

## Calcareous Onyx

**1.0 Introduction:** A resurgence in the use of decorative onyx has been noted over recent years, as designers and specifiers have rediscovered the exciting effects that can be done with this beautiful geological material. The striking colors available in this rock type, accentuated by strong veining character and unique translucent properties, have created bold statements within spaces designed by some of today's most imaginative architects. Effective use of this material, however, requires a deep level of understanding of the formation, structure, and composition of the rock. This paper will unlock some of the mysteries and secrets of working with this natural wonder.

The name "onyx" is derived from the Greek word "onux" meaning "claw" or "fingernail", so called for its resemblance with the translucence and color of a fingernail.

In ancient Egypt, onyx (also known as Egyptian alabaster) was highly appreciated for its colorful translucency. It was used to make small perfume bottles, unguent vases (called alabastra), canopic jars and various other sacred and sepulchral objects.

Reported in 77 AD by Pliny the Elder in his encyclopedic *Naturalis Historia*, marmor alabasterum was the name the ancient Romans called the calcareous material quarried along the Nile Valley in the Alabastron locality near Thebes, Egypt.

Further confusion around the use of the term "marble onyx" comes from its use as a synonym for the term "alabaster," which also refers to two distinctly different minerals: hydrated calcium sulphate (gypsum) and calcite. Gypsum alabaster has been quarried since ancient time in central Italy near the city of Volterra.

Modern day misunderstanding of onyx begins with the name itself, as it refers to two completely different rock types. The first is the familiar black-and-white banded siliceous rock consisting of cryptocrystalline quartz (a variety of chalcedony). The second is the topic of this paper: the calcareous type named "Marble Onyx." Banded, generally translucent and capable of being polished to a high gloss, this onyx originates in the dripstone deposits of limestone caverns where it forms stalactites, stalagmites, and other formations that can fill an entire cavern or void space. It is deposited by gentle, dripping water movement followed by evaporation between drops that deposits calcium carbonate from the water onto the formation, incrementally enlarging formations by thousandths of an inch or less per drop. Thus onyx is also a chemical sedimentary stone, and may envelop terrestrial fossil remains. Pre-historic human remains have been found encased in cavern onyx. Although this process of



**Photo 1: A Backlit Onyx Bartop**

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drop-by-drop addition of material does take time, large deposits of onyx begin to mature (filling caverns or fractures) in a relatively short period of geologic time. (Ref: Marble Institute of America *Dimension Stone Design Manual v 7.2*).

Understanding this particular stone begins with consideration of its chemical composition and physical properties.

## 2.0 Chemical Composition, Texture, Structure and Color:

Marble Onyx is usually composed of microcrystalline to coarse calcite and, more rarely, by aragonite. The microcrystals occur as a fibrous or a lamellar texture. Usually the rock is organized in translucent banded horizons with different colors depending on variable amounts of impurities like iron oxides. It is frequently yellow-brown due to the presence of iron oxides, but there are also whitish, light to dark yellow, honey colored, amber, red, or light to dark green varieties. Band contacts range from sharp to vague. Massive structure is less common. The Moh's hardness of onyx marble is 3 with aragonite varieties slightly harder than calcite varieties.

## 3.0 Occurrence:

Marble Onyx occurs in veins, big lenses, patches and stalagmitic deposits related to karst systems. Well organized bands with parallel orientation are related to very quiet environments in karst cavities and caverns. Deposition from water that flows in karst networks could be associated with other mechanism as the interference with magmatic intrusions (e.g. the Egyptian Alabaster). Marble Onyx is also found interlayered with travertine, in the water table phase that converts to calcite over time. Aragonite is far rarer than calcite, apparently being deposited from warmer solutions than calcite. The deposition in successive layers gives rise to the banded appearance.

Chemically, travertine and onyx are very similar. The most visible difference between these two materials is that onyx was frequently formed in



Photo 2: Onyx within a Travertine Deposit



Photo 3: "Traveronyx" - Onyx & Travertine Stone within the same Block



Photo 4: Onyx Quarries of Baluchistan

presence of hot water; therefore water springs in the vicinity of volcanic activity, while travertine was formed elsewhere where spring waters are highly calcareous. Indeed, in travertine quarries, it is quite common to find stratifications interspersed with layers of onyx. On the market there are onyxes that are inter-layered with parts of

travertine, commonly called “Traveronyx” (Ref: Photos 2 and 3 on page 2).

#### 4.0 Quarrying and Deposit Locations:

Onyx deposits are typically shallow, perhaps only a few meters in depth, unlike other carbonate deposits. Marble or limestone deposits can have depths of several hundred meters of harvestable rocks.

Quarrying of onyx is generally accomplished by means of the same equipment used for the other calcareous stone: diamond wire saws are the most frequently used technology, although drilling and blasting are still used in some small quarries located in some of the lesser developed countries.

Production rates of an onyx quarry are quite limited, and would not compare to the production scale of even the smallest marble/limestone quarries. For this reason, careful planning with proper evaluation of the quarry’s production and yield are required for even modest sized projects. It is frequently required to have all of the block material in inventory at the beginning of slab production, so that reliance on subsequent block deliveries can be avoided.

Location of the primary existing onyx deposits is strongly linked to the presence of an ancient volcanic activity, and the following countries are the origin of most of the commercially available onyx today:

- Afghanistan
- China
- Ecuador
- Guatemala
- Iran
- Mexico
- Morocco
- Pakistan
- Peru
- Tanzania
- Turkey

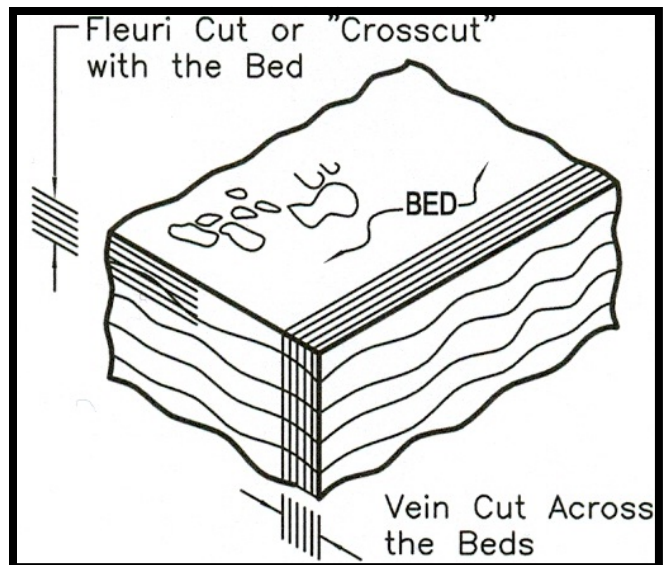
In all stone species, quarries are completely unique, although this may be more true of onyx

quarries than any other dimension stone type.

Perhaps the most impressive onyx quarries, as far as mass is concerned, are those located in Baluchistan (Eastern Pakistan) where the depth of the onyx layer exceeds 6 meters, and the onyx lenses are spread in a very large desert surface (Ref: Photo 4 on page 2).

#### 5.0 Processing:

As is true of all sedimentary rock types, onyx is largely “anisotropic”, or directionally specific in both visual and strength properties. It can therefore be sawn in two distinctly different directions. One method, in which the slabs are sawn parallel to the layers of stratification, is known as a “fleuri” or “crosscut” direction. The other, in which case the slabs are sawn across the layers of stratification, is known as a “vein cut” or “veiny” direction (Ref: Figure 1 and Photos 5 through 8 in Photo Appendix).



**Figure 1: Vein & Fleuri Slab Directions**

Since onyx is generally used as an interior, decorative stone, strength properties rarely govern the decision of which sawing direction shall be used. It is more common that the direction is determined by the specifier’s preference, or the general market demand. In the current marketplace, the crosscut direction is more common, as it generally exploits the translucent feature of onyx more vividly than the vein cut direction. Vein cut slabs

are typically used when slab matching techniques such as “book matched” or “diamond matched” are employed (Ref: Appendix A). In some cases, vein cut slabs are not obtainable or practical due to the limited bed height of the quarry, which limits the block dimension in this direction.

Onyx blocks are usually sawn to slab thickness using gangsaws of the same type with the same abrasive media as is used to saw marble blocks. While onyx can be sawn to any thickness, 20 mm slab thickness is overwhelmingly the most common. Due to limited stability of many onyx varieties, the block is typically reinforced prior to the sawing of the slabs. This treatment is for the prevention of slab breakage both during and after the sawing process. The block is covered with either plastic film or wood planks, but in either case the technique involves injecting epoxy resin which penetrates between the block and the covering material. A vacuum system is used to further draw the resin into the interior regions of the stone fabric.

After the sawing operation, further processing of the slabs is necessary. In nearly all cases, the rear face of each slab is reinforced with a fiberglass mesh adhered with an epoxy, or possibly polyester based resin. This is both for stabilization of the slab and safety in the handling of the slab. On the primary face of the slab, a resin, typically epoxy, is screeded onto the slab surface. In the more sophisticated and automated production environments, the slab will be positioned over a vacuum source on the rear side, thus drawing the resin more deeply into any pores or fissures within the stone slab. Although the production is mechanized, the experience level of the operators calibrating and preparing the slabs is still very important, as the natural features of onyx slabs are widely variable, and each slab must be evaluated as a unique entity. The treatment of the slabs during this phase is extremely influential in the overall performance and/or appearance of the material. (Ref: Photo 10 in Photo Appendix)

Once prepared as above, the slabs are ready to receive their face finish, which in most cases is a

polished finish. The processing lines that are used to polish onyx are usually the same as those used to polish marbles and other stone types, although there have been some lines specifically engineered and built to polish onyx exclusively. The emphasis in polishing onyx slabs is not placed on production rates, but rather the quality of the polish. The goal is to achieve a polished surface of the highest and most uniform gloss, while preserving a nearly perfectly flat plane to provide mirror-like reflective properties. Modern factory finishes utilizing resin impregnation and polishing rarely require retouching by hand. Pressure applied by the polishing wheels, feed rates of the slabs, and the abrasive differ greatly from what is used on other rock types (limestone, granite and travertine), and will even vary significantly between different varieties of onyx.

## **6.0 Practical Considerations when working with Onyx and Onyx-like Materials:**

The Marble Institute of America’s soundness classification for marbles is well known in the industry. In this system, soundness classifications “C” and “D” are not recommended for exterior or wet area installation. A number of onyxes have been classified by this same system, and they are all classified as soundness “C” or “D” stones, which makes them inappropriate choices for exterior application. The weathering characteristics of onyx are quite poor, to the extent that it is not recommended to store onyx slabs outdoors, even for short periods of time. Being products of nature, variability is to be expected when using any natural stone. Simply stated, no two slabs of onyx are the same. This fact, coupled with the typical usage of onyx as a decorative feature finish material, makes the selection and approval process particularly demanding. Onyx typically needs to be viewed in full sized slabs, and must be the actual slabs intended for use in the project. In many cases, the portion of the slab to be used, as well as the directional orientation must be clarified to ensure all parties have a thorough understanding of the intended stock utilization.

Despite its vulnerability to moisture exposure, onyx is sometimes specified as a shower lining material, both in tile and slab application. Contact area of the adhesive is critical, and the material's reaction to the water and steam might be deemed undesirable by some. Oftentimes a seam or other separation plane within the stone fabric will "swell" over time, causing a "lifting" of the surface, to the extent that the occupants can feel the raised lip within the stone surface. This is simply a property of the material, and not considered a defect.

Onyx is occasionally used in curtainwall applications as an accent or feature in interior or other weather protected areas. In this case, the onyx is generally polished on both surfaces, as the translucency of the product is exploited for visual effect. In some cases the onyx can be successfully captured by the the curtainwall system with 4-edge perimeter capture of a minimum  $\frac{3}{4}$ " (20 mm) embedment into the curtainwall frame. Larger panel sizes, reduced thicknesses (especially thicknesses less than 20 mm), or lower strength onyx may require that the stone be laminated to a glass panel for structural support.

Lamination of onyx to glass or transparent plastic backers is a highly specialized area, and is done when the onyx is to be backlit to show the striking effect of the light passing through the translucent stone. Lamination may also be required to achieve code compliance for public safety reasons.

Flexural strength of onyx is low when compared to many other stone varieties, and is frequently in the 500 to 750 lbs/in<sup>2</sup> (3.4 to 5.2 MPa) range. This property, coupled with a brittle breaking behavior, makes bonding area critical. Compliance with the MIA guidelines of coverage and void restrictions is imperative. Additionally, substrate rigidity is critical, and MIA substrate deflection limits must be observed.

Many varieties of onyx have reduced stain resistance, and measures should be taken to prevent staining from related construction products.

White portland cement based thinset adhesives are recommended, and tests should be performed with the actual adhesive and actual onyx to ascertain compatibility. These tests should be run for a minimum of two weeks to allow for substantial cure of the thinset. Grout dyes are probably best avoided altogether, but if used, must be thoroughly tested to assess staining potential. Many joint sealants have oil-based plasticizers included in their formulation, and these have been known to migrate into stone edges and cause staining. Stain testing of sealants should be performed per ASTM C1248.

When designing an anchored system with onyx, it should be noted that anchors (such as strap anchors) requiring a kerf preparation in the stone edge are of extremely low capacity in thin ( $\leq \frac{3}{4}$ ",  $\leq 20$  mm) slab onyx material. Anchors that require very small holes ( $\leq 1/8$ ",  $\leq 3$  mm diameter) such as stainless steel pins or wire anchors will generally perform better. Substrate and frame systems that allow the field mechanic to drill these holes on site and allow some latitude in the anchor placement are advantageous, as the field mechanic can then avoid positioning of the anchor coincident with a natural seam or other separation plane in the stone panel.

Due to the translucency of onyx, light will be transmitted through it even if not in a backlit application. The path of at least some of this light energy will be nearly parallel to the face of the stone. When an opaque joint filler is used, the opacity of the filler blocks the light transmission at that point. This can cause a dark shadow to appear along the perimeter of the onyx panels, even though there is no color difference in the material, only an interruption in the path of the light.

Onyx makes a beautiful flooring surface, but its low level of abrasion resistance generally limits flooring application to residential applications. Even in these light duty exposures, if a polished onyx is used, a reduction in surface gloss should be anticipated as a result of the foot traffic abrasion. It is advisable for the stone professional to

exercise caution when onyx is specified for commercial applications. Selecting onyx for a commercial application must be reviewed in the design phase, and expectations of traffic pattern wear and breakage due to every day use must be understood to all parties involved in the project.

Onyx is frequently used for bar tops, but surface degradation to the onyx should be anticipated. Mild acids can etch the surface, and the sliding of service items across the surface can abrade the stone. Honed surfaces are less likely to manifest the etches and scratches, since they won't exhibit the gloss variation as does a polished surface.

One of the primary vulnerabilities of onyx is its susceptibility to chipping during fabrication. Since all onyxes are unique, some experimentation will be required, but as a general rule, cutting with continuous rim diamond blades designed for marble and polishing using pads designed for marble is likely to be the most successful.

Ironically, what makes onyx beautiful is also what makes it challenging to work. As a heterogeneous material of sedimentary origin, natural onyx is typically going to have numerous "seams", "starts", "voids", and mineral discontinuities that require either repair or reinforcement before the material can be used. Whether performed in the shop or field setting, these repairs are both necessary and permissible, as outlined by the MIA's Soundness Classification system (Ref: Marble Institute of America Technical Bulletin on Marble Soundness, 2005).

Customer Education is paramount when supplying onyx products. The types and extents of repair and reinforcement, the vulnerabilities of the product, and the "patina", or anticipated changes in appearance over the service life of the application must be thoroughly discussed with the customer during the initial phases of the selection process.

## 7.0 Onyx Properties and Specifications:

Within ASTM, all Specifications, Guides, and

Test Methods for dimension stone are under the jurisdiction of Committee C18. This committee has drafted specifications listing the expected values for physical and mechanical property values for most species of dimension stone. For instance, limestone is governed by ASTM C568, Specification for Limestone Dimension Stone, and granite is governed by ASTM C615, Specification for Granite Dimension Stone. The work of this committee has traditionally focused more on stones used in exterior application, and has only recently begun publishing documents pertaining to interior stone applications. Because of this, there has never been an ASTM specification published governing physical and mechanical properties of onyx. So while the same test methods can be used to determine the values, there is no specification to which those values can be compared for evaluation. Many have used the marble specification, C503, as benchmark values, but this is not an endorsed practice, since marble and onyx differ greatly in structure and performance.

Typical property values of onyxes on the market are listed in the table on the next page.

## 8.0 Summary:

This highly decorative stone variety is appreciated by all, but none will appreciate it at the level of one who has actually worked "hands-on" with this challenging, yet rewarding creation of nature. Many of the processes involved in successfully completing a detailed onyx application can be executed only at the hands of a true artisan of the trade. While mechanization and computerization of many processes have made the working of onyx more efficient, these materials will never fully surrender their requirement to be recognized and treated as unique individuals. Therein lies the true beauty of onyx.

	Country	Absorption % by Weight	Density		Compressive Strength		Flexural Strength	
	of Origin		kg/m <sup>3</sup>	lbs/ft <sup>3</sup>	MPa	lbs/in <sup>2</sup>	MPa	lbs/in <sup>2</sup>
<b>Akhisar Onyx<sub>(1)</sub></b>	Turkey	0.30%	2,700	168.6	39.2	5,690	11.4	1,650
<b>Songwe Onyx<sub>(2)</sub></b>	Tanzania	0.07%	2,770	172.9				
<b>Onice Smeraldo<sub>(3)</sub></b>	Iran	0.19%	2,900	181.0	53.0	7,680		
<b>Onice Verde<sub>(3)</sub></b>	Pakistan	0.15%	2,548	159.1	48.1	6,970	11.4	1,650
<b>Honey Onyx<sub>(4)</sub></b>	Turkey	0.50%	2,690	167.9	84.5	12,260	7.7	1,120
<b>White Onyx<sub>(5)</sub></b>	Iran	0.03%	2,700	168.6	79.9	11,590		
<b>Orange Onyx<sub>(5)</sub></b>	Iran	0.03%	2,720	169.8	75.9	11,010		
<b>Light Green Onyx<sub>(5)</sub></b>	Iran	0.02%	2,730	170.4	105.1	15,240		
<b>Vista Grande Onyx<sub>(4)</sub></b>	USA	0.11%	2,589	161.6	46.0	6,668	4.5	656
<b>Multicolor Onyx<sub>(4)</sub></b>	Pakistan	0.12%	2,730	170.4	133.1	19,300	4.6	667
<b>Rosa Grande Onyx<sub>(4)</sub></b>	USA	0.11%	2,589	161.6	46.0	6,668	4.5	656
<b>Light Green Onyx<sub>(4)</sub></b>	Pakistan	0.01%	2,728	170.3	139.3	20,208	9.1	1,313

**Sources:**

1. Turkish Natural Stones,
2. Dimension Stone in ACP Countries,
3. Lombardy Stone Association,
4. Marble Institute of America, and
5. Royal Debid Stone

**Thank You:**

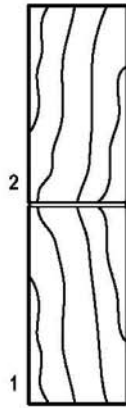
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Appendix A: Veneer Patterns

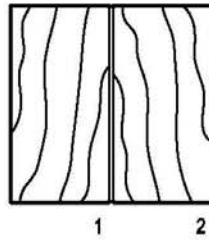
**VENEER PATTERNS**

Although the illustrations below depict a perfect match or mirror image of veining, such perfection is not realistic in actual stone veining. A portion of the block is lost due to the width of the saw kerf when the slabs are cut, and the veining position is likely to shift slightly across this offset. Brecciated marbles, for example, are extremely difficult to accurately cut into matched patterns. Ideally, jointery of the wall should plan for 4 panels of equal size.



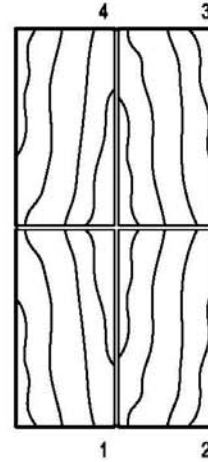
**END MATCH PATTERN**

The adjacent faces of panels 1 & 2 are finished. Panel 2 is inverted above panel 1.



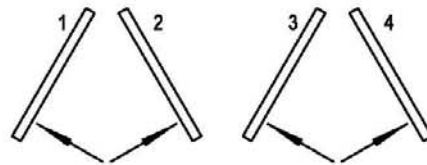
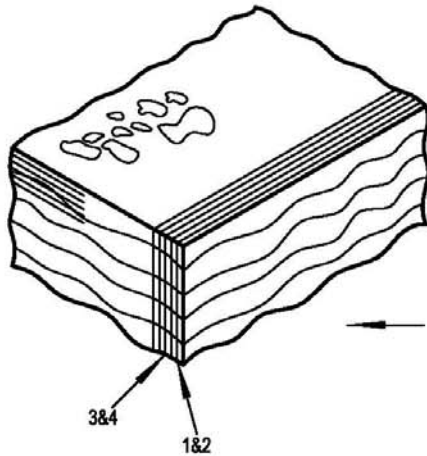
**BOOK MATCH PATTERN**

The adjacent faces of panels 1 & 2 are finished. Panel 2 is placed next to Panel 1 as the pages of a book are opened.



**QUARTER OR DIAMOND MATCH PATTERN**

Panels 1 & 2 are book matched. Panels 3 & 4 are book matched and then inverted over the top of panels 1 & 2.



← DENOTES SIDE TO BE FINISHED

**RIFT AND SAWING DIRECTIONS**

MIA DIMENSION STONE DESIGN MANUAL VERSION 7.2

**Appendix B: Glossary of Terms**

- Alabaster:** A fibrous variety of gypsum (porous)
- Anhydrite:**  $\text{CaSO}_4$  (essentially gypsum without the water of crystallization)
- Aragonite:**  $\text{CaCO}_3$  (same composition as calcite, but a different crystal structure)
- Calcite:**  $\text{CaCO}_3$  (primary mineral of limestone and marble)
- Chalcedony:** A cryptocrystalline variety of quartz...may be translucent or semitransparent and nearly a wax-like luster...varieties include onyx and sardonyx.
- Gypsum:**  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  (the water is part of the crystal structure)
- Onyx:** Variety of chalcedony that is like banded agate...alternating bands of different colors which are roughly parallel. The name onyx is used on two different rock types: siliceous onyx and calcareous onyx. In the mineralogical literature the term onyx indicates a (black and white) banded siliceous rock composed of chalcedony, a crypto crystalline variety of quartz. However, in recent time, the term onyx has been used in the commercial field for calcareous banded material. This is sometimes referred to as onyx marble or marble onyx.
- Onyx Marble:** Also “Marble Onyx”; Compact, usually banded, generally translucent variety of calcite resembling true onyx. Generally deposited from cold water solution.
- Siliceous Sinter:** Lightweight porous opaline variety of silica. Precipitated from waters of geysers and hot springs. Example, Mammoth Hot Springs in Yellowstone.

**Photo Appendix**



**Photo 5: Onice Orange - Cross Cut (Iran)**



**Photo 6: Black Onyx - Cross Cut (Turkey)**



**Photo 7: Onice Orange - Vein Cut (Iran)**



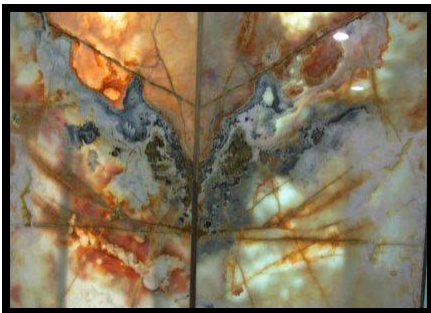
**Photo 8: Onice Smeraldo - Vein Cut (Iran)**



**Photo 9: Onice Azzurro - Diamond (Iran)**



**Photo 10: Resinated Onyx Block**



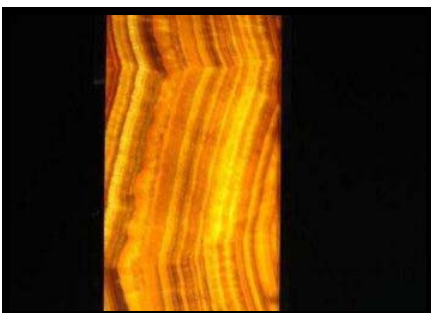
**Photo 11: Backlit, Bookmatched Onyx**



**Photo 12: Backlit Onyx**



**Photo 13: Backlit Onyx**



**Photo 14: Backlit Onyx**



**Photo 15: Backlit, Bookmatched Onyx**



**Photo 16: White Onyx Slabs**



**Photo 17: Jade Green Onyx, Crosscut, Bookmatched, and Backlit**



**Photo 18: Jade Green Onyx, Veiny Cut, Bookmatched, and Backlit**



**Photo 19: Tilting Laminated Panels of Honey Onyx Into Place**



**Photo 20: Gunsmoke Onyx Fireplace Under Construction**



**Photo 21: Gunsmoke Onyx Island Top**



**Photo 22: Reston Eastpoint Lobby**



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