3D Scanning and Printing

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Figure 1. NDGS Paleontologists Becky Barnes and Jeff Person using plaster-soaked burlap strips to remove a turtle fossil from the Golden Valley Formation.

Technology is a wonderful thing. The combination of technology into modern life continually makes our day to day lives easier and more productive.

The synthesizing of paleontology and technology has never been easy to accomplish. A large part of paleontology involves field work which is often messy and dirty. Grit and rain are not often good companions to modern technology. Sometimes adopted out of necessity, other times morphed to fit current needs, the combining of technology and the science of paleontology has led to amazing discoveries and protocols of field life that have had dramatic effects. Sometimes long-lasting inventions come out of brief flashes of extemporaneous actions. For example, in Montana during the summer of 1876 two pioneering fossil collectors by the name of Charles Sternberg and Edward Cope were collecting a very fragmentary skull of a dinosaur. The pair did not have any glue to keep the pieces together and needed some way to remove the broken skull from the ground while keeping all the pieces in their original positions. The usual method of packing the pieces into a box filled with paper and straw would not suffice for the long trip back to the east coast. These journeys were usually made by buggy over rough, unpaved roads for the entire trip back to the museum or at least to the closest rail station, often many miles away. As one can imagine rough, bumpy roads do not bode well for anything fragile packed in straw and paper. Sternberg and Cope devised a system of dipping strips of cloth in cooked rice and wrapping the bones into "packages" for the trip home (Sternberg, 1990; Rogers, 1991). These rice-dipped, cloth-strip packages would harden when dry, adding stability to the otherwise fragile bones contained within. Anyone trying to wash a rice coated pot after the rice has dried can attest to the food's hardness and cohesive properties. Sternberg and Cope's system quickly evolved into using burlap strips soaked in Plaster of Paris, rather than cooked rice and strips of cloth, and this slightly modified system is still used by paleontologists to this day, nearly 150 years later (fig. 1)!

As technology evolves, so do many associated jobs/markets, sometimes influencing each other, reinforcing the idea that necessity is the mother of invention. Modern technology is often better suited for needs in paleontology lab work and research. Photography, computers, ultraviolet light, magnetic resonance imaging (MRIs), and X-rays are all technologies that have been adapted for many different professions, including paleontology. The doorway into a new field of technology is just beginning to open, and we are getting our first peek into new advances that could change how very fragile fossil specimens are preserved, handled, and studied.

3D Printers

The first 3D printers used a “subtractive” method of carving material from a large block, much like an artist would carve a sculpture from a slab of marble. This process can be very wasteful with as much as 95% of the starting block of material being discarded after the final product has been rendered (Cummins, 2010). That’s like whittling a toothpick from a 2x4 and discarding everything you don’t use in the final product.

Modern 3D printers use an “additive” method of printing by which material is deposited in thin layers on top of one another, building a 3D product (fig. 2). The thickness of these layers can vary, but most modern 3D printers lay down individual layers less than a tenth of a millimeter thick with some printing in thicknesses of a thousandth of a millimeter. Since these printers are “additive” rather than “subtractive” there is no waste because the only material they use is what is required to create the desired object. “Additively” printed objects consist of two structures. In addition to the object itself, a support structure is printed at the same time, layer by layer, strengthening the 3D object until the printing process is complete.

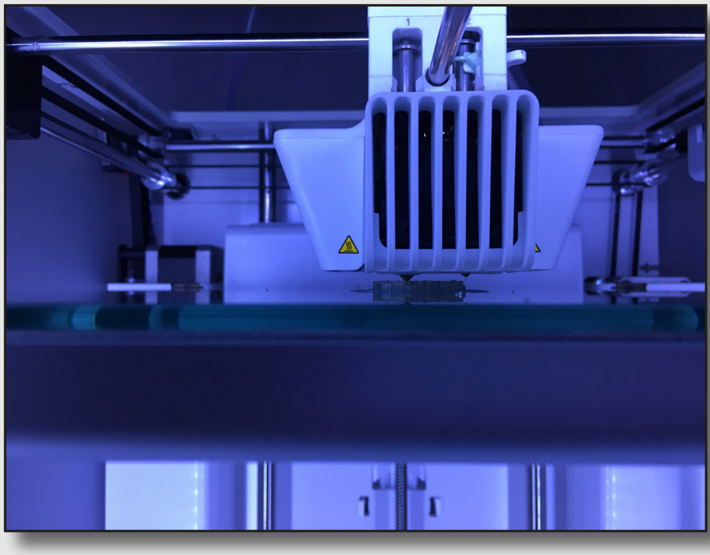

Figure 2. Image of the two print heads used by the 3D printer. One of the print heads is using PLA to create the desired 3D item, the other is using PVA to deposit the support structure. Both print heads are used on each successive layer, building a 3D product and its support.

The NDGS 3D printer uses a polylactic acid (PLA) material for printing and a water-soluble polyvinyl alcohol (PVA) for the support structure. Both materials come in long, thin strands (about the thickness of spaghetti) that are wound on a roll and fed into print heads (fig. 3). The printing material (PLA) comes in a variety of colors such as black, metallic silver, red, blue, green, yellow, white, magenta, and clear offering a variety of options when printing. The printing machine has two print heads, one of which extrudes the support material (PVA) and the other the printing material (PLA). When the PLA enters the print head it is heated to over 200° Celsius (approximately 400° Fahrenheit). At this temperature the PLA melts and flows out of the print head and the water soluble PVA is laid down at the same time in a supportive grid pattern. In this manner, the printed item is built layer by layer, each layer being less than a millimeter thick. The printing process can take hours to complete, with some large print jobs taking as many as 20-30 hours from start to finish. After the print job is complete, the supporting grid structure needs to be removed. Since this material is water soluble, it can be dissolved by soaking the final 3D print in a water bath for about an hour, which dissolves the support grid and leaves behind the final printed item (fig. 4). The only real restrictions on what can be printed are defined by the size of the area in which the 3D printer can print. For example, the NDGS printer has a printable area of 10” by 9” by 10” so that is the largest item our 3D printer can produce. The smallest item that can be produced is based solely on the smallest detail that can be printed. For example, printing a fossil tooth that is submillimeter in size would not only be impractical, but would also be impossible since the print head deposits material

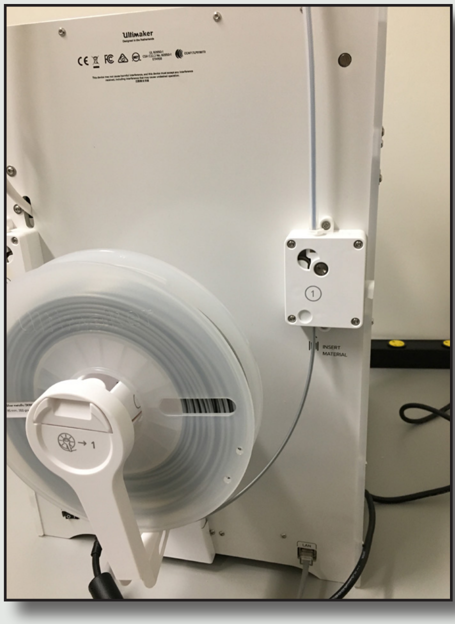

Figure 3. Spools of PLA and PVA are loaded onto the back of the machine and fed into the print heads. The size of the material is approximately the size of noodles of spaghetti.

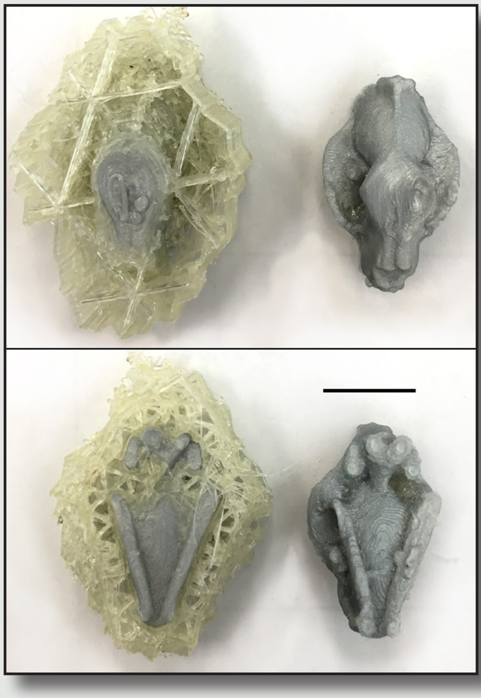

Figure 4. Top and bottom views of a printed and scaled down saber tooth cat skull. Note the complex structure of the PVA (yellow material) used to support the printed PLA replica of the fossil (grey material). Scale bar is 1 cm.

at that same size. The printed product would likely just be a blob of PLA rather than an identifiable object.

A wide range of materials are available for printing. Plastics with a variety of different properties (flexible, lightweight, durable, and others) can be utilized, depending on the needs of the final product. Other 3D print materials include metal, resin, and polymer powders, all with their own specific costs and benefits. Some 3D printing materials are used in the automotive industry and others are used in the medical industry. For example, with this technology a doctor could print a new knee cap, scaling it to the correct size and printing a left or a right side depending on the requirements of each individual patient.

3D Scanners

Unlike the 2D flatbed scanner ubiquitous throughout professional offices, a 3D scanner is a more specialized item. The addition of a third dimension for digital manipulation of objects is a powerful tool. Specimens can be measured and studied without the risk of damage or loss. As long as a digital copy is retained, unique and important type specimens can be preserved indefinitely. Different kinds of scanners exist on the market today including handheld models designed to scan very large items, and scanners that work in conjunction with rotating tables designed for hand-sized objects (fig. 5). Micro scanners are also available and are used to scan very tiny millimeter to submillimeter sized objects such as the peaks and valleys of a fossil tooth that is less than a millimeter in size.

Figure 5. NDGS 3D scanner working to scan a specimen of *Dinictis* from the North Dakota State Fossil Collection.

Within the last decade the 3D scanning of objects has begun to find its way into paleontology. Because of the inherent fragility of fossils it is not surprising that a technology allowing researchers to manipulate fossils in a digital space is a popular and useful tool. Handling fossils digitally is not always ideal but it is still the best way to keep fragile and unique specimens from being damaged or lost. Being able to scale up features on a bone or tooth that are too minute to study or are only visible through a microscope is something with enormous potential and scientific value to a researcher. The ability to scale specimens up or down or create mirrored versions are also very attractive qualities to those building exhibits with in-house specimens that are incomplete. If a left leg is missing from a skeleton, but the right leg is present, 3D scanning and printing technologies would allow the missing piece to be filled in. The exhibit team could 3D scan the right leg and mirror the specimen digitally to make a left leg. That missing leg could then be printed, helping to fill in missing pieces of an incomplete specimen. Alternatively, pieces from skeletons that are different sizes can be scaled to fit. The exhibits team could 3D scan a piece that is too small or large for the exhibit being created and scale the specimen accordingly. There is also a time saving aspect to this process. Once the scanning and printing processes are started, they are fully automated and require very little human input. A researcher can set the printer to the task and literally walk away for 20 hours or more, not interacting with the printer in any way until the job is complete. The printer has an associated camera and is networked through an internal Wi-Fi connection so the researcher can login to a website to check on the process at any time.

Although 3D printing is a useful and time saving tool, it is not without its downsides. It is true that the machine can scan and print at the sub-millimeter level, but it cannot compete with high-quality casting and molding with liquid plastics and plaster done by hand in the lab. This older process is slower and needs lots of human input and experience, but the end result is far superior to what we can produce with the 3D printer. The serrations on a 3D-printed *Tyrannosaurus rex* tooth would be very hard to replicate with the NDGS scanner and printer, but the old-school painted cast of a *Tyrannosaurus rex* tooth produced by tried and true methods, can fool all but the most trained eye. It all comes down to using the best technology for the job at hand. Sometimes that job will require old-school molding and casting, and other times it can be done with 3D scanning and printing. Both technologies have their place, it is up to us to figure out which to use in which situation.

During the fall of 2019 the NDGS had a company come to Bismarck to 3D scan our fossil duck-billed dinosaur “Dakota” at a very high resolution, much higher than we can do in-house with our current scanner. “Dakota” is North Dakota’s unique duck-billed dinosaur, with large patches of preserved skin, currently on exhibit at the North Dakota Heritage Center and State Museum in Bismarck. These scans will be used to create future exhibits as well as digitize the various aspects of Dakota’s skin, and allow researchers to manipulate Dakota in a digital space. The rarity of dinosaur skin in the world places this project at a high priority. It is an opportunity that would not even be possible without the 3D scanning technology we now have at our fingertips.

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