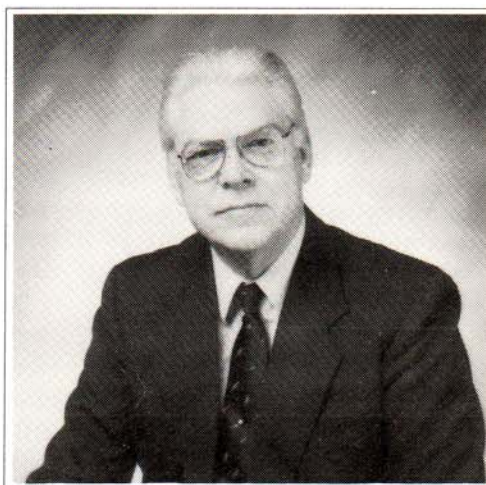
"Philip Low is a statesman and an educator as well as a scientist," says William W. McFee, head of Purdue's Department of Agronomy. "He has a

tremendous depth and a beautiful ability to talk to any audience. He is a great communicator."

Low was recognized for nearly 40 years of research on the physical properties of water in contact with clay particles. According to his nomination, "Dr. Low has revolutionized our understanding of the nature and properties of interparticle water in clay systems."

The interaction of clay and water affects the structure, permeability and erodability of agricultural soils, the stabil-

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Philip F. Low, 1992 CMS Distinguished Member, and recently elected member of the National Academy of Sciences.

Courtesy P. F. Low

Joint symposium explores historical interactions

The CMS and the SSSA's Council on the History of Soil Science, Division S-5 (Pedology) and Division S-9 (Mineralogy) are co-sponsoring a symposium at their joint meetings in Minneapolis. The symposium title is "Historical Interactions in Clay Mineralogy and Soil Science." This symposium is planned to be a half-day session of invited and volunteered papers. We encourage those interested in aspects of the history of the clay mineral and soil sciences to par-

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SSSA and CMS plan November meeting in Minneapolis

The Clay Minerals Society will hold its 29th annual meeting with the Soil Science Society of America in Minneapolis, Minnesota. The regular CMS program will be fully integrated with those of Div. S-9 (Soil Mineralogy) and other SSSA/ASA divisions. A pre-meeting educational workshop, a Sunday field trip and several symposia are being planned.

The pre-meeting workshop will be held on Saturday, Oc-

tober 31, from 8:00 a.m. until 5:00 p.m. and will be organized by Dr. A. R. Mermut, University of Saskatchewan. The subject will be "Layer Charge Characteristics of Clay." A workshop notebook, refreshments, lunch, and

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Letters

Houston vindicated

Editor:

A statement was erroneously attributed to me by Dr. Dewey Moore in the February, 1992 edition of the *CMS News*. The statement was "it may have been better if Galveston hadn't raised its dockage fees, causing Houston to have been founded."

Firstly, I have never thought this and have certainly never said it.

Secondly, the statement is not quite correct. The City of Houston was not founded because Galveston increased its slip/dock charges. Houston already existed. The dredging of the 50 mile long Houston Ship Channel made an existing inland city into a port city. As I understand it, the businessmen who sponsored the channel did so to compete with Galveston and to eliminate the transportation charges from Houston to Galveston. The dockage fees in Galveston may have contributed to the decision.

I hope that Dr. Moore was joking when he said that the "Clay People" were "trapped" in a hotel in Houston. The Nassau Bay Hilton was chosen for the meeting headquarters because of its proximity to the hosts, NASA Johnson Space Center and the Lunar and Planetary Institute. The location of the Hilton is admittedly not conducive to walking. Given proper mobilization, though, Houston has many wonderful attributes that the meeting participants probably did not have time to see. To name a few, on any given weekend you can see live theatre at any of the dozens (yes, plural) of theatres around town; museums; the Astrodome; NASA; fine dining; the Azalea Trail—you can get an idea of how green Houston is merely by flying in to it in the daytime in the Spring or Summer; the Equestrian Center; water sports six months of the year; boating and fishing twelve months of the year; and four distinct major business areas inside the City Limits. I would appreciate it if you would make this correction. Thank you for your time.

Sincerely,
Lisa Tuck
Native Houstonian

Moore responds

Dear Ms. Tuck:

I have just learned of your letter of February 28, 1992. I apologize for any misunderstanding on my part. Although I was sure you had said this, and

obviously in a joking manner, I must have been mistaken. When I next visit Houston, I will have a car, and I had also better remember to take my tongue out of my cheek.

Sincerely,
D. M. Moore

People wishing to serve on a CMS committee should contact Dave Pevear at 716-965-4452.

Thanks...

To the following people who contributed to this issue:

S. W. Bailey
Jerry Bigham
Dave Bish
Joe Dixon
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Steve Guggenheim
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Dewey Moore
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Bob Newnham
Gay Lynn Olsen
Dave Pevear
Rich Pollastro
Jeff Post
Bob Reynolds
Steve Rice
Rustum Roy
Don Scafe
Lisa Tuck

Low, *continued from page 1*

ity of roadbeds and building foundations, and the production of oil wells.

Clay is composed of ultra-thin mineral layers stacked one above the other like the pages in a book. When the particles come in contact with water, the water penetrates between the layers and causes them to separate from each other.

When Low began his studies, it was commonly believed that the clay layers are forced apart by the osmotic pressure of the ions in the water between the layers. However, Low theorized that something else might be happening. He proposed that water molecules near the mineral layers are influenced by the surfaces of the layers, and that the water between the layers has different physical properties than ordinary water.

This proposal proved to be controversial because it challenged conventional ideas. In order to test his proposal, Low examined the properties of water in clay-water mixtures containing high concentrations of clay. He thought that these properties would differ from the corresponding properties of water not mixed with clay.

After many years of effort, he succeeded in proving that when water is near the surfaces of clay layers, it reacts differently, being less dense, more viscous and less compressible than ordinary water. From his research, Low theorizes that the water between clay layers forms a dynamic structure from which water molecules have difficulty escaping. As a result, more water enters the space between the layers than escapes, and the pressure build-up forces the layers apart.

Low's discoveries have far-reaching significance. Most of the water in the pores of the earth's crust is in close contact with the surfaces of clay and other minerals. The total volume of this water may approach the volume of all the water on the earth's surface, but it does not behave the

same as the water in oceans, lakes and rivers. This information is important to civil engineers, petroleum engineers, geologists, soil scientists and other earth scientists.

"Water-clay research applies to many different aspects of our lives," Low says.

There is more to Low's life than his research, however. He has made four trips to China to teach soil chemistry, and because of these trips, numerous graduate students and visiting scholars have come to Purdue. Low and his wife, Mayda, were among the first Westerners to teach courses in China after the normalization of diplomatic relations with that country. Mrs. Low taught English while in China.

Born in Carmangay, Alberta, Canada, Low obtained his bachelor's degree in soils from Brigham Young University, his master's in meteorology from the California Institute of Technology and his doctorate in soil chemistry from Iowa State University. He joined the Purdue faculty as an assistant professor in 1949 and has been a professor since 1955.

Low is the father of six children, including Phillip S. Low, a professor of Chemistry at Purdue. This June, Low and his wife, Mayda, will celebrate their 50th wedding anniversary. Low has been active in the Church of Jesus Christ of Latter Day Saints, serving for more than 14 years as president of the Indianapolis Stake of the church.

Although Low will officially retire from Purdue this June, he says that he will not soon stop working.

"It is a retirement in theory only," he says. "I'll continue to be active in my research and in the National Academy of Sciences, and I plan to finish a book and make at least one more trip to China."

Low has served as a fellow and past president of the Soil Science Society of America, and has received that society's research award and Bouyoucos Distinguished Career Award. His academic memberships

include fellowship in the American Society of Agronomy, and at the joint CMS/SSSA annual meeting in November, he will be awarded with Distinguished Membership in The Clay Minerals Society.

At Purdue, Low has received the Herbert Newby McCoy Award in Science and the annual research award given by the Purdue chapter of Sigma Xi research society. In addition to his career at Purdue, he has also taught at the University of Sydney (Australia) and Zhejiang Agricultural University in Hangzhou, China.

The National Academy of Sciences is a private organization of distinguished scientists who are dedicated to the advancement of science and its application for the public welfare. The academy was chartered by Congress in 1863 and acts as an official advisor to the federal government on matters of science and technology. Membership in the academy is by election only and is granted in recognition of major scientific achievements.

Archival contributions

Thanks to Bull Bailey, Dave Pevear, and Joe White for recently sending archival materials to the Society Office.

Directory changes

The following frequently used faxes need to be changed in the CMS membership directory: D.R. Pevear: 713-966-6115; J. R. Glasmann: 503-929-5674 (phone and fax).

**Answers to Clay Names Quiz
(page 31)**

- | | |
|------|------|
| 1. C | 3. D |
| 2. C | 4. C |

Interviews with the clay scientists

David L. Bish

David L. Bish is a staff mineralogist at Los Alamos National Laboratory. This interview took place in Houston, Texas, in October 1991, and was conducted by R. C. Reynolds, Jr.

CMS: You did your doctorate at Penn State, and you worked with George Brindley?

BISH: I did.

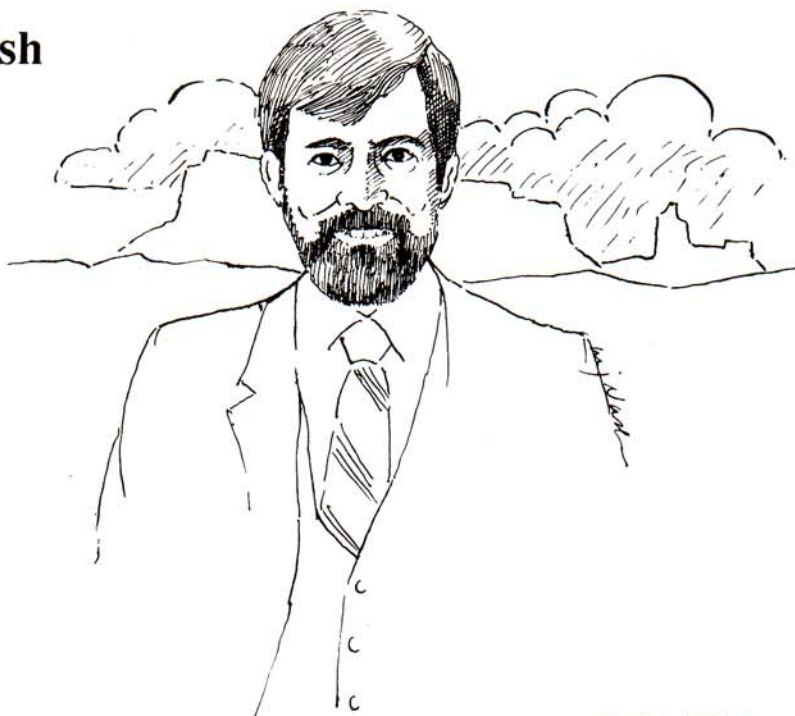
CMS: Tell me about Brindley.

BISH: Let me tell you how I ended up working with Brindley. I was an undergraduate at a little school in South Carolina by the name of Furman University. The first day of school, I met a senior who showed me an x-ray diffractometer. I had a sample of autunite, but I didn't have the slightest idea what it was. It looks like mica, only it's iridescent green and yellow; it's a uranium mineral. Someone had given it to me when I was in high school. I put it on the x-ray diffractometer, and we quickly identified it. I'd been at Furman for one week, and that was when I decided this x-ray stuff was for me.

When it came time to go to graduate school, I wrote to a couple of places. I applied to Harvard. Didn't get any money from Harvard, but I got into Penn State and a few other places with stipends. Then I got a letter from George Brindley, and I had been into clay mineralogy enough when I was a senior to know who he was.

CMS: What did you do at Furman in clay mineralogy?

BISH: Most of the clay mineral work came out of what I did at Woods Hole. After my junior year at Furman, I was a summer student fellow at Woods Hole for Fred Sayles, who had been interested in the process of dolomitization. I was interested in that too, and had written a little proposal to study it. He had seen it, and he asked me to work with him. I worked on that for part of the summer and got some experiments going. But at the same time, I started studying sediments from the Bauer Deep off the East Pa-



Drawing by M. J. Nash

cific Rise which contained some interesting smectites.

CMS: Did you ever find out what kind?

BISH: There are some nontronites, but the material I looked at wasn't nontronite. It looked as if it were just an iron-rich, dioctahedral smectite. So I spent hours and hours in the library reading about clay.

CMS: So that's what got you to

Brindley and Penn State?

BISH: That's what got me interested in clays. I'd read Brindley a lot, and then my senior year we looked at nickel-laterite deposits, so I applied to Penn State, and I applied to work with Bailey at Wisconsin. I got a nice letter from Bailey and from a couple other places. Then one day I got a letter from George Brindley saying he was working on nickel-laterite.

CMS: Oh, I remember his papers, a number of years ago.

BISH: He had retired, but he still worked in the lab every day, and he asked if I would like to come and work with him. Of course, I just about fell out of my chair, getting a letter from George Brindley. So that was a difficult decision, but I decided I would probably enjoy working with Dr. Brindley, not knowing anything about him. In fact, he was always a little bit of a slave-driver. I think he'd gotten spoiled by having a number of foreign students, who had come over as students to be nothing but students, twenty-four hours a day, seven days a week.

CMS: Hard work ethic.

BISH: Well, not that. Americans have that. But no going home for Thanksgiving to see Mom and Dad.

continued on next page

Bish, *continued*

CMS: I know what you mean.

BISH: So he said, "Well, I want you to come June 15th to graduate school, to start some research." And I said, "No, I want to go to field camp." It was a geology field camp. I'm a geologist *and* a mineralogist, and I wanted to do this. "Oh, all right, come July 15th then." I said, "No, August 1st." He just really wanted to get me in there. So I went to field camp and had a wonderful time. It put everything together for me as a geologist. Then around August 1, I went to grad school. So by the time classes started, I had about a month and a half of research under my belt: It was very enjoyable.

CMS: What did you work on with him?

BISH: I actually worked on some of the materials from North Carolina, trying to understand the nature of the disorder in these very poorly crystalline materials: kerolite, pimelite, deweylite.

CMS: So you did that for your doctorate?

BISH: I did that. I did a bunch of other things, too. Dr. Brindley was always supportive of any odd little thing I wanted to do.

CMS: He was like that. When I was having trouble getting my mixed-layer clay paper published, I sent it to him to review, and V. Vann was there as a visitor. I said, "I can't get this published. I'm a kid. What's wrong with it?" He and Vann read it over and said, "We thoroughly approve of it." That gave me the confidence to persevere and finally get it published. It was a renegade paper. So I think he would thoroughly approve of renegade ideas.

BISH: Yes, he did.

CMS: Let's look at your training. You didn't have matrix calculus at this point, or matrix algebra? You were like the rest of us in the clay society who live in a one-dimensional world?

BISH: Well, I had had a little bit of that in college, but most of what I got was in my crystallography classes at Penn State. Penn State was interesting. It seems like there are two end member types of grad schools. There's the type where you go and take two or three classes, and the rest is research. But at Penn State, you actually take a lot of classes, which is nice. The listing of classes just makes your mouth water. A whole course on geometrical crystallography; a whole course on crystal structure re-

finement.

CMS: Who taught that?

BISH: Bob Newnham taught that, together with Deane Smith. Bob Newnham was a wonderful teacher. When I first got there, there was an introductory crystal chemistry class that Bob Newnham taught. And then there was the famous crystal chemistry course that Rustum Roy taught, which was really crystal chemistry for material science. There were all kinds of classes like that. There was an X-ray diffraction class that Earl Ryba taught that was fantastic. We learned about reciprocal lattice, strain, pole figure measurements, and things like that. Then there was Will White, who taught a lot of courses in spectroscopy, which I really enjoyed.

CMS: So what did you do for your doctorate?

BISH: Well, it ended up being kind of an odd smattering of things. I studied the ten-angstrom nickeliferous materials, but I also studied a suite of materials called deweylites, which are very interesting magnesium end-member materials that precipitate at room temperature or below room temperature under ambient conditions, and in ultramafic rocks. They are very common and interesting because they are an infinite mixture of serpentine-like materials and talc-like materials, but very, very disordered. It

At Penn State, you actually take a lot of classes. The listing of classes just makes your mouth water.

was then when I first got into your paper on the effects of peak-breadth and variations of structure factor across broad peaks and how you can shift peaks.

CMS: There's a problem with that, you know. A lot of illites don't show it. Some do, but not all. It's one of the things we're worried about these days. If you fit the shapes of the higher order illite reflections to any model at all, you can fit them perfectly, but the 001 never works. The reason it doesn't work is that the structure factor is screaming up right across the 001, and the calculated pattern has really shifted to a lower 2-theta, unrealistically. Some real materials look like that, but most don't. So we think there's something on the surfaces of some illite crystals that change the structure factor. What this means is that the idea of a structure factor that's an average value for a bulk crystal doesn't take into account the surfaces of

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Bish, *continued*

illite. Pevear thinks you get kaolinite layers on the surface. And indeed, if you take NEWMOD and randomly substitute 5 % kaolinite layers, the problem goes away. Doesn't mean that's the answer, but it means something like that is going on. But anyway, you were talking about the paper on the non-Bragg character of peak positions as a function of particle size. But Brindley had a student who worked on that, too, didn't he? Maybe before your time. As a matter of fact, Mac Ross wrote one, too.

BISH: Yes, Ross wrote one about the same time. It was kind of odd. By the time I got there, Dr. Brindley had quit teaching, so I never took a course in clay mineralogy in

They're essentially an inverse clay. The layers are positively charged, and they have interlayer anions.

the classroom. I worked on these deweylite materials and the nickel-silicates, and also on the hydrotalcite materials, mixed hydroxides, really interesting. Tom Pinnavaia talked a little bit about it today.

CMS: Natural pillared clays?

BISH: Well, they're essentially an inverse clay. The layers are positively charged, and they have interlayer anions. Serendipity struck, as it has many times. I was working on some materials, and we presumed that they had carbonate interlayers. Not much was known about these clays, and I was doing some infrared spectroscopy to try to understand them—they were carbonated material. It looked like there was calcite in this stuff; so I put a little bit of acid on, HCl, and I x-rayed it. It was a little bit different, but for the most part it was the same. I took the infrared spectrum and there was no carbonate left. I said, "Wow! I've substituted chlorine for carbonate." And sure enough, when I said, "Let's try sulphuric acid," and put some sulphuric acid on, the basal spacing went from 7.7 to 8.4. Looked at the infrared spectrum, and there was a sulfate signature. I put on sulfate, nitrate, carbonate—it was fantastic. Move the anions all around just like cations in a smectite.

CMS: You were just changing the anions, then.

BISH: That's right. Really fantastic materials. We're still interested in those materials at Los Alamos as sorbents of anionic radionuclides. Anions are poorly sorbed

by most materials. The trouble with these materials is, as Tom pointed out today, they're relatively unstable.

Finally I talked to Deane Smith and said, "I want to do some crystal structure work before I leave Penn State." At one time I had taken a sample of the nickel-magnesium kerolite, and had put some in a hydrothermal bomb, cooked it up, and said, "Let's just coax it up a bit in crystallinity. Let's order it a little bit and see what happens." Well, this one leaked a little bit, or got too hot or something, I forget now; but I opened it up, and I had a mass of nickeliferous talc, and sprinkled within this nickeliferous talc were beautiful, euhedral, 200 micron crystals of nickel magnesium olivine. They were emerald green, beautiful. I said, "I want to do a single crystal study on the nickel magnesium olivine." So at Penn State I collected a set of data on our old Picker, and did the structure refinement with cards and everything. So I had all these weird things, they were a smattering of very interesting research topics, and oddly enough, they all had something to do with nickel silicates. So essentially I wrote my thesis on the crystal chemistry of nickel in silicate and hydroxide minerals.

CMS: You say nickeliferous talc, though. How much nickel was in the talc?

BISH: It was substituted at about 50 percent; so it was about 50/50 nickel/magnesium.

CMS: That's really very impressive. You know two or three percent nickel in talc isn't that uncommon in serpentine ultramafics, for example. Fifty percent is something else. Anyway, now you're ready to go to Harvard. And you're working with Charlie Burnham.

BISH: Yes. I think one of the reasons Charlie was interested in hiring me as a post doc was that I had worked with Brindley. It was obvious that Charlie appreciated the importance of clay minerals, and he wanted to learn more about them. I had occasion to do some work on the interlayer bonding studies that Ross Giese did on the micas and talc. I wanted to do chlorite. Ross gave me his programs, and I did a lot of neat things with chlorite. I think Bailey said one time that you actually have to have a negative charge on the 2:1 layer of chlorite for them to be stable and hold together. I thought that this material must get a lot of stability just from the hydrogen bonding. And I said, "Let's do this model and see what we can learn about charges on the layer versus hydrogen bonding versus fluorine substitution."

Judging by the results of this study, and this depends on how much you believe these kinds of models, it looked as though, in comparison with Ross's previous work, a neu-

continued on next page

Bish, *continued*

tral set of layers in chlorite, a two-to-one layer and an interlayer hydroxyl sheet, would have as much interlayer bonding as, say, mica. It really held together well with only hydrogen bonding.

CMS: No kidding! But you can't intercalate it, can you?

BISH: No.

CMS: So there's something else going on there besides hydrogen bonding, or it should intercalate. I mean, things like hydrazine and so forth should go in.

BISH: I wonder how much people have tried that.

CMS: I don't know. Wouldn't that be interesting? See if it can swallow those babies up. It's very difficult even to intercalate dickite.

BISH: I know. Cliff Johnson's trying it right now, and he can't get dickite to swell. He can't even get kaolinite to swell with DMSO. It's very slow. It's a slow reaction.

CMS: Wouldn't that be a way to determine the relative importance of hydrogen bonding vis-a-vis electrostatic bonding?

BISH: Yes. But that's the first thing I worked on, and that worked out very well. Ross Giese had been one of my idols.

CMS: I keep forgetting what a kid you are, because Ross is not my age, but he's getting there!

BISH: Charlie liked that line of research. He was very supportive of that, and he was very gung-ho on clays, as I mentioned, and on environmental concerns. He asked me if I'd like to teach a class in the winter term at Harvard on clay mineralogy.

CMS: That's very nice. The first and last course that Harvard ever had in clay mineralogy, I'm sure.

BISH: Yes, probably. I was under a research assistantship with Brindley the whole time I was at Penn State, so I never had to teach. Actually, I think that was a shortcoming in my education. Even though I didn't go into academics, I think teaching would have helped in my public speaking.



Dave Bish giving opening remarks at CMS Annual Meeting in Socorro, New Mexico in October 1987.

High Iron Photos

CMS: It might, but you don't seem to suffer from that.

BISH: Yes, but this is 15 years later! I'm sure that then it would have benefited me.

CMS: There isn't any doubt that if you really want to understand a subject, you have to teach it to a bunch of smart kids. The things that you don't know, they will ferret out just like instinctive weasels. They'll ask you the questions that you're the least prepared to answer. Once you discover that, you panic if you don't know all the answers. Teaching is a very good way to sharpen up. Now, were you at Harvard when the gang like Hazen and Veblen were there?

BISH: I got there right after they left.

CMS: That was a really prestidigitatory gang.

BISH: Yes, it was, a pretty amazing group of people. They were all with Charlie Burnham. That was right after the time Dave Veblen discovered biopyroboles.

CMS: They were Jim Thompson's invention, weren't they?

BISH: Yes, they were in his head before they found them.

CMS: That's what you call real science. When you say to yourself, "This ought to be," and go out and look for it and find it. Anyway, you taught your clay mineralogy course. How many people?

BISH: Probably ten or fifteen grad students. It was pretty good. Shortly after that, I started doing some other things, like looking at some real strange twinned micas, and decided I didn't like them.

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Bish, *continued*

CMS: I'd like to fight with you about that some time; I'm really worried about that. You know, if you calculate the diffraction patterns for disordered micas, and you take into account all the possible combinations and permutations of rotations, some of them turn out to be twins of each other. And that brings up the question, how do you tell a twin from a polytype? Do you know what I mean? Perhaps this isn't the time to explore it.

BISH: It was terrible. It was a lot of messing around in reciprocal space.

CMS: That does indeed excite the imagination, you've got to admit. Life is never dull, particularly in monoclinic reciprocal space. God help us in triclinic reciprocal space. I think what you have to do is accept a mathematical transformation, and then shut off your imagination in terms of any real world that you live in, and just think in terms of that. You can't relate it to your common experience.

BISH: When you're in mononclinic or triclinic, especially, you can't figure it out in real space.

CMS: You know, the British mathematician Turing, for whom the Turing machine is named, pointed out once that if you're going to do mathematics, you set up the problem, then you forget about the problem and manipulate the symbols according to legal mathematical principles. You don't ever worry about whether it's physically sensible to move this term into the denominator. You know it's legal! See what I mean? And at that point you must forget all about the physical meaning of what you're doing and manipulate the symbols like a chess game, according to rules that everyone accepts, and then you get the answer. But you are in trouble if you try to think of the physics all the time you're manipulating the symbols. And maybe reciprocal space is like that. Anyway, you had that at Penn State, too, so this wasn't new to you.

BISH: We didn't do a whole lot of powder diffraction at Harvard.

CMS: But you know it's come back now with Rietveld, which is one of your specialties. I mean, powder diffraction has been saved for the rigorous crystallographers because of Rietveld analysis.

BISH: I think another thing that's showing is that you can get a lot more information out of powder diffraction



Dave Bish and Jose Fripiat in Columbia, Missouri, 1990.

High Iron Photos

tion patterns than just saying there's quartz and calcite and dolomite in there.

CMS: I hope so. That's Ice Age technology.

BISH: There's so much information in a diffraction pattern. That's what the Rietveld method shows you. Gosh, you can calculate from first principles a diffraction pattern that matches your observed ones, if you measure your observed ones properly. So there's a lot of information in there. That's what I'm interested in investigating.

CMS: Let's go back to your chronology. You finished your postdoc at Harvard. Did you go straight to Los Alamos from there? How did you ever get a job at Los Alamos?

BISH: There was a fellow named Joe Smyth there, J. R. Smyth, a very good mineralogist, petrologist, crystallographer. Joe had a very nice diffraction laboratory at Los Alamos. He and his group put out an ad. They wanted someone who knew something about powder methods, someone who knew something about clays, because they wanted someone to look at the Yucca Mountain rocks and to look at the clays, someone who had some familiarity with single crystal methods. Wierd combination of stuff.

CMS: Just what you needed.

BISH: And I applied for that job, and visited... and it's a very nice area. I fell in love with it.

CMS: Let me ask you a question that's a little bit loaded. When I look back on our field, I think of the giants. I think of the British, like George Brown, and D.M.C. McEwan, and the French like Mering, and, of course, Brindley, and Bradley.

continued on next page

Bish, *continued*

These were all people who were essentially physicists or physicist-mathematician-crystallographers, and they built our field. Where are those people now? Do they exist? Is the rigor in our field gone with them? Are we becoming an empirical bunch who run diffraction patterns and fit them and look at them and say, "Well, I just know that if it's a 10-angstrom peak, it's illite, but I don't really know why it should be there." In other words, are we becoming an empirical field because we've lost the guidance of the solid theoreticians who really built this field in the first place? I look around, and I see people like you and Guggenheim and Giese who are crystallographers, and there's almost no one else in the Society who is. Bailey certainly is, but he is retired. Where are the Baileys of the next century? We run the risk of losing our fundamental hard science grounding in x-ray diffraction because we've lost the influence of people like that.

BISH: Well, Steve Guggenheim is one of the top.

CMS: I agree.

BISH: But there really is no one with that kind of physics background. Steve Guggenheim and I don't have that.

CMS: You're closer than most.

BISH: Several of us, like Jeff Post and Steve Guggenheim and I, often talk about the situation in mineralogy in the country today.

CMS: It's not just clay mineralogy, it's mineralogy.

BISH: Who's teaching our students in our universities mineralogy?

CMS: The petrologists in their arrogance think they can study rocks without knowing anything about minerals. The whole nature of mineralogy in academic institutions is really dying. Mineralogists are perceived as fuddy-duddies who putter around in dusty museums cluttered with cobwebs and gloat over pretty crystals. That's not the new mineralogy. The new mineralogy is very different. Somebody like Tom Pinnavaia understands the new mineralogy.

BISH: The new mineralogist today, though, is a mineral-physicist.

CMS: That's right, or a material scientist, or a solid-state physicist, or something like that.

BISH: So mineralogy, as Steve Guggenheim and Jeff Post and I know it, is going away; but there's mineral physics. Maybe we're three people who have resisted saying, "We're mineral physicists," so we kind of stick out in an odd way.

CMS: Still there's the issue of rigor, and that's alien to many geologists. I've often told people that geology doesn't work very well. Geologists settle for very, very weak conclusions, based on terrible correlations. I mean they get all excited about an R^2 that is 0.4. You can't do that in mineralogy; it's a much more exact science. And there's something about the mental conditioning of that rigor that's essential to a field like ours. People bring it in who used to be physicists, like Brindley, or physical chemists, like Bradley, or crystallographers of the Martin Buerger-type or the Charlie Burnham-type. I think that's an essential ingredient to stiffen our backs. People like Phil Low and Tom Pinnavaia, in a different aspect of clays, are absolute rigorists. But I'm thinking of the diffractionists, the empirical nature of the diffractionists. They need stiffening with the rigor that good crystallography can bring.

BISH: That is something that you see quite often with Rietveld refinement. Everybody thinks it's great. It's very, very powerful. It'll do a lot of simple things for you very well, plus it will do more complicated things for you very

You can get a lot more information out of powder diffraction than just saying there's quartz and calcite and dolomite in there.

well. You'll hear a talk tomorrow by Steve Chipera who used it to monitor hydration of a zeolite. How else can you monitor hydration of a zeolite? You can't stick it in water and heat it.

CMS: How did he do it.?

BISH: What we did was dehydrate a zeolite, and then we monitored the rehydration of it. You stick the sample in water and leave it there for x amount of months at y temperature, and take it out, and just get it barely dry, and x-ray it. But you couldn't do this with normal thermal methods because you have all this free water in it, and how do you differentiate it from bound water? With the Rietveld method, we were able to refine the occupancy of the water site. We got beautiful rehydration kinetics out of it. So

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Bish, *continued*

the method works with so many neat things.

CMS: You're leading the pack in that. Obviously, that's the direction you've decided to go, and it's a fruitful one.

BISH: It's such a nice method that a lot of people are interested in it, and they come to you, and you talk to them about structure factors and things like this, and they often find it a bit confusing.

CMS: That's the mistake you always make. You go to another field and you think it's a magic elixir. Then when you discover how complicated it is, you lose interest. Nothing is simple.

BISH: Everyone sees what a neat method it is and wants to get into it, but unfortunately the average geologist hasn't the background.

CMS: I've seen proposals for automated x-ray labs by people who are not diffractionists, they're petrologists. They think you buy a Scintag or a Siemens and you plug it in and you feed it rocks and you get answers out of it. They don't realize that someone has to love that machine. They have to make it their business to understand its limitations.

Every sample from the top to the bottom of the 6000-foot hole had illite/smectite in it. People were interested in the multiple barrier philosophy at Yucca Mountain, where you have multiple sorptive phases that behave differently with different radionuclides.

BISH: Exactly.

CMS: What did you do first at Los Alamos?

BISH: I looked at the clay mineralogy of Yucca Mountain tuffs. They'd done whole-rock studies, but they didn't have the slightest idea about the clays. But I looked at a whole set of drill cores, and it turned out to be very interesting because, number one, there were a number of people who said there were no clays in volcanic tuffs, all the clays we saw were in drilling mud. Well, the first thing I said was, "I want some drilling mud. I want to see the bentonite." They didn't want to mess up the hydrol-

ogy, so there was *no* bentonite drilling mud. The other interesting thing was that every sample from the top to bottom of the 6000-foot hole had illite/smectite in it. People were interested in the multiple barrier philosophy at Yucca Mountain, where you have multiple sorptive phases that behave differently with different radionuclides. And here's another sorptive phase that behaves differently. So we found that there were certain zones enriched in smectite. As we went deeper into Yucca Mountain, toward the north end, we actually found the smectite-to-illite transformation.

CMS: Interesting!

BISH: It's related to a volcanic center north of Yucca Mountain. As you go south across Yucca Mountain, the transition to illite goes deeper.

CMS: I seem to remember that you used Rietveld to do quantitative analyses of zeolitic-bearing rocks.

BISH: That was later. It was kind of interesting where the Rietveld method came in. When I was a first-year grad student in 1974, I went to the ACA meeting in Charlottesville. A guy named Ray Young stood up there and gave a talk about this incredible method. He was fitting this calculated thing to the whole diffraction pattern. Of course, Ray Young had been into that for several years, and is renowned in that field. In, I think, 1981, Wiles and Young wrote a paper about the new, up-to-date DBW program. I wrote Ray Young and got a copy of it, and started doing some things with it. I worked with Jeff Post off and on, and that really was stimulating. It was a nice thing because you know, you think of Los Alamos as a high-tech place, but I'm the only mineralogist out of 7400 people.

CMS: That can be lonely.

BISH: It was lonely. I didn't have anyone to talk to about mineralogy or crystallography.

CMS: How did you know Jeff?

BISH: Jeff was a post-doc at Harvard after I left. He took my spot. So I had heard him give talks at the GSA. It's not the fraternity that The Clay Minerals Society is, but if you're a mineralogist at GSA, you know everybody pretty quickly.

CMS: Where do you see yourself going from here? Are you going to stay in Rietveld, and apply it to new systems perhaps?

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Bish, *continued*

BISH: Yes, I definitely want to do that. I want to write up about twelve papers that I have so far.

CMS: Obviously, Los Alamos supports this effort.

BISH: Los Alamos has been superb. They've supported me when, probably in about '83 or '84, I got the idea to use the method for-quantitative analysis. By this time Joe Smyth had left Los Alamos for Boulder, and I was the mineralogy guy there. I'd written some of my own programs to do quantitative analysis, and I was also doing Rietveld. I thought, "I can do quantitative analysis with Rietveld." It was an idea that wasn't really a part of my job. So I messed around with it for a couple of years. By the time I got around to publishing it—I'd given a couple of talks on it—Rod Hill in Australia published a paper. I guess it was submitted within days of when mine was, and I probably screwed around for three or four years with it. But that was something my management has supported very well. They support my participation in CMS and MSA. When I did that book for MSA, they viewed it as something good. It's not a situation where they say, "You're not spending enough time on your job. Get to work."

CMS: That *is* your job.

BISH: Partly. So that's been really nice.

CMS: Do you have any children?

BISH: I do. I have a daughter who will be seven in a month.

CMS: Let's say that your daughter is 19 years old, and she's going to Harvard or Penn State, and she says, "Daddy I want to be a geologist." How would you tell her to prepare for a career in geology in the year 2010? I'm asking you to be a seer. The kind of background that worked so well for us may not work in the future.

BISH: I'd tell her to take mathematics through differential equations. I'd tell her to take physical chemistry and



Dave Bish and his daughter Rebecca *Courtesy Dave Bish*

probably organic chemistry.

CMS: Interesting. Couldn't agree more. They'll never do it, but you always advise them to.

BISH: I probably wouldn't tell her to take physics.

CMS: You wouldn't!? We've got to edit that out!

BISH: Now wait, think about what you get in the first two classes of physics.

CMS: Well, it depends on the coverage.

BISH: Maybe it was my physics class, because I like physics. But as far as using the $f = ma$ stuff you learn in the first two classes of physics, it's just not something

you ever get into again. But the best chemistry class I ever took was p-chem.

CMS: What kind of geology would she take? That's sort of a loaded question, because there are the more rigorous classes, like igneous-metamorphic petrology, and the more descriptive types.

BISH: I'm a bad person to ask because I feel like I'm not that much of a geologist any more. If you think about what I do, I'm probably more of a chemist. I'm not a physicist.

CMS: That's funny. I think of you and Brindley as physicists.

BISH: So she just needs to be up on the fundamentals in a quantitative way, and make sure she feels very comfortable with computers.

CMS: "Comfortable" is the word. It's a much stronger word than "literate."

BISH: She can do what she wants.

CMS: And she will.

BISH: You're darn right!

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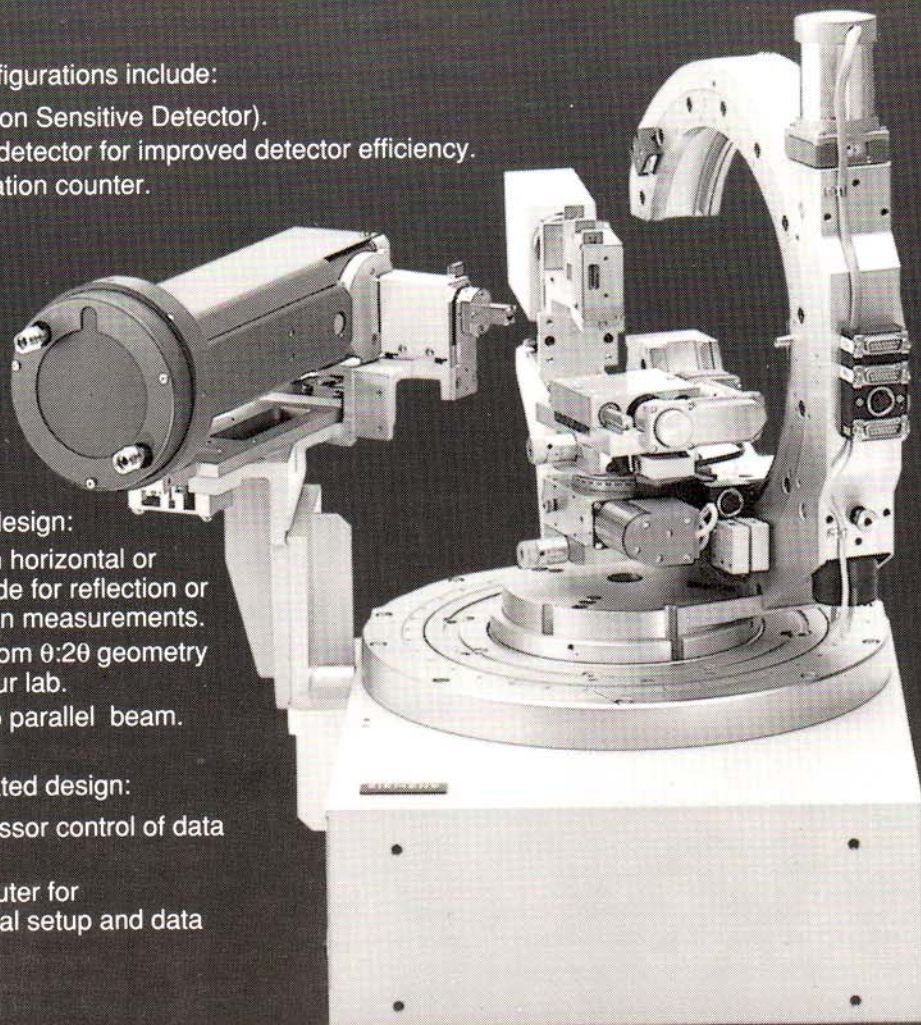
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Minneapolis, *continued from page 1*

an evening social will be included as part of the registration fee. The workshop will be limited to 100 participants.

A field trip that will be of interest to both CMS and SSSA members is being organized and hosted by the Minnesota Geological Survey. Soils and clay stratigraphic units along the Minnesota River will be observed on Sunday, November 1, 1992 from 8:00 a.m. until 6:30 p.m.

CMS/SSSA symposia will include the following:

- Historical Interactions in Clay and Soil Science
- Synchrotron X-ray Sources in Clay Research
- Organo-Clay Complexes and the Bioavailability of Sorbed Contaminants
- Genesis and Properties of Smectites
- Environmental and Regulatory Aspects of Clays

These and other symposia will be co-hosted with various SSSA/ASA Divisions.

The organizing committee for the joint CMS-SSSA meeting is W. H. Hudnall (CMS General Chair), Louisiana State University Agricultural Center; J. M. Bigham (CMS Co-Chair and Division S-9 Chair), Ohio State University and D. G. Schulze (CMS Program Chair), Purdue University.

CMS/SSSA Pre-meeting Field Trip Clays of the Minnesota River Valley and Southwestern Minnesota

Weathering of Precambrian crystalline rocks in Minnesota has produced saproliths as thick as a few hundred feet. They are a significant clay resource, providing raw materials for cement, bricks, and possibly paper-coating. The relationship of the parent rock composition to the resulting clay product will be explained during the examination of several exposures. Shales of Late Cretaceous age commonly overlie the saprolith. Their composition reflects reworking of the weathering profiles together with contributions from western sources via the Western Interior Seaway. These shales, which provide clay to the brick industry, have potential for other uses as well. Soils with pisolitic texture overlie the saprolith. The genesis of these soils is unique and is not fully understood. These soils and clay will be examined at several locations.

Leave Minneapolis 8:00 a.m., November 1; return to Minneapolis by 6:30 p.m., November 1. Limit 100 participants. The field trip has been organized by Dale Setterholm, Minnesota Geological Survey, St. Paul, MN, and John Heine, Natural Resources Research Institute, Duluth, MN.

Note: Average weather for November 1 would be a low overnight temperature of 30 degrees Fahrenheit and a daily high of 49 degrees Fahrenheit.

Symposium, *continued from page 1*

participate. We welcome papers about the life and work of individual scientists and their influences on others, developments in thought and/or technology at particular schools, organizations, and institutions. We are particularly interested in how clay mineral science and soil science have influenced each other.

To participate in the symposium or to request additional information, contact either John Tandarich, Hey

and Associates, 53 W. Jackson Blvd., Suite 1015, Chicago, IL 60604, (312) 922-0777, FAX (312) 033-1833; or Dewey Moore, Illinois State Geological Survey, 615 E. Peabody Dr., Champaign, IL 61820, (217) 244-0080, FAX (217) 244-7004. Title summary forms should be sent to Darrell Schulze, Program Chair, The Clay Minerals Society, Department of Agronomy, Purdue University, West Lafayette, IN 47907, (317) 494-8062, FAX (317) 494-6508.

Student Travel Grants for Xth International Clay Conference in Australia July 18-26, 1993

The Clay Minerals Society, in collaboration with AIPEA, plans to award a few travel grants to aid doctoral students in presenting papers at the Xth International Clay Conference. The grants were developed to encourage students to take advantage of this special opportunity to visit two island nations with contrasting climates and landscapes that exhibit many of the wonders of earth science in vivid and dramatic fashion. Such a trip should provide a rich professional experience in view of the field trips in Australia and New Zealand.

Applications will be judged on a competitive basis, based on the quality of the abstract of the paper to be presented, the scientific merit of the work, and supporting professional plans related to the trip.

To receive a travel grant application, contact The Clay Minerals Society, P.O. Box 4416, Boulder, CO 80306.

Society Archives

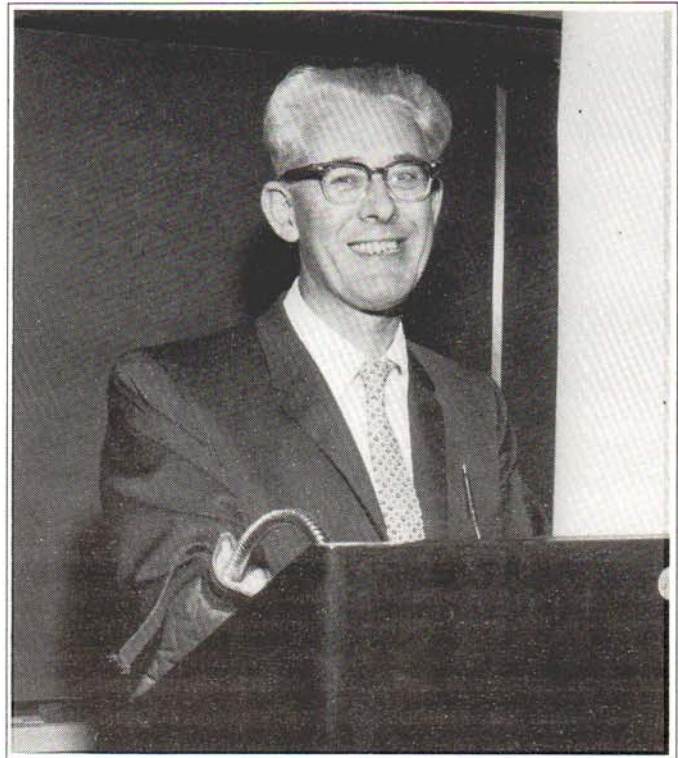
George W. Brindley

George W. Brindley is a legend among clay scientists. As W. D. Keller has said, "Outstanding among the earlier X-ray researchers was George Brindley, renowned for his work on the structure of kaolinite, editorship and personal publications in books, and his presence on the front row at clay meetings from which he 'kept speakers honest.'" Brindley is remembered for his spirit and intellect, the way he lived whole-heartedly, as well as for his elegant science. Some of his students and colleagues generously share glimpses of him in this retrospective. We are indebted also to his daughter, Patricia Milstrey, for many of the photographs.

S. W. Bailey

I first met George Brindley in 1951 when I was in the last year of my graduate study at the Cavendish Laboratory at Cambridge University. George was at Leeds University at that time, but also served as the external Ph.D. examiner for Keith Robinson, a fellow graduate student at Cambridge who had earlier studied with George at Leeds and had published jointly with him on some of the earliest crystallographic research on kaolinite and halloysite. I am especially indebted to Keith Robinson for a series of lectures he gave at Cambridge that first alerted me to the neat structural relationships that existed between the different clay mineral groups. I mentioned to George that I was returning to Wisconsin that fall, and he confided he was packing up also to move to Penn State and that perhaps we would next meet in the U. S.

My own research at that time was on feldspars, and I didn't really expect to see George again. But my interests changed remarkably in the next few years, and I did meet George again at the 1953 clay mineral meeting at the University of Missouri. He was very interested in the clay mineral research I was starting at Wisconsin. And thereafter he was a very special source of encouragement and inspiration for me in switching my main research interest to clay minerals. He supplied me with specimens, reviewed many of my manuscripts, and encouraged me to join him in consideration of matters of nomenclature. We cooperated closely in publication of the monograph *Structures and X-ray Identification of Clay Minerals*. He was especially interested in me, I believe, because my research advisor at Cambridge had been W. H. Taylor. Brindley and Taylor had been fellow graduate students at Manchester University under W. L. Bragg, and Brindley confided in me that Taylor was the brightest of the many students working with Bragg at that time. For whatever reason, I have always been very grateful for George's friendship and his help in my research career. He was the ultimate clay mineralogist in that he was interested in almost all aspects of clays. I doubt that the diversity of his research will ever be equalled. He was a very important factor in



George W. Brindley

Courtesy Pat Milstrey

the development of clay research in the U. S. and abroad. Newcomers to clay science fortunately will have access to his publications. Unfortunately, they can never experience his personality nor enjoy his masterful oral presentations.

William F. Moll**Quisiera otra cerveza, por favor: George W. Brindley, Culiacan, Mexico, 1975**

Amateur linguist, brilliant crystallographer, disciplinarian, nice guy, scholar, home gardener, teacher, adventurer. All these were George Brindley. How can we describe such a complex and wonderful man in a short space? Perhaps by a series of vignettes. Others certainly can add many more.

After a torrid three hour trip in an un-airconditioned, sealed

bus, we arrived at the airport in Culiacan, Mexico. We first found no record of our confirmed reservation. We next found the lounge, to drink beer and plot our way to Mexico City. Brindley gave me a lesson in the proper way to order beer in Spanish, emphasizing that the verb form "quisiera" means "I would like" rather than "gimme." The plane came in eventually, and the ticketed passengers boarded. Brindley magisterially approached the implacable agent and blurted, "Our luggage is on that plane, but we are not!" This shattered the agent's composure, whereupon he produced two boarding passes, and we left Culiacan forever.

Brindley believed that the best science came from wringing secrets from Nature with one's own hands, not at a computer with data generated by a technician. He also believed this to be a minority view, and he perfected an effective tool to put every Newcomer on the path of righteousness, the paint brush. The Newcomer would arrive in fine clothes, intending to plunge right into a tough solid state reaction problem or a new organoclay concept. The initiated in the laboratory could hardly stifle chuckles. Brindley would suggest that a particular table was scarred and needed painting. Brindley: "Surely you know how to paint," and, "Oh, I see, you don't. Well, roll up your sleeves and let me show you." For at least a week, new objects would appear to be painted, with the paint-spattered Newcomer now sufficiently humble to address the challenges of Nature. For the particularly recalcitrant, there was welding breaks in the platinum furnace winding. It had recrystallized so often, we half-suspected it might be a single crystal and not a wire. Through the years, it certainly reverberated late at night from oaths in at least six languages.

After a few weeks of research on a carefully-chosen problem and a mass of incoherent results, the Newcomer would disappear behind the frosted

glass door of Brindley's office for help. Newcomer: "I don't understand these numbers and I've thought of everything." Brindley, "Did you try several temperatures?" "No."

"Similar systems

have some unusual phase changes, you know." "I didn't know..." "I also recall there are some unusual solubility changes." "Oh?" And finally, "When you have given some thought to the problem, maybe you won't waste your time and my time with this sort of discussion. Good day." After this inquisition, the Newcomer would imagine any sort of question or approach Brindley might ask, and often a solution would appear. Sometimes a solution would not appear, and another visit behind the frosted glass door was inevitable. If, after a series of searching questions, Brindley was convinced the Newcomer had indeed given proper thought, he would become very comforting. Perhaps for hours, they would examine the situation, and in a flash of insight a fruitful new path would appear. All along, of course, Brindley was not being distant or rude; he was putting a great deal of planned effort into making the Newcomer a more insightful and better scientist.

Brindley ran a tight ship. He picked the projects underway and expected everyone to work long hours, just as he did. He believed in a critical mass of at least six or eight because "someone's work will always go sour, and we need the rest to lift him or her out of the pit." The group usually was very cosmopolitan, rang-



J.J. Fripiat, G.W. Brindley, and others (possibly in Oxford, 1978).

Courtesy Pat Miltrey

ing from new graduate students to well-known professors on sabbatical, and from experimental physicists to geologists. He liked to have a variety of programs running simultaneously, such as a high-temperature reaction study or two, a crystal structure determination, an organoclay project, and a crystal chemical study. His mind indeed could encompass a wide world.

He might ask searching questions at any moment. During the afternoon tea he held in the laboratory, he would like to pose a problem such as "calculate the empty space in cubic closest packing." He would ask whoever was by the diffractometer to give reasons for a certain peak profile. Brindley believed that all of us should have a firm understanding of the reciprocal lattice so that x-ray diffraction patterns were not mere fingerprints. The reality of the Ewald sphere moving through reciprocal space was something we all should share. Those associated with "easier" professors would say, "How can you work for someone like him?" We worked for him because he was giving his last measure to teach us how to think and to be better scientists and because we all loved him.

One would give Brindley a first draft of a paper with carefully col-

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Moll, *continued from previous page*

lected data, elegant calculations and impeccable conclusions, only to have him return it with all sorts of corrections to the English. Early in his career, Brindley had taught English in secondary school and realized the power of clear communication through proper English. He insisted on a rigorous organization of a paper presented with simple, direct words. Any difficulty of reading a paper by Brindley arose from the subtlety and elegance of the ideas, not from the exposition.

Brindley considered himself a teacher as well as a researcher and never let the latter supplant the former. He would labor as mightily on giving a lecture, carefully grading an examination, or helping a student as preparing an invited paper for an international conference. Although he had a considerable research organization to administer, he always found time to

teach.

Brindley chose his battles carefully, and did not waste time dueling with trivia. When a visiting Englishman questioned him about his pronunciation of element 13, he replied, "When you have been here as long as I have,



John Sharp, Narahau Achar, G. W. Brindley, Sally Wentworth, October 1964 at Penn State.

Courtesy Bill Moll

you just join them and say 'aluminum.'"

One of Brindley's great achievements was the understanding of the crystal chemistry of the nickel silicates. He once asked if I knew his motivation. I thought it was probably that nickel, although it has an ionic size similar to magnesium, had d-orbitals that would make the thing interesting. He replied, "No. I studied them because they are green and I have always been fascinated by the color green."

Brindley had several hobbies, which he pursued with characteristic precision. One certainly was travel, another was stamp collecting, and another was photography. He liked gardening, and had a cubo-octahedral yew in the front yard.

The Clay Minerals Society Council decided to honor him in 1983 by creating the annual Brindley Lecture. I hurried over to State College to obtain his approval, which he graciously gave. He then shared some of his recent research findings on the nature

of sepiolite gels. He had borrowed from the biological science the technique of critical point drying to eliminate surface tension effects and preserve the structure of the gel. Microscopic examination revealed that the sepiolite laths arranged themselves in

long chains. These chains gave the gel strength. He asked me what I was doing with attapulgite. I muttered some platitudes, whereupon he replied, "I jolly well expect you will have something worthwhile to report on your next visit." Brindley died two days later. This might well have been his last scientific discussion. To the very end, he displayed a disciplined curiosity, a willingness to explore

new domains, and an expectation that others should strive to achieve excellence.

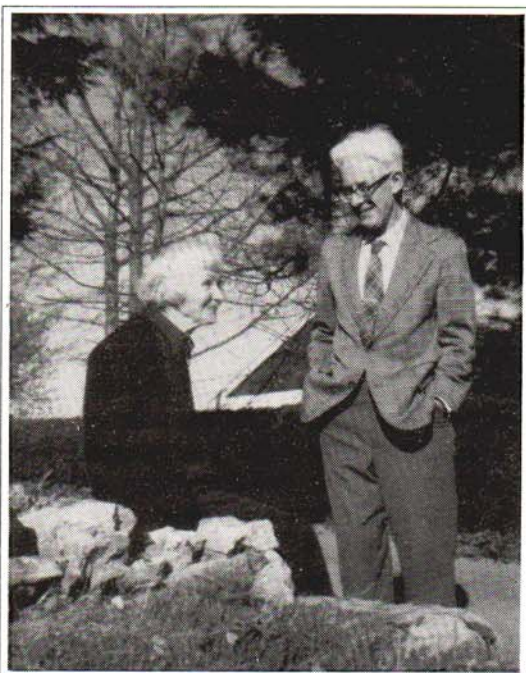
Newton said, "If I have seen farther than Aristotle, it is because I have stood on the shoulders of giants." Today, all of us find that Brindley's shoulders are broad indeed.

Robert E. Newnham

Life is a series of phase transitions from birth to death—and Dr. Brindley and I were involved in several together. It was the winter semester of 1954 when we met at Penn State. At the time, I was a new graduate student in Professor Ray Pepinsky's crystallography laboratory in the physics department, and Dr. Brindley had just been appointed Professor of Mineral Sciences a few months earlier. He set up his x-ray group on the third floor of the Mineral Science Building next to the Mineral Constitution Laboratory. The constitution lab was directed by min-



Drinking Contest, July 1975, La Morena in the Mexico City area, including Chukrov, Bailey, Jordan, Brindley, and others. Courtesy Bill Moll



Brindley and his wife Catherine, May 1981.

Courtesy Pat Milstrey, Steve Corfidi

erologist Tom Bates, and he and the other members of the staff, spectroscopist Harold Lovell, microscopist Joe Comer, chemist Joe Bodkin, and crystallographer Herb McKinstry helped immensely in getting things started. Two graduate students, Howard Gillery and Fred Harrison, accompanied Dr. Brindley in the move from Leeds University. Howard's wife, Marie, later became a secretary in the lab.

In the spring of 1954, I became Dr. Brindley's first American graduate student. After attending his course on x-ray diffraction and crystallography, I was convinced he would make an excellent thesis advisor. The lectures were presented with remarkable clarity and carefully chosen home problems. Atomic structures of kaolinite, olivine, and other important minerals were drawn on the blackboard in colored chalk. A sample page from his lecture notes on the structure of clay and its importance in ceramic processing, is shown on page 20.

Near the conclusion of the course, Dr. Brindley offered me a Fellowship he had obtained from the Gulf Oil

Company. I was overjoyed to learn that it paid \$2400 a year, about twice what other graduate students were paid, and I accepted immediately.

Herb McKinstry and I shared an office between Dr. Brindley's office and the x-ray lab. George was something of a slave driver in those days, and when we heard his leather heels clicking in the hallway, we knew it was time to get busy. He expected us to be at work by 8:00 a.m., and to make progress on our thesis topics every day. As a result, I finished my Ph.D. thesis in two years, something that seldom happens with modern graduate students.

The structure of kaolinite had been published several years before I joined his group, and Dr. Brindley was interested in how the structure changed under comminution. This was to be my thesis topic, but I didn't like it. The x-ray patterns of most clays are rather poor to begin with, and after grinding they are even worse. In Pepinsky's lab, I had been studying large single crystals of ferroelectrics (a subject I later returned to), and the diffraction patterns of clay were dreadful by comparison. But in searching through Tom Bates' mineral collection, we chanced upon a dickite specimen from a coal mine in Eastern Pennsylvania. The snow-white hexagonal platelets 100 μm across were too beautiful to grind in a mortar and pestle, so Dr. Brindley relented, and we made what I believe was

the first single crystal structure analysis of a clay mineral. X-ray intensities were measured from Weissenberg photographs, and the Fourier analyses leading to electron density maps were carried out on Professor Pepinsky's XRAC analog computer. This was in the days before high speed digital computers, and long before crystallographic software became available, so Dr. Brindley showed me how to use Beevers-Lipson strips, and how to calculate structure factors by hand, using the James and Brindley scattering factors. We were very proud of our dickite structure analysis [Acta Cryst. 2 759 (1956)] which showed the distortions present in the tetrahedral and octahedral layers, and gave an accurate tabulation of the bond lengths and bond angles.

Then, as now, life was not all work. On Sunday afternoons, the other students and I were invited to the Brindley home for tea and supper. During their thirty years in State College, Cath and George lived in a modest three-bedroom home on North Allen Street in the part of town known as



George Brindley and the Newnham children sharing goodies during holiday celebrations.

Courtesy Robert Newnham

North Hills. Their children, Patricia and Peter, were teen-agers in the '50s and attended local schools. After supper, on those Sunday evenings, we talked of international events (Dr. Brindley always read the *Christian Science Monitor*) and

continued on next page

Newnham, continued

played games. I especially remember some hard fought ping-pong games played on a table in the basement of the Brindley home. George played ping-pong with great gusto, and sometimes took advantage of the fact that I often hit my head on the cellar ceiling.

In 1955, we moved our lab to the Mineral Industries Building, now called Steidle Building. Professor Brindley had been appointed head of the Ceramics Department and occupied a suite of rooms on the second floor. By this time, Fred Harrison had completed his doctoral studies and returned to England. Dr. Brindley, Howard Gillery and I were joined by Dr. Nakahira, Jack Zussman, and Alan Ahearne. Naki was from Japan, and Jack and Alan were from England. Experiments on other clays, and on the crystal chemistry of ceramic reactions were now in full swing, and the lab was really humming, day and night. Naki, Howard, and I shared a room in the back of the building, and all three of us were smokers. Naki and I were addicted to Marlboros and Howard had a curved Sherlock Holmes pipe. George hated smoke, and when he entered our room, he would fan his face, cough and complain loudly. In later years, we learned how right he was about smoking.

Following graduation, I moved away from Penn State for ten years. Dr. Brindley helped arrange an ICI Fellowship for me at the Cavendish Laboratory with his friend, Will Taylor. Two wonderful years in Cambridge, England, were followed by eight more at M.I.T. in Cambridge, Mass., and then I returned to Penn State as a professor. In 1966, Dr. Brindley and Dr. Rustum Roy arranged my faculty appointment at the Materials Research Laboratory, where I have remained ever since.

Over the next two decades, Dr. Brindley and I continued our friend-



T. F. Bates, F. V. Chukrov, G. W. Brindley, August 1967.

Courtesy Pat Milstrey

ship. Our labs were at opposite ends of campus, but we saw a lot of each other socially and at faculty meetings. After their children moved away, Cath and George became honorary grandparents to our children, and we gathered together for holiday celebrations at our home. Stuffed with turkey and all the trimmings, George and I would sit in front of the fireplace and talk about "the good old days" when people worked a lot harder than they do now. Later we joined the children for games.

In their later years, Cath suffered from Parkinson's Disease, and George from cancer. Through it all, they kept up their good spirits and never complained. George continued to go to work until two days before he died.

As the cancer advanced, he became very weak, so that it became necessary to drive him to work and help him up

the stairs to his office. The last time, he said, "This may be the end for me," and it was said in such a mournful way, I thought my heart would break. His work was his life, and he set a wonderful example for us all.

David L. Bish

To me, Dr. Brindley was a man who was fascinated with many areas of life, not just mineralogy. When I was his student, after he had retired from teaching, Dr. Brindley loved spending time at home with his lovely wife, Cathy, working in the garden, and entertaining guests. Their "garden" in State College was much like an English garden; in fact, they continued to emulate the English way of life in many ways. They had shrubs in the front yard trimmed in the shape of crystals, and

their backyard was filled with flowers and shrubs. I'll never forget the lampshade in their living room made from a scarf given to spouses at a mineralogy meeting; I believe the pattern on the scarf was a real Patterson map. His students spent many evenings at their house, usually having a wholesome dinner with those



Brindley and John Hower, Oregon Coast, August 1976.

Courtesy Dave Bish

wonderful plump apple pies for dessert. Of course, after dinner we retired to the living room to look at slides of one of Dr. Brindley's many world trips. He kept a small brush with his projector and would individually brush off each slide before projecting it.

Fortunately for clay mineralogists, Dr. Brindley also loved spending time in his laboratory, which he did from 7:30 a.m. to 5:00 p.m., Monday through Friday and usually half days on Saturday. After I had been with Dr. Brindley for a few weeks, he made a great concession by allowing me to arrive in the laboratory by 9:00 a.m. (8:00 a.m. was too early for a graduate student who had just left the lab eight hours earlier). Because Dr. Brindley was retired from teaching when I was his student, I was able to spend innumerable days discussing science and/or world problems with him in the lab; we had coffee every morning in the lab and talked for 15 to 30 minutes. It was during those coffee breaks that I learned much of my clay mineralogy and began to understand Dr. Brindley's conception of doing research (and, of course, his opinions on national and international problems). Clearly, if one was to undertake a project, it had to be done carefully and completely. If it took two weeks, eight hours a day to obtain a pure separate of an interesting mineral, then that was how long the graduate student would sit by the microscope. But in the end, we all knew that the results were new and believable.

Dr. Brindley, like any other great scientist and teacher, had definite opinions about everything. In the

early part of his career, he spent a great deal of time working on the kinetics of thermal reactions of clay minerals. Although thermodynamics later became the thing to do in geochemistry, particularly at Penn State, Dr. Brindley used to (half) jokingly call it thermostatics, in reference to his firm belief that many of the reactions we deal with do not represent equilibrium processes. Interestingly, the Penn State department began to



Brindley with students: Ron Wardle, Gozem Ertem, Tom Thompson, Brindley, Atsumu Tsunashima, March 1970.

albeit particular man. As with many university professors, Dr. Brindley felt that his students were much like a family. The only time he met my wife, Karen, he took her aside and asked her, much like a concerned father or grandfather would, when we were going to start a family. He was certainly more than a Ph.D. advisor to me.

Rustum Roy

The fifties were best of times for American research. I had met George Brindley in person for the first time at Walter Keller's first Clay Minerals Conference, at which time I recall clearly his acerbic comment on my paper with Bruce Nelson. In it we had shown that not only could we synthesize hydrothermally 7Å aluminous

serpentine but that we could also convert them hydrothermally into 14Å chlorites. Hence they were clearly polymorphs of chlorite. We proposed to call them "septchlorites." Brindley objected vigorously to the term, choosing to ridicule them as "septic chlorites." But he was very impressed by our capacity to synthesize all the suites of his beloved clays. And I, by his thorough knowledge of clay minerals and their x-ray identification.

When the opportunity arose, I strongly recommended to E. F. Osborn, my thesis advisor, founder of the entire experimental oxide synthesis 'school' at Penn State, and then-Dean, that Brindley might be moveable from Leeds to Penn State.

Quick decisions and six months later, in 1953 Brindley was installed two doors from my office on the third

continued on next page

engage wholeheartedly in kinetic studies in the late 70's.

Although Dr. Brindley was not one you would call a field geologist (he used to joke that he did his field work in museums), he had a great appreciation for the field. The only trouble with going into the field with him was that every rock he found interested him and he wanted to take it back to the lab; not surprisingly, his graduate students were the ones nominated to carry the rocks. He used to say there was a Ph.D. thesis in every rock or hand sample, and many of his interesting papers had their origins in investigations of hand samples out of curiosity.

I think about Dr. Brindley often, mostly when I am in my own X-ray diffraction lab. Although he could come across to young students as a gruff professor, he was a kind, caring,

Kaolinite

1) Application of Pauling's Rule 2

OH → Al → Si ← edge of crystal

Al³⁺, bond str. $\frac{3}{4} = 1$

Al³⁺, bond str. $\frac{3}{2} = 1.5$

Basal oxygens connected to 2Si. Total incoming bond str = 2(1) = 2 ✓

Intermediate level OH + " 2Al " " " = 2($\frac{1}{2}$) = 1 ✓

" " O " " 1Si, 2Al " " " = 1 + 2($\frac{1}{2}$) = 2 ✓

Upper level OH " " 2Al " " " = 2($\frac{1}{2}$) = 1 ✓

Special conditions at edges

Basal oxygen connected to 1Si. " " " = 1 Deficient by one unit
∴ Tends to take H⁺, i.e. become OH

Intermediate level OH + " 1Al. " " " = $\frac{1}{2}$ Deficient by $\frac{1}{2}$ unit
∴ It appears as $-\frac{1}{2}$, or takes on H⁺ (whole unit) and becomes $+\frac{1}{2}$

Upper level OH " " 1Al. " " " = $\frac{1}{2}$ Deficient by $\frac{1}{2}$ unit

Variation of edge charge with pH of liquid medium.

	low pH	pH=7	high pH	Effect on flocculation and dispersion
Basal oxygen	$+\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}$	Low pH edge-face flocc ²
Intermediate level OH	$+\frac{1}{2}$	$+\frac{1}{2}$	$-\frac{1}{2}$	High pH face-face "
Upper level OH	0	0	$-\frac{1}{2}$	pH=7 dispersion
	positive edge charge	edge charge small	negative edge charge	



G. W. Brindley, December 5, 1967. Courtesy Pat Miltrey

The crystal structure of clay and its importance in understanding flocculation and dispersion in the clay-water system (Brindley notes, 1954). Courtesy R. Newham

Kazantzakis, in which he talks of his attachment to the "clod of his native soil"—and all the clay minerals within it.

Roy, continued

floor of the new Mineral Science Building. As he kept me straight on x-rays, I became his mentor on all matters of "proposal writing" and University politics. And it is certainly worth recording that the very first major crisis which George brought to me was phrased thus: "Rustum, when I was in Leeds and I wanted some chemicals, or glassware or whatever, I would write it down on a chit and give it to the laboratory boy, who would get the material from the 'Stores.' Now can you tell me who the lab boy is and where he sits so I can ask him to get me some items from the store?" It was all I could do to persuade him that in the U. S. there were no "laboratory boys," and everything required a budget number.

Over the years we collaborated on a continuous basis and jointly managed the API 55 project—but we wrote perhaps only a few papers together. In 1955 the Clay Minerals meeting was held at Penn State, and Brindley, Roy, Bates, Griffiths, and Jeffreys worked on it together. In 1963, when the Materials Research Laboratory was founded, Brindley, of course, became a charter member of the faculty that eventually put Penn State's MRL at the top of the world's ceramic research institutions.

By appropriate scheming long after he had retired officially, we kept Brindley's research funds flowing in to let that creative active mind continue to have its way with sheet structures. And it was only fitting that in designing the liturgy for his funeral, I should insert a passage from Nikos

Brindley's Students

At this time, we are unable to find a complete list of Brindley's students. We would appreciate people sending us partial lists so the names can be compiled into something more complete.

The George W. Brindley Lecture

In 1983, the CMS established the George W. Brindley Lecture to recognize a clay scientist who has injected new ideas into the Society, someone who is both a dynamic speaker and involved in innovative research. Dr. Brindley himself approved the concept of the lecture: the speaker should deliver a lecture that Brindley himself would applaud.

Anyone else who would like to share a reminiscence of Brindley is welcome to send it in to CMS News.

New Members

We welcome the following people who have recently joined The Clay Minerals Society.

Mr. Jessie L. Bonner
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Waco, TX 76798-7354

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Ask the Clay Doctor

(Not a real doctor)

Dear Clay Doctor: Who is the smartest clay scientist of all time?

Ophelia Toot, Hamburg

Dear Ms. Toot: Two scientists vied for this honor, B. W. Grindley from the Institute for Advanced Clay Studies at Princeton, and B. F. Wadley from the the National Clay Lab at Harvard. At first these rivals argued about the nature of illite, but as competition intensified, their arguments became increasingly mathematical. The 1966 meeting featured their famous exchange concerning the number of clay particles on Earth. "A googolplex," said Grindley. "Whatever you say, plus one," said Wadley. "Twice that!" countered Grindley.

The rivalry came to a sad end when Wadley was made Dean of Science and began to wear a necktie to work. One evening his tie became entangled in a sample holder, and he was burked by his Siemens goniometer as it slewed at 400° 2θ/min. At the memorial service, Grindley offered this touching eulogy: "Wadley might have had feet of clay, but his head was solid granite."

Dear Clay Doctor: As an etymologist I have been unable to identify the origin of the expression, "Here's mud in your eye." Can you help me out?

Wordless in Wapakoneta

Dear Wordless: The expression to which you refer has its origins in late 17th century Bavaria, where local miners working in the Rhine Valley kaolin pits amused themselves during lunchtime breaks by competing to see who could throw a roughly 1 kg ball of clay the farthest. At one point, the reigning champion was a rather robust Rhinelander named Hans who had an unpronounceable last name. In a desperate effort to defeat him, supporters of his nearest challenger, also named Hans, conspired to lure the pit foreman, a cruel and much despised fellow, to a point well beyond the record mark, but in full view of the competitors. As Hans 2 prepared to throw, he spotted the foreman and mustering all his energies heaved the wet goeey mass directly at him yelling, "Hey foreman, here's mud in your eye." History is vague on the rapid succession of events that followed, but it is clear a direct hit was scored and a new record set that stands to this day.

Dear Clay Doctor: Illite fundamental particles have been described as having the appearance of a wet noodle in atomic force microscope images. Could you explain the

meaning of this observation?

Befuddled in Burbank

Dear Befuddled: The use of atomic force microscopy in clay studies is so new that researchers are still struggling with ways to verbalize their interpretations of the images they see. Food metaphors are well established in clay science, however, and it thus seems appropriate that the AIPEA Nomenclature Committee has recently mandated their continued application wherever possible. In 1854 the Ukrainian clay historian Eugenie Bestopova noted that early Greeks referred to clay-rich earths variously as sausage-like, fritter-like, chip-like, prune-like, and banana-like. These expressions were modified in the Middle Ages, mainly by Italians who saw little difference between clays and food. Thus, we have the familiar but archaic terms such as rotini clay clumps, interlayer gelato, tetrahedrally coordinated mortadella, and exchangeable pepperoni. Diet-obsessed North Americans have shown a preference for low calorie, low cholesterol metaphors, and thus we are hearing more expressions such as tetrahedral tofu, soybean smectite and of course, wet noodle illite.

Dear Clay Doctor: I am worried that clays are disappearing during metamorphism, and that they may eventually become extinct. What can be done?

Save Our Smectite, Reno

Dear S. O. S.: Do not worry. The disappearance of clays during metamorphism is balanced by clay formation during weathering. The destruction of clay is a natural part of the rock cycle. Hey, schist happens.

Dear Clay Doctor: Don't you ever get tired of studying clay?

Dee Fractometer, Central City

Dear Dee: Clay studies are so boring that I frequently wish that I studied sand, or that I was a carbonate petrologist instead... NOT!

The Clay Doctor is available for consultation. Please send contributions to the Society Office.

Feats of Clay



Victor A. Drits receiving the award of Doctor Honoris Causa and an epitoge from Prof. William Marois, President of Orléans University, at Orléans University, February 1992. *Université d'Orléans*



Norbert Clauer accepting the Silver Medal of CNRS from from Professeur André Berroir, Directeur de Département "Sciences de l'Univers" du CNRS and Directeur de l'INSU, in Strasbourg, June 1992. *Jo Eberl*

Victor A. Drits was awarded the title of *Doctor Honoris Causa* at Orléans University (France) in February 1992. He has been involved in numerous collaborations with French scientists. He has spent the last few months in Orléans and visited **Alain Manceau** and **Rachel Glaeser** in Paris.

Norbert Clauer received the Silver Medal of the CNRS in June 1992.

Lisa Heller-Kallai was honored at the annual meeting of The Israeli Society of Clay Research in October last year. Lisa recently spent several months in Strasbourg working with **Dennis Eberl**, **Christine Mosser**, and others.

S. W. Bailey was elected to Honorary Membership in the Mineralogical Society of Great Britain and Ireland. This honor is restricted to 20 living mineralogists.

George Kacandes won first prize in the Physical Sciences Division of the 1992 Penn State Graduate Research Poster Competition.

Walter Keller is teaching geology classes at the senior retirement center where he lives.

Jean Hemzacek gave birth to a son, Christopher, in the winter.

Reed Glasmann has moved to Oregon, where he will work part-time at Oregon State and do consulting.

Wayne Bundy has moved to Bloomington, Indiana.

P. W. Schindler visited **Alain Manceau** in Paris for a month in the Spring.

Alain Manceau has moved from Paris to Grenoble.

Ginny Colten-Bradley has taken a position with the U.S. Nuclear Regulatory Commission.

Prakash Malla has recently taken a position as Group Leader in Research and Development at Thiele Kaolin.

Dennis Eberl recently spent the several months in Strasbourg working with **N. Clauer**, **L. Heller-Kallai**, **S. Chaudhuri**, and **A. Lerman**. He visited **A. Manceau**, **J.-P. Muller**, **B. Velde**, **R. Glaeser**, and **V. Drits** in Paris, **A. J. Herbillion** in Nancy, **M. Frey** in Basel, **M. Kralik** in Vienna, **V. Sucha** in Bratislava, **J. Srodon** in Krakow, and **Shirley Temple Black**, Ambassador to Czechoslovakia, in Prague, to discuss the state of science in Czechoslovakia.

Ada Swineford, former Editor of *Clays and Clay Minerals*, was featured in the July/August 1991 issue of *Rocks & Minerals*. While this issue of *CMS News* was in press, we learned unhappily of her death. We hope to have a memorial to her in the next issue.

The Society expresses its sorrow to S. W. Bailey on the loss of his wife Marilyn in January.

International Centre for Diffraction Data Crystallography Scholarship Awards

The science of crystallography has played a key role in the development of x-ray diffraction, electron diffraction, and neutron diffraction for the elucidation of the atomic structure of matter. Crystallography is an interdisciplinary branch of science taught in departments of physics, chemistry, geology, molecular biology, metallurgy, and materials science. To encourage promising graduate students to pursue crystallographically-oriented research, the International Centre has established a Crystallography Scholarship Fund. While the Ewald Prize is awarded every three years to an internationally recognized crystallographer, little effort has been made by science departments to cultivate aspiring crystallographers. Convinced of the beneficial scientific impact of the proposed scholarships for crystallographically-oriented research, the ICDD Chairman has solicited funds from private and industrial sectors to reach the goal of \$250,000. Approximately one-half of this goal has been reached. The ICDD has awarded two scholarships for the calendar year 1992 and intends to award two additional scholarships in 1992.

Qualifications: A graduate student with major interest in crystallography (crystal structure analysis, crystal morphology, modulated structures, correlation of atomic structure with physical properties, systematic classification of crystal structures, phase identification and materials characterization).

Submit: A. A one-page proposal by the graduate student describing the type of crystallographic research to be partially supported by scholarship. B. A supportive letter from the sponsoring professor of an accredited university or institute of technology.

Restrictions: A. The scholarship stipend of \$2000 is to be used by the graduate student to help defray tuition and laboratory fees. A portion of the stipend may be applied to registration fees to accredited scientific meetings related to crystallography. B. No more than one scholarship will be awarded to any one accredited institution per year. C. The funds of the scholarship are not to be used for travel.

Applications should be mailed, prior to 31 October 1992, to: Secretary, International Centre for Diffraction Data, 1601 Park Lane, Swarthmore, PA 19081-2389. For more information, write to the same address.

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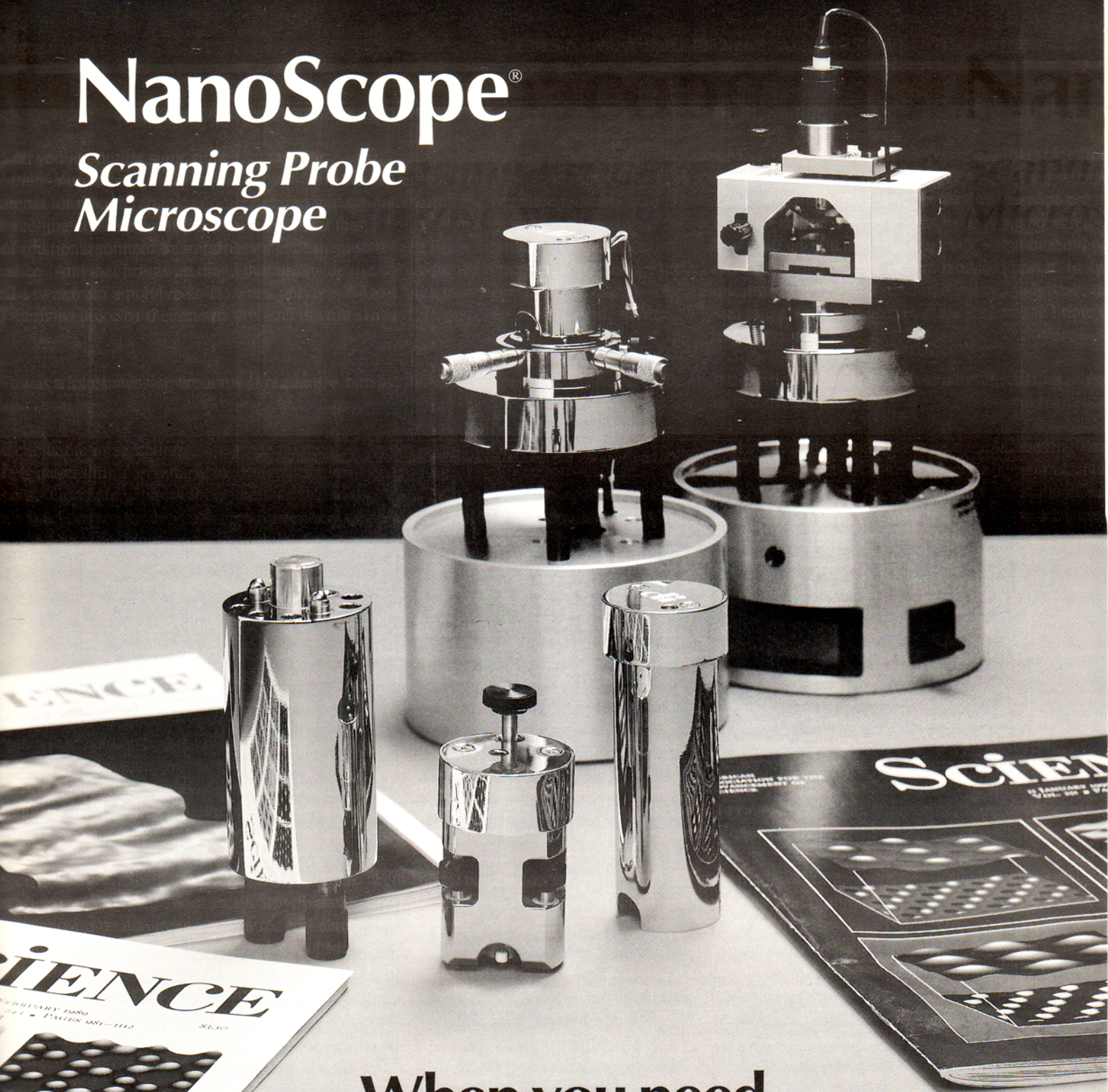
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Very low grade metamorphism goes down-under

The Geothermal Institute of Auckland University, New Zealand, hosted the fourth meeting of the International Geological Correlation Programme Project 294: Very Low Grade Metamorphism (VLGM), 8-21 November 1991. It would be hard to find a country of comparable size to New Zealand better suited for a symposium entitled "Low Temperature Metamorphic Processes in Contrasting Geodynamic Settings," a point made by keynote speaker Doug Coombs, who is one of the pioneers of VLGM. North Island provides one of the best documented geothermal regions in the world, whereas South Island is a collage of terranes with contrasting pressure and temperature conditions of VLGM.

A four-day pre-conference excursion to geothermal areas of the Taupo Volcanic Zone proved a spectacular introduction to low temperature processes operating around geysers, fumaroles and boiling mudpools. As conference convenor Pat Browne observed, "It all boils down to piles of mud and pools of scinter, but generates 10% of New Zealand's electricity in the process."

Some 53 oral and poster presentations were made at the symposium. In the sessions devoted to regional studies, the terrane assembly concept emerged as a clear favourite for modelling contrasting P, T conditions. It certainly better explains VLGM in the western USA, than does the "myth of widespread contact metamorphism," according to Howard Day and his co-petrologists. It was also clear that clay geologists from

several XRD laboratories are reassessing illite crystallinity measurements, following the development of better line profile analysis software. Reflecting on bygone days of a simple 10\AA peak width measurement, a few of us (in a fully expanded condition), composed this very low-grade lament:



The good ship "IGCP Project 294" cruising in Milford Sound.

Dick Merriman

There was a young man from Neuchatel, who perfected a very fine trick

Of measuring the width at 10\AA , of illites below two microns thick.

Others soon followed his methods, and then VLGM 294

Held meetings, with workshops and field trips; there were scientific papers galore.

Alas, then came deconvolution, and one peak became three or four,

What you and I held to be illite, is smectite and phengite, and more.

And then there's this fellow called Ostwald, who's ripening our clays all the time,

Now he's thrown away delta two thetas; so who's for a last glass of wine?

The post-conference excursion to South Island was a magnificent tribute to Doug Coombs, both for his organization of the excursion and to his work on burial metamorphism. For the past 250 million years, South Island has been an unusually dynamic part of the crust, with evidence of several terranes appressed along the

Median Tectonic Zone. The contrasting pressure and temperature conditions of alteration preserved in the varied lithologies along this zone make it something of a VLGM paradise. One of the high points of the excursion was a cruise in Milford Sound, where we "prograded" into an area of relatively high-grade rocks. Naturally, we viewed the amphibolites and schists forming the spectacular walls of the sound

simply as potential converts to VLGM.

Preparation of a thematic issue of the *Journal of Metamorphic Geology* presenting papers from the Auckland meeting is now in hand. The next meeting of IGCP Project 294 will be at the 29th International Geological Congress in Kyoto, Japan, 24 August through 3 September, 1992. This will be closely followed by a symposium, "The Transition from Basalt to Metabasalt: Environments, Processes, and Petrogenesis," to be held at the University of California, Davis, 9-15 September 1992. The final meeting of the project is being planned for Santiago, Chile, in November 1993.

Dick Merriman

British Geological Survey
Keyworth, Nottingham, UK

Special clay symposium at Goldschmidt Conference

Feldspar, carbonate, quartz, skutterudite? No, *clays* were the topic of a special symposium at the Geochemical Society's Goldschmidt Conference this past spring in Reston, Virginia. "Diagenesis of Clay Minerals in Sedimentary Basins" was organized by Lee Kump, Ginny Colten-Bradley, and George Kacandes.

Symposium contributions included 12 papers and one poster.

The conference as a whole attracted 425 attendees. The clays symposium provided a good sampling of current research in the area of clay mineral diagenesis and meshed well with the conference's focus on fluid/mineral interactions.

Papers concerning textural and crystal chemical changes that occur during diagenesis were presented by R. Freed and P. Schroeder. A poster by S. K. Sears and R. Hesse discussed



Some clay attendees of the Goldschmidt Conference: back row, Reed Glasmann, Paul Schroeder, Kathy Nagy, Blair Jones, Hu Barnes; front row, Jim Howard, Dave Pevear, Bertrand Fritz, George Kacandes.

Courtesy George Kacandes

factors affecting the reliability of mixed-layer phase determinations. S. Aja, K. Nagy, and G. Kacandes presented the results of laboratory experiments on the kinetics and thermodynamics of clay mineral reactions. A variety of basin-scale models for clay mineral diagenesis were given in presentations by D. Pevear, R. Glasmann, M. Ohr, J. Howard, and B. Ransom. A recurring theme

throughout the symposium was the importance of fluid chemistry on the nature of clay mineral diagenesis.

While most speakers were clay people, the symposium attracted the interest of all sorts of geochemists. For example, the "modeling types" are interested in incorporating clay phases into their large-scale rock weathering/climate models. Many of these models approximate the surface of the

earth as a sphere of feldspar, carbonate, and quartz. This is clearly a poor approximation, and data on the surface distribution, weathering properties, and thermodynamics of clays must be included. Perhaps this would be a good topic for the next Goldschmidt symposium on clay minerals.

George Kacandes
State College, Pennsylvania

Meeting Calendar

October 25-29, 1992, Berlin and Liepzig, Germany: U.S. Environmental Technology Trade & Investment Mission. Registration deadline is September 20, 1992. Contact: Ms. Frederica S. Wheeler, International Trade Specialist, Energy & Environmental Systems Division, U.S. Dept. of Commerce, Room H2213, Washington, D. C. 20230. Telephone: (202) 377-5665; Fax: (202) 377-5665.

October 26-29, 1992, Cincinnati, Ohio, GSA Annual Meeting: Contact: GSA Meetings Department, P.O. Box 9140, Boulder, CO 80301. Telephone: (800) 472-1988; fax: (303) 447-1133.

October 31-November 6, 1992, Minneapolis, Minnesota: CMS/SSSA Annual Meeting. Contact: Dr. Jerry M. Bigham, Dept. of

Agronomy, Ohio State University, Columbus, OH 43210. Telephone: (614) 292-9066; fax: (614) 292-7162.

April 4-8, 1993, Strasbourg, France: Project 294: Very Low Grade Metamorphism. Contact: R. E. Bevins, Dept. of Geology, National Museum of Wales, Cathays Park, Cardiff CF1 3NP, U.K. Tel: (0)222 397951 ext. 281; Fax: (0)222 373219.

July 5-16, 1993, Xi'an, China: Very low grade metamorphism: mechanisms and geological applications. Contact: Song Suguang, Xi'an Institute of Geology and Mineral Resources, 166 East Youhi Road, Xi'an 710054, P. R. China.

July 18-26, 1993, Adelaide, Australia: 10th

International Clay Conference. Abstract deadline: November 1, 1992. Contact: 10th ICC, Elliservice Convention Management, PO Box 753, Norwood 5067, South Australia. FAX: (61) 8 364 1968.

November 15-30, 1993, Santiago, Chile: Low temperature metamorphism: processes, products and economic significance. Contact: Professor Mario Vergara, Universidad de Chile, Depto. de Geologia y Geofisica, Casilla 13518, Correo 21, Santiago, Chile.

September 25-30, 1993, San Diego, California: CMS Annual Meeting. Contact Dr. Richard W. Berry, Dept. of Geological Sciences, San Diego State University, San Diego, CA 92182. Telephone: 619-594-6394; fax: (619) 594-4372.

Phosphate minerals in some fireclays of Missouri

Phosphate minerals have been identified in some Missouri fireclays, according to Walter Keller (Professor *Emeritus*, University of Missouri-Columbia), Robert Hall (USGS, retiree), Gene Foord (USGS), and David Keller (graduate student, Univ. of Missouri-Rolla). The amounts of phosphate minerals range from just detectable (about 1-2 vol. %) by x-ray diffraction (XRD) to major (greater than 10 vol. %) by x-ray diffraction (XRD) to major (greater than 10 vol. %) proportions. So far as is known to them, phosphate minerals were not previously reported in refractory raw materials from Missouri. Discovery of phosphate minerals began when Hall observed extraneous peaks in the XRD profiles of a diaspore-rich sample that he had collected in Missouri during the "Keller 90" field trip, held in conjunction with the CMS annual meeting in Columbia, MO, in October, 1990. The non-clay XRD peaks were tentatively identified as natroalunite; however, Foord's EDS (energy-dispersive spectrum) analysis of the sample revealed significant amounts of calcium and phosphorous. A careful second examination of the x-ray pattern indicated crandallite ($\text{CaAl}_3(\text{PO}_4)_2(\text{OH})_5 \cdot \text{H}_2\text{O}$), as the source of the extraneous peaks. Minerals of the crandallite and alunite groups have very similar unit-cell dimensions and structures, and consequently, very similar XRD profiles. Chemical and/or optical data are needed to distinguish species present, especially in mineral mixtures where XRD alone is not definitive.

A diaspore-rich sample from Osage County, Missouri, sent to Denver by Prof. Keller, also contained crandallite (Fig. 1). According to Prof. Keller, this material has been characterized (by A. P. Green Co.) as "high-alkali junk clay," unsuitable for refractories because it failed the py-

rometric cone equivalent (PCE) test. A sample of "junk flint clay" contains carbonate-fluorapatite (francolite), $(\text{Ca}_5(\text{PO}_4)_3(\text{CO}_3)(\text{OH},\text{F}))$, identified by XRD (Fig. 2) and EDS techniques. This flint clay also had failed the PCE test. It is not yet clearly established that the so-called "high-alkali junk clays" are unsuited for refractories because they contain phosphate minerals, *per se*, or whether Ca or other alkaline earth and alkali elements alone may cause the failure of PCE tests. Preliminary results by David Keller show a correlation of PCE test-failure with the presence of carbonate-fluorapatite in flint clays from a clay pit in Gasconade County, Missouri (Fig. 2).

Concurrently with the discovery of crandallite in the Osage County diaspore and carbonate-fluorapatite in the Gasconade County flint clay, David Keller identified wavellite, $\text{Al}_3(\text{PO}_4)_2(\text{OH})_3 \cdot 5\text{H}_2\text{O}$, (Fig. 3) in thin veinlets in some flint clays from Gasconade and Maries Counties, Missouri. Soon after the wavellite discovery, he also identified variscite, $\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$, (Fig. 4) in a 1-2 mm thick veinlet from a drill core from another flint clay pit in Gasconade County. Optical microscope examination showed that variscite particles in the veinlet have outer rims of strengite, $\text{FePO}_4 \cdot 2\text{H}_2\text{O}$, the Fe-analogue of variscite, verified independently by Foord's SEM and EDS analyses. Strengite and variscite form a complete solid-solution series, with strengite being favored by slightly more acidic solutions than variscite.

The diffraction profile of the variscite veinlet (Fig. 4) shows a 24\AA 001 d-spacing which was first thought to be due to rectorite; however, the 24\AA peak did not expand to 27\AA after overnight glycolation. Dennis Eberl (USGS) suggested that the 24\AA clay may be 1:1 (Reichweite 1) mixed-layer illite-chlorite, but the identifica-

tion has not been verified. It is not certain that the 24\AA clay was formed in the veinlet simultaneously with variscite-strengite. X-ray diffractograms of the flint-clay host adjacent to the variscite veinlet show no evidence of 24\AA clay and only traces of variscite. Instead, crandallite is the principal phosphate mineral in the flint-clay host.

The occurrence of wavellite and variscite as thin veinlets in flint-clay host contrasts with the crandallite and carbonate-fluorapatite that occur as very fine crystallites uniformly dispersed in host diaspore and flint-clay.

Phosphorous is not commonly looked for or reported in chemical analyses of clays and clay minerals. However, this element is widespread in the environment, is one of the elements essential to life, and probably could be found, at least in trace amounts, during the analysis of almost any clay. Clay mineral structures do not allow incorporation of a significant amount of phosphorous, which probably explains why clay scientists do not generally report P in clay analyses. We suggest that phosphate minerals in very small to trace amounts may be more common in clays than generally thought.

Although not previously reported in Missouri fireclays (so far as we are aware), the association of phosphate minerals with clays is well-documented in the literature, generally in the context of commercial phosphate rock deposits or in discussions by soil scientists of the interaction of clayey soils with phosphate fertilizers.

Research is continuing to determine the significance of phosphate minerals in the Missouri fireclay deposits, both with regard to genesis and the possible effect on refractory properties.

We gratefully acknowledge the cooperation and assistance of David Allerton and David Wilson (USGS,

Branch of Central Mineral Resources) and Kenneth Esposito (USGS, Branch of Sedimentary Processes) in providing preliminary x-ray data. We are especially grateful to Dennis Eberl (USGS, Water Resources Division) and his assistant, Douglas McCarty, for providing the Siemens x-ray diffractograms used here. James Cathcart (USGS, phosphate resource geologist) provided useful information about characteristics and occurrence of crandallite and carbonate-fluorapatite. David Keller acknowledges the advice and guidance of his faculty advisors, Drs. Sheldon Grant and Ernst Bolter. We also thank Charles F. Stack of A. P. Green Industries, Inc. for his donation of the Landwehr Pit No. 1 flint-clay drill-core sample containing carbonate-fluorapatite.

Walter D. Keller, Robert B. Hall, Eugene E. Foord, and David J. Keller

Note added in press: The authors have learned since submittal of the above report that certain phosphates in Missouri fireclays were reported earlier. For example, metatorbernite ($\text{Cu}(\text{UO}_2)(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$) was reported by Grawe (1943), and gorceixite ($\text{BaAl}_3(\text{PO}_4)_2(\text{OH})_5 \cdot \text{H}_2\text{O}$) by Tourtelot and Tourtelot (1978). One of us had forgotten his own finding of torbernite ($\text{Cu}(\text{UO}_2)(\text{PO}_4)_2 \cdot 12\text{H}_2\text{O}$) in Missouri fireclay (Keller, 1952).

References:

Grawe, O.R. (1943) Metatorbernite in Missouri flint fire clays, in McQueen, H.S., Fire clay districts of east central Missouri: Missouri Geological Survey and Water Resources, v. 28, 2d series, p. 153.
 Keller, W.D. (1952) Torbernite in Missouri refractory clay: Amer. Mineral., 37, 125-128.
 Tourtelot, H.A., and Brenner-Tourtelot, E.F. (1978) Lithium, a preliminary survey of its mineral occurrence in flint clay and related rock types in the United States" Energy 3, 263-277.

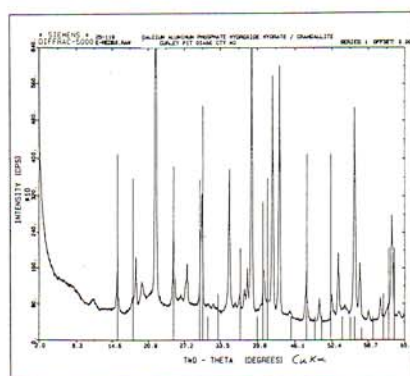


Fig. 1 Diaspore-rich rock from Curley Pit in Osage County, Missouri. "Sticks" mark crandallite peak positions; unmarked peaks are diaspore. Broad, weak peak at about $11.6^\circ 2\theta$ may be gypsum, which has been identified in some Missouri fireclays.

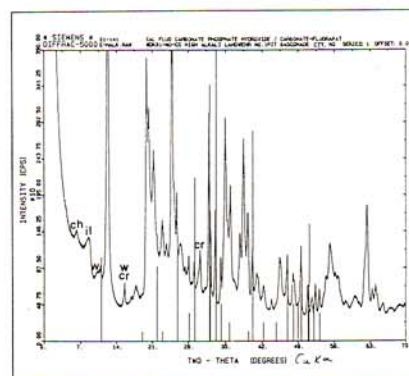


Fig. 2 "High alkali junk clay" from Landwehr No. 1 Pit, Gasconade County, Missouri. "Sticks" indicate positions of carbonate fluorapatite (francolite) peaks. Unmarked peaks are mostly kaolinite. Chlorite (ch), illite (il), wavelite (w), and crandallite (cr) are minor constituents. Many phosphate peaks are masked by the dominant kaolinite.

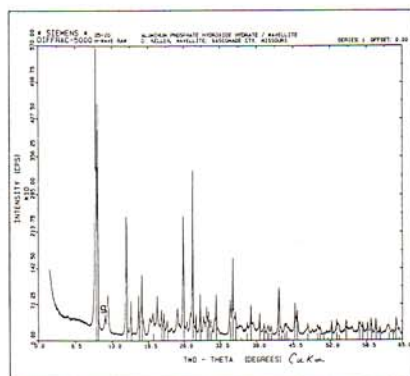


Fig. 3. Wavelite veinlet in flint-clay from drill-core taken from Zeman No. 5 Pit, Gasconade County, Missouri. "Sticks" indicate wavelite peak positions. Unmarked peaks are mostly kaolinite. Small peak near $11.6^\circ 2\theta$ probably is from gypsum (g).

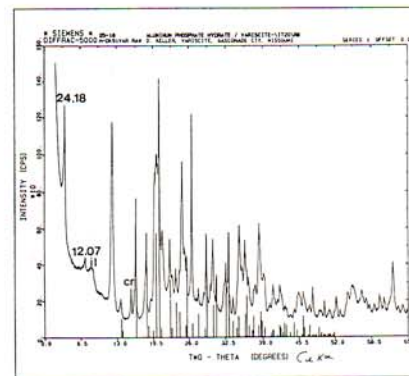


Fig 4. Variscite from thin veinlet in flint-clay drill core, Secco No. 7 Pit, Gasconade County, Missouri. "Sticks" indicate variscite peak positions. Unmarked peaks are mostly kaolinite; small amounts of crandallite (cr) and illite (il) are also present. Variscite particles in the veinlet have outer rims of strengite. See text for discussion of strengite and the 24\AA constituent. The 12.07\AA spacing is a second-order basal spacing of the 24\AA constituent.

Position Wanted

Recent M. S. graduate in geology and geophysics from the University of Missouri-Rolla interested in an entry level geologist position. Areas of specialization include environmental geology, clay mineralogy, geochemistry, and aqueous geochemistry. One year (three summers) work experience as a geologist in the refractory industry in Missouri. For more information, contact David Keller, 1308 Oak Street, Rolla, MO 65401, or call (314) 341-3119.

Kaolinite: katamorphic and anamorphic mineral

Kaolinite, although highly esteemed now by loyal clay mineralogists, did not make many spectacular headlines in the annals of old-time classic petrologists, those savants who placed greatest petrologic emphasis on the process of change, collectively called metamorphism, in the record of earth materials. For example, "Kaolinite is a product which forms extensively in the zone of katamorphism", wrote Charles R. Van Hise in his scholarly "Treatise on Metamorphism" (1904). And, "The zone of katamorphism may be defined as the zone in which the alterations of rocks result in the production of simple compounds from more complex ones" (p. 43). A visual illustration of the origin of katamorphic kaolinite is shown in a scanning electron micrograph (SEM) of the direct weathering of feldspar to kaolinite, Figure 62 (Keller, 1977). Presumably (obviously?), the kaolinite in the commercial Georgia kaolin deposits is katamorphic.

Not all kaolinite originates by the katamorphic process, however; that conclusion is a further thrust, or purpose, of this report. For example, "our" amazing versatile kaolinite which occurs in, i.e., comprises, large commercial-size flint clay deposits, not mentioned by Van Hise, is interpreted to be anamorphic in genetic process. The zone of anamorphism was defined by Van Hise as, "the zone in which the alterations of rocks result in complex compounds from more simple ones" (p. 43).

Probably the most significant petrologic evidence for the anamorphic origin of the kaolinite in flint clay is its texture. Flint-clay texture mimics that of syenite, another monomineralic silicate rock but of igneous origin, in that the kaolinite crystals exhibit mutual contact, boundary texture (each one indents the other, as the other indents the one) characteris-

tic of igneous rocks; see textures of kaolinite in Missouri and distant south African flint clays in Figures 15 and 16 in Keller, 1982, p. 32. The "magma" from which typical flint clay crystallized was a colloidal gel presumably close to kaolinite in solute composition (Keller, 1968, 1981, 1982). The flint clay rock is "more complex" than the chemically simpler colloidal solution from which it came—this is in parallel similarity to the syenite by being more complex than its parent magna. Is not this adequate proof of flint clay being an anamorphic rock, and the kaolinite comprising it to be an anamorphic mineral? Kaolinite merits, because of its versatility, a high rank in mineralogy and petrology.

Another genetic mode by which kaolinite may form is the conversion, or recrystallization, of halloysite (and or allophane) to kaolinite. Such change is essentially from the simpler to the more complex in crystal structure, hence would be categorized as anamorphism. To recognize and validate such change on an actual large scale geologic occurrence is usually not easy however; the problem with it is to prove with unquestionable scientific evidence that dominating recrystallization took place over such a large scale.

One possible example of large-scale recrystallization of halloysite to flaky kaolinite is in the kaolin saprolite overlying the granite at the Sparta, Georgia (kaolin region), granite quarry. Halloysite spikes and large cluster-groups of them occur on the cleavage and fracture surface along joints and cracks in the relatively fresh granite of the quarry, as shown in numerous SEMs; see Figures 31, 32, 33, 34, 35, 36, 37, 38, 41, 42, 43, 44, 45, 46, 47, 62 in Keller, 1977, 311-345. However, in a thick layer of saprolite above the quarry rim, most of the mass is composed of

stacks of kaolinite, but lesser amounts of elongates (such as occur on the feldspar surfaces below) are intimately intermixed with the kaolinite stacks, as shown in Figures 17, 22, 23, 24, 25, 26 of the 1977 publication.

The crucial question is whether the kaolinite was weathered directly from the feldspar, a katamorphic process, or whether it was recrystallized, an anamorphic process, from halloysite as the initial weathering (katamorphic) product. Inferentially, halloysite was formed first, here, as is observed forming today at commercial-size deposits of it in North Carolina, but inference is not proof! Let us hope that undeniable evidence of mode of origin will be found, one way or the other, in future investigations. A similar question of origin can be asked about mixtures of dominant kaolinite crystals with lesser amounts of elongates in other large kaolin deposits, as in Belitung, Indonesia, Figure 3, the Yamaka Mine, Japan, Figure 10, and at Suzhou, China, Figure 11, discussed in a report on the diversity of kaolin (Keller, 1982, 27-36). Kaolin (kaolinite) is a petrologic wonder, so versatile, tantalizing for investigation, and abounding in research problems.

W. D. Keller

Columbia, Missouri

References cited:

- Keller, W.D., 1977, Scan electron micrographs of kaolins collected from diverse environments of origin—IV. Georgia kaolin and kaolinizing source rocks, *Clays and Clay Minerals*, v. 25, 311-345.
 Keller, W.D., 1982, Kaolin—A most diverse rock in genesis, texture, physical properties and uses, *Geol. Soc. Amer. Bull.*, v. 93, 27-36.
 Van Hise, Charles R., 1904, A treatise on metamorphism, U.S. Geological Survey Monograph 47, 1286 pp.

Minerals & Reactions at the Atomic Scale- High-Resolution Transmission Electron Microscopy

*Mineralogical Society of America Short Course
Hueston Woods State Park Lodge, College Corner, Ohio
October 23-25, 1992 (before GSA Meeting)*

Organizer: *Peter R. Buseck (Arizona State University).*

The goals of the course are to (a) provide a background into the TEM as a mineralogical tool, (b) give an introduction to the principles underlying its operation, and (c) explore mineralogical applications and ways in which electron microscopy can augment our knowledge of mineral structures, chemistry, and origin. Special attention will be devoted to mineralogical applications. We expect to have a modern TEM for hands-on demonstration and exercises. An attempt will be made to examine prepared specimens brought to the short course by participants.

Topics and Speakers: general principles of transmission electron microscopy (*Peter Buseck*); principles I: electron diffraction- SAED & CBED (*John Steeds*); principles II: high-resolution image formation, simulation, and analysis (*Peter Self*); inelastic interaction EDS chemical analysis (*Donald Peacor*); EELS & electron channeling (ALCHEMI) (*Peter Buseck*); non-stoichiometry, polysomatism, and reactions in minerals (*David Veblen*); polytypism & stacking disorder (*Alain Baronnet*); phase definition by HRTEM (*Fred Allen*); diagenetic reactions & processes: clays & shales (*Donald Peacor*); carbonates (*Richard Reeder*); analysis of deformation in geological materials (*Donald Green*); imaging transformation-induced microstructures (*Gordon Nord*).

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Clay Names Quiz

(From the Nomenclature Committee)

Answers from: Mitchell, R. S. (1979) *Mineral Names, van Nostrand*, 229 p.

Answers on page 3

- | | |
|---|---|
| <p>1. GOETHITE is named for</p> <ul style="list-style-type: none"> A. Dutch lens grinder, Piet Goet (1901-1960) B. Found in the path of its discoverer, who tripped on it—hence "goeth before the fall" C. Johann Wolfgang von Goethe, German philosopher, poet, novelist D. Sherry Hite's first husband <p>2. ILLITE is named for</p> <ul style="list-style-type: none"> A. Residue in silver extraction process: argillite — illite B. In homage to disease, a precursor to deathbedite C. State of Illinois D. Founder of the musical team Illi Milli Vanilli (ousted because he insisted on using his own singing voice) E. Product of a sick mind | <p>3. CARYOPILITE is named for</p> <ul style="list-style-type: none"> 1. Upstairs tenant asking for a beer (Cary-op-i-lite, please!) B. Italian surveyor Cary Opili (1888-1954) C. Apprentice in Australian opal mines D. From Greek for <i>nut</i> (brown color) and <i>felt</i> (felted structure) E. Feeble misspelling of "acropolis" <p>4. ANTIGORITE is named for</p> <ul style="list-style-type: none"> A. Movement opposed to blood and dismemberment B. Antigone, a figure of Greek legend C. Locality at Antigorio, Italy D. Someone who dislikes Edward Gorey cartoons E. Igor's father's sister |
|---|---|

