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Collection Name: Climate Change Institute 40th Anniversary Oral

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Description: **4003 Stephen Norton,** interviewed by Adam Lee Cilli, August 27, 2013, in his his office in Sawyer Hall at the University of Maine, Orono. Norton talks about the beginnings of his career in geology; his beginnings at UMaine and the Climate Change Institute; his own research experiences; his contributions to geology and climate science; the reality of anthropogenic climate change; his current interdisciplinary project; and his status as professor emeritus.

Text: 12 pp. transcript
Recording: **mfc_na4003_audio001** 61 minutes

Related Collections & Accessions

Restrictions

Formats Included Document: Original= .docx, Master= .odt, Access= .pdf; Sound: Original= .mp3, Master= .wav, Access= .mp3

Notes

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Narrator: Steven Norton

Interviewer: Adam Cilli

Transcriber: Adam Cilli

Date of interview: August 27, 2013

ABSTRACT: This interview took place in Steven Norton's office in Sawyer Hall. Adam Cilli, a Ph.D. Candidate in the Department of History, conducted the interview. In the beginning of the interview, Norton discussed how he became interested in geology and his early undergraduate and graduate studies. Later, he talked about his first years at the University of Maine (in the department of geology), and he shared some of his experiences with the Quaternary Institute. In the final third of the interview, he described his own research experiences, shared what he believed were his greatest contributions to geology and climate science, and offered his opinions on the climate change debate.

Note: This is the transcriber's best effort to convert audio to text, the audio is the primary material.

Cilli: This Adam Cilli, Ph.D. Candidate in the Department of History, and I'm here in the office of Steven Norton, Professor Emeritus with the Climate Change Institute, and we're here to talk about his experiences with the Institute. So, to start us off, I'm wondering if you can tell me a little bit about the kinds of research you've done.

Norton: It's a very tortuous path. I became interested in geology, the broad topic of geology, when I was about 12 years old in the Boy Scouts. And I was climbing Mt. Washington in New Hampshire and I came across a rock and it had an interesting mineral in it and I didn't know what it was, and I asked my scout master what it was and he didn't know, and so, being compulsive, I set out to find out what it was. And ever since then I've sort of been interested in geology, and I even got my geology merit badge in Boy Scouts. There were two levels of interest. One was, "what is it?" which is very descriptive. But the fun part is finding out "why is it, or how did it come to be as it is." So all the way through high school I was pretty darn sure I wanted to be a geologist, and I didn't understand anything beyond that. I was interested in the Earth. And so I applied to undergraduate schools, and, basically after a good undergraduate education then I would go on to graduate school in geology. I had it all mapped out. I was going to go into industry and get some experience, then go into academia, thinking the experience in industry would be a good thing to do. And a funny set of circumstances occurred in my undergraduate. I got a National Science Foundation Fellowship for all five years at Harvard; worth a lot; nice thing to have had. But at the end of my first year I had nearly flunked out of Harvard because of some social/emotional things that happened to me. And as a consequence I lost my National Science Foundation Fellowship for five years. So I had to "fall back on," and I say that in quotes, the other opportunity which immediately came along, which was to be a teaching assistant in a beginning geology course at Harvard. It's the equivalent of Geology 1 here, or Geology 1 anywhere, it was called Natural Sciences 10.

Cilli: And this was when you were just an undergraduate?

Norton: No, I was a first year graduate student and I flunked out of… not flunked, but did not do well enough to justify me being continued as a National Science Foundation Fellow. And so I became a teaching assistant my second year in graduate school, and I loved it. And I was reasonably successful at it. And I continued as a TA for three more years, and then, when I got my Ph.D., I was put in charge of the course for a year, a sort of post-doctoral assignment where I just had to teach one course and I got a full salary. It was a very nice situation. And then the chair of the department of geology here at the university of Maine… I was working in the Berkshires, western Massachusetts, and I was assigned to him as a field assistant. And I still didn't really know exactly what I wanted to do in geology; I was trained as what we call a bedrock geologist, to understand the kinds of rocks that are part of the bedrock. Not what's on top of the soil, but the bedrock, and the history of it—how it came to be in the condition it's in. Whether igneous rock, metamorphic rock, sedimentary rock; whether it's been folded, faulted, metamorphosed and so on. And so, I worked with Phil Osberg, who was the chair here at the time, from 1964 until 1968, which was the end of my post-doc year at Harvard. Back in the old days, chairs of departments could reach out and say, "We want Adam to be a part of our faculty." Nowadays you wouldn't do that, you couldn't do that; equal opportunity would insist that you have a national search or an international search and that every type of person, every color person, every ethnic group is encouraged to apply. But at that time you could reach out and say, "Steve, we'd like you to come and teach structural geology." That was one of the things I had worked in as a graduate student. And I came here in 1968, in the fall, and I was the sixth member of the department. There were five. And now there are 16 in the department of Earth Sciences. And I continued to do research on bedrock in the Berkshires, and then switched to doing bedrock work in Maine. And after, perhaps, two or three years, I said, "I'm not having fun in my research." And I didn't get a Ph.D. to not have fun. What I was doing was no longer on a steep, steep learning curve and it didn't really excite me, the way I hoped it would. "What else can I do?" And I just naturally gravitated into what I do now, which is what I describe as aquatic geochemistry. I worry about what determines what's in water and how water impacts soils and bedrock. And how water behaves in lakes and streams, and how water behaves when it interacts with humans—spans all the way from natural processes to pollution. And I'd had a couple of really fine courses in graduate school that got me started and the rest was just lots of reading and lots of doing and making mistakes and, slowly but surely, learning the trade and becoming better at it. And that's where my graduate teaching ended up, too, is in the field of aquatic geochemistry, where I taught two graduate courses. I taught one of them a year ago. I continued to love to teach that beginning course, and I taught that up until six years ago. And I always loved it because I felt most students will take only one or two courses in science, and if they're lucky it will be a geology course. And if they're really lucky, that course will set them up to be better able to enjoy what they travel through, and over, and under. Rather than not even seeing what's there and trying to figure out what's going on. That's my job, not to turn them into geologists, but to turn them into curious observers. So that's how I came to be where I am now. And, except for two sabbatical years in Norway, the country, I've spent all my time here and I've had a wonderful time, with wonderful students and a wonderful place to work. And I never called it work; I always went to school every day. I always described it as, "gotta go to school today." That was kinda neat. And I got reasonably well paid for it, so that was kinda nice too. If I go back to… the department was formed… it split off from civil engineering back in the early 60s. And our first chair (and this is a story about serendipity) was Phil Osberg. He's the guy who hired me, so I owe him my whole career. It's just a fork and the road and he said,

"Steve, we want you to go down that fork and come join us." And I did. At the time, in the early 60s, University of Maine was largely a teaching college. I wouldn't describe it as a university. To me a university is a comprehensive establishment that has graduate programs, research, and is very diverse. There wasn't much of that going on. Most people just taught. And they had appointments which said, "You'll teach three courses in the fall and three courses in the spring." You might do a little research on the side but it was never part of your job description. Phil, bless his heart, went to the administration and said, "I want to make a deal with you. I want my new faculty to be 50% teaching and 50% research. And they will do the following and be held accountable for it. If they don't do those things, then they're gone." And so when I came in, and everyone subsequent to me, and a few people before me, it was with the understanding that you will teach a couple of undergraduate courses and you will teach a couple of graduate courses; no more than three or four total, and then you're gonna seek and be successful at getting outside resources to support graduate students like Adam. And that's the way you'd be judged; and of course produce the peer reviewed publications.
Cilli: Was there a set number of publications you needed?

Norton: No. That would be way too artificial, because a publication every other year in one journal is just as important as three publications in so-so journals every year. Case in point, I had a Ph.D. advisor, who perhaps had 20 publications in 35 or 40 years, but he was in National Academy of Sciences by the time he was about 45 because the first ten were so seminal to the discipline he represented; I mean they were earth-shaking articles. Much more important than just going out and describing the geology that's here in Maine. That's important, because that's the way bigger concepts evolve, is putting the pieces of the puzzle together. But if you just had a few pieces of the puzzle, and you only had one every three years, that's not gonna do it. You either have to have a really big idea every three years or lots of little ideas.

Cilli: And for the listeners the National Academy of Sciences is, what, the most prestigious scientific organization?

Norton: The most prestigious scientific organization in the United States. Every major developed country has one. It is more or less recognition of international status and a long career of very high productivity.

Cilli: About how many scientists are admitted to…

Norton: I would say less than a tenth of a percent. I only know of two in the state of Maine, and one is George Denton, in our department. And I think he was the first person in the state of Maine to be elected to the National Academy of Sciences. And you are elected by your peers, and there's probably a little bit of political aspect to it, but it's, I would say, probably 95% of "look at what this person accomplished, in terms of his or her contributions in their discipline." So, Phil made this arrangement and that's the set of conditions I came into the department with. I was the sixth member. And we had Phil Osberg and Harold Borns, whose name comes up again and again and again. He is the grandfather of the Climate Change Institute. Grandfather because the Climate Change Institute came from the Institute for Quaternary Studies, which Hal founded. But there's a serendipitous story there, too. Hal Borns was trained at Boston University, with a Ph.D. in bedrock geology. That's not what he does for a living, either. So, in a sense, I'm parallel to Hal. He mapped geology in Maine, and did it well. And I think he got to a point where he said, "I'm not having fun." So he said, "I wanna go back, as a post-doc, and get retooled as a quaternary geologist." And he did, and he went to Yale. And you can confirm that by checking on his CV, but I think that's correct. And he studied with somebody named Richard Foster Flint, the premier glacial geologist in New England. Well, Richard Foster Flint was getting close to retirement. And when Hal came back here, with this new training, and this new vision, new glasses, he said, "we have an opportunity, at the University of Maine, to occupy a niche which, in the very near future, is gonna be empty." Harvard had gotten rid of its quaternary geology. Yale was losing its quaternary geology. No other college or university in New England had more than one or two people teaching quaternary geology; in glacial geology, in glaciology, or anything close to it. So, he said, "we have an opportunity to occupy a niche." The nearest competitor was Ohio State. So Hal said, "let's go after that niche. It's a place we can compete. We can't compete with Harvard in Petrology, we can't compete with Dartmouth in something else, we can't compete with Yale in something else, but here's a niche." And it was his vision and his persistence that enabled us to convince the administration that, in the pattern that Phil Osberg had established, if you give us some resources, this is what we'll produce. And we'll be held accountable for it. So, the next year, with this permission, we went out and got George Denton. He was the first hire. And he was a wonderful hire. He's been a fantastic teacher and a fantastic scientist. He's produced fantastic students, both undergraduate and graduate.

Cilli: So, you say "we." So, that implies that by that point you had already become involved in the Quaternary Institute.

Norton: Well, the department made the decision.

Cilli: So, pretty much by default all faculty in the department of geology became…

Norton: No. This was going to be a separate Institute. The original member was Harold Borns. And then Denton. And then several other people were identified on campus. But more importantly we said if we fill out the disciplines appropriately we're gonna have to go after a paleoecologist (and that's George Jacobson), we're gonna have to get another aquatic paleoecologist (that's Ron Davis, over in Botany, which no longer exists; it's now part of the School of Biology), and so on. And so, quaternary geology is not just geology. It's a multidisciplinary area. It came out of thought processes that occurred in geology, and of the group of six of us who said this is the way to go, only one ended up in the Quaternary Institute right away, and that was Hal. I was doing the kind of research (after about three years here) that was totally consistent with the Climate Change Institute. To me, climate change is both physical and chemical climate. And the chemical climate of earth has changed, over the short-term and over the long term. And then when water sheds are glaciated and then deglaciated, things happen over the next five to ten thousand years that are controlled by my kind of chemistry. The lakes change in response and the soils change in response. So, the evolution of our ecosystems is something that I was working on, but it wasn't identified as being central to the original mission of the quaternary institute. So, the Quaternary Institute grew. And it was highly successful because it was very selective, in terms of getting very good people and holding them accountable. And a few people came and didn't fit, either because they weren't productive or they weren't part of a good working group and they left, in most cases of their own free volition. In a few cases they were told to leave. And those decisions are made by faculty, and administrators. And it just grew, and grew, and grew. And I was working with people in the Institute all the time. But I never felt the need to be a member of it, because at the University of

Maine we're small enough, friendly enough, so that I can go downstairs and work with anybody; or I can go in the next building and work with anybody. Or I can collaborate with somebody in civil engineering, which I do.

Cilli: Were you involved in some of the early brainstorming sessions, say with Hal, about forming the Institute itself.

Norton: Oh, yes. That was an entire collective effort of the department of geology.

Cilli: But some of whom, like you, knew that you would not be in that. But you participated in…

Norton: I never even thought about it, as being important. I was a geologist; I was in the department of geology; I could do my thing, and if we could build this other program, and it has more dimensions than just geology, that's fine. I wasn't covetous of the resources, and I wasn't afraid for my own position. It just seemed like a good thing to do. And everybody agreed on that, and everybody got behind it 100%. And Hal, he was the quarterback, and he carried it, and just did a magnificent job. Figuring out how to organize it. That's one of the strengths of the Climate Change Institute is how it's organized. Every member of the Climate Change Institute has a mother department. They're either in geology and CCI or they're in chemistry and CCI or they're in biology and CCI. Everybody has a mother department. They're all joint appointments. Paul Mayeski, the current director, is a member of geology. And when you get tenure, CCI, the Climate Change Institute, does not grant tenure; the mother department does. So, people get tenure in a department. And that was a brilliant thing to do, because that keeps the departments engaged in the success of the Climate Change Institute. We want our people to succeed, and if they're in the CCI that's great. The CCI has people on what's called the peer committee, which helped make the judgment that, you, Adam, are judged worthy to continue or not. Both parties have a vested interest in the outcome of the success of you, me, all the other people in the Climate Change Institute. It was a brilliant move on Hal's part to design it that way. If you set up a separate Climate Change Institute and it has its own faculty lines, its own salaries, then it becomes a battle. We're not going to let you use our geologist over there. We want our geologist. But shared works. Shared works. And that was the genius of the organization. And it's worked very well, indeed. And not all universities figured that out. Anyway, moving forward in time, we went through several directors, and I say that in a positive way. George Jacobson was a director in the Institute for Quaternary Studies, and George Denton served, Hal served, and I hope I'm not leaving out somebody from outside geology, but it's traditionally been geology. Then, I don't remember exactly when it was, we reached out to other universities. Paul Mayeski had been here, working as a post-doc with George Denton. And Paul changed his career, too. He was a glaciologist, I think, or a glacial geologist; not an ice core geochemist. He went off and did some time at, I think Ohio State, and then went of the University of New Hampshire. And he built a very successful program, and they were emphasizing something there that we didn't do at all. They were emphasizing ice core chemistry, from coring sites in the Antarctic and Greenland. And Paul had headed up some very important projects, international projects. And he had another dimension that he could add to the Climate Change Institute, or its predecessor, that we didn't have, and we had dimensions here that they didn't have at UNH. So, let's get together and talk about exchange of faculty, exchange of students, and cooperating on research. So, one serendipitous day, George Denton, George Jacobson, and I (I was chair of the department at the time, I think) we went down to UNH to spend a day with Paul Mayeski and his group. And there were presentations about our program, their program, we got a tour of their very nice facilities at UNH. And it was clear that they had some dimensions that we didn't and vice versa. So, we started collaboration, and it was very positive. And that night we went out to dinner, and I'll shorten the story a little bit… basically, Paul said, "There's only one place else that I would consider going, and that's to Maine." I went and told the two Georges, and a year or so later Paul was here. And, again, it was because of a change in attitude at the University of Maine that, we can compete; we can't compete in all fields, but we have some resources, and in this case we put those resources into bringing Paul here, and several other scientists, and making it comfortable for him to do the kind of science he wanted here, and the rest is just a very positive history. He's continued to build the diversity of the Climate Change Institute and strengthen it and he keeps adding dimensions to it, with concurrence of all the CCI people. We have people from at least a dozen departments; two or three engineering departments, computer science, and biology and geology, on and on, through the university…. That about brings everything up to speed, and it was actually after Paul got here that Paul looked at me straight in the eyes and said, "How come you're not a member of the Climate Change Institute." I said I am in everything but name. I work with half a dozen people in the Institute. And he said, "the procedure is, you have to submit your CV, which says what you've done in your life, and then you give a public talk, and if you don't fumble that one too badly then you are invited to be a member of the Climate Change Institute, with all the rights and privileges thereto. No money. No transaction. But it's good for me to have that affiliation. I can say I am a member of the Climate Change Institute, and it's probably a little bit good for them to say that we have a geochemist on the staff who does the following kinds of things, and he's a productive guy, and so on. So, it's a mutually beneficial thing. And a lot of people, like me, have joined CCI simply because we do have something we offer to them. And, so it's worked.

Cilli: So, I understand that the Quaternary Institute (and now the Climate Change Institute), one of the ways it's changed since it first began is that it simply grew. There are many more members now. But I'm wondering if you can talk a little bit about how the scope of inquiry has changed.

Norton: Well, the original scope, from its infancy, was glacial geology. Which is the study of the formation of and distribution of land forms and materials related to ice. And then it expanded when we hired a glaciologist, which is a person who deals with the physics of ice and the movement of ice. And ice's ability to move materials. And then we added computer modeling, because ice movement is not just ice flowing down hill. Very intricate physics, almost down to the molecular level. And that lends itself to computer analysis, so you can almost predict how glaciers are going to move, and how fast their rate of movement, and their rate of accumulation, and so forth. But we also didn't want to ignore the terrestrial part of it; not everything is ice and snow. So, out in front of the glaciers you have dynamic landscapes. And they have vegetation which is evolving, and so you have paleobotany, which is George Jacobson, you add aquatic paleoecology, which was Ron Davis, and then you add geochemistry, and I can look at chemical changes through time by looking at lake sediments, and then you add ice cores, which tell you about atmospheric chemistry and the circulation of the atmosphere, and the source of pollutants in the atmosphere and pretty soon you start adding engineering expertise, and people start saying, well, if the climate is changing, that means not only is the flora changing (the plants) but plants support the food chain and so all the animals are changing. So then you get into people who worry about migration of organisms and birds, insects, and disease vectors. For example, we have ticks that are now migrating up the interstate highway into Maine, with their various diseases. And all of this is related to climate change. So, it's getting more and more holistic. Climate change is the biggest problem our species faces. And so, understanding, not just the fact that climate changes (that's pretty easy to do; just measure the temperature every year, take long term averages, or look at the ice outs on lakes and see that ice is going out earlier and earlier every year, or look at tree growth or migration of tree species). But we're right in the middle of all that. We're at a point where we are going to start dislocating where we grow food, where we have enough water, and so on. All the limiting resources for humans, and that means we're getting economists involved, we're getting climate modelers involved, we're getting the social side of things involved. We know historically from archeology and anthropology that humans have suffered as a consequence of climate change. That wasn't really well-recognized several decades ago. But now it's pretty clear, humans over time have been subject to the vagaries of natural climate change. But now we're into something, apparently, that's very different and faster. And, so, the Climate Change Institute, I suspect, is going to continue to grow by adding selective people who are interested in the interaction of some aspect of human species and the natural world. And the only worry I have is that we get so big that we start to feel amorphous. One could argue that most of the University of Maine could be reorganized around one fundamental problem, and that's climate change. It is such a big thing, down the line; Columbia University organized their undergraduate curriculum around Earth. Not every course… but a lot of stuff could be related to Earth. Well a lot of stuff is gonna be related to climate change. Everything we say, everything we do, how we grow things, how we travel. It's all going to be linked closely, or maybe tentatively, related.

Cilli: Outside the scientific community, the human role in climate change seems to be very much still up for debate. I'm wondering if you can comment on why that might be the case.

Norton: My answer for that question is the same as the answer for any situation where somebody has either beliefs, based on their history or an ulterior motive. I think it's sad that there might be people whose ulterior motive is to be in denial about climate change—because of economic arguments, because of them personally or somebody they work for or the people who vote for them. But I believe there are people like that; don't ask me to identify them, but that's true. But the other part is your own personal experience, your own education, makes it hard for you to accept something that runs counter to your experience. And I go back to my undergraduate teaching, when we'd talk about evolution, for example, and there are people who don't believe in evolution. Fundamentalists do not believe in evolution, and yet their position is not testable. But evolution is testable. You can ask questions of evolution. If evolution is true, then we should be able to make the following observations. The absence of being able to make that observation doesn't mean you're wrong; it means we can't make that observation yet. But we keep seeing more and more evidence that evolution has occurred, by any criterion we want to come up with. And we can see evolution occurring in the laboratory: antibiotics, the development of antibiotic-resistant-bacteria, these are things happening at a speed sufficient for us to observe them. So evolution is pretty darn clear, and there's no other explanation that comes across that works. So there are two kinds of things that make people not able to accept a new idea. I teach about radioactivity to students, because I thought it was and important social problem. People are afraid of radioactivity. By the end of a week we had talked about the periodic table and the fact that there are radioactive nuclei that occur naturally. You've got radioactive carbon in you:

carbon 14. You've probably heard of it. We use it to date, to age, organic materials. You have radioactive potassium in you. Anything with radioactive, or radio, in it sets off alarms in people, because they've been told about how terrible radioactivity is. Well, in the form of a bomb it is, or in the form of accumulating a lot of unnatural radioactivity, it is. There have been thousands of people killed by radioactivity, thousands. But there are 40,000 people killed each year in car accidents in the United States, but you don't hear about people being terrified to drive a car. And you can't always control the other guy. You might be a good driver yourself. So, the only way to get people comfortable with climate change if they're not scientists and they're in denial, is to present them with data that they can grasp, perhaps with your help, that undeniably leads to the conclusion that it's getting warmer. Isotopes, for example, or mean annual temperature for forty or fifty years. From this year to last year, that's not climate change; that's weather. Climate change is long-term. There's a lot of noise in the climate; there's normal variation. The last few days have been abnormally cold. If we had a whole summer like these we'd say, global warming is over. No, it isn't. That's just one summer. But if you had a fifty year average and the slope was getting warmer and warmer, on average, then one has to say, in general the climate is warming.

Cilli: I think a lot of people would say that, "Well sure, there is global warming, but humans didn't cause it; it's just a natural, cyclical warming."

Norton: Now that's more rational, but there are still people who say there is no warming. Assigning a portion of blame, to natural variation, versus you and me, that is more problematic. And then you get a little less secure, based on the ice core chemistry and what we see about rates of change of temperature, it's changing rapidly right now. It's warming rather rapidly. The five hottest years in the last hundred years have been in the last ten years. It's getting warmer, faster. But that's also happened naturally, too. There was a period of time, about 11 thousand years ago… called the Yunger Dryas, when the climate just prior to that was not too dissimilar to what it is now. In the space of maybe a short a period of time as ten years, we climbed into full glacial climate, full glacial. And when that happened, a lot of biological processes were incredibly shocked and shut down. You have forests which die down, like on Mount Desert Island, which you've seen in your four years here. We went from a forest to tundra vegetation. And back to forest a thousand years later. And going into the forest and coming out were very fast. So, fast change is not unprecedented. And so, the argument that it's changing fast now doesn't quite enable us to say that humans are responsible for all of it. But then you can fall back on physics. Carbon dioxide, all the laws of physics that you can read about. Every physicist would agree to, say, if you increase Co2 in the atmosphere that increases the ability of the atmosphere to absorb infrared radiation. That warms earth. If you increase it a hundred parts per million. If you would just hold it there, then the earth would warm up to a certain level and stay there. But Co2 is increasing. At about a half a percent per year. And the laws of physics say more infrared radiation must be absorbed. And that means Earth's atmosphere warms. That means the surface of earth warms; that means that the surface of the oceans warms. That doesn't mean the climate is going to cool or warm everywhere, because he is redistributed on the Earth's surface. So, a blanket statement that more Co2 is going to make everybody warmer isn't correct. But the earth will warm. That doesn't mean some places won't get cooler but on average earth *has* to warm. The laws of physics dictate it. If the earth's atmosphere gets warmer more water evaporates. If more water evaporates, it just can't accumulate in the atmosphere. It has to precipitate. So if there's more evaporation, then there must be more precipitation. And so we would expect the amount of precipitation to change on earth. On average it will increase. And the intensity may increase because, when we evaporate water, it takes energy to do that. When you precipitate water from the atmosphere, that releases heat. And so there's tremendous heat exchange going on and that exchange of energy (heat) is accelerating because of the warming of the atmosphere. There are certain laws of physics that are undeniable. It's not just Co2; it's not just water. It's dust; it's contrails from planes; it's volcanism; it's changing the surface of the earth's color. While taking off the forests of the earth, you change its color and its reflectivity. If we could make the whole earth white things would cool down. If we can get rid of all the ice on the poles it will warm up. So there are lots of things playing into the temperature… some of which enhance the effects, some of which diminish the effects. Now those arguments are a little harder for the average layperson to grasp. But all of those concepts can be taught in high school. And there are teachers out there now that are touching on all these concepts…. So changing people's minds who are not scientifically comfortable with, or don't want to believe in, climate change is difficult. And it's a matter of time. How much proof are we gonna need that it's warming. In your lifetime, and maybe in mine, we're gonna lose all the ice during summer across the North Pole. And you turn a huge area of earth… there's a globe here. [points to arctic circle on a globe] Most of this area is covered by ice during the winter. And in the summer it shrinks. And the amount of shrinkage last year was the greatest it's been since we started recording it. And it was thinnest. This was all floating ice up here. There's no land up here. The arctic ice is nothing but floating sea ice, and it gets up to three or four meters thick, and then it shrinks down in the summer and shrinks in its areal extent. When that disappears, that means a huge part of the globe goes from white to blue. Blue absorbs. I mean, the blue ocean absorbs more heat than ice. Ice reflects most of the incoming radiation. So that's an amazing experiment that's going on. When that happens, my guess is the circulation of the polar area is going to change rather dramatically… those are the catastrophic types events that may eventually force people to say, "Oh, gosh. I guess climate is warming." And it's too late then. Too late. It may be too late now. Most scientists would say, climate change is here, and we're not going to convince people to scale back their carbon emissions to the atmosphere by 50 percent, particularly India and China, both of which are developing very rapidly. So, Co2 is going to continue to increase. Even if it didn't increase any more, the emissions, Co2 in the atmosphere, will still go up at ½ percent per year. Even if we froze emissions, we still exacerbate the problem for the foreseeable future. Decades at least.

Cilli: Before it would level off.

Norton: Before it would level off and get into a new equilibrium. Everyone that I know of in the Climate Change Institute, sort of understands this; they're concerned about it, and some of us are trying to document past climate. And in so doing you are better able to predict future climate. It involves, as you've brought up, many, many, many, many disciplines. Any one discipline by itself is just going to discover more and more evidence of the same kind. But with groups of people working in diverse fields, you can all the sudden start to assemble the diverse pieces of the puzzle.

Cilli: I'm wondering if you can give me an example of some of the interdisciplinary work you've done.

Norton: Well, I'm still involved in one. And since that's right in front of my brain I'll tell you about it. I've been working on a lake called Sergeant Mountain Pond; it sits atop Sergeant

Mountain in Acadia National Park on the coast of Maine, at an elevation of about eleven-hundred feet. If you roll back the movie up to 20,000 years ago, all of Maine, including…the Gulf of Maine, was covered with ice. And on the coast it was at least a mile thick. When the climate started to warm, for natural reasons, about 25 to 22 thousand years ago, the ice margin started to move forward as ice calved into the Gulf of Maine and melted. And it melted on the surface, and the ice sheet margin moved northwards and it thinned. So the pancake of ice over Maine moved north and it thins, and thins, and thins. On the coast, Cadillac Mountain and Sergeant Mountain Pond were the first to emerge through the ice. Sergeant Mountain itself would have been what's called a nunatak, sticking up through the ice. Here's this little pond right at the top; so it's Maine's first lake. We took a core from that lake in 2007, and the core was about 5 and a half meters (that's about 17 or 18 feet) of mud. You would call it mud, but I would call it a tape recorder. Because each year about half a millimeter of sediment is deposited, layer after layer after layer. And in that half-millimeter of sediment is recorded…climate. And the climate can be reconstructed by looking at the pollen in that little slice of sediment. And George Jacobson looked at that core with me and he found that, for about the first 3½ thousand years, from about 16,000 years ago (which was the bottom of the core) to about 12,500, it was tundra. That's colder than here now. That's like northern Canada. And then all of a sudden the forests appeared. And about 12,500 years ago the forests shut down, because of this younger dryas event that I spoke of, the rapid climate change for a thousand years. The temperature went down 5 to 8 degrees centigrade; and stayed, average temperature…. The average temperature in Maine is 6 degrees centigrade. So if it went down 6 degrees, that means the average temperature was zero, freezing. Well that's what happened, and we see that in the core, we see it in the vegetation, as reflected by pollen. But we also saw it in terms of chemical changes that occurred in the sediment that are related to the presence of the forest. So, as the climate warms, the soils are changing, the vegetation is changing, and the chemical signals in the lake sediment are changing. And I can pick up the cold snap, the thousand-year cold snap, and back into the forests again, and all the processes that had occurred before the younger dryas now start to happen after the younger dryas and we see the evolution of the chemistry of the watershed: how the soils are developing, how the trees are changing. So that's an example of the kinds of interdisciplinary work that I've done. And another person involved in that is Jasmine Saros, who's a member of the Climate Change Institute. She studies algae in lakes. She looked at the algae in that core, and at the beginning of the history (17,000 years ago when it became ice-free) the first diatoms that were there were growing in water that had a lot of phosphorous and a lot of high-Ph, which means not much acid, very alkaline. Within a few thousand years the diatoms diatoms that grew with less phosphorous in the water and also lower Ph, more acidic. And all of that is reflected not only in the diatom record in the core, which she studied with us, but also in other chemical indicators in the sediments. And I just completed a study now, of the same core, looking at the suite of elements called the rare-earth elements. And it turns out that there's one element that controls the abundance of about 17 other elements in the core—aluminum. And aluminum is an element you're aware of; you've heard of aluminum ladders and aluminum screens. Well, same kind of aluminum, except it's in rocks. And aluminum has the ability to control phosphorous and its abundance in water and it controls a whole group of elements, called rare-earth elements. And we can study all these things coming up the core, and their all behaving together, and their all drive by the presence and absence of trees. And the presence and absence of trees is controlled by climate. So it all fits together. It's an evolving ecosystem. And this happens all over the northern hemisphere where we have had deglaciation. Starting 15 or 20 thousand years ago, depending on where you are. And so, all the ecosystems in Maine, everywhere north that the glaciers got to, are evolving fairly rapidly. Not in your lifetime or my lifetime, but certainly in five lifetimes. We can see changes going on that are natural, but then superimposed on that we can see anthropogenic changes, such as air pollution. And I could study all those, in that same core. And if I could draw, in sound, a graph for your recorder, if you could visualize the amount of led that is deposited in the lake sediment over the last 16 thousand years, it's been fairly constant. And then all of a sudden a hundred years ago the amount of led that's been deposited in that sediment in that pond increased to fifty times what it was—fifty times. And that's because of tetra-ethel led in gasoline (which you're not familiar with; we use different additives now for gasoline, so you're engine doesn't knock). And it's also due to the burning of coal and smelting of led ores for batteries. In 1970 to 1980 we took a series of cores, one of which came from Sergeant Mountain Pond, and it showed a tremendous increase in led. That's when Senator George Mitchell, from the State of Maine, and Senator Muskie, passed the Clean Air Act and the Clean Water Act. And the result was, the recognition that what we put up in the air comes down. And they said, "We must implement measures that reduce the amount of led and other things going into the atmosphere." We did, and now the most recent core that I spoke of, that we took back in 2007, shows led rapidly declining in lake sediment. So we can use lake sediments to document recent changes in the atmosphere as well. And that's all from one lake.

Cilli: Interesting. Well, that's all the questions I had, but before we conclude the interview I'd like to give you a chance to maybe add something that I didn't ask you about.

Norton: From my perspective as a researcher, what we learn about the past enables us to do several things. One is identify when things are going wrong. And there are various biological and chemical indicator in sediments, my research area, that enable us to identify when things are going wrong. If you just take a photo of what's happening today, that's what's happening today. If you take a photo of what's happening today, that's what's happening today. You don't know whether you're getting better or getting worse. If you have this time perspective, you can say, "things are getting better or things are getting worse." It also enables you to see processes that are linked. Inadvertent changes occur when you and I tinker with the atmosphere or with a landscape, and we can see those things, too. We get a better feeling of how things are connected, so we can anticipate what's going to happen better. They may not have happened yet, but we get the linkages. If we get more precipitation, we haven't had that experiment yet in Maine. What's gonna happen? Well, we can get some insights by either looking at one site and its variation and see what happens in the short term and then predict what will happen in the long term, if you have a persistent increase in precipitation, or a decrease. So it's a learning tool. It teaches us about remediation to climate change. On an even more personal basis, though, doing science is really fun. It's really fun. Some of my most exciting moments have happened in the last ten years when, by virtue of making a lot of mistakes and having a lot of experience, all of a sudden pieces of the puzzle fall together and you think "that's the way nature works." And that's a publication, of course, but more importantly it's so satisfying to figure out how the puzzle works. And sometimes nobody's gonna use that right away, but sometimes it gets picked up right away and becomes a very useful tool. I mentioned aluminum. Aluminum and water controls phosphorous and water, and we discovered this about ten years ago here. And it's now generally understood pretty much around the world. And it explains why some lakes have lots of algae and others don't. And you grope around for an answer and all of a sudden a piece of the puzzle falls into place. So you have a solution to at least explain it. Now you can use that information to maybe design remediation, which is done with aluminum. We weren't the first ones to use aluminum for remediation. Engineers discovered that in sewage treatment plants. But nobody suspected that it was happening naturally. And those kinds of moments just supercharge you. It's such fun to unravel something like that. Now I do it for nothing. It's fun.

Cilli: You had mentioned before I started the recording that even though you're retired, you're obviously still an active researcher and it was just last year that you taught a graduate seminar.

Norton: Yes, well a course. A formal course. And, teaching is fun. It's exciting to see people pick up something and all of a sudden start using it in a constructive way. The young lady who just walked in, Bess Kauffman, she recently got a Ph.D., she went through my geochemistry courses and just to watch her all of a sudden start using the kind of thinking that you need to understand process is very exciting. It's very positive feedback for a teacher. I sometimes wonder how some teachers who teach the same thing over and over again and get a real thrill over it. And then I realize, well, for them, maybe teaching French well is just as exciting, just as rewarding. It just so happens I love geology and I love figuring out how nature works, and other people are into other kinds of creative activity: art, music, philosophy, English literature, whatever. Everybody has their little gig that they do and I really feel very privileged to have spent my career here, actually getting paid for having fun, when you think about it. I mean, it's hard work. As a younger faculty member I probably worked 60 hours a week year after year after year. Now I work 20 hours a week, so maybe on average I worked 40, so that's just about right I guess. But I really feel privileged to have done something all my life that's been just plain fun. Sometimes when you're on a few committees it's not fun but that goes with the territory. And seeing bright young Ph.D. students like you, who are involved.

Cilli: Well, thank you. I'll go ahead and stop the recording now.