The AEL AMS webinar series presents: Radiocarbon and Canadian Archaeology

[Carley Crann] So, welcome this is the third webinar. First, we covered radioiodine then actinides, and now we're on to radiocarbon and archaeology. There will be more webinars, and there will be more radiocarbon webinars so if you have any suggestions for future topics please feel free to email me or Christabel and we can add that to our plans for the fall. With me today as co-host I have professor Meghan Burchell from Memorial University. Meghan is an associate professor and director of the Applied Archaeological Sciences Lab at Memorial University. Her research uses sclerochronology and geochemistry to understand long-term human environmental relationships. Meghan will be introducing our speakers today and moderating our question sessions, so go ahead Meghan.

[Meghan Burchell] Thank you everyone for joining us today. As Carley mentioned I'm Meghan Burchell from Memorial University and I'd like to start our webinar series today by sharing with you the land acknowledgments from the University of Ottawa where Carley is coming from today and from Memorial University where our speakers will be coming from today. We pay respect to the Algonquin people who are the traditional guardians of this land we acknowledge their long-standing relationship with this territory which remains unceded. We pay respect to all indigenous people in this region from all nations across Canada who call Ottawa home. We also respectfully acknowledge the territory in which we gather as the ancestral homelands of the Beothuk on the island of Newfoundland, as the ancestral homelands of the Mi’kmaq and Beothuk. We would also like to recognize the Inuit of Nunatsiavut and NunatuKavut and the Innu of Nitassinan and their ancestors as the original people of Labrador. So our first speaker today in our series is going to be Dr. Alison Harris who is a postdoctoral fellow at Memorial University working under the supervision of Dr. Vaughan Grimes. She's investigating infant feeding practices among Newfoundland settler communities using stable isotope analysis of dental collagen and amino acids. So, for each one of our talks today we have about 15 minutes for our speakers, followed by five minutes of question and answer where we welcome you to use the chat function or turn your microphone on and then at the end of our three presentations we've left some time aside to have discussion and questions. So without any further ado, I'll introduce Alison's presentation about marine correction and the importance of radiocarbon and interpreting past diets.

[Alison Harris] Thank you Meghan. Just one moment; bear with me, please.

[Alison Harris] Okay so my presentation is titled oops. It's not entitled oops; it's entitled how to date a pescatarian: Calibrating radiocarbon dates from mixed marine and terrestrial consumers. So, this was a big problem that I had during my graduate research - it's not really so much of a problem now because I work with historic populations so I know that they had to have died within at least the last 300 years; which is about as good as we can get with radiocarbon calibration error anyway - but during my graduate
research, I was studying hunter-gatherer populations, so specifically the Beothuk and their ancestors and the Dorset Paleo-Inuit and with those situations or with those archaeological contexts we do have to do a lot of radiocarbon dating of human remains and we did this with the permission of local indigenous populations. One of the main issues that we run into is that we have to calibrate the radiocarbon dates against two radiocarbon calibration curves, so Marine20 and IntCal20 - so the terrestrial and the marine curve.

[Alison Harris] So, just a brief outline of the talk today: I'll spend a little bit of time describing the problem, and then I'll go into a bit more background into what we're actually trying to date. So, this is bone and tooth collagen and the way that these tissues actually incorporate carbon from diet is really really important when we're trying to consider how to actually calibrate radiocarbon dates of collagen. Then I'll present sort of our main solution to this problem which is using diet from stable isotope analysis of collagen and then I'll give an example from my own research of how I've done this looking at Paleo-Inuit putative dogs in Newfoundland.

[Alison Harris] So, cultural adaptations are of great interest to archaeologists because they often come with, or are characterized by, specific tool technologies and the development of certain social organization systems. Just to preface most of my research has been conducted in the eastern Arctic and subarctic which includes Newfoundland and then also a little bit of work down in Atlantic Canada, so I can't really speak to any of the experiences that archaeologists have had working on the west coast of the country because I know preservation conditions are often quite different there but I think that Marisa will be taking this up a little bit in her talk. But, in the eastern Arctic and subarctic we're quite limited in terms of what analytes are actually available to radiocarbon date. So, there's driftwood but this is plagued by the old wood problem, so we don't really know how long a driftwood has been in circulation for. There are the bones of terrestrial animals, but in the case of Paleo-Inuit sites these are often quite rare. More commonly, we find the bones of sea mammals, fish, and shellfish, and then much more rarely human bone.

[Alison Harris] So, why don't we date human bones from archaeological sites, or from coastal archaeological sites specifically? And I guess more generally, why aren't human bones incorporated into sort of larger absolute chronologies for sites? The problem is really about these two sources of radiocarbon that are present in the environment. So, if you have prior consultation and permission obtained from local descendant groups then you can proceed with radiocarbon dating of human bone, but then you're of course confronted with this problem. The problem can be traced back to the actual abundance of 14C that's present in marine environments. So, they tend to be depleted relative to
atmospheric sources of 14C, or rather the atmospheric source of 14C, and this results in an offset of about 400 years. So, if you were to date contemporaneous samples from the marine environment and the terrestrial environment you would find that the marine sample would be on average about 400 years older. Now, of course there are local deviations that relate to upwelling, ocean currents, how deep the body of water actually is, and those are termed the delta-R value. So, the delta-R really does need to be determined on a case-by-case basis, and I won’t really be dealing with that very much today except for where I’ve estimated it for my own case study at the end of the talk.

[Alison Harris] So, to solve the main problem of mixed diets we first need to understand how carbon is actually becoming incorporated into collagen. So, bones are composed of protein and a biominal called hydroxyapatite. The protein component is largely dominated by type 1 collagen. So, this is a triple-helical protein. It contains a lot of glycine, quite a lot of proline, and then the hydroxylated form of proline. It’s found bundled into these sort of fibrils and the carbon and nitrogen atoms that are actually in those fibrils are largely obtained from diet.

[Alison Harris] So, if we’re thinking just about carbon, it’s been calculated that about 75 percent of the carbon atoms in collagen actually come from dietary protein; and, if you’re interested in reading about this further there’s a great paper by Ricardo Fernandez which is from 2014, and Carley I believe has put together a list of references. So, that is included in her references.

[Alison Harris] So, all the nitrogen atoms also come from dietary protein and the way that we can understand this, since we’re particularly interested in carbon, is to consider how macronutrients are broken down [sound cut out for 8 seconds] and how they actually join to amino acids or constituent atoms to form new compounds. So, with bone collagen we’re getting proteins broken into amino acids which then find their way into collagen. With carbohydrates it’s a bit more complicated, far fewer carbon atoms from carbohydrates end up in collagen, but it does form much of the carbon skeleton for biominal and tooth enamel, and then the carbon in dietary fats is often found in the lipid but that, analytically, is very very difficult to access.

[Alison Harris] So, multiple sources of 14C. Foods from marine and terrestrial environments contribute multiple sources of 14C to an individual's diet-

[Alison Harris] Just one moment, I just realized I can only see half of my slides. There we go.

[Alison Harris] So, marine fluids are depleted in 14C (which I discussed earlier) and people and domestic animals - like animals that would be dependent on humans for their food so dogs, rats (in some cases), cats, pigs (in most cases) - all of these individuals and species who are consuming marine foods would
actually date older than they actually are. But, luckily before we date a sample we can conduct stable isotope analysis to estimate what the diet was of that individual.

[Alison Harris] So, there are two benefits to conducting stable isotope analysis before you do radiocarbon dating, and I know in most radiocarbon labs - including the Lalonde lab, I believe - these two analyses are actually paired together. So, if you get a radiocarbon date a fraction of the sample will also be taken for stable isotope analysis. So, stable carbon and nitrogen isotope analysis itself will inform on diet because the collagen is composed of dietary carbon and nitrogen. And then elemental analysis - so the weight percent of carbon and nitrogen - in a combusted sample can also yield information about collagen preservation because there are parameters that have already been laid out - and they're constantly being refined, every couple of months it seems - that can act as a guideline for how much carbon, how much nitrogen, and then what the ratio of those two elements should be within a well-preserved sample.

[Alison Harris] So, how do we use carbon isotope values to estimate diet? Stable carbon isotopes can be used to distinguish different photosynthetic pathways, and then they can also distinguish between terrestrial and marine foods. So, I think this part is so cool. So, C3 plants are actually really really inefficient photo synthesizers, and because of that they have this large fractionation effect, and they tend to have much lower delta-13C values than other types of plants. So, we're talking like minus 25 to minus 30, and then the animals who eat those plants also have pretty low carbon values. C4 plants, because of the time period and the environmental conditions in which they evolved, they're much more effective photo synthesizers than C3 plants, and as a result they have a smaller fractionation effect, and they have higher stable carbon isotope values. So, minus 9 to minus 15. Now obviously, C4 foods are not really a big problem in the Arctic, or on the east coast of Canada, or the Atlantic but they're an interesting endpoint. What we're actually really concerned about today is, of course, the carbon isotope values of marine foods. So like C4 foods, marine plants don't tend to fractionate the carbon atoms very much, or the carbon isotopes very much, and they also have higher carbon isotope values. Usually you see like around minus 12 for a seal, minus 13; and when you compare that to C3 plants, which are the other dominant source of carbon in these Arctic and subarctic environments there's quite a difference. So, the low minus 20s to the low minus teens.

[Alison Harris] And another way that we can estimate diet is using nitrogen isotopes. So, nitrogen isotopes can help us figure out where an individual falls in the food chain. They increase by about three to five per mille between trophic levels. That's usually the number that's given, it could be broader than that. It could be from two to six per mille, just depending on what experimental research you use or that you look at, but most people tend to assume three to five per mille change. As marine environments are more complex, they tend to contain more trophic levels and thus if you look at an upper tropic level marine carnivore, like a harp seal, they would have the highest nitrogen isotope values.
And to give an example of how radiocarbon and diet can be combined to give sort of a richer analysis, I want to first discuss an example from a paper that has always been one of my favorites. So, I'm sure many of you are familiar with the town of Herculaneum - the former town of Herculanum - there's a modern town there now. So Herculanum, like its sister city Pompeii, was destroyed in the A.D. 79 eruption of Vesuvius. It was long assumed that most of the population escaped, but in the 1980s hundreds of skeletons were found in the boathouses of Herculanum. So those are pictured on the right hand side of the slide. We know that Roman populations consumed relatively small contributions of marine food, but they did still eat marine foods. So because of that, and I don't want to get too ahead of myself here and like blow the whole story, but because of that we know when these people died, we know they ate a little bit of marine food, so we can try to figure out what the offset is and what the influence of that marine food actually is, on the radiocarbon dates from those individuals.

So in 2013 Craig et al. (and this paper is also in the references that Carley has) they conducted a stable isotope - so stable carbon and nitrogen isotope - analysis, and paired that with 14C dating of the human skeletons and then one lonely sheep. I don't know if he was lonely; he was lonely in the study. So, the sheep only ate C3 plants - that's the assumption. And what Craig et al. did then was they compared the human radiocarbon date to the sheep radiocarbon date and calculated the offset between them, and then plotted that in the image on the right hand side of the slide, against the delta-13C values from those individuals. And what they found was that with both the delta-13C values and delta-15N values, was that if people had higher stable isotope values they also had a greater offset from the sheep radiocarbon date and also...

So, the takeaway then from that is we know that with increasing marine input we see a greater offset in radiocarbon age from what the true age would actually be. A this is all great if we already know the answer, but how do we then work backwards from diet when we don't actually know what time period a sample dates to? And for this I'd like to draw on a really small example from my own research on the northern peninsula of Newfoundland. And this question is did Paleo-Inuit peoples in Newfoundland keep domestic dogs? So canid remains... or rather I'll just give you a bit of archaeological context. The Paleo-Inuit crossed the Canadian Arctic from Siberia about 4 000 years ago and they appear in Newfoundland around 3000 years ago represented by the gross water archaeological culture. Unlike their direct descendants the Inuit, the Paleo-Inuit...there's very little evidence that they actually relied at all on dog sled traction or kept domestic dogs. Canid remains have been recovered in very low numbers from some Paleo-Inuit sites in Arctic Canada and here in Newfoundland, but they're not identifiable based only on the morphology to species. But several recent genetic studies actually have identified the presence of haplogroup A in canid remains from the Canadian Arctic. So, haplogroup A is an ancestral domestic dog haplogroup that is found primarily in the Americas and I think eastern Siberia too. So this was present in some of these canid remains, which would imply then that they were domestic dogs. So, here in Newfoundland we have archaeological traces of two Paleo-Inuit groups: the Grosswater, who are here
between about 3000 cal BP to 1700 cal BP; and the Dorset, which have been dated sort of at the extremes at 2100 cal BP and they probably were present until about 1000 years ago.

[Alison Harris] The relationship between those two groups is still kind of unknown, but it's not really relevant or germane to the conversation right now.

[Alison Harris] So, my hypothesis going into this is that if the Paleo-Inuit - who were known to consume a lot of marine foods, they had very specialized tool forms, their sites were mostly located on the outer coast of Newfoundland where they could access migrating herds of seal, different fish species, and sea birds - if they were keeping domestic dogs they were probably feeding them marine foods. What's really fascinating about the Dorset archaeological culture in particular is that at many of the sites there's very very little terrestrial species, like the remains of terrestrial species. So, during my graduate research I obtained two of these unidentifiable canid bones from the site of Phillip's Garden West on the Port au Choix peninsula. So, this is a figure from Patricia J. Wells' book and it shows Phillip's Garden West facing south, I believe.

[Alison Harris] So, I conducted stable isotope analysis and radiocarbon dating on both of these canid remains, and also a whole bunch of other types of animals from Newfoundland. So I try to get as much of a representation of different marine and terrestrial species as I could in order to try to determine what a marine and terrestrial endpoint would be for this region.

[Alison Harris] I'm trying to think of the best way to explain this. So, the results were quite as expected based on other regions. So our seals have very high carbon isotope values, terrestrial species have very low carbon isotope values; when we look at the nitrogen isotope values they are generally separated, in the terrestrial environment anyway, they behave as we expect. The marine environment is a little bit messier but we're not really worried about nitrogen today, although we could be because it's pretty interesting, but we're not. So the canid isotope values when we just look at them, so here the shaded areas: the blue shaded area is the marine species, the green shaded area is the terrestrial species. This isn't a detailed Bayesian analysis or anything like that, this is just the average plus or minus two sigma for these groups of animals. So we can see that the canids, so F5 would be a canid from feature five, and F18 is a canid from feature 18, both of which are from this site of Philips Garden West which predominantly dates to the Grosswater period but it does kind of trickle into the Dorset period as well. So we can see that they both plot very very closely with the marine species so F5 is right in the middle of the marine animals, and F18 is on the edge which is kind of - I don't know, I haven't looked at this data for a long time so now that I'm looking like I want to look at that more. Anyway, what the data suggests is that F5 was consuming a mostly marine diet F18 was consuming some marine food but probably not as much. If we use endpoints, such as based on the carbon data for marine and terrestrial species, then we can calculate the proportion of marine food that would need to be consumed to produce the measured delta-13C
values within each canid. So for F5 it would be about 80 percent of their diet or 80 percent of their carbon would have to come from a marine environment, and for F18 it's much less, it's closer to 30 percent.

[Alison Harris] There are other ways of calculating this with more precision (most likely) and these would use Bayesian modeling. So again, I've included some references with Carley that would provide much more detailed instructions on how to use some of these Bayesian models that calculate estimated proportions based on the data that you feed into them; but for sort of a quick way to do it this does seem to be quite effective.

[Alison Harris] So, the radiocarbon results: F5 dated to 2020 plus or minus 20 years BP. F18 was dated a little bit older, and the radiocarbon age was 2260 plus or minus 15 years BP, so this is before calibration. I used a delta-R of minus 34 plus or minus 65 years. Calculating the delta-R in Newfoundland is really quite complicated because we have so many migrating species that migrate between - and I'm particularly thinking of seals right now - but that migrate between the Gulf of St. Lawrence and then the Labrador Sea. So they're getting two quite different sources, potentially, sources of radiocarbon. But for this purpose I only included points that were within about 200 kilometers of the site and only suspension feeders rather than deposit feeders. Using the marine and terrestrial endpoints that I devised based on the final data, I mixed the IntCal20 and Marine20 radiocarbon calibration curves to calibrate the samples. And this is what they look like when they're calibrated. So, the calibrated two sigma range for F5 is between 2000 and 1890 cal BP so that does fit within the Dorset period, which is really interesting when we think about the stable isotope values from this animal. F18 seems to fall more securely within the Grosswater phase of the site. And that is more difficult to interpret, just basically.

[Alison Harris] So it leaves us with a couple of questions, or leaves me with a couple of questions anyway, do we have two domestic dogs that were kept by the Grosswater and the Dorset, or do we have wolves feeding in a marine environment? So there is reason to believe that the F5 canid could have been very easily cohabitating with humans and consuming similar types of food as the humans. So we know that the Dorset regularly hunted seals. Dorset humans however do tend to have much higher nitrogen isotope values than were measured in this dog, or sorry this canid. The older canid from feature 18 is of course much more enigmatic. Its stable isotope values are less fishy, but it still consumed more marine protein than I would expect based on other studies that I've done of Labrador wolves. Now however we don't really know anything about the ecology of the extinct Newfoundland wolf. Was it more comfortable occupying sort of intertidal environments? Was it more comfortable scavenging from say, gross water middens? Or was it a domestic species that may have been given to Grosswater people? There's so many questions. Ancient DNA could probably answer some of these. Particularly since the haplogroups are getting to be much more defined in this region, but for now a lot of questions still with me.
[Alison Harris] So I'd like to thank Carley and the lab for inviting me to do this. As well as Meghan Burchell and my supervisor Vaughan Grimes, and John Southon and who did the radiocarbon dating. I should add that these were dated quite a long time ago. And then also the Provincial Archaeology Office for funding the study to begin with. So thank you very much and I'm happy to take any questions.

[Carley Crann] Thank you Alison.


[Carley Crann] No, you go ahead.

[Meghan Burchell] Thank you Alison for that talk. We started our webinar a few minutes late and we're just running a moment or two behind. So what we're going to do is we're going to wait for question and answer period until after Marisa's talk and we'll check in and see what we're going on with the time, but thank you so much for that talk Alison. If you do have questions for Alison please feel free to use the chat function and we can visit them after Marisa's talk, or stick around and turn your microphones on. So our next speaker in our webinar series is Marisa Dusseault who's doing an M.A. and an M.Sc. at the same time in the departments of Physics and Physical Oceanography and Archaeology at Memorial University; and she's going to be talking about her research today that's looking at inter-shell variability in radiocarbon. Welcome Marisa.

[Marisa Dusseault] Hi. Hopefully you can all hear me and see my presentation. Yeah so, again, thank you to the lab for having me. As Meghan mentioned I'm an M.A. and M.Sc. student at Memorial University so I'm in the department of Physics and the department of Archaeology. So today I'm going to be talking about radiocarbon dating marine shells and looking at some implications for archaeological interpretation here in Canada.

[Marisa Dusseault] So, there we go.

[Marisa Dusseault] Yes, so marine shells are really useful and a really interesting material to be looking at from an archaeological perspective. We find them in all kinds of contexts: artifacts; beads, like the ones shown here; they were harvested for food. So they have this really cool place in archaeology at this intersection of subsistence and environment which we can study through their geochemical signatures and culture, and then of course we can radiocarbon date them to look at time and anchoring these interactions in time.

[Marisa Dusseault] So in the archaeological context we often find shells in shell middens. So these exist from coast to coast to coast and across the globe, and they're really useful. So they're essentially these
kind of like refuse dumps of shells. So people will harvest shells, and then discard them and thankfully they preserve pretty well, and as you can see there's an abundance of material that we can study and we can look at. So this is really useful for us.

[Marisa Dusseault] So my study area specifically is British Columbia. All my samples are coming from around the Salish Sea. So shown on the map there I have samples coming from Comox, Deep Bay, and Sechelt, British Columbia, and this is a really rich region of Canada and of the world. I have a little snippet from a really great resource called Native Land, and you can see that there's just so many indigenous groups and this region has been occupied continuously for the last about 15 000 years so throughout the Holocene. So this is a really rich region to study, and I'm continually learning more and more about these indigenous cultures so I'm really thankful I get to work with some of these materials.

[Marisa Dusseault] So for my research for my M.Sc. I focused entirely on samples of the butter clam, so Saxidomus gigantea, and this is the most commonly recovered bivalve on the Pacific Northwest Coast. So it's really abundant in these archaeological sites. So before I talk about radiocarbon dating these samples, I want to kind of get you up to speed on just the basics of how these mollusks grow because this will become important. So they grow kind of like trees, they have these lines that they deposit at specific intervals. So for Saxidomus we see annual winter growth lines that form in that outer layer. So the picture here. I'm not sure if you can see my mouse but in that outer layer of the shell you see those dark lines. Those are those annual winter growth lines, and so the shell will grow outwardly from the hinge to the ventral margin. So out at the ventral margin is where we have the region of most recent growth, and in this figure the inner and outer portion are colored differently but I just want to emphasize that the entire shell is composed of calcium carbonate in the form of aragonite and I'm going to talk about that a bit more as well.

[Marisa Dusseault] So on to radiocarbon dating these samples. Just some basics - I'm sure most of you are familiar with kind of the basics of radiocarbon dating, but for these materials when the shell grows and it biomineralizes that calcium carbonate it does so in equilibrium with primarily the dissolved inorganic carbon in the seawater. So as it grows, it incorporates that carbon in equilibrium from, you know, oldest to newest growth, like I mentioned. So we can measure the remaining carbon-14 and then work backwards and typically we might talk about like the time since death. In this case it's the time since that biomineralization when that exchange stopped, and then I just have a picture of the entire range of the IntCal13 curve and you can see that nice exponential decay shape.

[Marisa Dusseault] So before I talk about radiocarbon dating one of the really really important things to do with these samples is to look for digenesis. So digenesis is a pretty general term, it just means any change that happens to your sample either chemically or structurally after (in this case) biomineralization. So I mentioned that these shells are composed entirely of aragonite. So a really common form of digenesis
is when we have the recrystallization of aragonite as calcite. So not to get too technical, but aragonite and calcite they have the exact same chemical formula. They're both calcium carbonate. The only thing that's different is the crystal structure - so the way that the calcium and the carbon and the oxygen are organized with respect to one another. And so what's important about looking for calcite versus aragonite isn't necessarily that it's a different crystal structure but what can happen is that when the aragonite dissolves and then re-precipitates, and can it can incorporate new carbon. So now you might have carbon in your shell that isn't reflective of that time of biomineralization. So that's really important to look for to make sure that we can build confidence in the measurements that we're getting on the radiocarbon.

[Marisa Dusseault] And so there's a lot of ways that you can do this and the way that I've been working with for the past few years is infrared spectroscopy. So essentially what this does - sorry, I saw the chat go off there - So essentially how infrared spectroscopy works is you have your sample and you bombard it with infrared radiation and your sample will absorb certain frequencies of that radiation depending on the vibrational modes in your sample. So for calcium carbonate samples it's mainly coming from the stretching and the bending of the carbonate ion and those frequencies that are absorbed just appear as peaks in the spectrum. So it's actually quite straightforward to distinguish between calcite and aragonite using this method. So here I have two spectra: one calcite, one aragonite; and a couple of things just to note is that you see that new three peak shifts a bit, the new two peak shifts a bit, and that new one peak is only present in aragonite, and aragonite has a new 4A and 4B peak where calcite only has a new 4B. So I used this method to kind of investigate the shells in a few different locations; so I sampled them near the hinge in the middle and near the ventral margin on the inner and the outer portion of the shell. And so all of them except for one came back as pretty pristine aragonite. So at the inner portion of the shell near the hinge I saw a mixture of calcite and aragonite in the IR spectrum - so that spectra is just shown on the bottom there and you can see that looking at the new three peak I have a peak that lines up pretty nicely with aragonite but I also have a shoulder on it that looks like it might be due to calcite. Same thing with the new two peak; I see a really prominent calcite shoulder there so we wouldn't radiocarbon date this sample because it's likely contaminated but thankfully the other ones were good so we went ahead with those.

[Marisa Dusseault] So here is the radiocarbon analysis and these data were collected back in 2018, and I actually had the opportunity to go to the lab in Ottawa which was really great and I got to see the whole sample preparation process and I learned a lot that week. So what me and my supervisor Dr. Burchell did while we were there is we sampled three shells at three different locations - so same locations as I mentioned before: the hinge, the middle, and the ventral margin - just to see if we saw any variability. And for two of the shells we didn't see much variability, but for this top shell in that first row in the table those F14C values - that's the un-calibrated fraction of modern carbon values - those values don't overlap within uncertainty. But of course I'm an archaeologist so I care about the time ranges. So when we calibrate those ranges actually do overlap, and the reason that I look at both the F14C and the calibrated
age ranges is because that is informative to determine whether or not we expect there to be variability and I can talk a little bit more about that if some people are curious to know. And I’ll also mention that this isn’t the first time that this type of variability has been documented; it has been documented in other geographic regions and with other species, but this is the first time that we know of that this has been done in British Columbia and with this species.

[Marisa Dusseault] So a couple details on the calibration, and Alison touched on a lot of this stuff so I can kind of move more quickly through it, but again, my samples are fully marine so I’m using the marine calibration curve. And just to reiterate what Alison mentioned, on average marine samples will appear about 400 years older than atmospheric samples and this is kind of nicely illustrated by showing both the atmospheric and marine calibration curves and you can see that they’re offset with respect to one another and that corresponds to about 400 years. But for my samples because they’re marine I also need to apply an appropriate delta-R, so that’s the local marine reservoir correction, and in the figure on the right that’s how it works in practice it just shifts the date appropriately to account for more local variability in the marine reservoir.

[Marisa Dusseault] And it turns out that for shells this is actually a really really important factor to consider when calibrating. So Alison also mentioned that this can be linked to upwelling. So upwelling is just when you have deep, cold, carbon-14 depleted seawater that’s pushed to the surface and it mixes with that surface water shifting it usually to older ages (but not always); and where these samples - these molluscs - are living (close to the surface) that’s what’s reflected in the shell chemistry. But because these species they live for several years, decades sometimes, depending on the species even centuries, if it happens to grow through periods of more intense upwelling or less intense upwelling then you’ll see older apparent ages and younger apparent ages within the same shell. And this is quite hard to pin down without having time resolved records of delta-R, which are not super common and we don’t know of any in British Columbia, so this is challenging; and what typically happens is you just apply one delta-R to the whole shell because we don’t have the ability to determine what the delta-R may have been decades, or you know a couple centuries before. There are databases that have a lot of delta-R data available, so one of them that I’ll just mention is the 14CHRONO database and this compiles delta-R data from lots of different resources so that’s really useful to look at.

[Marisa Dusseault] And we can actually calculate delta-R using shell. So typically this would be done using a shell-charcoal pair that come from the same archaeological context, then you can radiocarbon date them both and compare the value and that will give you the delta-R. So that’s what’s illustrated in this figure on the right. In the figure, they use a sample that has a known year of collection - of course for archaeological samples that’s... I don’t want to say impossible, but pretty rare - so you can use a terrestrial sample to do this as well. A publication from 2018 highlighted that the more shell-charcoal pairs you have,
usually, the better so if you can obtain multiple charcoal pairs analyze them all that will give you a more confident delta-R measurement.

[Marisa Dusseault] So it, unfortunately, isn't always possible to calculate your own delta-R. It is ideal, but not always possible. So for my samples we did not have the ability to calculate our own delta-R, so we're kind of stuck having to make a little bit of a judgment call about what the best delta-R would be to use. So the data that I have in the table here is the shell from Deep Bay that showed that variability, and so there are two delta-R's that are reasonable choices: one is from Texada Island, which is shown on the map. That one is a modern sample, so I believe that was calculated using live collected samples back in 2006, and then the other one is from Pender Island and that one is archaeological. So you might end up with kind of a trade-off between something that is archaeological - so it might be closer temporally to your samples but it might not be as geographically local, so that that's a challenge and you can see that depending on which one you pick the calibrated ranges do shift.

[Marisa Dusseault] So some conclusions, some takeaways: detecting digenesis is a really crucial step for analyzing these samples and I kind of just gave a pretty brief overview, but if you're interested to kind of know more or you have thoughts or ideas I would love to chat. Again intra-shell variability - this has consequences for sampling strategies, so how we understand that variability within a shell, and it has potential to be used for environmental interpretation. So if we can analyze within a shell that variability and look at that time resolved delta-R, that would be really really valuable for B.C. archaeology. And I might be a little bit naive but I think that understanding all of these complexities in marine shell radiocarbon, and understanding that sometimes the errors are a little bit larger than just that range, that calibrated age range, I think that this makes us better archaeologists because we look at the data more critically and then hopefully we look at the interpretations we make with that data more critically as well, and I think that's a good thing. Something else to highlight: at the beginning I think I briefly mentioned that these shell middens they exist coast to coast in Nova Scotia and for my M.A. I'm going to be looking at data from Port Joli, Nova Scotia and - oh sorry, my slack is going off - but there is no delta-R for Port Joli yet, so hopefully that's something that I'll get to do and hopefully incorporate more marine dates into the existing chronology there.

[Marisa Dusseault] I would just like to reiterate thank you, and I'm conducting this research here in Newfoundland which is the ancestral homelands of the Beothuk and Mi'kmaq, and all of the samples that I talked about today are coming from British Columbia, which is the ancestral homelands of the Coast Salish and Shíshálh peoples. And again, thank you to my supervisors Dr. Burchell and Dr. Poduska for their guidance, and as well to the Lalonde lab for allowing me to come and visit back in 2018 and hopefully we can do that again soon.
Thank you so much Marisa. That was fantastic. So what we'll do right now is we'll open the floor for maybe about five minutes of questions. So Alison and Marisa, I'm just going to ask that, maybe if you're comfortable, pop your cameras back on. And it looks like we have two questions in the chat for Alison. So we'll start with this question for you, Alison. Are you there?

Hi! All right. So here's a question from Sarah Murseli from the Lalonde Lab: "The Marine20 curve is intended for marine 14C samples arising from non-polar locations - 40 degrees south to 40-50 degrees north latitude. How can Canadian researchers working in polar marine environments who wish to calibrate data outside Marine20's intended range get around this limitation?"

This is a really good question and I had to research the answer. Carley had actually asked me this earlier and I did a lot of research, talked to some people, and then didn't answer her, so I'm sorry about that. Yeah I personally am lucky in that I haven't had to do any radiocarbon dating since Marine20 came into effect, but from what I understand from talking to people who are actively radiocarbon dating both human and animal remains right now in the High Arctic is that what you really need to do is to just get as many local delta-R measurements as you can, and that is the really the only way to work with Marine20 and IntCal20. I can direct you to people who would have more of an answer than that, like a more specific answer, because they actually do study this, like that is their purpose I guess. Not their purpose in life, but you know. So I can pass on some names if you like.

That's great. Thank you very much Alison. I see there's a question from Jacob. Hi Jacob, thanks for joining us. I believe - are you still in Louisiana maybe? But welcome and thanks again for being here. So Jacob's question for you Alison is: "Have you considered including trace element geochemistry as another line of evidence for dietary source and/or tropic level?"

I would love to do zinc. We may have the capability to do it here at Memorial. I would have to talk to my supervisor; he would know more about that because he uses the Neptune all the time. What I actually do is amino acid analysis so delta-13C and delta-15N analysis of specific amino acids rather than looking at the bulk protein. So with that what you're able to do is use certain amino acids within the nitrogen isotope system (they're called source amino acids) and you can compare those to other amino acids that are called trophic level amino acids. With carbon we have a lot more options I think because then we can sort of look at what ecologists have developed as the isotope fingerprinting method. So it's looking at a suite of essential amino acids which are routed directly from diet to bone collagen and they tend to vary quite a lot with - I don't want to say micro-environments but they do tend to vary sort of within marine systems; there's a lot of variation. Terrestrial systems - less has been published. Ecologists have been quite focused on applying these amino acid methods to marine ecosystems. I'm hoping to do
some work here in Newfoundland looking at how much they vary in a single terrestrial species if we just look across the island of Newfoundland, but I think that that is going to hold a lot of promise in terms of getting more refined paleo-dietary reconstructions. So thank you for that question. I was happy to answer it.

[Alison Harris] Thank you Alison. So I think what we'll do is I don't see any more questions in the chat, so if anybody has any questions for Marisa or more questions for Alison what we'll do is we'll incorporate them at the end of Carley's presentation. So thank you very much again for your questions and answers. So our third speaker today is Carley Crann, and I think if you have had the privilege of working at the Lalonde lab most of you have had the opportunity to meet her already. Carley has been working at the Lalonde lab since day one. She's a geologist with a Master of Science from Carleton University, and formal training and radiocarbon analysis from the Chrono Lab at Queen's University in Belfast. So Carley's going to be talking today about the analytical capacities at the A.E. Lalonde AMS Lab in support of archaeological research.

[Carley Crann] Okay so today specifically I'm going to focus on the capabilities in support of archaeological research. So if you have other questions, or other topics related to radiocarbon that you'd like us to cover in a webinar that I haven't covered today please send me an email and we can arrange for a future webinar, or I could even give a lecture, or just a personal conversation. This is a picture here of the Advanced Research Complex. It was constructed less than 10 years ago on the University of Ottawa campus. The sample prep labs are up on the fourth floor, and on the on the main floor from the street view you can see right into the accelerator lab. So it was designed to be the show piece of the whole building, and hopefully maybe this time next year we'll be able to open our doors and please contact us we love to give tours and we'd love to have you in for a visit. If the radiocarbon staff are here and could turn on their videos I'd love to just put some faces to names. Thanks Jen and Brett. If anyone else is here please turn your cameras on. Everyone shown in this picture has been involved in the radiocarbon lab in some way or another to provide you the best quality service. You probably know our lab manager, Sarah Mursele - she's not showing up on my camera but maybe she's showing up on yours; and up at the top here we have our three primary lab technicians: Carolyn, Karolina and Troy who process all of our samples; and you would also probably know Christabel Jean, she takes care of all the admin and billing.

[Carley Crann] In the prep lab we have the motto "our doors are always open". So we give tours, lectures, we host film crews, we do photo shoots, you name it. If you're giving a talk and you'd like to have some pictures to show how your samples were processed we'd be happy to provide that. We provide our protocols; we try and make everything as transparent as possible. So just if you have any questions, don't hesitate to contact us. We're always looking for development opportunities and collaboration opportunities. So I've got a little bullseye symbol here to show different topics that I'm actively seeking collaboration initiatives. We sponsor conferences, we give booths, free radiocarbon dates, and we also
have an in-house training program. So with this program you come to the lab and you process your own samples - it takes about a week. And I couldn't resist putting James Connolly on the spot with his super rad lab goggles from a few years ago.

[Carley Crann] What do we analyze? So I took a look at the last 5,000 samples. 55 percent was solids and 45 percent was fluid. So the fluids aren't so relevant here to archaeology, so I'm not going to cover those. Of the solids, the majority is wood, charcoal, organics, and some bulk sediments; and 15 percent of the solids are bone, 10 percent are carbonates. There's a reference here in the corner and also in the attached document that outlines all of our lab protocols so if you'd like to look further into that it's available there for you. And one other point I'd like to make is that a good radiocarbon date starts with sample selection, and so if you have any questions on the most optimal sample to help answer your research question, please send us pictures. We can have a phone conversation and we can help you at that stage.

[Carley Crann] So I've also provided a link to a virtual lab tour I did in 2017, and it's mostly accurate to where we are today, but we've moved a few things around for new equipment that's come in. The bottom left-hand corner is the room where we batch all of our samples, we examine them carefully under the microscope and then we crush them and prepare them for the wet chemistry, which is performed up here in the fume hood. It's all very standard chemistry. We do a few unique things and I'm going to talk about those in a later slide. Once the samples have been cleaned and purified, then they're combusted in in a Flash Elemental Analyzer, and the advantage here is that the EA will give us percent carbon, percent nitrogen and then we can calculate the atomic carbon to nitrogen ratio. And that's an important quality indicator at that stage because, for example if we're looking at collagen, the C:N ratio is a very key indicator. We also know at this stage how much material we have, so our current accelerator is tuned for one milligram of carbon, and so we know at this stage whether or not we have enough material for the analysis. The purified CO2 is then converted to elemental carbon using our custom graphitization lines. Again, there's a reference down here and in the attached, and I've also provided a link to a video made by a company called Swagelok and it's really slick. I highly recommend you watch it. It's not just about our very clean orbital welds, it's also about the impact of those clean welds on the work that we do and it touches a little bit in archaeology, so it's not just technical. I highly recommend you watch it.

[Carley Crann] Bone is one of the most finicky sample types that we work on. We are currently doing an investigation into our collagen yields to try and increase the yields and to improve the consistency from batch to batch. So if this is something that you know a lot about, or you're interested in collaborating on because you process a lot of bones please reach out to me. We're just starting this program right now, so I'm all ears and I'm open to suggestions. How do you know that you have good collagen in a bone? Well I always tell people if when you're sampling if you're not swearing trying to break that bone up then probably the collagen is not very good. So the harder the bone, the better. We prefer to analyze the cortical bone, which is on the exterior of the bone, not the spongy bone on the inside, and in the lab if we
do the sampling and the sample is very friable and it samples easily then we'll send it for a nitrogen test in the element analyzer. If it has less than 0.5 percent nitrogen then that's not looking good for that bone collagen. We then do a collagen extraction and if we're going to do ultrafiltration then we use the Vivaspin ultrafilters and the material that remains on the top part of the filter is what we would pipette out and then freeze dry and it forms nice collagen. If the yield by mass is under one percent collagen we may try the sample a second time if it's borderline, but if it failed the nitrogen test and it wasn't a hard bone then it's considered a failed sample unfortunately. The other collagen quality indicator is the C:N ratio, but typically if we get nice collagen we don't have any issues with the C:N, and then another thing that we employ is we send a split of every collagen sample down to the Ján Veizer stable isotope lab for carbon and nitrogen stable isotope measurements, so you can vet that with the species or the diet that you're looking for.

[Carley Crann] Very quickly I'm going to touch on calcine bone. So when bone is cremated above 600 degrees Celsius the bioapatite recrystallizes into a more stable form that doesn't exchange carbon with hard water, but there's no collagen remaining. If the sample has been burned at under 600 degrees Celsius then it's considered charred bone, and it has these more gray colors/brown colors and unfortunately those bones are just S.O.L. because you don't have any collagen and you don't have nice recrystallized bioapatite. In the lab we've recently gone through our protocol again and made some modifications. The one that I'll just mention here is that calcine bone tends to have high sulfur, and so in our graphitization process sulfur impedes the reaction. So to get rid of the sulfur we make sure to bake our extracted CO2 with a lot of silver cobaltous and we've had a lot of success in the most recent batches, and I have to say thank you to Tim Allen from Tree Time Services because he gave a nice talk at the C.I.A. earlier this month mentioning the work that we've done with him on calcine bone.

[Carley Crann] Bone in museum collections has sometimes been shellacked or treated with a preservative, and a number of years ago we worked on this bone from northern Algeria and the radiocarbon date that they had previously done with another lab didn't line up with the mortuary practices. So what we did was we took a cross-section through the bone and we looked at it with the SEM here at the Advanced Research Complex, and we found that the shellac that was applied was purely surficial. So we had the question on how to remove the shellac and I wanted to avoid using too many extra chemicals. So using the SME we found that it was purely surficial and abrasion would be sufficient to get rid of it, and it was, and the resulting radiocarbon date was very much in line with the theory of how old it should be.

[Carley Crann] So I want to highlight here a technique that we do not currently have in the lab, but I'm garnering interest in, because it's very useful and that's FTIR. FTIR could have been used here to determine whether or not we removed the shellac successfully from the bone, and it can also be used for things such as materials characterization. So if FTIR is something that you think would be useful for your research, or
a complementary technique for radiocarbon analysis please send me an email because I'm building a case to purchase this equipment and add it to our capabilities.

[Carley Crann] This is another case where FTIR would have been very useful: we received these beautiful well we received the carbonized residuals from these beautiful vessels recovered from Charleston Lake and there was a bit of a miscommunication. We didn't get note that they had been vacuum impregnated with PVA glue. So long story short, the radiocarbon dates were far too old. We then did an acetone treatment, removed the PVA and then the results of the radiocarbon dates were fine. But I had it in my head that glues were made from animal bones, and so I didn't understand how it could make a radiocarbon date older because animals are modern. So I contacted Tara Grant at the Canadian Conservation Institute and she gave me 20 samples of the commonly used consolidants and glues at CCI, and we found that there's three groups. So one group falls into the modern biogenic products, and that's your rabbit skin glue, wheat starch, sturgeon glue, etc; and then on the other end member are your petrogenic products so they're all radiocarbon dead; and then there's a group in the middle that are biogenic products that have been modified so they have mixed ages; and again FTIR would have been very helpful in this case, not only to study the contaminants, but also to study the nature of the carbonized residuals themselves if they're from cooking fish or maize or something else.

[Carley Crann] So circling back to how we produce a radiocarbon date, this is Canada's only accelerator mass spectrometer and it's produced our first 15 000 radiocarbon dates, and counting. The typical error is 25 to 35 years on an age that's around a thousand years old. Our minimum sample size, we're limited to about 400 micrograms of carbon, so to relate that back to what you would submit to the lab if it's an organic it has to be 10 milligrams or larger so that we have enough material; that's just organics. See our website for the other sample types. We run a 200 sample carousel wheel which takes 10 days, it's slow considering the capabilities of some other accelerators. Right now we've been running up to 4 000 samples of radiocarbon per year but it's a 3 million volt accelerator and it was designed to be this big because there are other radioisotopes that we measure for you know nuclear applications or cosmogenic dating and it has a very large footprint. So if you've been to the lab you'll know how big it is; it's quite impressive. In the bottom right hand corner you can see a picture of two grown men right inside the tank, and yes, one of those grown men is our director Liam Kieser, happy because he's in his element down there. B

[Carley Crann] But I'm very pleased to announce that soon we will have a MICADAS. So MICADAS stands for MIni Carbon Dting System and the footprint on the MICADAS is much smaller. It's only a few meters, so there'll be no crawling around inside this machine. We're going to see improved error on our radiocarbon dates, we will run a 60 sample carousel - it can be run - each day, so improved turnaround time. And the installation date - I don't want to promise anything because of COVID-19 - but we're working on it. Hopefully later this summer, maybe the fall; and I've in the in the notes I've provided a video to learn
if you want to learn a little bit more about the MICADAS. But the main takeaway is that there will be a significant reduction in the minimum sample size that we can run, so on the machine we only need tens of micrograms of carbon. So from your submission point of view we can now accept samples that are less than 10 milligrams of organics. New applications will be opened up, so we could analyze unique delicate museum specimens, we could analyze human remains with minimal destruction, individual tree rings on small pieces of wood, individual seeds or forearms; but then of course you have to keep in mind that that puts the onus on you the submitter to really understand. If you're going to send us one seed I hope you know that that seed is representing the thing that you're trying to date, but we now will have the capability. And my take home message from this is that we will have the technology, but what we need from you is the applications and we would like to hit the ground running in the first year. And if you've got interesting applications, interesting things that you haven't been able to date in the past because they're too small or too precious please contact us because we now have the technology. We're really excited to get started.

[Carley Crann] And I have to say thank you to everyone who's been sending us your publications (publications that use our radiocarbon dates) because our lab is supported by a major science initiative with the Canadian Foundation for Innovation and we have to put together key performance indicators and sending us your publication is really helpful. It also gives us more meaning in our work. So to know the impact of the work that we do it just helps; it's not just sample and sample out, it's a lot more meaningful for us. So thank you for the people who have already been sending us your publications.

[Carley Crann] And also I wanted to say thank you to Grant Zazula for bringing our lab in on this very interesting project that's gotten a lot of media attention lately. This wolf pup who is referred to as Zhūr, which means wolf in the Tr’ondëk Hwëch’in Hän language. We radio carbon dated the wolf pup in the lab and she was 50 000 years old or older (so it was beyond our limit), and then ancient DNA was used to constrain that age to 56 000 to 75 000 years old, oxygen isotopes were then used to further constrain the age. The oxygen isotopes suggested that she had to be alive during an interglacial period, so the age was further constrained to 56 000 to 50 000 years old. It's a remarkable find; it's a really cool story, and so I've also provided a link to a video that gives you a little bit more information about Zhūr. And I'm going to stop there. I think I've covered most of these bullet points here, but we want to hear from you. So if you have any questions or you'd like to get involved or collaborate please contact us thank you

[Meghan Burchell] Thank you so much Carley. I think this wraps up all three of our more formal presentations, and we have booked this zoom room for another 20 minutes. So if you have any questions I invite you to use the chat function, and you can use the chat or turn your microphone on. Maybe I can ask the speakers to pop their email address into the chat box or your twitter handle in case any of the audience would like to get in touch with you.
[Meghan Burchell] So I see Chris Jass has a question for Carley: "With the new device that requires smaller samples, does that mean smaller samples of bone collagen as well?"

[Carley Crann] Yes, everything. I don't want to uh get too much into the details... [connection issues]

[Carley Crann] And Meghan I was wondering about, you guys analyze different parts of an individual shell. So I was wondering if smaller samples is something that you'd be interested in for your work as well? Marissa comes online "yeah".

[Carley Crann] So we're going to have on the MICADAS we're going to have a gas source which means for carbonates you can [connection issue] and put it into an exetainer and then line up all your exetainers right beside the accelerator and then it will acidify and then directly sample that headspace CO2 and it goes into the accelerator. So it eliminates the whole graphitization step.

[Carley Crann] I think Meghan is frozen.

[Carley Crann] So we're going to have on the MICADAS we're going to have a gas source which means for carbonates you can [connection issue] and put it into an exetainer and then line up all your exetainers right beside the accelerator and then it will acidify and then directly sample that headspace CO2 and it goes into the accelerator. So it eliminates the whole graphitization step.

[Carley Crann] I think Meghan is frozen.

[Carley Crann] So we're going to have on the MICADAS we're going to have a gas source which means for carbonates you can [connection issue] and put it into an exetainer and then line up all your exetainers right beside the accelerator and then it will acidify and then directly sample that headspace CO2 and it goes into the accelerator. So it eliminates the whole graphitization step.

[Brett Walker] Guys, I can't speak - I just wanted to pipe in because it's related to delta-R. I can't speak to wood-shell pairs but we are also looking at extrapolating delta-R values from deep-sea corals and in situ DIC in the Labrador Sea. So there's some other initiatives on the marine side that we're taking.

[Marisa Dusseault] Yeah, hi. Sorry, I'm just having a look at your question.

[Meghan Burchell] I'll just read it out while you take a gander. "What kinds of processes are responsible for the diagenesis that degrades the reliability of seashell samples? Does this in some way help inform your sampling choices before the IR spectroscopy?" Well that's a good question.
[Marisa Dusseault] That is a good question. So diagenesis is kind of - I'm not going to say kind of - it is quite tricky because it can be really unpredictable. So I mean typically with shell you would only sample near kind of the ventral margin, so like the outermost portion, because that is most closely - most temporally close, I guess - to the time of deposition. So if you're focusing on that portion, then that's where you would look for any traces of calcite in the IR spectroscopy. I have done some other - it's not per se a screening technique yet - but I have looked at the IR in other ways to look at more kind of subtle changes that isn't necessarily a complete change from aragonite to calcite. And another challenge is that because these shells, there already is a lot of kind of natural variability (or there can be) it's kind of difficult to separate that from changes that might be due to digenesis. So this is definitely... I find this stuff really interesting. So hopefully I can look at this a bit more and of course this can be informed by methods other than IR, but IR is quite useful because you get like a complete picture even though it's kind of hard to pick out the little details. Yeah, I guess the short answer is that it's very unpredictable and is tricky, but hopefully that helps.

[Meghan Burchell] Thank you Marisa. Ah there's a question from Brynn, who I believe is probably on the other side of the country. As far away as you could possibly get in Canada from Newfoundland. Hi Brynn, thanks for coming today. So your question for Marisa is: "Multi-delta-R values for a single shell sound terrifying to me, in addition to spatial and temporal variations in delta-R up and down the coast. To your mind, what is a productive way for archaeologists to develop confidence in dates on archaeological shells. Somewhat related to Duncan's question, what would be required to sort out what delta-R values to use for where and when?" That's a really great question. Marisa, I'll let you field that one.

[Marisa Dusseault] So I agree; it's pretty terrifying because there's just so many different moving pieces here and it is really challenging. So I think the best way would be to use a short-lived sample if you can. So Saxidomus I think typically lives around like 20 to 25 years on the upper end, which isn't extremely long. But I mean the shorter the better, because then you have less variability within one shell. And if you can, if you're able to calculate, I think Alison mentioned this as well; like one-off delta-Rs for just when you need it. So if you're looking at a site and you have the materials like a shell-charcoal pair, it's best to use your own because you know exactly kind of where you're getting it from, where it's coming from and it's as local as possible to the region. Yeah so i'm just having another look to see...I think that's at this point probably we're at with kind of best practice. But yeah it definitely is terrifying, I totally agree with that statement.

[Meghan Burchell] Thank you for that answer Marisa. If anybody wants to turn the microphones or cameras on and not use the chat box for a question, we still have a few minutes left. But it was really nice to see so many archaeologists from across the country joining us today, so thank you - and other kinds of
researchers as well. Radiocarbon dating isn't exclusive to archaeologists. So if it doesn't look like we have any more questions in the queue, so Carley do you think it's time we could wrap up?

[Carley Crann] I am back.

[Meghan Burchell] Oh hi! You joined us just in time. We've run out of questions.

[Carley Crann] Sorry about that, I don't know my connection was... anyway. If we have no further questions let's go ahead and wrap up.

[Meghan Burchell] All right well I see there's some chat going on with some great links. As well as the beginning of the chat we have links to our next upcoming webinar. I did bring my students to the lab in 2018 and this experience fundamentally changed the way I treat archaeological radiocarbon dates, but also how we can teach this and how we can better teach our students in undergraduate courses in archaeology. So I hope some of the talks from the webinar today might be helpful in some of your online teaching, and if you do have any questions please reach out to the Lalonde staff or follow up directly with any of our researchers. Carley, that's all I have to say, so thank you.

[Carley Crann] Thank you. Thank you very much Meghan.

[Meghan Burchell] All right, goodbye everyone.

[Carley Crann] Bye everyone.

[Meghan Burchell] Thank you so much.