



A PRACTICAL AND HISTORICAL PERSPECTIVE OF THE HOW AND WHY OF WHITENING FOSSIL SPECIMENS AND CASTS AS A PRECURSER TO THEIR PHOTOGRAPHY

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Abstract: Whitening fossils and casts to enhance photographic detail has evolved from the early twentieth century in step with advances in photography in both film and digital technologies. Whitening began with clouds of NH_4OH and HCl being blown together to form a fine white coating of NH_4Cl . The wet method has disadvantages in not being very stable and forms thick coatings in humid environments. Heating dry NH_4Cl in a calcium chloride drying tube and variously expelling it in a concentrated vapor came into use in the mid twentieth century. It is a more advantageous method and the one commonly used by most invertebrate palaeontologists. Most dry methods differ in delivery of air to the heated drying tube (blowing over superheated NH_4Cl) – directly by mouth, squeeze bulb, aquarium aerator, compressed gas bottle, or from a centralized compressed air system. It produces a fine-grained coating and works best when performed in a fume hood. Heating antimony in a drying tube or burning magnesium ribbon to produce whitening vapor or blowing fine grained powder with an airbrush have their adherents but are rarely used. Whitening electronically is a technique in its infancy but holds a great promise, especially in photography of large invertebrates and vertebrates.

Key words: Ammonium chloride, wet whitening techniques, dry whitening techniques, specimen photography, fossil preparation, whitening apparatus

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Introduction

Photographing fossils for palaeontological publication is over a century old and techniques to enhance morphologic detail have been developed by palaeontologists and technicians in numerous countries. Many of the enhancement techniques have evolved along with advancement in photographic equipment, optics and photo sensitive materials (films and papers). These enhancement techniques seamlessly carry over into the digital age.

Fossil specimens and casts of fossils (especially darkly stained latex casts) can be coated to bring out greater surface detail, when photographed, by whitening with a very fine-grained, off-white powder. The slight thickening of whitening agent on topographic highs of a specimen accentuates subtle differences in surface detail when illuminated by low angle oblique light. The whitening agent is in fact, a vapor. We do not use the term “smoke” when it is in fact not smoke

but sublimate due to a chemical reaction or by heating of a dry substance (hence; a cloud of particulate matter or a vapor – term first used by Sass (1962)). The only true smoke used for whitening is from burning magnesium ribbon to form magnesium oxide. The sublimates commonly look like smoke; hence, the commonly used term “smoking fossils”.

There are several techniques for whitening fossils. They utilize coatings of various compositions and employ various methods of delivering the whitening agent to the surface to be photographed. The necessity to coat a specimen, especially one with a translucent or mottled surface, is to obtain even and maximum definition of surface detail. This necessity was recognized early in the days when photography was coming into use to illustrate fossils in publications. We are dependent on the published record concerning the early history of whitening and the actual beginnings are unknown. Gilbert van Ingen (1902) appears to be the first to describe an apparatus to produce NH_4Cl whitening by combining an

air mixture of HCl and “ammonia water” (NH₄OH dissolved in water) that was forced by compressed air (a foot pump) into a large, (one gallon) container (serving as a pressure equalizer) and from it through tubes into smaller bottles containing the active reagents. The outgoing currents from the reagent bottles are directed by parallel glass tubes that neck down to form small openings. The whitening NH₄Cl vapor forms as the outflow of the two reagent bottles react in the atmosphere forming the whitening vapor adjacent to the closely juxtaposed small openings.

Variations in producing NH₄Cl vapor as a whitening agent is what is used in many whitening applications today. Using liquid reagents to produce whitening vapor is termed the wet method; heating powdered NH₄Cl to produce whitening vapor is termed, the dry method (Sakamoto 1970). Variations of heating and blowing vapor from heated dry NH₄Cl in a heated tube described by Teichert (1948) is the most common whitening technique used by palaeontologists and has been so for at least (minimally) 70 years. Other forms of whitening have been employed over the same period – smoke from burning magnesium ribbon, blowing fine white powder, and whitening by electronic means to name a few.

General discussions on whitening have been published in volumes on palaeontological techniques; the sections on specimen photography are generally useful when it comes to whitening. Chapters by Kier et al. (1965), Feldmann (1989), Siveter (1990) and especially Green (2001) are important. We make no claims that this text is comprehensive, new variations on whitening technique come to our attention with alarming frequency. At best, it outlines general approaches to the subject and the problems whitening can solve in the photographic process of illustrating fossil specimens and casts.

Ammonium chloride whitening is not limited to lithified fossils and casts. Hegna (2010) has photographed lightly-sclerotized preserved modern crustaceans by first staining the specimen, drying the surface of the animal with hexamethydisilazane, and then whitening the specimen using conventional heated NH₄Cl or magnesium oxide smoke methods. By using proper photographic (especially lighting) methods, surface topography is dramatically enhanced.

Whitening is not however a panacea for all types of fossils. Specimens in clay or clay shales can be damaged when ammonium chloride is to be removed. Washing with water to remove the coating expands the clay minerals causing cracks that can damage or destroy the fossil. (In some cases a water/alcohol solution may be acceptable if the matrix is well indurated). Similar problems arise in weathered limestones where hydration of the ammonium chloride (forming HCl) can etch small carbonate specimens.

Fossil preparation

Before specimens are coated they need to be clean, dry, free of oil, grime, and loose particles. Often macro fossils are best cleaned by a detergent/water mixture and lightly scrubbed by a soft brush to produce a bubbly surface. (Detergent bubbles help lift small particles away from the fossil surface). Compressed air can also remove particles from the surface and help dry the specimen.

Latex casts need to be free of lint and loose particles. Lightly patting the surface with clear adhesive tape works well in removing loose lint and particles. Sometimes patting the tape on the cast will produce static electricity. It can affect the coating making it stand up in fiber-like filaments. Usually the charge will dissipate if the cast sits on a metal surface for several hours before coating.

To obtain the maximum detail the specimen/cast should have an even, dark tone. (In obtaining maximum detail the technique is to discern topographic differences with as sharp a focus and depth of field as possible (Feldmann 1989)). High intensity low angle lighting accentuates the topography and provides a uniform shadow pattern across the specimen when highlighted from the upper left as well as from the left and right sides of the frame. The surface of the specimen should also be non-reflective and opaque. Translucent, sparry or white reflective surfaces are difficult to impossible to bring into a sharp focus by the camera lens. Such surfaces can be rendered opaque and essentially non-reflective by coating with food colouring (McCormick red) or water soluble inks (black, dark blue and red work well). Food colouring and water soluble inks can be washed off but on some specimens, some residue or blush will remain in cracks, sutures and/or porous surfaces. When using latex, black India ink can be added as a thinner and darkening agent for the latex. The coating is non-reflective and India ink gives the extra benefit (because of its carbon granules) of making the latex less sticky, makes peeling the cast easier and is potentially less destructive to the mold.

The specimen to be whitened should be warm, dry and held in the inwardly and upwardly directed air current of a fume hood. Whitening in a fume hood works best with the “smoke” being directed laterally upwards in the air current across the face to be whitened.

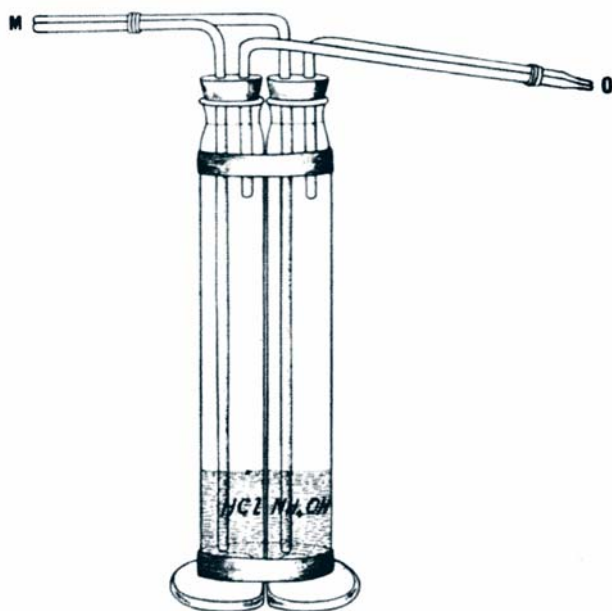
Equipment described in older papers is not uncommonly reported in English/American units. The authors have converted most such measurements into metric units.

Types of whitening coatings

Wet method

The first report of whitening a fossil (by any method) was by van Ingen in 1902. Similar methodology was reported eight years later by Grabau and Shimer (1910) but the methodology was accredited to J. E. White of the palaeontological staff, Columbia University. This was also a three-bottle method (eight-ounce wash bottles) and was powered by blowing into a tube connected to an equalizing bottle and it connected directly to the bottles partly filled with ammonia and HCl. Short outgoing tubes from the wash bottles merged into a larger tube and the resultant outgoing vapor was forced through a U-tube filled with calcium hydroxide to remove as much moisture as possible. The three-bottle method was simplified by Ulrich and Bassler (1923, 1926) who eliminated the equalizer bottle and paired tubes were directly connected to two wash bottles – one filled with hydrochloric acid (HCl) and the other with ammonium hydroxide (NH₄OH). Tubes leading into each wash bottle were taped together and air current

directed into the system was generated by blowing into the ends of each tube. Similarly tubes came out of each bottle and they too were taped together. The two exit tubes had narrowed openings to the exterior and the moist vapor from each bottle produces NH_4Cl powder at the juxtaposed exit apertures (Text-fig. 1). Bassler (1953) repeated description of this method in The Bryozoan volume of the Treatise on Invertebrate Paleontology. The leading practitioner of this method certainly was G. A. Cooper (e.g. 1956) who produced many monographs and papers on Palaeozoic brachiopods. He used the Ulrich and Bassler methodology but added a squeeze bulb at the inflow end of the tubular apparatus (D. Erwin, pers. com.) to produce the needed amount of vapor at the outflow end of the apparatus. (We use the term “squeeze bulb” – a hollow rubber bulb – that produces a one-way excurrent of air. In older literature, this bulb is sometimes referred to an “atomizer”).

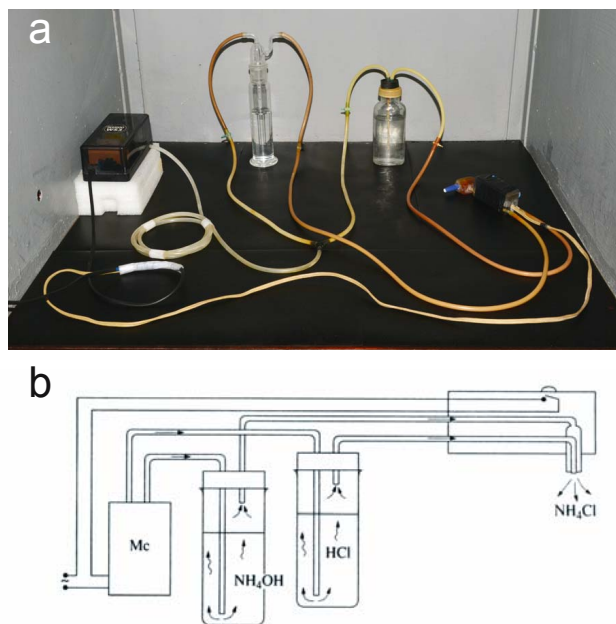


Text-fig. 1. Two-bottle apparatus (NH_4OH and HCl) first used by Ulrich and Bassler (1923) and widely used well into late 20th century (especially G. A. Cooper, U. S. National Museum). Drawing from Ulrich and Bassler (1923, 1926).

This process was mechanized by Ivantsov (1999) of the Paleontological Institute of the Russian Academy of Sciences in Moscow (Text-fig. 2). The containers containing the $\text{NH}_4\text{OH}/\text{HCl}$ reagents (each bottle with ca. 150 ml) were pressurized by an aquarium aerator producing $5,600 \text{ cm}^3/\text{min}$. at the inflow end. The control of smoke production was by a nozzle with on/off switch at the outflow end. The machine is still in use and whitens specimens illustrated in many papers produced by the museum’s palaeontologists. The current user of the machine (S. Bagyro) reports that the machine works best in an enclosed environment where the air is warm and atmospheric humidity can be controlled.

This technique of producing Ammonium chloride vapor is what we call the wet method. The environment must be warm and low humidity conditions must prevail for this method to be successful. The NH_4Cl produced by this

method is especially subject to deliquescence and easily breaks down into its constituent compounds. This breakdown process, by any method that produced it, can etch the surface of fossils made of CaCO_3 or CaPO_4 by reacting with the HCl component.

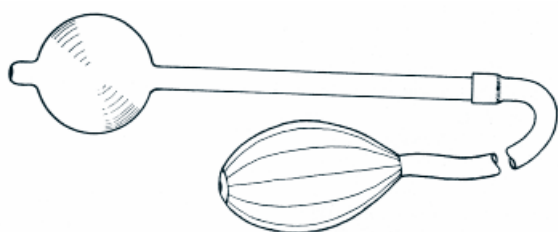


Text-fig. 2. (a) Mechanized wet method whitening machine invented by A. Y. Ivantsov for the Museum of Paleontology, RAS, Moscow. (b) A schematic of the machine. Mc = micro compressor. (Illustrations used by permission, A. Y. Ivantsov).

Dry method

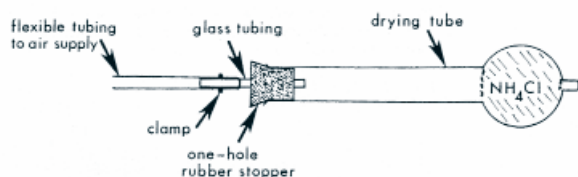
We are uncertain when simply heating dry NH_4Cl to produce vapor (dry method) came into use. The first published record of this method was by Branson and Mehl (1933) and they described the apparatus as a tube with one end drawn out to form a small aperture. Powdered NH_4Cl was placed in the attenuated end and heated over a gas flame. The vapor was forced out of the tube by a squeeze bulb. The technique was described in a paper on conodonts with very favourable results. The authors warned that blowing at the non-attenuated end was not a good idea as the moisture in the breath produced larger grained particles (a problem with the wet method in general).

A modernized and simplified version of Branson and Mehl’s system was described by Teichert (1948). It is composed of a Pyrex drying tube (or more precisely, an Absorption Tube Calcium Chloride Straight Form with One Bulb). The tube was ca. 8 to 10 mm in internal diameter and 100 plus mm long with a spherical bulb of up to 40 mm in diameter at one end (Text-fig. 3). Extending out from the spherical end of the bulb is a short extension, less than 25 mm long, of the same diameter as the long tube with its distal end drawn down to a ca. 5 mm, or slightly more, diameter opening. A short length of rubber tubing is attached at the long end of the tube and a one-way squeeze bulb is attached to that. The spherical bulb was half-filled with dry powdered NH_4Cl and was heated by a broad-mouthed



Text-fig. 3. Drying tube with squeeze bulb (Dry method of whitening) invented by Teichert. Illustration from Teichert (1948) (*Journal of Paleontology*, used by permission).

burner. The resultant vapor was expelled from the spherical bulb by pressing on the squeeze bulb. Teichert warned that the short tube extending from the spherical end of the Pyrex tube should be kept very hot so the narrowed aperture would not clog up and recommended a large diameter burner for heating the bulb with NH_4Cl . This design is still used and may well be the most common design used for dry method whitening. However, there are many variations to the dry method that have been successfully employed; most of them related to delivery of air to the heated glass bulb – commonly a drying tube.



Text-fig. 4. Drying tube with rubber airline attached. This basic pattern, in addition to Teichert, was used by Sass, Meyer, Turek and Pojeta in their versions of dry method whitening. Illustration from Feldmann (1989).

In recent years, the Teichert method has been modified by palaeontologists in the Czech National Museum in Prague by blowing on the end of a rubber tube in place of squeeze bulb. In addition, they have inserted a blob of cotton-wool into the drying tube adjacent to the stopper to adsorb water vapor from the breath. The cotton-wool is occasionally



Text-fig. 5. The Michigan tube. This version of a drying tube is bent to trap moisture from the breath from reaching the heated NH_4Cl . These tubes were made by a glass blower at the University of Michigan, Ann Arbor. Illustration courtesy Dan Fisher, Director, Museum of Paleontology, Univ. of Michigan.

replaced, as needed (also see Feldmann (1989) and Green (2001)). The method is simple and practitioners using it have produced very good results (Text-fig. 4).

A whitening apparatus employed at the Museum of Paleontology at the University of Michigan is similar to that of the Teichert's drying tube and may pre-date it. The "Michigan Tube" (Text-fig. 5) differed in that the tube leading to the bulb was longer and bent to produce a U-shaped trap to contain moisture. Some users placed a glass fiber mesh into the trap to help with moisture capture (B. Macurda, pers. com.). The tube was simply blown into by mouth. The apparatus dates back (apparently) to the 1940's and is still in use today (George MacIntosh, Rochester Natural History Museum) and produces a high quality, fine grained vapor.

Cooper (1935) took Branson and Mehl's design: lengthened and expanded the size of the tube (150×25 mm) and wrapped asbestos paper around it. Over the paper he wrapped a heating coil (500 watts, in a 110-volt system) around it and three more layers of asbestos paper were wrapped over it. Eight mm apertures were drilled at each end of the tube; a rubber hose connected to a squeeze bulb was connected to one of the apertures. The other end was left open. A tablespoon of NH_4Cl was placed into the tube and heated, and when it began to vaporize the cloud was expelled from the tube by squeezing the bulb. While the system seems elegant, easy to construct, and efficient, it never seems to have been widely used.

A similar device based on similar principles was constructed by Sakamoto (1970). A Pyrex glass tube, 250×15 mm, with one end tapered down to a five-mm opening over 40 mm of length, is wrapped with Nichrome wire over half the length of the tube (half with tapered end) and especially closely wrapped on the tapered part of the tube. Over the entire tube two or three layers of asbestos cloth is wrapped it to hold heat inside. The half tube with the Nichrome wire wrapping is filled with powdered NH_4Cl and is held in place with a half centimetre plug of glass wool. The non-heated end is plugged with a cork or rubber stopper but bored so a glass tube can be inserted into the glass wadding holding the NH_4Cl in place. The glass tube extends out from the end plug 50 mm or so and on it end is a squeeze bulb to propel air into the tube. The Nichrome wire is attached to a variable current transformer. The transformer is turned on which in turn heats up the Nichrome wire (see Sakamoto 1970: D231). When the NH_4Cl is heated to the point of producing sublimate (vapor) the bulb is squeezed and whitening vapor is ejected from the narrow aperture. It is not known if this type of unit was ever used outside the United States Geological Survey labs in Menlo Park, California.

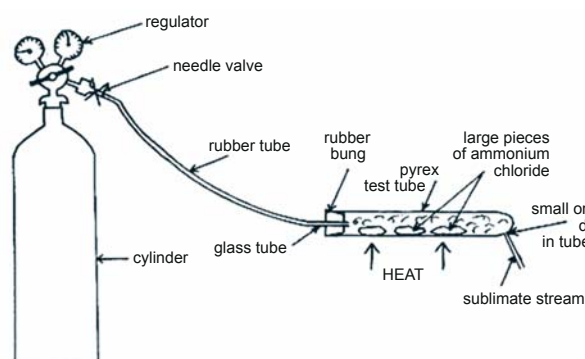
This unit works best in a hood where the vapor moves in a set direction and the specimen can be placed into the vapor column to be whitened. Sakamoto (1970) appears to be one of the first practitioners of whitening to recommend doing it in a fume hood. It not only confines the vapor to a limited area but directs it unidirectionally so that the fossil/cast can be more efficiently and evenly whitened. Whitening in a fume hood has become almost a universal practice.

In the last several decades of the twentieth century a novel and whimsical modification of the Teichert whitening method was used in the palaeontology lab at the University

of Cincinnati and described to the authors by Prof. David Meyer. Between the drying tube and the squeeze bulb, a rubber balloon-like bladder enclosed in a mesh bag was interposed and inflated with air by the squeeze bulb. The outflow from the bladder was greatly reduced by a small exit aperture. A constant air flow was produced by squeezing the bulb and a consistent pressure was maintained by the constricting pressure from the bladder wall and aided by the constraining mesh bag around the bladder. The bladder and drying tube with NH_4Cl was connected by a short length of rubber tubing. The steady measured flow of air from the inflated bladder to the heated drying bulb produced very good quality NH_4Cl vapor. (The bulb-balloon apparatus is a proctological insufflation bulb used in proctological/colon examinations and is available from medical supply companies). This innovative method, however, has fallen into disuse primarily due to the short life of the bulb-bladder apparatus; apparently from destructive back flow from the heated bulb.

Sass (1962) modified the Teichert system by using a small aquarium aerator pump to deliver a steady stream of air to the tubular end of the drying tube and in turn, produced a steady stream of vapor. The method requires frequent reheating of the bulb to produce vapor (during which time the motor can be switched off) but overall the method is very efficient. This system is in common use and, as in all dry methods, is best used inside a fume hood.

Marsh and Marsh (1975) made several interesting departures from this system. They took a large test tube and drilled a small aperture (? 2–3 mm) near the end. They placed in the tube three or four large clumps of NH_4Cl and aligned them along the length the tube but left a small space with no NH_4Cl near the drilled aperture. The end of the test tube was plugged with hollowed stopper with a bore large enough for a glass tube several millimeters in diameter to pass through it. A rubber hose was connected to the glass pass-through tube and the other end was connected to a compressed gas cylinder. Flow from the cylinder was controlled by a needle valve. Gas flow (dry nitrogen) was regulated to a pressure of 0.15 to 3.0 Kg/cm² (Text-fig. 6). Either gas burner(s) or



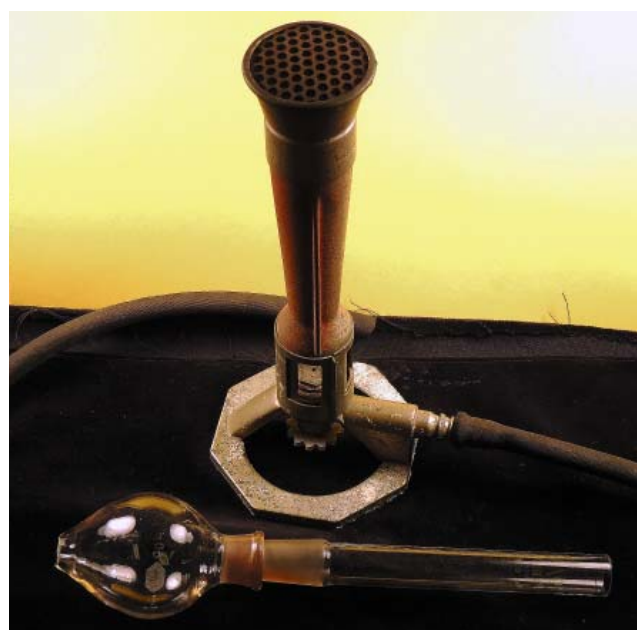
Text-fig. 6. The Marsh and Marsh apparatus is a distinct departure in both “air current” by using outflow from a bottle of compressed Nitrogen and production of vapor by primarily heating large lumps of dry NH_4Cl in an elongated tube. Heat can be produced by electric coils around the tube or by one or more gas burners. (Journal of Paleontology, used by permission).

an electric coil can be used to produce vapor. The apparatus works best in a fume hood.

One of us (J.P.) further modified the Sass (continuous flow) method by simply placing a drying tube charged with NH_4Cl in a clamp on a ring stand (or simply hand holding it) over the flame and connected the heated tube to a centralized compressed air system by a long rubber tube, i.e. to an outlet air valve off the centralized system. The system is effective but requires frequent reheating (during which time the air is usually cut off). Some skill is required to get just the right amount of air flow by adjustment of the air valve.

An easy to learn simple dry method of whitening

Many of the dry whitening methods described here and elsewhere are variations of Teichert’s (1948) system. For over forty-five years one of us (R.L.P) has simplified Teichert’s system even more by using only the drying tube with the straight outflow tube removed so that the smoke exits directly from a hole in the curved wall of



Text-fig. 7. Simplified Teichert method. “Air drive” is simply by blowing into the end of the drying tube. This method works best when using a large (Fisher) burner and constantly rotating the tube while heating.

the bulb. (However, practitioners at the Czech National Museum in Prague maintain that a one to one and a half centimetre “spout” is desirable when targeting small areas to be whitened). No squeeze bulb, aquarium motor, or compressed air/gas is used. One simply blows into the long part of the drying tube connected to the bulb with the end of the tube about 15 to 20 mm from the lips (Text-fig. 7). The method is very close to using the Michigan tube but without the bends in the inflow tube part of the apparatus. It also closely resembles the method used in the Czech National Museum where one simply blows into a connecting rubber tube attached to the end of the inflow part of the drying tube.



Text-fig. 8. Whitened latex cast of the Middle Cambrian edrioasteroid *Kailidiscus* from Guizhou Province, China. Whitening apparatus is the simplified “Teichert drying tube”. Note evenness of the coating and the elaboration of surface detail.

There are two accompanying factors that help make this simplified method especially successful.

First: the bulb is filled with powdered NH_4Cl so that forms a level line from the lower margin of the exit hole in the bulb to the bottom of the long connecting tube. The bulb is held close to the gas flame until the powder starts to melt and congeal next to the wall of the bulb. The tube is then slowly rotated so that a ball of NH_4Cl is formed inside the bulb. The ball is usually hollow and when air is blown into the bulb vapor is emitted from both the inside and outside of the congealed ball. The reheating to produce more vapor should always be accompanied by rotation (also see Green 2001: 426–427). The first puffs of air into the tube should be intense enough to blow out any large crystals or blobs of NH_4Cl that could land on the specimen followed by long, moderate blowing to produce an even flow of vapor.

Second: A key aspect to this method is to use a large diameter Bunson Burner (Fisher Burner) and adjusted to produce a very hot flame. The bulb and exit orifice are kept very hot and there is little to no buildup of reconstituted NH_4Cl around the exit aperture. The resultant “smoke” is very fine grained and the humidity injected into the system from the breath is negligible. As is common practice with the dry method, “smoking fossils” is best done in a chemical fume hood (Sakamoto 1970, Marsh and Marsh 1975, Feldmann 1989, Siveter 1990). Using the updraft of the hood to draw the vapor from the tube onto and past the specimen helps even out the discharge from the bulb and promotes even specimen coating. This is especially useful when trying to coat evenly, larger specimens. The intensity of blowing into the tube becomes intuitive and one shortly

can attain a level of proficiency to obtain very good quality thin, off-white/light gray, opaque coatings (Text-fig. 8).

Other methods

Early attempts of whitening of fossils may have been by applying smoke from a burning magnesium ribbon. The method was first described by (Rasetti 1947) but the technique seems to be deeply rooted in palaeontological laboratories of museums and universities worldwide and the technique may have originated in the early twentieth century (a viewpoint also shared by Rasetti (1947)). A piece of magnesium ribbon, ca. 50 to 60 mm long is held by a pair of long forceps and set alight. A specimen held in the rising smoke from the ribbon would coat the fossil with a very thin, bright white layer of magnesium oxide (E. Vokes, pers. com. in 2017) described the process by: attaching a fossil specimen to the underside of a specimen box by a piece of clay and continuously wafting the specimen in the rising smoke. The constant movement, to some degree, evens out the coating on the specimen. The specimen could then be placed on the stage of a microscope or under a camera and photographed directly. The inability to coat evenly and the bright white reflective character are disadvantages of its usage. The method, or some variation of it, is still used with varying degrees of success in some parts of the world.

Poulsen (1957) essentially took Teichert’s apparatus and, instead of heating NH_4Cl in a drying tube replaced it with metallic antimony. Under high heat the antimony reacts with oxygen to produce antimony tetraoxide (Sb_2O_4 , the mineral Cervantite). The method apparently produces a very fine-grained white coating (up to $200\times$ without sign of grain was claimed) and is not affected by atmospheric humidity. The method is not in general use and its main disadvantage probably is the toxicity of the vapor.

Jeffords and Miller (1960) seeking a rapid and effective way to use uniform camera settings in photographing fossils utilized a two-step process. First, fossils were coated with India ink to produce a uniform background and were then airbrushed using a mixture; (one-part) magnesium oxide or scouring powder (like Bon Ami) with (twenty-parts) alcohol. The nozzle was held about 50 mm from the specimen and moved in broad strokes across its surface. The coating would quickly dry (about one minute) and the specimen could then be photographed or further sprayed, if necessary. The method produces a very contrasty surface and can, in fact, diminish surficial detail. The method has never seemed to be widely used.

Vertebrate palaeontologists experimented with a spray can product (Spotcheck) in the early twenty-first century on large bones and skeletons. The whitening ingredients are kaolin, talc, hydrated alumina and calcium carbonate. (The product is intended for spot checking welds for small cracks and imperfections). The product has shown problems in achieving an even coating (usually too heavy and obscures details) but it is generally rejected because of the difficulty in removing it after it has remained on the specimen for more than several hours.

A novel variation of this method by Farke and Williamson (2006) involved photographing a rather large section (parietal) of a ceratopsian frill. Spotcheck, NH_4Cl , and other

methods were not satisfactory in producing uniform results. They sprayed the specimen with commercial aerosol foot powder bought from a drugstore. The whitening agents in such products are talc and zinc oxide. This method on such a large specimen proved to be satisfactory because a very fine grained coating was not necessary.

Electronic whitening – polynomial texture mapping

In recent years, whitening has been accomplished by electronic means. There is no actual coating and whitening is done by “virtual relighting and modification of surface reflective properties to bring out subtle detail” (Hammer and Spocova 2013). The technique can not only be used to whiten the specimen but also to darken or blacken it to eliminate color/tonal differences across the specimen. This technique is in its infancy so far as its use is concerned and would seem to have great promise, especially in evenly whitening large invertebrates and large vertebrates.

Conclusions

There is no one way of whitening fossil specimens and casts. Both wet and dry methods are successfully used today. The dry method, especially when NH_4Cl is subjected to high heat tends to give finer-grained coatings, and maintain stability longer in humid conditions than the wet method. There are many variations in use of the dry method and use depends mostly on personal preference. Blowing fine grained white powders, antimony smoke and magnesium smoke can be successfully utilized but have clear disabilities. Most do not give as good results as the hot “vapors” of NH_4Cl . Large specimens still present problems for palaeontologists (e.g. vertebrates, invertebrates such as large ammonites) and traditional methods tend to not work well. Electronic whitening, still in its infancy, holds great promise in this area.

With the development of high-resolution digital photography photographing fossils and casts has become much easier. Contrast, brightness, tone and when used, colour, can be electronically controlled. However, basic photographic skills are still necessary to produce photographs that capture maximum surficial detail. In addition to proper whitening, low oblique lateral lighting with a low oblique lighting highlight on the upper left is necessary. Using a photographic copy stand with fixed lateral lighting is fine for documents but specimen photography requires lateral lighting that is vertically adjustable. Each specimen requires individual adjustment of each light, both lateral and highlight, to bring out the proper shadowing to maximize surficial detail. Properly whitened and lighted specimens will almost always bring out more detail than an unwhitened specimen photographed in colour.

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References

- Bassler, R. S. (1953): Treatise on Invertebrate Paleontology, Part G, Bryozoa. – Geological Society of American, University of Kansas Press, Lawrence, xiii + 253 pp. (pp. G20–G21: Photographs and drawings)
- Branson, E. B., Mehl, M. G. (1933): Conodonts. – The University of Missouri Studies, 8(1): 17.
- Cooper, C. (1935): Ammonium chloride sublimate apparatus. – Journal of Paleontology, 9: 357–359.
- Cooper, G. A. (1956): Chazy and related brachiopods. – Smithsonian Miscellaneous Collections, 137(1): 1–1275.
- Farke, A., Williamson, T. (2006): A ceratopsid parietal from New Mexico and its implications for ceratopsid biogeography and systematics. – Journal of Vertebrates Paleontology, 26(4): 1018–1020.
[https://doi.org/10.1671/0272-4634\(2006\)26\[1018:ACD-PFN\]2.0.CO;2](https://doi.org/10.1671/0272-4634(2006)26[1018:ACD-PFN]2.0.CO;2)
- Feldmann, R. (1989): Whitening fossils for photographic purposes. – In: Feldman, R., Chapman, R., Hannibal, J. R. (eds), Paleotechniques. Special Publication, Paleontological Society, 4: 342–346.
<https://doi.org/10.1017/S2475262200005323>
- Grabau, A. W., Shimer, H. W. (1910): North American Index Fossils, Invertebrates, Vol. 2. – A. G. Seiler & company, New York, xiv + 909 pp. (pp. 818–819)
- Green, O. R. (2001): A Manual of Practical Laboratory and Field Techniques in Palaeobiology. – Kluwer Academic Publishers, Dordrecht, xiv + 538 pp. (pp. 418–440)
- Hammer, Ø., Spocova, J. (2013): Virtual whitening of fossils using polynomial texture mapping. – Palaeontologica Electronica, 16(2): 4T (10 pp.).
<https://doi.org/10.26879/384>
- Hegna, T. A. (2010): Photography of soft-bodied crustaceans via drying, whitening and splicing. – Journal of Crustacean Biology, 30(3): 351–356.
<https://doi.org/10.1651/09-3253.1>
- Ingen, G. van (1902): A method of facilitating photography of fossils. – Annals of the New York Academy of Sciences, 14: 115–116.

- Ivantsov, A. Y. (1999): An improved machine for spraying Ammonium Chloride on paleontological specimens. – *Paleontological Journal*, 33(5): 592–593.
- Jeffords, R. M., Miller, T. H. (1960): Air brush for whitening fossils, and notes on photography. – *Journal of Paleontology*, 34(2): 275–276.
- Kier, P. M., Grant, R. E., Yochelson, E. L. (1965): Whitening Fossils. – In: Kummel, B., Raup, D. (eds), *Handbook of Paleontological Techniques*. W. H. Freeman, San Francisco, pp. 453–456.
- Marsh, R. C., Marsh, L. F. (1975): New Techniques for coating paleontological specimens prior to photography. – *Journal of Paleontology*, 49(3): 565–566.
- Poulsen, C. (1957): Improved method for whitening fossils for study. – *Journal of Paleontology*, 31(5): 1029.
- Rasetti, F. (1947): Notes on techniques in invertebrate paleontology. – *Journal of Paleontology*, 21(4): 397–399.
- Sass, D. B. (1962): Improved techniques for the photographing of fossils. – *Journal of Paleontology*, 36(1): 171–172.
- Sakamoto, K. (1970): Some techniques for whitening fossils. – *Geological Survey Professional Paper*, 700-D: D230–D232.
- Siveter, D. J. (1990): Photography. – In: Briggs, D. E. G., Crowther, P. R. (eds), *Palaeobiology: A Synthesis*. Blackwell Scientific Publications, Oxford, pp. 505–508.
- Teichert, C. (1948): A simple device for coating fossils with Ammonium Chloride. – *Journal of Paleontology*, 22(1): 102–104.
- Ulrich, E. O., Bassler, R. S. (1923): Paleozoic Ostracoda: their morphology, classification and occurrence. – In: *Silurian*. Maryland Geological Survey, Baltimore, pp. 281–283.
- Ulrich, E. O., Bassler, R. S. (1926): A Classification of the toothlike fossils, conodonts with descriptions of American Devonian and Mississippian species. – *Proceedings of the U.S. National Museum*, 68(12): 4–5.
<https://doi.org/10.5479/si.00963801.68-2613.1>