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Vincent Santucci's NPS Oral History Project, 2016-2024

Dave Elliott
June 23, 2020

Interview conducted by Vincent Santucci
Transcribed by John-Paul Hodnett
Edited by Molly Williams

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Harpers Ferry Center
P.O. Box 50
Harpers Ferry, WV 25425
HFC_Archivist@nps.gov

Narrator: Dave Elliott
Interviewer: Vincent Santucci
Date: June 23, 2020
Signed release form: Yes
Transcribed by John-Paul Hodnett

Transcript

[START OF INTERVIEW]

Vincent Santucci (VS): Are you ready?

David Elliott (DE): I'm set.

VS: Okay, I'll provide a quick background, then I'll jump in with the first question. So today is Tuesday, June 23rd, 2020 and my name is Vincent Santucci. I am the senior paleontologist for the National Park Service's Paleontology Program. Today we will be speaking with paleontologist Dave Elliott, recently retired as a professor at Northern Arizona University. The interview is being conducted by telephone from Dave's office in Flagstaff, Arizona and I am at my home in Gettysburg Pennsylvania. So, are you ready for the first question, Dave?

DE: Yes indeed!

VS: Ok. So, a little background about you, when and where were you born, and growing up any information you could provide regarding your early education or things that got you interested in geology or paleontology?

DE: Ok, I was born in Loughton Essex which is located southeast of the UK and I guess my family has always been interested in the outdoors. We lived next door to a very large forest, Epping Forest, and my dad had grown up in the same area so we spent quite a lot of time going for long walks in the woods. We had a basic understanding of trees and birds and things like this, and so I think for some reason that was something that interested me.

So, I got interested in natural history in general and then when I was about 10 I think, a teacher at school brought some rocks and minerals to school and that urged my interest particularly for some reason. Again for many of these things you have no idea really why you got interested but somehow I did. So things really developed from there but I had a basic interest in natural history then I added that to geology, and so geology and paleontology then were the things I was interested in.

We moved to a couple of different places, we moved to Kent, and then to Sommerset, to Bath in Sommerset. Those of which are areas that were great in the point of view of collecting fossils. I spent a lot of time in chalk quarries collecting all sorts of things, including bits and pieces of vertebrates. Then my high school years in Bath, I did a lot of collecting there and in fact that's the area where William Smith produced his first ever geological map. So, that was particularly interesting, so then the south coast, not that far away, is Lyme Regis interestingly is

very near and I did go collect from Lyme Regis as well. So I built up quite a large paleontology collection and really developed my interest in it. I was also actual able to take geology at my high school for two years, for what we call the "A Levels", so that gave me a good grounding in geology as well – and that doesn't help with as far as you want me to go.

From there I took on an undergraduate degree at New Castle, which is up in the Northeast, close to the border with Scotland, and came under the influence of the extent of professor Stanley Westoll, who's a big name in the early vertebrate studies, published quite a lot in various areas. I can remember that I was the only person in the vertebrate paleontology class. So he would just lecture to me but we also got talk about big topics as well. For some reason I started getting interested in early vertebrates, particularly early fish.

Again I don't know what turned me on to that direction, but somehow that became something that I was interested in. So when I finished my degree I contacted people in universities in the US, sorry, the UK to um to see if there was anybody who was interested in taking me on to do a PhD. One of the people who was interested was Professor Dave Dineley at Bristol and had an interview there and Dave did a lot of work in the Canadian Arctic.

Dave had been a professor in Canada before coming back to the US and the UK and he was continuing the work that he'd started up in the Canadian Arctic. So they were working particularly on the early jawless vertebrate, agnathans, which are a very small part of the vertebrate group at the moment only hagfish and lampreys. But if you go back into the Silurian and the Devonian, there is a very large number of them. There is a very extensive group called the heterostracans, they were armored by bony plates, sculptured, and it was possible to work on those. So I spent, in fact, my very first summer strait out in the Arctic and working there for a summer, and then, that was graduated as an undergraduate in 1974, so it wat that summer, so the summer of 1976 I spent out there as well, and did a lot of um, certainly the second one, did a lot target collection because I knew what it was I wanted and where I needed to go.

Graduated with my PhD in 1979 and then got a job in the United States. So I came over here and spent a year in West Virginia where I was teaching the structural geologist, not the paleontologist, I was sitting in for a structural geologist who was away on sabbatical. That was a bit of a stretch but I did manage it. Then on to Duluth for a year where I also was standing in for the paleontologist. Then after that, the job here in Flagstaff opened up and I applied to that and I got the job here. So, I came here in 1981, and I have been here ever since then, just retiring last year, November 19th.

VS: So when you went on to college or university, did you know you were going to go into geology or paleontology as a major area of study?

DE: Yes indeed, I think I've always already a dedicated paleontologist by the time I turned up as an undergrad.

VS: Ok.

DE: That was definitely the direction I wanted to go. Quite what I was going to do was a little vaguer at that time. Certainly in the UK you don't have the same help at the school level to prepare you for moving on. So really I got very little information what I can do with

paleontology and certainly the academic route going on and getting a PhD is something I didn't know anything about.

I did know I wanted to be a paleontologist and wanted to do paleontology. So I was able to take the paleontology option in my final year. The system is a little different over there, I'm sure you are aware, you really don't have much in the way of options. You just work through the program as it is set up and in the final year you have options, and I took the paleontology option then.

By then I realized that one possibility was the oil industry which does in fact take, well at that time certainly, take paleontology classes, museums, and also continuing with the academic route and taking a PhD. I did apply to the oil industry, I did apply to a number of museums, and got a number of interviews and did not get any further than that. Of course everybody was telling me there was no point in taking a paleontology PhD in early vertebrates because that is a dead end, you'll not be able to get job out of that.

However, I decided that this is something I really wanted to do. I'd kicked myself forever if I didn't do it and we'll see what happens afterwards. So I went ahead and did it. That feeling and it did actually work out, I guess I was pretty lucky.

VS: (laughs) What was your dissertation project?

DE: Dave Dineley was working up in the Arctic look at early vertebrates primarily from the late Silurian up to the early Devonian. Interesting thing up there was that eventually until he got going on it, nobody was up to really much paleontological work at all. Only in the 50's that the Geological Survey had decided that it would undertake a geological surveys in the major Arctic islands. So prior to that, even the geology was not well known at all. As a result of that survey work, and the continued it, and they are continuing it, they're still working up there, one of the geologist up there, Ray Storesteinson, took an interest in the early vertebrate he started finding.

He, I think, must have connected with Dave Dineley, not as sure what happened, and so Dave got information from him and started funding his own expeditions in particular areas that already have known vertebrates present. As a sidebar, Ray Storesteinson spent his entire career working on the Arctic and he also spent his entire career working on collecting these early vertebrates, and working on them, even though they were not a part of his job at all to be doing that. So it was a spare time activity and once he retired he'd been very close about the material, hadn't really allowed people to look at it. Even though he and I corresponded because I have been in contact with him went there as an undergrad and I had maintained that contact. Particularly from the point of view of not stepping on his toes by describing things he was already working on.

So, he continued developing his collection until he had a lot, and in many cases extremely interesting and important heterostracans. So he retired, continued working on them, pulled me in actually to work on them because he realized that he had so much there and he needed somebody who was more in tuned to what was happening because he shut himself off rather. So I started working with him and we got quite a long way but that ended with difficulties

because of the fact he did not use cladistics and in fact didn't believe in cladistics and he'd come up with some rather strange ideas of his own about relationships, within this group.

We never really could resolve that and so I sort of stepped out of it for a little bit. Although we maintained contact with him, but then he died and the Geological Survey in Canada asked me to take the whole thing over and revise and write it up as a memoir. Recently the Geological Survey was going to publish the memoir but then they decided that they would get Palaeontographica Canadiana to publish it, they published one memoir a year. So I worked towards completing that, got it done, it's actually a 500 pages of text and almost 200 pages of photographs and my illustrations. So a pretty massive thing.

I sent it off last year and at the moment I am trying to find out when I am likely to get it back. I know one of the reviewers completed the review. Apparently they are awaiting from the second reviewer. So sometime in the near future I should get that back and that will be a major job revising it for publication but it should be published next year. That'll be a big addition to what we know about the Arctic fauna but also about the phylogeny of this particular group, heterostracans, because the material that he had included the earliest known heterostracan but also material that enabled him to make complete reconstructions of some of these animals that were otherwise very poorly known. Although we had a name and various plates have been found were give a name but we had no idea how these plates went together because we hadn't anything very complete to come up with a way to producing a phylogeny. I'll say that heterostracan have no preserved internal anatomy, there isn't a single preserved heterostracan with internal anatomy, probably are cartilaginous, and I guess the conditions were never right, and we just don't have anything. So in order to produce a phylogeny we are working entirely with the external bony plates. Which makes it rather interesting of course.

So, just as a side bar, it takes us now to the importance really of the work at the Canadian Arctic. I worked on a number of localities for my PhD. Particularly found an early represented important group of heterostracans called the pterapsids, which are well known in Western Europe and have been used in biostratigraphy. It turns out that the Canadian Arctic is the center of the development of the heterostracans. So I discovered these early members of the group which indicated a connection with another member, another heterostracan called the cyathaspids, and was able to link the two together from that new material. I have to say that recent cladograms support that, so I wasn't able to run cladograms at that time, but published that idea that they were interconnected.

So, I was able to do that work. During my second trip in 76, I worked with Martin Gibling, who was a graduate student in Ottawa who was doing his PhD, a sedimentologist who was working on the stratigraphy of the sequence we were collecting the fossils from. He got very interested in the vertebrates as well and between us we did some rather primitive taphonomic work but we never got around to publishing it. Only in recent years we both retired and we've come back to the idea of putting this together and publishing it, because there is a lot of interest in the environment that these early vertebrates lived.

Nothing very concrete that anyone has come up with so we are combining the vertebrate data and the sedimentological data in order to get a picture over some of the localities that we've worked on. Also, I went up there again in 1990, I got NSF funding, went up there, to get with an

old colleague of mine, who was a graduate student with me, another sedimentologist, a Devonian sedimentologist. He and I deliberately aimed this in doing taphonomic study. We got quite a lot of data and so really there is Martin, another colleague, and myself working on a publication on the environment where these early vertebrates inhabited.

Based on the work we did out there, we're sort of cleaning up work we did in 1976, which was a long time ago but some of us still think this is valid. We're lucky that it is bit of an open field, hardly anybody getting into it, to work out what is going on here. Now pluck out how these animals lived around the edges of the Old Red Sandstone continent. We find them up in the localities in the western US, from California, up through Nevada, also in Western Canada, and then of course across the Canadian Arctic and then down the other side into western Russia, then the Baltic state, and Western Europe in general. So the distribution of them is in the edges of the Old Red Sandstone continent. That enabled me really then to develop the background to branch out to looking at the localities in the western US and providing notes how they related to each other. I'll stop there as I am sure you have questions at this point.

VS: No, that is a perfect progression, so thank you. So, how did you wind up at Northern Arizona University?

DE: It is just one of those things that happened. I had two one year jobs, and I decided that I really didn't want another one year job, in moving on you're moving on, and I wanted something more established. So I tried for a number of things and ended up being hired by Conoco to work down in the Gulf as an oil geologist. It wasn't something I really wanted to do, but it was a full time job. So I thought I would take it and see how it went.

I got that job in the beginning of the summer in 1981 and I asked them if I can wait until the end of the summer as I had a number of papers I wanted to clear those before going on with the job, and the said "fine". However, in the interim, Northern Arizona University here in Flagstaff had lost the paleontologist. What had happened was that they already had two and a half paleontologist in a department of twelve and they had taken on another one who was a graptolite worker. He stayed a year, then he decided that he didn't like it, and he was going elsewhere. So rather late, midsummer, they were advertising the position and they decided then that they wanted a vertebrate paleontologist.

So, this was pointed out to me and I went ahead and applied to it and I came down here to interview. I guess I fitted in pretty well with what they wanted because I was a geologist and I could take students out to field map with them for their geologic background. I was also a general sort of paleontologist, though I work on early vertebrates, I always had an interest in a number of other things including trace fossils. So I was willing to turn my hand to all sorts of things which I have done in my career.

I did it, and they offered me the job, so I decided to take it, which is what I really wanted than the oil industry. It meant about a third cut in salary for what I would've gotten in the oil industry, but in fact only about a year to 18 months later the oil industry went into a tailspin. They really stopped hiring anybody and we had people here who were students who got positions in the oil industry who were told now, "sorry we can't take you on". So, things were pretty dire and as it turned out I made the correct decision because I would've been a recent hire

who would be turned out and I'd be out searching for a job, along with lots and lots of other people of course.

So, things worked out alright for me at that point and I was able to move into what I wanted to do here at NAU. So we had, as I said, two and a half paleontologist at the time. Larry Agenbroad, I'm sure you know was the half geologist because he had not only did paleontology on the faculty but other things including geoarchaeology, archaeological geology, at that time. So a lot of us, but in fact I ended up, not necessary the principle one, but third in line, but I ended up teaching the undergraduate paleontology course from then on right through my career.

So I was teaching that. I also started a vertebrate paleontology course and I taught our advance paleontology course as well. Then in addition to that, I taught the field mapping courses, I also taught a big introductory course called Ancient Life which was based as a paleontology course that we took students out to field at the Grand Canyon. Also in later years I taught our geologic communications course, which is really teaching the students how to write, basically. How to write articles, how to write grant proposals, and that sort of thing.

So ended up teaching a very good range of things and also historical geology at one occasion as well. Of course, during my tenure, we lost Larry Agenbroad, we lost the other two paleontologist, all to retirement. Leaving me which was fine. Now I've retired and the school was trying to hire somebody but initially had been unsuccessful in getting the university to provide a position. Of course now it is all up in the air. In fact Geology has lost several positions. The university as a whole is contracting and being able to hire someone as a paleontologist seems very remote now. In fact the undergraduate course is still part of the degree is being taught these days by one of my last students who stayed on here to get a PhD in Biology. So that is how they are filling in that position and I frankly think that is what she'll keep doing. I don't really see the possibility another paleontologist being taken on here so the point of view of having a fully-fledged faculty member who got a graduate student and funding that sort of thing, producing research, that's not going to happen. It's a pity, there awful lot to do around here, as I know you are aware—

VS: Yes—

DE: (Garbled) —he is the sort of paleontologist you want to have around here. Just the way it goes, the virus is really messing things up in the university.

VS: Very good. So you've been involved in research collecting in national parks, Death Valley National Park and at Grand Canyon National Park. Did you become involved with those two national parks after you've arrived at Northern Arizona University or prior to coming to NAU?

DE: That was after I arrived here. Again, a number of lucky happen stances took over here. I continued my interest in early vertebrates but I didn't know that much about what could be done in the United States. So I started looking around. There were famous localities in Wyoming, the Bear Tooth Butte localities. So initially I went up to look at them. Very large channel in the side of a large butte. Interesting locality in fact. That had been worked on for vertebrates by Bob Denison, who was a early vertebrate worker in at the Field Museum in Chicago. He worked on them, then he worked on the Water Canyon Formation in Northern Utah and described a lot of

material from there as well. So he was the only person who worked in that area, and he retired around the time I came here to Flagstaff, and then died a few years later. So in fact the collections were all at the Field Museum in Chicago, all the early material he'd worked on.

So just about shortly after I arrived here I was sent a photograph of a specimen that had been collected in Nevada in the Northern Ekon Range. I could see quite clearly it was a part of a Devonian pteraspid. The People who collected it were actually an undergraduate student field mapping class, and they thought they were in the Ordovician. So actually that would have been incredibly exciting, except I looked at it and realized that can't be true. I has to be early Devonian. I met up with the professor who been up there and they got themselves in misplacement from one ridge to another. So that is sort of what had happened. It turned out to be a very rich and interesting locality, so I started work there.

I had one graduate student who was working on that in the early 80's and made quite a large collection of vertebrate material there and published just about all of it. Then another… I started working on the Water Canyon Formation and realized that, despite of Bob Denison's work, there were new things there and working on that. So I continued with that. Then a couple of other localities came up in Death Valley.

It was a situation of a structural geologist doing his PhD, John Snow, a Harvard PhD instructor out there, had come across a locality where there were bits and pieces of vertebrate material. He needed to know this was Tertiary or whether it was Devonian. Luckily he sent the material along to me and I was able to say it was nearly early Devonian and that is what started the work in Death Valley.

I went and did a reconnaissance in 1990, just to see the locality and see what was there. Immediately it was clear it had important information particularly we found one completely articulated small fish, which is very rare and unusual. Subsequent preparation showed that the articulated mouth parts were there and that was more unusual. So that turned out to be a very important locality and I continued working there and I got a permit in 1991 and I continued through 1994 doing work there until we got what we needed.

The locality is one where get a channel, many of these localities are in channels, at least in Mount Vert, and these are channel fills. So they were cut into the Devonian carbonate platform Paleozoic rock in the early part of the Devonian, actually into the middle Devonian. The infilling contained the vertebrate, they were living there. So we able to collect vertebrates from the channel in Death Valley and one interesting thing about the channel is that it was now vertical. No longer horizontal, been tipped up vertically. So when you look at it, the cliff the back was the base of the channel, the floor of the channel, and what we were seeing is vertical beds coming off that to the ones being deposited into the channel it contained the vertebrates we were interested in. We worked through collecting and bringing that material to be worked on. In fact I did the last bit of work I did on that would have been 2016. I published a paper in Journal of Paleo on a new subfamily of heterostracans that included one of these from Death Valley and other species from Nevada.

So, that is how I got into the Death Valley work. Part of it was a push to see what was going on in the western US and particularly I got interested in the biostratigraphy because a lot

of what happened in the past was people working on these channels just assumed that if it had early vertebrates in it that it was the same age as the Bear Tooth Butte, where everything was called the Bear toothed Butte, and assumed it was all the same age. Well, that's really because people who worked on the early vertebrates never looked at that fauna. I started looking at it and realized that a lot of these channels believed to be earliest Devonian and the age of the Bear Tooth Butte was down in the Early Devonian. Some of them were actually middle Devonian. So people started describing the faunas as they started working on these channels to try to put together a stratigraphy. Relating them to each other and deciding to what these ages were.

So, that proved to be very interesting actually connecting them across. We published a paper in 1997 that we pulled all these things together. Showed how they were related across the US.

VS: The collections that you've made at Death Valley, they are part of the Lost Burro Formation?

DE: Yeah. That's right, the Lippincott Member of the Lost Burro Formation. That linked up age wise basically the same presence of vertebrates from some of these channels. A little bit of micro vertebrates work has been done and be useful. Some botanical work has been done at Bear Tooth Butte, it was also very useful. By sort of linking these together, linking the bits of microvertebrates with information we had we were able to pull these together for the channel stratigraphy.

VS: The locality, were you near Lost Burrow Gap, where you far from that locality in Death Valley?

DE: You know I am not sure. We were close to Trail Canyon, in the pediment on the west side of Death Valley. So there was a Pediment Canyon coming down with an alluvium fan coming from it. So a little way down around south where the locality was. Not an area you ever think of looking for vertebrates or even fossils because not only was it structurally tilted and messed about but there was a lot of volcanic there, Tertiary volcanics, that covered larges areas there and left you with odd exposure of Paleozoic rock. John Snow had a problem trying to relate with place because if you don't know the age you don't what you are dealing with. So in fact the locality that we were looking at had been tossed up vertically, we also had a dyke running across it and it was surrounded by Tertiary volcanics. The fact that we were able to use the early vertebrates to put a date on it was really quite helpful.

VS: The specimens you collected from Death Valley where were the reposited at this point? Are they at the Museum of Northern Arizona, at the park, or where are they?

DE: I agreed with the park that the material would go to the Field Museum and I continued doing that with all of my Western US stuff mainly because it made life better and easier in that the US collections were already there at the Field Museum. It didn't seem sensible to have the collections I've been working distributed among various museums and various places. So the park agreed that I could deposit at the Field Museum and the Field Museum is perfectly happy because they are developing their early vertebrate collection. So I used Field Museum numbers and that material is all in the Field Museum.

VS: And were there two separate type specimens that you named?

DE: Let's see, there was two, actually three, four, I think. There were two pteraspids and one of them was brand new. *Panamintaspis snowii* and the other one was the same as one of the ones that Bob Denison had described from the Water Canyon Formation but it was a more complete specimen. He just had the one specimen, the posterior part was missing. We had a more complete material with the posterior part so we were able to give it a complete description. In fact it was one of those specimens that, probably comes across these, that they keep getting new generic names. So this had been given a new generic name by a colleague of mine in France, Alain Blieck. Then, based on our new material it was clear that we got it in the wrong place, and the description was incorrect there, so we decided to give it another new name. In order to make sure it didn't get changed again, we called it *Bleickaspsis* so he wasn't tempted to change. So *Bleickaspis priscillae* which is the species name Bob Denison had used. So those were two new ones.

Then I described the small articulated specimen and additional material and *Poraspis thomasi*, *Poraspis* is very widespread, well known genus, of early vertebrate, cyathaspid in fact. So I described that then. In fact it was quite interesting material because as I said the mouth parts were there and I was able to prepare out the mouth parts and compared these to other cythaspids. Also there is a specimen of ventral shield that showed growth lines. It was interesting because it allowed you to see the direction of growth on the bony plates.

A lot of arguments over the years of how those bone plates developed because they never because they are covered by bony plates. In some groups they've clearly been separated at one point then fused to make a single carapace. In other clades they stayed separate. In rare occasions you can see growth lines along and they indicated the direction of growth. In this case they were showing the direction of growth being posterior, under the plate the growth line indicated growth continued along that posterior edge, back. Just a few years before, some very nice material from District of Mackenzie, worked on by Stephen in Alberta, had demonstrated that growth was generally in the opposite direction. So for some reason, this one was different but there is only one specimen so you can't do much more than that and you just point out the different setup.

Just in 2016, I described this member of a new subfamily, *Phyllonaspis taphensis*, the name relating to Death Valley. I had two other species, from elsewhere in the US, so I described all together and also related them to an animal I described from the Arctic together into one subfamily called the Boothiaspidnae, Because *Boothiaspis* was the name of genus in the Arctic. So I was able to relate all those together. Other than that, the fauna included a small arthrodire, which is a small armored jawed vertebrate, which hasn't been described, but I sent anyway to Field Museum, they have one or two of them there. It is normal in these western US localities you get one small Botheriolepid arthrodire, as well as varying number of heterostracans and other bits as well. In fact we had the usual bits and pieces of an acanthodian spine, acanthodians being they think now a very basal form of chondrichthyan. We also have something that I originally didn't know what it but a number of specimens of what appear to be crushing teeth, which would presumably be chondrichthyan. If so, they're about the earliest chondrichthyan members with crushing teeth that are known.

So I kept those specimens with the intention of doing something with it in the future. That is what we had from there. We also had few bit of micro vertebrate work. We have some thelodonts from there, which seem to indicate to fit with what we determined to be the biostratigraphy there, that this is Early Devonian. Probably the middle upper boundary or around there.

VS: Did you attempt a paleo-environmental interpretation of the unit in which the Devonian fish were preserved at Death Valley?

DE: We didn't do it specifically but in fact there is not a lot to go on as we don't get a lot invertebrates in these faunas. What we do get though are lingulids. So we have lingulids from there and from the other channels that I worked on, particularly one in Nevada, are lingulids are there as well. So lingulids are brachiopods that certainly now live in very marginal environments, marginal marine environments, particularly ones that are stressful where you have a bit of water shallow. You get areas where water is in and out. There are also areas where you got a mix of fresh water, so you got brackish conditions there. The temperature is varying, salinity is varying. The conditions for most invertebrates are happy with, so the normal suite of marine invertebrates isn't going to be found there. The main thing about it is that lingulids are still marine and live right on the edge of marine environments, but they are marine and they are not indicating fresh water. That had been the argument about the environment which these animals lived, people had thought for a long time that these were freshwater animals.

This was based on work that was done on the Welsh borders fairly early on when a suite of fossils were thought to indicate fresh water. Actually then it became less and less supported and it moved towards the feeling that all of these are marine invertebrates, marine vertebrates, but actually they are living in very marginal conditions. So we can't be thinking of them as being animals that lived in fresh water although there seems to be a indication in some places that they did. Again they are very shallow as well, they keep close to the coast line. Thought we worked it out.

The Arctic is interesting because we do have localities there that can go from actual fresh water localities to right out to normal marine localities. One of the ones I am working on with my colleague is one where we are looking at sediments that have been deposited on the edges of the Boothia Uplift. This was a finger-like extension of the basement projecting north, which was rising periodically during the late Silurian to early Devonian. When that happened, you got sediment developed from the flanks of the Humpnid and so one particular hump island, Prince of Wales Island, actually goes from the east coast where you got the Boothia Uplift, to the west coast where you have marine carbonate. The sediment have basically angled in in which they were deposited, so they were deposited and nothing happened to them after that. So you can go from a conglomerate close to the uplift, out through sandier conglomerate, to sandstones, to sandstone carbonate, and out into carbonates. You can collect vertebrates all the way through.

So that is an important area where we can start to get an idea of what is going on. From what we can see at the moment it's pretty clear we don't have vertebrates in the true freshwater environments, even though the environment we find them is close to the uplift is very impoverished. Again they have lingulids. What we are thinking that in the past people felt that it was an impoverished fauna that they would call it fresh water, but you can't if its impoverished if

you have something that is marine. Lingulids are clearly marine. That enable us to come to agreement between the three of us that we are looking at a situation where some of them lived in right up into estuaries but they are animals that lived further out. That was a long answer to your question wasn't it?

VS: No, thank you that was great. So one last question regarding Death Valley then we can move on to Grand Canyon. In your opinion is there additional work that can be done in the Devonian at Death Valley related to fossil vertebrates?

DE: Yes, I'm sure there is. As I said the locality we were working at was a very… it was a small one and it was surrounded by Tertiary volcanics. We were able to go laterally and follow it out some distance and find other places where we can pick up vertebrates. But it wasn't a very rich locality. The assumption is that it was a channel that cut down into the early Silurian dolomite so perhaps looking for the boundary elsewhere would able us to find other channels possibly. I do know that vertebrates have been reported higher up in what must be middle Devonian, I think. Certainly a larger piece of a large placoderm. Also what was reported to me was a articulated jawed armored vertebrate though I wasn't able to nail that locality down. I don't remember where that was. It does seem that there are other places worth looking. A lot of hiking to venture around to see what is there.

VS: Very good. Shifting to Grand Canyon National Park, how did you get involved in work at Grand Canyon?

DE: Well I guess coming here from the UK, I of course covered something about the Grand Canyon as a undergrad. It is the sort of place you think you never going to get to visit. It's an outstanding geological locality but you don't really expect it going to happen. So really it was a great pleasant surprise to me that I find myself sort of working on the rim of the Grand Canyon. I guess I was taken down there by Larry Middleton, a sedimentologist here, and by Stanley Beus who was the invert paleontologist. Larry had worked on the Cambrian, so he was very interested in the Cambrian so he was doing work on the Tonto Group. Stan Beus had been interested in traces, he never collected material, and he never published anything. So I went down with him and had a look and immediately taken by the fact that this is an outstanding locality from the Bright Angle Shale that is just bursting with trace fossils. I realized that it is probably the best place in the world to have a look at invertebrate traces. So though I wasn't a trace fossil worker, I was officially interested in that something ought to be done about it.

I got a student started working down there with the intention of really describing the traces and putting them into the biostratigraphy so we can see about any sort of environmental change and how that was reflected in the traces. I had one Daryl Martin who did his masters and finished in 1985. With him I did do a fair amount of field work, we went on several day hikes down there, looking at sections down there. Looking back on it, it would be great to do that again but I am too old, I would not be able to something like that. It was wonderful to do it at that time. He in fact got rather more interested in stratigraphy and sedimentology, he felt needed, he did some work to see about that. So he concentrated more on that. We published a couple of papers on a new trace in the Bright Angel, called *Angulichnus alternipes*, which we published in 1987, which was an animal trace which was very weird which is why we were interested in doing it. That's what I like about traces, you look at them and much of them are strange and you try to

work out how on earth something formed it and what sort of animal formed it. I look at it from the point of view of a biological point of view. To see something formed by an animal from one point in time and what sort of animal, what was it doing to make that trace, and this was a very strange one. It was sort of a zig zagging trace, which had footprints along it as well.

So we described that, we suggested that it might have been made by an animal called *Habelia optata*, which was and animal that was described from the Burgess Shale in British Columbia. Burgess Shale is a world famous locality where middle Cambrian organisms are preserved completely. It is an enormous fauna with beautifully preserved material. An animal there called *Habelia optata*, a kind of arthropod, and it seemed to us it was an animal that could possibly make those sorts of traces, we suggested that. We also published another paper in 1987 on a thing called *Chancelloria*, and these are spicules, many rayed spicules, again known from the Burgess Shale. We think they go together to form a rather sponge-like animal. I think at that time, a lot in common with other Burgess Shell animals, anything you found a little bit odd are thought to belong to a new phylum. Certainly that's what it was when I was an undergrad and graduate student. The two main workers, at that time, were graduate students working in England and I remember going to their talks and there was a graduate student standing up there showing you all sorts of new phyla which no body had seen before.

It's come round since then so that many of the new phyla have now been fitted as basal members to known groups, particularly the arthropods. So *Chancelloria*, wasn't sure what it was but rather sponge-like and not quite sure what has happened to it since then, maybe it's related to *Wiwaxia*, which has not exactly spicules but little leaf-like structures. So anyway, we published that from a thin bed in the Bright Angel Shale which actually had body fossil material, had some of these Chancelloria spicules there, also had little pieces of brachiopod and things like that. The Bright Angel Shale in general it is not very rich in body fossils, although a number of localities have a lot of trilobites.

So I worked with Daryl on that and never continued with it or published more. However, in 2003 I had another graduate student Even Roads, he published his masters in 2003. Again, he actually he did thing rather differently, he was a river runner so he took his own boat down there and did most of his sectioning, section work, from the river. I never did go on a trip with him and never went with him in the field really. He got much more interested paleo environment, the stratigraphy, and sedimentology and wound up publishing a number of papers on it but I did not wind up publishing with him and he gave it really a cursory overlook to the trace fossils, there was nothing really new there to be worked on. Finally, as you are well aware, Anne Miller wanted to work on Bright Angel Shale and work on the traces. She became my last master's student. Daryl Martin was my first, working on Bright Angel and then Anne is my last, also working on the Bright Angel. She did work on the traces and got things worked out, she was able to show that the traces were related to the depth of the environment and as it deepened you got particular traces as appose to more shallow areas. She and I will be publishing her entire thesis in a bulletin of the Museum of Northern Arizona, but again that has all got on hold for the time being while various things get all sorted out in relation to the virus. At some point we are hoping we'll get published.

I'll say that one additional paper that got published by my Bristol group, Lane, Braddy, Briggs and myself published a paper in 2003 on a particular trace on the presence of a

onychophoran. An onychophorans is an interesting animal that currently are terrestrial in humid environments. But at that time they were marine in the Burgess Shale, rather compact bodied with elongated fat stumpy legs and the sort of tracks that we were looking at seem to indicate an onychophoran had made them. So that was published in 2003, there were a couple of papers there that allowed the connection between the traces and the organisms in the Burges Shale. It interesting and I am sure there are more possibilities doing that sort of thing. Certainly Anne didn't come up with anything particular we could use except one trace that might possibly be formed by a very large predatory arthropod with big grasping arms. Some marks look very much like arms sweeping across the sediment, sweeping for food. That is a possibility of interpretation, which is a close we've come with. So we'll publish an additional paper there.

VS: And you've had the opportunity to work with JP Hodnett on the Surprise Canyon fauna?

DE: Yes, and that is an interesting story actually. Again, I was interested in working on, and still am, working on early vertebrates and I was disappointed to find that basically the Grand Canyon doesn't have the strata I am interested in. There is a little bit of Late Devonian in the Temple Butte channels down there, and that's it. There is no other Devonian, no Silurian, and no Ordovician. So all that complete sections is totally missing from the Grand Canyon, and incidentally the other area I got interested in is the Ediacarian fauna below the base of the Cambrian. I've looked at that in Newfoundland, Namibia, and really fascinating stuff. That is also missing from the Grand Canyon. So really all of the sections I found interesting are missing from there.

However, a few vertebrates have been known from the, have been reported from the Temple Butte but actually I never followed it up to look at it. However, in the 1980's a new formation was recognized in the Grand Canyon. It was a series of channels that had been filled. They were cut from the top of the Redwall Limestone, so Mississippian, Early Pennsylvanian in age. So Stan Beus, a paleontologist here, in working with George Billingsley, worked to describe the facies and describe the fauna from them. It's difficult to get to, it's one of these localities that is not easy to get to and they got to it by helicopter. It was difficult work down there but George Billingsley actually surveyed every single one, certainly mapped every single one. What they show actually is a dendritic pattern of channels running across the Redwall at that time and coming together to opening estuaries that went into the ocean. It's interesting that it sort of fit right on top of the Grand Canyon and now been exhumed.

The work that they did there, they published a memoir in 1999 in which they described the sedimentology and stratigraphy and also chapters on the invertebrates and a chapter on the conodonts. At several localities they'd taken a series of samples right way through the Surprise Canyon Formation and sampled for conodonts. So that got published and I had not thought much about it except I knew that the macro vertebrates had been sent to somebody who actually works on chondrichthyan spines and things and he provided a basic identification but then it all gone to the Smithsonian, so that was in the Smithsonian. So that material was there.

However, Stan Beus retired, he kept an office for a while, then he left and took with him what he wanted and the office was cleaned out. So the material was stacked just outside so that if somebody wanted could take what they might use and everything else was just left there. Well one of faculty came along and they came across a box which had a series of vials and said you

know I think you ought to have a look at it because the vials seem to have shark teeth. So I had a look at it and sure enough these were shark teeth that looked as though there was a residue of some kind. So I thought about it a bit and wondered whether they came from the work that came from conodonts for the Surprise Canyon Formation because there was no labeling on the box. So I had no idea what it was. Each of the vials had a little letter and number on it. So I pulled out the 1999 publication and looked at the conodont chapter and realized that all these numbers were sample numbers from the conodont work. This was what was left over from each of these conodont localities.

So clearly something needed to be done about it and I was working with JP at the time and he was still an undergrad here. Anyway we got together on it and he took over the bulk of the work on it and we were able to… the Surprise actually has a wide range of sharks, 31 taxa and 5 new taxa, one of them named after you Vince—

VS: Thank you.

DE: —It's an extensive fauna, the only problem with the fauna really, in fact, it had not been collected with the idea of micro vertebrates in mind because the biostratigraphic value was the conodonts. For us it would have been much better if a number of localities were much more widespread over all these channels.

However, we use what we had and that was published by Journal of Paleontology as a memoir in 2018, a couple of years ago. It's quite an extensive fauna, but it doesn't seem likely that we'll be able to get out there again, go to those localities, it just seems too difficult to get out there to collect. Think we'll just have to deal with what we have. At least it has been published. So that really draws a line after that. Its still an important addition to what the shark fauna was like with the Late Mississippian and Early Pennsylvanian.

I guess more recently I've been working with JP on the sharks from the Kaibab around Flagstaff. We had published a number of papers in 2012 and 2013 and we still have an extensive fauna to work on. JP was able to work on your PaleoBlitz and work on the Kaibab in the Grand Canyon. He has been preparing that and has a number of new organisms and feels that there are some differences in the faunas between Flagstaff and the Grand Canyon which is expected. Certainly what we should start doing now is trying to look at a series of localities at right angles to the shoreline, which is more east, and see if we can pick up differences if we work along that. Work from the shallow end to the deeper and the Kaibab does show that the invertebrate faunal differences that are quite clear. Like a fauna you find quite close to the coast than you do when you go out to deeper water. There should be some differences in the sharks, and it would be interested to carry that out, to do more collecting. Some of that could be done at the canyon. Others we might have to find some other places to look. We can do it, but it would certainly be interesting to get that sort of transect.

VS: So certainly there is much more work to be done at the Grand Canyon in the future. During your career, early into your career, did you have the opportunity to meet Eddie McKee?

DE: Yes, briefly when I was first here, I remember meeting him at a meeting we had at the Museum of Northern Arizona. Yes, I did meet him. He was the one that would get together with

George Billingsley actually to do the initial work on the Surprise Canyon Formation but of course he did so much work, he did all the work on the Coconino, he did all the work on the Kaibab, and all the work on the Supai. He left a very large mark on the geology of the Grand Canyon.

VS: Absolutely. Any of—

DE: I was just going to say, just as a final thing though I never really published much on it I did do some work on the Coconino and some trace fossils. Together with Larry Middleton who was interested in that. We… just more in observation, than just interest, but we came up something interesting the Coconino near Ash Fork. We found that erosional surfaces showed desiccation cracks and they were not the sort of thing to see in the desert. Particularly the sort of desert that was represented by the Coconino, which basically a sand desert, a lot like the Namib. I've been out to the Namib to look at that. We found these desiccation cracks in pretty much in every erosional surface we've looked at. So we think a quite a bit of time trying to thought out how you get desiccation cracks in sand. You can't, it just falls apart when dries.

We decided that there has to be some sort of mineral which we find inside is probably gypsum that actually consolidated the outer part of the sand and allowed it to crack before getting infilled by the next dune. So that is something that nobody has described before in desert sandstone. Also the cracks are polygon and very symmetrical, they almost look like a tiled floor that somebody put down. Very interesting. So Larry and I did a fair amount of work on that and we're sort of at the point to put together a rough paper. Now he and I are both retired and I have a lot of other things I have to work on and its gone by the wayside a little bit. I hope at some point to complete that and get it published and just to say I have by looking closely at the Coconino in places in the Grand Canyon that I have seen those desiccation cracks, so they are occurring in that part of the Coconino as well.

In case in those sort of thing its knowing what you are looking for and in cases of quarries in Ash Fork, they are just laid out there. Beautiful great big surfaces covered in traces.

VS: Very good. I want to thank you for both your time today to do the interview but also for the work you've contributed to Death Valley and to Grand Canyon and the students that you had mentored along the way that also contributed. So thanks very much.

DE: Well, I am not sure if I need to be thanked because it is something I've enjoyed so much. Yeah, it's been great really and of course I hope to continue doing some things. At least maintaining some connection with the Grand Canyon with the work with JP probably on the sharks and with Anne on the Bright Angel Shale. I know she is continuing her interest there and I think she's been funded for 4 years now to work in the Canyon. I am hoping she ends up with a permanent position there, it will be great to have her there.

VS: Absolutely. And final note, so J.P. is really finding a very diverse shark fauna at Mammoth Cave National Park, and I know he is going to be sending specimens your way as well.

DE: Yes, yes, I don't know how J.P. does it frankly, he seems to become the go-to guy on Paleozoic sharks, he's it really. He's developed that all himself because he really is an extremely good researcher in the way he works, he is just an excellent researcher and he is so enthusiastic

about all this and producing an enormous body of work, really impressive. The only thing I worry about is that he could overload himself, probably already done so already, from taking on new things. So many things happening, but he seems to be keeping his head above water at the moment anyway—

VS: (laughs).

DE: —there you go. You're working with him quite a lot anyway.

VS: Yeah he's a real pleasure to work with.

DE: Obviously and very enthusiastically as well. It rejuvenates you.

VS: Absolutely, and one other connection we share – so thankful that you took Tom Olson under your wing and helped him along as well. He had a very difficult young life, that you provided him the opportunity and guidance that you did I think was very important.

DE: Well again, I was happy to do that. Tom certainly an interesting character, again very enthusiastic, incredibly enthusiastic. Though he had academic problems, he was able to get out with a general degree with a geology emphasis and I thought that pretty good. He's continued with his interest, developing his own courses to teach to local schools and to any of the locals interested in it. He's been in contact every now and then with what he's been doing. So it's obvious that he is continuing all of it. I'm impressed that after with all the problems that he had and really made good. He really did it on his own. More power to him.

VS: Yeah, his observational skills in the field were incredible. A lot of times he was finding things he did not know what they were but he had the ability to really observe and pull things out of the sediment that have not been seen before.

DE: Yes, he is very good at that and also had very good field notes. I was embarrassed looking at his notes and thinking, well, mine were not anywhere as good as his—

VS: (laughs).

DE: —he really did a great job with them, and kept all the information together, knew exactly where he found things, always had his permits in there, and that sort of things. He was just really good.

VS: Yeah. Hey, you are right. He is inspiring a whole another generation of young people.

DE: Yes, I mean I know from my own experience that somebody to turn up with some rocks and fossils, like my teacher did at school, that inspired me, and here I am with my career as a paleontologist. Tom could well spark interest in some kid at school, takes it on and goes on from there.

VS: Well very good. Well I really appreciate your time and information that we been able to capture. We'll try to get a transcription pulled together and send it your way. Thanks again.

DE: I am happy to do it, I'm just hoping you did get the information you wanted.

VS: Absolutely, yes.

[Long pause]

DE: So you still there?

VS: Yes, uh huh.

DE: Ok, so I just was going to say any additional information you'd like to have I am quite happy to add that. As I said in the beginning I wasn't sure if you wanted any specific information you need. Think um, if you wanted, no limit to what you can do with that with a form like this but I think it sounds like I covered all the bases.

VS: Yeah and I think one of the things I really enjoy is the history of science and the history of paleontological work in the National Park Service. So each one of these interviews allows us to preserve the details of that work by the scientists in their own voice and their own language, and their own recollections. Collectively it tells a wonderful story.

DE: Yes, I'm sure it does and it is certainly a very good idea to pull this together. Talking to you it is interesting to me to see, why you started with the question why I started in Death Valley, and it made me realize that all the work I did in the western U.S. was really related to chances. Somebody wanted a paleontologist who was doing something quite different, came across something, and by luck sometimes it ended up with me, and I was able to explore a locality and publish on it that had known nothing known about it. It was interesting chances that made me realize made it difficult to work in the western U.S., it's such a vast area, with enormous areas of outcrop, you can't really go out to an area with a formation, I am going to walk here till I find some vertebrates. You are dependent on somebody finding something just by chance. They are in the wrong place, they don't know why a vertebrate is there because it should be in the Ordovician, like that. It shows me how dependent we are in that sort of thing.

VS: Absolutely. Well, very good! Well, you be safe and I look forward to future communication, particularly through J.P. and thanks again.

DE: Well thanks for asking me to do this and it turned out to be a lot fun actually. Yes, you stay safe and I hope to bump into you in a meeting, but not quite sure when that likely will be now.

VS: (laughs). No idea.

DE: A long way ahead—

VS: Yeah – well, you have a great day and thanks again.

DE: Ok, and you! Bye-bye then.

VS: Bye-bye.

[END OF INTERVIEW]