Figure 1. a) Termites in Colombian copal showing gas bubbles; b) Close view, showing termites in Colombian copal showing gas bubbles.

Mushrooms in Mexican Red Amber and Colombian Copal

– A Fantastic Voyage

Elinoar Shavit

"Among the most unusual substances on Earth, amber combines alluring physical properties with an unparalleled archive of ancient life on our planet. No other substance brings together such richness in art and science."

David A. Grimaldi, American Museum of Natural History (Ross, 2010)

Figure 2. A rough piece of blue Dominican amber.

My quest for mushrooms in amber and copal lasted about a decade, from the mid-1990s to the early part of the 2000s. During this period of time, I found mushrooms in Mexican red amber from Chiapas, and in Colombian copal from the Santander region; these pieces make up the bulk of my collection. The unique fossils of mushrooms, amber, and copal in this collection are still waiting to be studied. They could be made available to individual researchers or institutions involved in the study of mushrooms in amber and copal.

I saw my first fossilized mushroom in a piece of amber in 1996, at the American Museum of Natural History (AMNH) in New York City. The museum's legendary entomologist, David Grimaldi, put together an exciting exhibit: an elaborate collection of amber pieces and artifacts from around the world. It was called, "Amber: Window on the Past" and was as spectacular as it was educational. Mushroom lovers were treated to a small, extremely rare piece of light-colored amber, inside which a tiny gilled mushroom was barely visible. Through a strategically placed magnifying glass, excited visitors could get a glimpse of what the ancestor of today's *Mycena* looked like, down to its cap, delicate gills, and stipe. Though an extinct species and millions of years old, the fossilized mushroom looked fresh and current in the soft light, almost as if it was picked just a few days before. The tiny mushroom, forever suspended in its unassuming piece of amber, took my breath away.

I am a gemologist and mycologist, I have always had a passion for both gemstones and mushrooms, but when I saw that fossilized mushroom in amber at the AMNH, I realized what unique advantages this combination of qualifications could offer a collector.

Amber has always been one of my favorite gemstones, because it is pretty and so versatile. As a gemologist, amber was an organic, semi-precious gemstone for me, soft for a gemstone (only 2-2.5 on the Mohs scale), and with multiple places of origin around the world. It came in multiple colors, and lended itself to carving and the creation of beautiful works of art. As a mycologist seeking mushrooms inside the amber, amber was the fully polymerized tree resin that formed millions of years ago in what were then thick forests, rich with resin producing trees. Amber was the perfect vehicle for preserving and displaying a delicate fossil.

As a GIA (Gemological Institute of America) gemologist, and a member of the AGTA (American Gem Trade Association), I have attended the annual Tucson International gem, mineral and fossil mega-show almost every year since the mid-1990s. Each January and February, this huge array of conventions, shows, and open markets take over the entire city of Tucson, Arizona

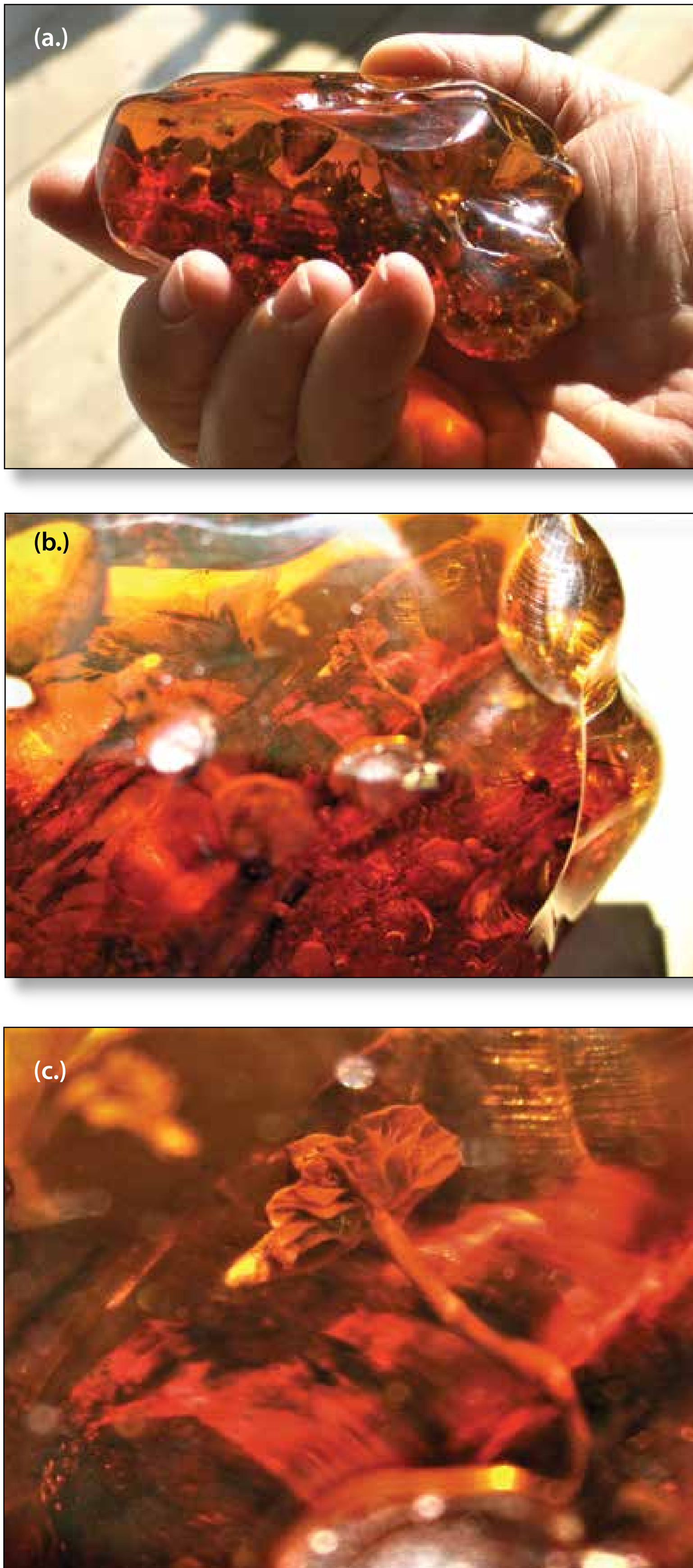

Figure 3. a) A piece of 25-million-year-old Chiapas red amber, with a *Marasmius*-like mushroom; b) A closer view of the extinct *Marasmius*-like mushroom in the piece of Mexican red amber; c) Close-up of the *Marasmius*-like mushroom in the Mexican red amber piece.

and beyond. Thousands of dealers from around the globe congregate there and offer specimens of fossils, minerals, and gemstones to buyers, collectors, museum curators, professional and amateur paleontologists, wealthy jet setters and the general public. Bags of amber and copal pieces, rough and polished, are laid out in convention halls, parking lots, dining rooms, dealers' motel rooms, lawns, and even in the sand. Huge dinosaur skeletons can be seen being cleaned and identified, Brazilian amethyst "cathedrals," large enough for a person to stand in, can be admired everywhere, and there is so much to see, touch, and discover. It is at the Tucson show that I have made most of my connections in the world of fossils and gotten to know other people with quests similar to mine. I must have "louped" thousands of amber and copal pieces, looking for elusive mushrooms in amber.

Few fossils of mushrooms preserved in amber have ever been reported and fewer yet have been studied and the research published. Through the years, I have seen at least a dozen authentic pieces of amber with mushroom inclusions pass through the Tucson show and end up in private hands and museums around the world. Regretfully, most are never heard of again.

I believe that the main reason why mushrooms preserved in amber are rare is their fragility, and the aggressive process in which amber is formed. Most mushrooms do not have the type of skeleton that can survive through millennia, like dinosaurs do. They are composed mostly of water, their cell walls are made of thin chitin, and they are particularly prone to decay (Shavit, 2010). Mushrooms that survive the formation process of amber are usually small, fragmented, and difficult to spot, even by experienced amber dealers and miners.

Amber is fossilized ancient tree resin, and the manner in which it is formed makes it perfectly suited to be a time capsule. Amber begins life as an oozy, sticky resin that is produced by certain trees like species of the extinct *Hymenaea* in Mexico and the Dominican Republic as defense against all kinds of burrowing insects. The sticky resin oozes and flows down branches and trunks, engulfing anything loose in its path. Parts of plants, insects, lizards, fragile mushrooms, and even mammals, too slow to get out of the way, have been found in amber. Living organisms engulfed by the resin usually expire so rapidly, that they look life like, forever preserved inside the amber as if they were still doing what they did when they took their last breath.

The small piece of Colombian copal in Figure 1 shows termites in the moment of their death, each little termite with its own tiny gas-bubble attached to its behind. The oozing, viscous resin flow provides an air-tight seal around the insects or mushrooms it engulfs along its way, which protect them from decay. If the resin flow eventually gets buried in oxygen-free sediment, then both the resin and the objects inside it stand a chance to survive the millennia-long process in which the resin will eventually become fully polymerized amber. The resin will become amber when the layer of buried resin slowly loses its volatiles (such as alcohols, oils, acids, aromatic terpenes) and undergoes a process in which its small organic molecules join chemically to form much larger chainlike or network of molecules called polymers, and harden. When its volatiles have evaporated, and the resin is fully polymerized, it has become amber: an insoluble, gem-quality polymeric "glass-like" material, which can now preserve the encapsulated objects inside it in a strong encasement. This polymerization process could take millions of years (Ross, 2010).

Amber comes in many beautiful colors. The majority of amber is in the spectrum from clear to yellow and dark yellowish-orange, but it can form in other colors, such as red, white, blue, green, dark brown, and more. Amber can be transparent, translucent, and opaque. The carved piece of Dominican amber on the cover of this issue of FUNGI, is a piece of rare blue amber.

Blue amber (Figure 2) is only found in the Dominican Republic, especially in amber mines around Santiago. This amber is the fossilized resin of the now extinct *Hymenaea protera* trees, and is some 20-30 million years old (Penney, 2016; Poinar and Poinar, 2001). While blue amber is amber-colored, it has the property of showing a milky-blue glowing cast when it is placed in direct sunlight. The blue amber carving on the cover was carved by the master gem-carver Pedro Michel, who used the unique property of the blue amber to his advantage when he expertly carved little "magic-mushrooms" in the amber, allowing them to "glow" blue in the sunlight.

Another rare and beautiful color in amber is red. Red amber is found in Mexico, mainly in the region of Chiapas. It is the fossilized resin of the now extinct *Hymenaea mexicana* trees, and was produced in the late Oligocene/early Miocene epochs, making it around 25-30 million years old (Penney, 2016; Poinar and Poinar, 2001). The piece of amber in Figure 3 is extremely rare. This piece of red Mexican amber was collected in the 1980s, in Totolapa, Chiapas, Mexico. Visible inside the stone is a fossilized yet exceptionally well-preserved *Marasmius*-looking mushroom sharing close quarters with a one-legged grasshopper (Shavit, 2010).

This ancient *Marasmus* in red Mexican amber is as important as it is rare, because it could be an ambassador for its kind, bridging some 25 million years of mushroom evolution. It is a rare occasion when we can look into the past and see where our natural world has been. According to Penney (2016), some areas in the state of Chiapas show similarity of floral composition to that of the former amber forest (like the biosphere *La Encrucijada*). Almost all the living plants in this region have also been identified from palynological records of the amber-bearing sediment, including the genus *Hymenaea*, which was the original resin-producing tree of Mexican amber. "In the case of Mexican amber," Penney quotes the leading authority on Mexican amber, Monica Solorzano-Kraeme, "existing forests could provide excellent opportunity for comparing the diversity of extant and fossil faunas" (Penney, 2016).

The amber stone in Figure 3a also tells a human story: one day I received a photo of this breathtaking piece of

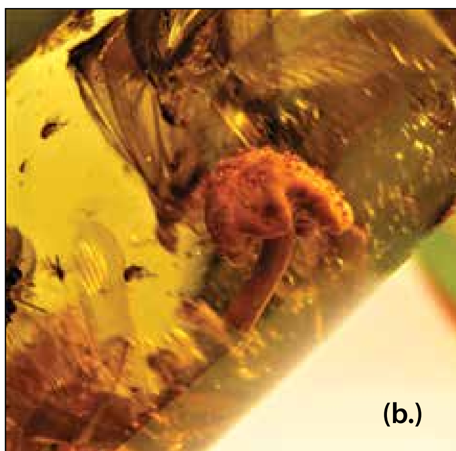

Figure 4. a) A piece of Colombian copal with a mushroom-like object; b) A closer look at the object in Fig. 4a, showing gills in the right side; c) A closer look at Fig. 4b – could it be a species of *Cordyceps*? A parasitized mushroom?

Figure 5. a) Is there a bolete in this young piece of tan Colombian copal? b) Is the object beneath the termite a mushroom? c) Can you see the *Mycena*-like cap of the mushroom in the center, closer to 2 O'clock? d) Is there a *Lycoperdon* in the young Colombian copal?

amber through an agent. A letter from the person who dug it up and collected it accompanied the photo. It told the story of this stone, which the writer came to own in 1980s Chiapas, and through it one can get a glimpse of what it must have been like in the Chiapas amber fields in those days,

"…After that trip to Simojovel, I came to know about another village that was still pretty unknown, and where the villagers were more "campesinos," living more on the products of their fields, than on amber. I decided to go and see over there. The place is called Totolapa, and is also in Chiapas. The road taking up to the village was going across really green jungle. But when it was getting closed to the village it was like God had forgotten about that place. The countryside was getting really dry, and in the village, I could hardly get a place to sleep in a villager's house. I only stayed one or two nights over there, but enough to meet this campesino that had his little mine—no more than a small hole—dug under his corn field. From him I bought a few pieces, and one was bigger than the others, and you could clearly see a quite big insect in a corner: that was the cricket. And that insect raised the price of the amber pieces, together with my long blond hair, of course!"

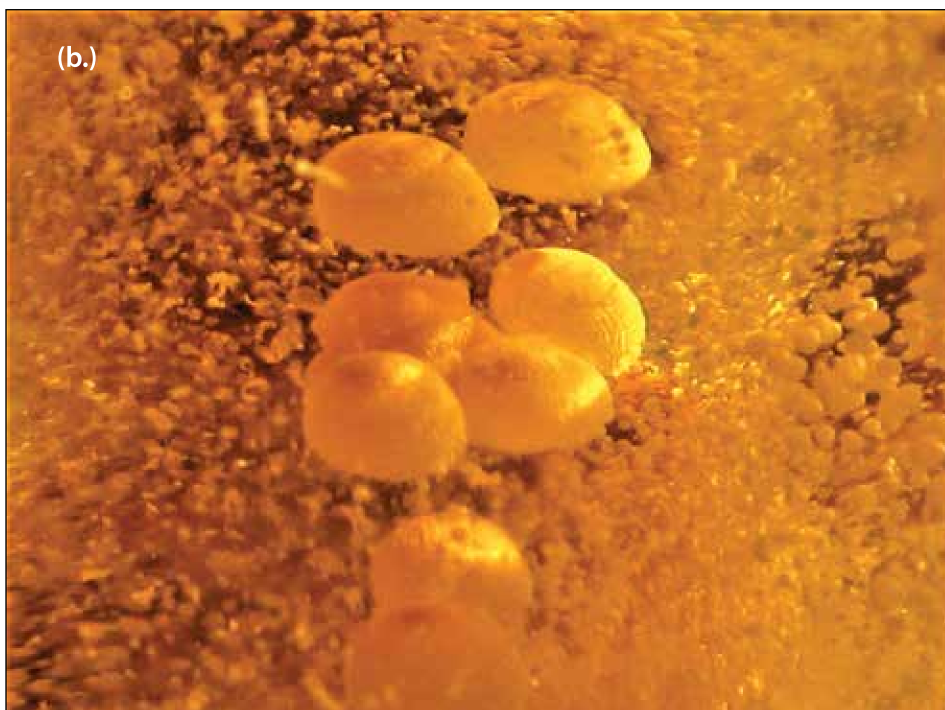

Figure 6. a) A large chunk of Colombian copal, showing a cluster of mushroom-like inclusions, and a number of solitary mushrooms; b) A close-up of the cluster of mushroom-like inclusions; c) A close-up of one of the solitary mushrooms in the copal.

Not all the material that looks like amber and is sold as amber, is actually amber. If amber is the fully polymerized, stable tree resin, then the material coming from Colombia is certainly not. In the early 2000s, it was determined that Colombian amber, though yellow and full of extant and extinct life, has not yet completely polymerized. It was found to be different in its chemical and physical properties than amber. Poinar and Poinar (2001) suggested that the Colombian material was not amber but copal, that it was not fully polymerized, and that it was not millions of years old but could be as young as 65,000 years old (Poinar and Poinar, 2001; Penney, 2016).

Colombian copal from parts of Santander can be spectacular, clear and looking like honey, with only a few inclusions. Most Colombian copal is slightly tanner in color, and swarming with ancient life. Parts of plants, branches, mushrooms, all kinds of insects, including modern-looking mushroom mites, reptiles, amphibians, reptiles, and even mammals can be found in it, often in abundance. If Colombian copal is indeed this young, then it stands to reason that analyzing the immense variety of life in it, some

(c.)

extinct and some still around, could teach us volumes. Particularly on the evolution of our current mushrooms. Judging by the research that Dr. George Poinar has been doing in DNA extraction, it seems to me that this less fossilized, much younger copal material with numerous mushrooms, deserves special attention. Figures 4 and 5 are just a few examples of Colombian copal, which include inclusions that may be mushrooms.

Amber and copal have one essential property in common, which make them the perfect vessels to house fossils, certainly mushroom fossils: the material surrounding the fossilized mushroom is clear, the mushroom is easily observed, and researchers have the advantage of being able to see all parts of the mushroom (often even inside it) with the naked eye, as well as with microscopy. This is very different than in the case of petrified fungi, for example. As Dr. Grimaldi put it, objects preserved in amber "are preserved with a life-like fidelity, unlike any other fossil" (Wilford, 1996).

Records of petrified fungi date back to about 460 million years ago, to the Ordovician period, when glomalean fungi were found preserved in dolomite (Redecker et al., 2000). To the eye, these fossils look like pieces of stone, not unlike the snails and clams easily seen in a slab of kitchen marble, because these fungi have turned to stone. For this reason, it is complicated to assess them and easy to make identification mistakes. One such example is the petrified fungus that Singer and Archangelsky excitedly described in 1958 as a Jurassic period fossil bracket mushroom from Patagonia. They named it *Phellinites digiustoi* and declared it to be the oldest homobasidiomycete (mushroom-forming fungi) ever found (Singer and Archangelsky, 1958). Almost 40 years later, at the height of the Jurassic Park excitement, their identification was overturned and the specimen was determined to be just another piece of petrified tree bark (Hibbett et al., 1997).

I had the opportunity to look for mushrooms in the clear material of Colombian copal, full of ancient life and obviously representing a lively forest community in a warm and humid place, yet I could not find even one single mushroom in this material. I must have peeked inside thousands of Colombian copal pieces. I could not understand the lack of mushrooms in them. If George Poinar was correct in dating Colombian copal, then mushrooms should have been represented, despite their fragility.

One sunny Tucson morning I stopped to see a Colombian copal dealer I knew. He greeted me by saying, "look how beautiful these large new Colombian amber pieces are, even if they don't have mushrooms!" He pointed up to a line of well-polished, large copal pieces on the top shelf. I followed his finger and looked up, and everything suddenly went silent. Up on the top shelf, a large free-form chunk of Colombian copal, teeming with subfossilized life, boasted a nearly perfect cluster of little tan *Mycena*-looking mushrooms (Figure 6).

Back in my room, I finally had time to look closely at this beautiful piece of copal. I noticed a single mushroom close to the "skin" of the stone, and then another, smaller, deeper inside. The large piece of copal seemed to be alive: crickets, stingless bees, termites, ants, rotten wood, and leaves, little air bubbles, something looking like lots of small different sized balls on a piece of tree bark—and even this bunch of mushrooms, with two of the same mushrooms easier to make out.

One thing became abundantly clear to me on that day: it was time to stop chasing after elusive amber and copal objects and begin the process of studying the ones we already had.

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