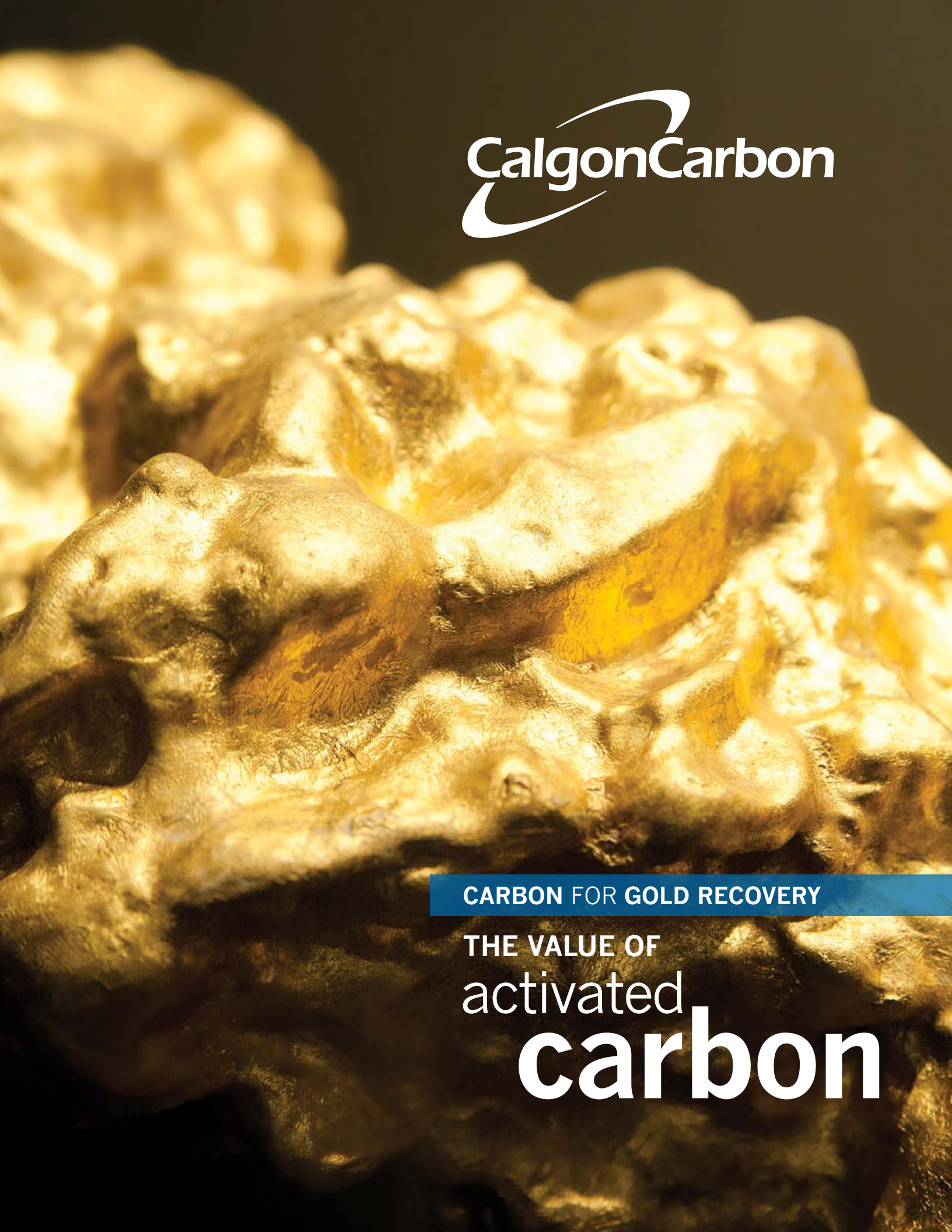


CARBON FOR GOLD RECOVERY

THE VALUE OF activated carbon

In your line of work, every ounce counts. As a result, it's critical that you choose an activated carbon that minimizes loss and maximizes loading. Our activated carbon products for gold recovery applications accomplish these goals. And with the introduction of our new Gold Plus product, we can help you meet your treatment objectives at a lower cost.

Calgon Carbon's high-quality activated carbons for gold recovery have been developed and proven to maximize efficiency by reducing the loss of precious metals and carbon consumption with three precious metal extraction techniques: Carbon-in-Column (CIC), Carbon-in-Pulp (CIP), and Carbon-in-Leach (CIL). Our granular activated carbon (GAC) products offer:

- Higher gold adsorption capacities for maximum gold loadings
- Excellent gold adsorption rates for high throughput
- Superior hardness to minimize gold losses and prevent plugging of screens
- Ability to liberate gold quickly and efficiently

In addition to our product advantages, Calgon Carbon's expertise in activated carbon application technology is a valuable resource for designing and optimizing your entire gold recovery process.

Calgon Carbon's activated carbon products for gold recovery provide our customers with exceptional value by maximizing yield and minimizing loss.

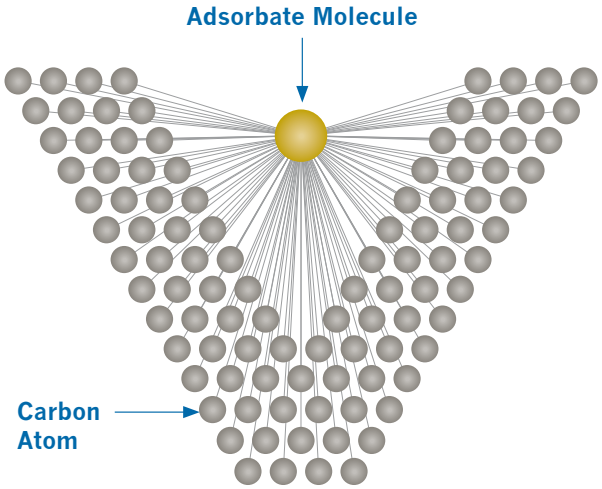
ACTIVATED CARBON ADSORPTION

Activated carbon is a highly porous organic material comprised of a series of graphitic plates, which are interconnected by carbon-carbon bonds. This creates a highly porous structure and gives an extensive internal surface area, where "adsorption" occurs. Adsorption is a surface reaction that causes compounds to "stick" to the surface of the carbon. The phenomenon is the result of intermolecular attractions or forces inherent to the carbon surface. In gold recovery applications, adsorption forces remove gold from solutions and adhere the metal complex to the carbon surface.

Because the reaction occurs at the surface of the carbon, the adsorption process is relatively easy to reverse, a process called "desorption." While it is important to maximize the adsorption of gold from the solution, it is equally as important to subsequently desorb the gold from the carbon. Any molecules that remain adsorbed after elution or stripping translate into gold that cannot be recovered. As a result, it is important to select an activated carbon that efficiently adsorbs and desorbs to maximize overall yield and profitability.

Activated carbon can be produced from a variety of different precursors, including coal, coconut, wood, and lignite, which are the primary materials used to make commercial-scale activated carbon. The starting material dictates the pore size distribution of the final activated carbon product. Typically, coconut is the precursor for gold recovery applications because of its tight pore structure, high activity pores, and hardness.

HOW ACTIVATED CARBON WORKS

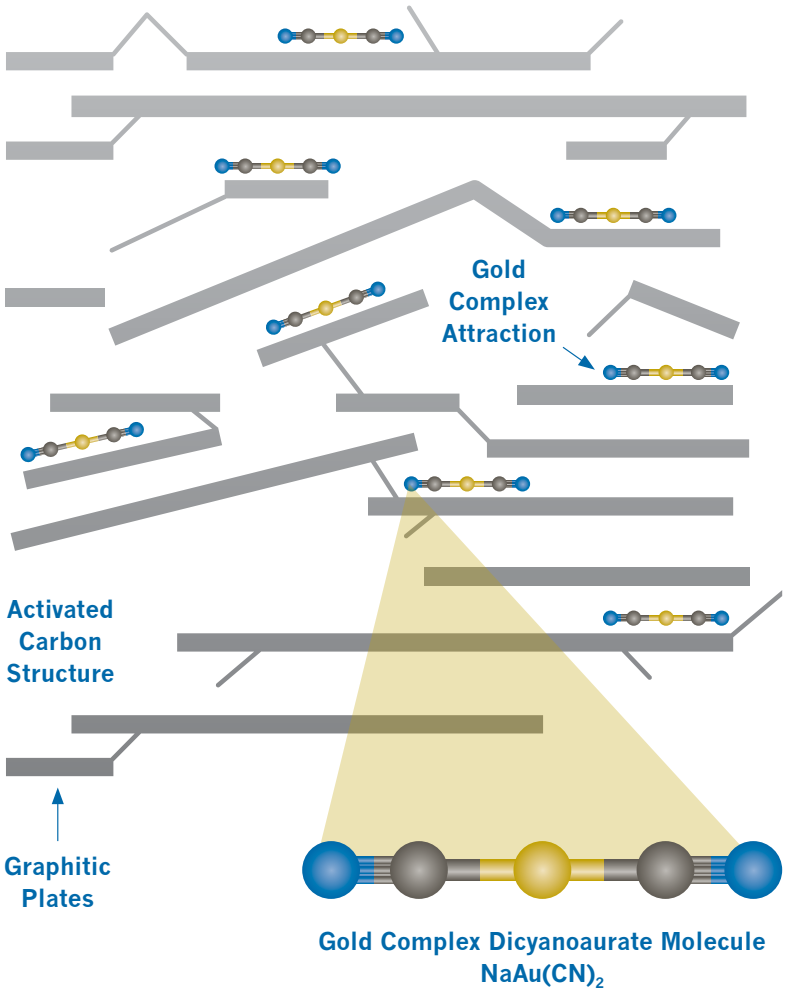


In physical adsorption, contaminants are adsorbed and held on the internal surface of activated carbon due to Van der Waals Forces of attraction between the carbon atom and the molecule. The force of attraction diminishes as the distance between the pore wall and the adsorbate molecule increases.

One handful of activated carbon has a surface area equivalent to that of a football field. The massive surface area of activated carbon makes the material an ideal adsorbent.

THE **GOLD RECOVERY** PROCESS

ADSORPTION OF GOLD CYANIDE COMPLEX

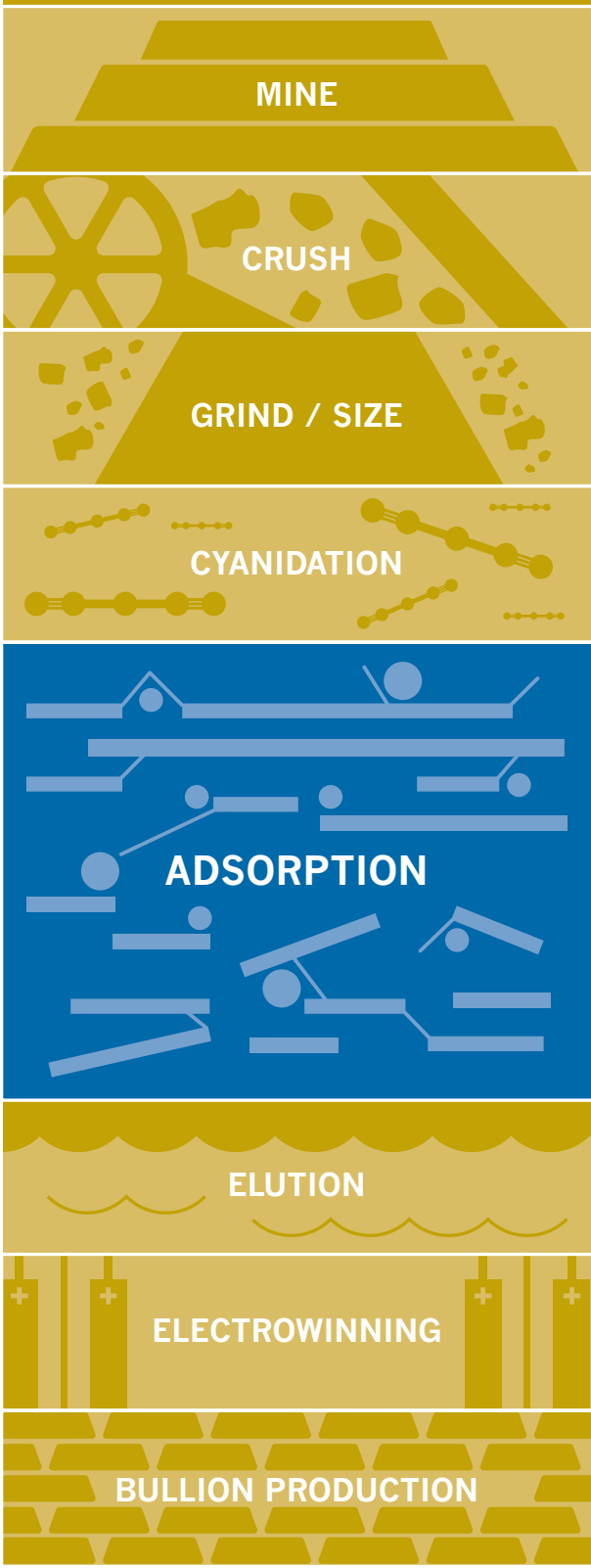


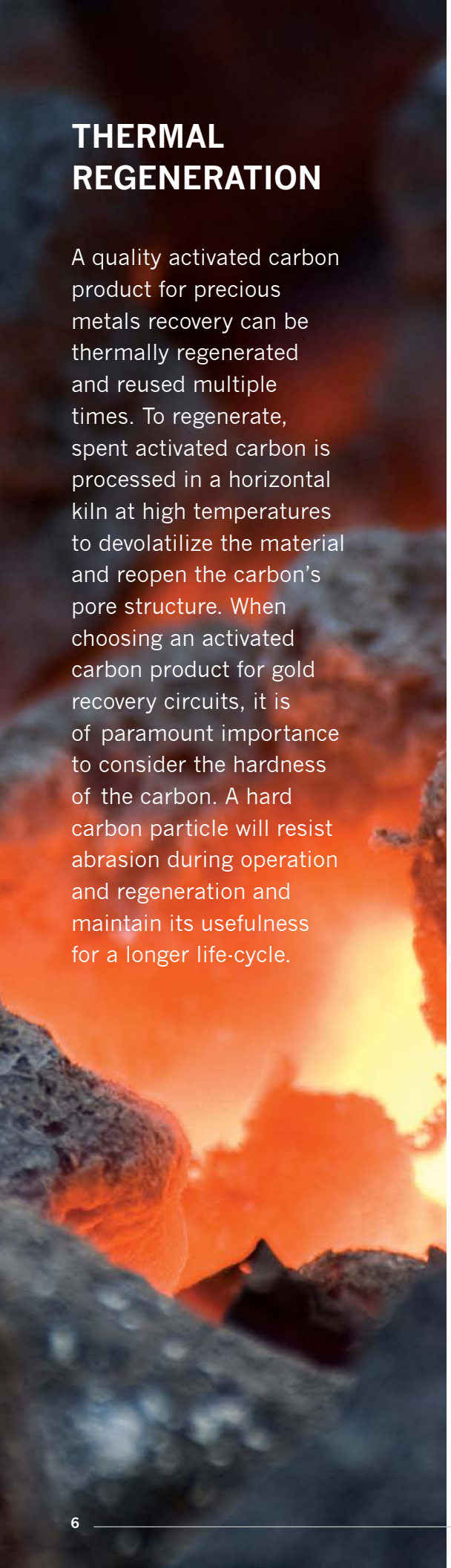
Gold Complex Dicyanoaurate Molecule
$NaAu(CN)_2$

ACTIVATED CARBON ADSORPTION

The diagram above depicts gold adsorption on activated carbon's graphitic plates. Gold alone is not soluble, and will not be readily adsorbed by activated carbon until it is cyanidated, forming a gold-cyanide coordination complex called dicyanoaurate. It is this gold-cyanide complex that is attracted to the tremendous surface area available on activated carbon, allowing for a variety of recovery techniques.

GOLD RECOVERY
PROCESS FLOW





THERMAL REGENERATION

A quality activated carbon product for precious metals recovery can be thermally regenerated and reused multiple times. To regenerate, spent activated carbon is processed in a horizontal kiln at high temperatures to devolatilize the material and reopen the carbon's pore structure. When choosing an activated carbon product for gold recovery circuits, it is of paramount importance to consider the hardness of the carbon. A hard carbon particle will resist abrasion during operation and regeneration and maintain its usefulness for a longer life-cycle.

ADSORPTION PROCESSES WITH ACTIVATED CARBON

A variety of extraction techniques are employed to liberate gold from crushed raw ore. These processes make the gold available for release into the cyanide solution.

CARBON-IN-COLUMN

CIC is most commonly used to recover gold from heap leaching operations, processes in which a sodium cyanide solution percolates through a "heap" of crushed and agglomerated ore, causing the gold to leach into the solution. The gold-bearing solution is then pumped to a series of adsorption columns containing activated carbon. Heap leaching followed by CIC circuits is a preferred method for gold recovery from low grade surface deposits and waste rock because of its low capital and operating costs.

CARBON-IN-PULP

In CIP operations, mined ore is milled and mixed with water and thickeners, creating a slurry of ore and water called pulp. The pulp is then pumped to air-agitated leaching vessels, where the gold is leached out of the ore using a sodium cyanide solution. The pulp is transferred to a series of adsorber tanks containing activated carbon, which mixes with the leached pulp and flows countercurrent to the pulp in a series of tanks. The gold-bearing activated carbon is separated from the pulp by a mesh screen that blocks the carbon from passing through, while the smaller pulp particles are filtered away.

CARBON-IN-LEACH

CIL operations are very similar to CIP, but activated carbon is instead added directly to the vessels in which cyanidation is taking place. CIL is an especially beneficial technique when ore contains high levels of carbonaceous material. Naturally present carbon competes with the activated carbon in adsorbing gold in a process called "preg robbing," which causes gold losses. Therefore, in CIL, the cyanidation process is carried out simultaneously with adsorption on activated carbon, which is in direct contact with pulp in the cyanide solution. The CIL process minimizes the time that cyanidated gold can be in contact with competing carbon native to the ore.

Typically, gold is not directly recovered. Instead, ore is crushed to release gold, which then reacts with sodium cyanide in a process called cyanidation. The process is characterized by the following chemical reaction:

$$4\ Au + 8(NaCN) + O2 + H_2O = 4\ NaAu(CN)_2 + 4\ NaOH$$

After the metal complex ($NaAu(CN)_2$) is formed, activated carbon will adsorb the gold cyanide complex from the gold bearing stream (pregnant liquor). To maximize loading on the carbon and overall yield, it is important to select a high quality carbon with the appropriate physical characteristics, which impact the performance of activated carbon for gold recovery applications. These properties include:

- **Hardness Number**
  Hardness is the resistance of particles to crack and/or break apart on handling. Poor activation can negatively impact hardness, resulting in high attrition and platelet generation within the gold circuit.
- **CTC/Butane Activity**
  CTC/Butane Activity are both measurements of the area available for the gold complex to bond and relate to the adsorption capacity, or k-value.
- **Particle Size Distribution or Internal Screens**
  The size of individual activated carbon particles has a significant impact on kinetics, the speed at which the gold complex is adsorbed. Smaller particles tend to adsorb more quickly, while larger particles tend to have slower kinetics. It is important to have a consistent particle size distribution or internal screen distribution to minimize gold loss and maximize gold loading.

Calgon Carbon's products for gold recovery are manufactured using high quality coconut feedstock and rigorous manufacturing processes to maintain the quality and consistency required for maximum performance.

Physical Characteristics of Gold Recovery Carbons

	DG-11 6x12	Gold Plus 6x12	GRC-20 6x12
Apparent Density, Oven	0.53 g/cc	0.54 g/cc	0.50 g/cc
Ash	1.9%	2.1%	1.9%
ASTM Hardness	100	100	99
Butane Activity—ASTM	19.5 g/100g	19.5 g/100g	17.5 g/100g
Moisture	3.2%	2.5%	2.5%
CTC	50	50	45
Mesh % <12	0.8	0.7	1.0

The adsorption capacity, or k-value, is highly dependent on the gold solution used for the test.

DG, GRC, and Gold Plus products can be purchased in different activities and screen sizes based on your application's requirements.

While we do not specify our carbons to K and R values, we do recognize that these are important considerations for gold mines. Therefore, we have established guidelines to help you evaluate our products.

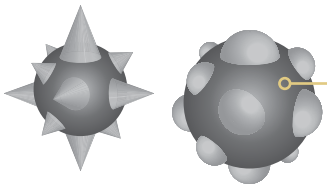
K VALUE
>30
KG Au/t

R VALUE
>50%
after one hour

Calgon Carbon's experience in the last decade has provided great advancements in knowledge of the adsorption process and carbon specifications as they relate to precious metal recovery. With the understanding that cost is a key driver for metals recovery operations due to the inherent volatility in metals pricing, Calgon Carbon has rigorously evaluated the manufacturing process to identify areas for cost reduction and developed a new product, Gold Plus, which offers equivalent performance to the DG product family and superior performance to the GRC product family, at a significantly reduced cost.

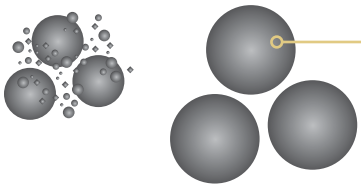
"Processing is important, region is not."

Previously, many believed that coconut from Sri Lanka provided the best activated carbon for gold recovery, but our studies prove that the manufacturing conditions of the activated carbon have a greater impact than the source region.

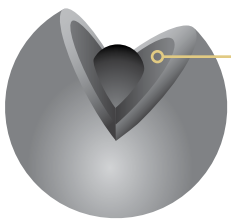


Some of the most critical processing steps for producing a high quality activated carbon for gold recovery include:

Pre-attrition is the process by which an activated carbon is subjected to force or attrition before it is sent to the customer site. This process breaks off sharp edges that would otherwise readily adsorb gold and be lost in screening, and reduces the initial degradation that the customer will see on site.



De-dusting is another step that removes fine carbon particles. Typically, after activation, the carbon will have a film of dust that is not removed through screening. These fines or dust will have a high affinity for the gold complex. In fact, the dust will have much higher kinetics than the granular carbon, but they will be lost in the circuit. As a result, it is critical to perform de-dusting in the manufacturing process.



Activation is when the graphitic plates react, and carbon, nitrogen, and hydrogen atoms are plucked from the carbon skeleton, creating pores. Activation conditions have a big impact on the carbon properties. Proper temperature control ensures that the activity of the carbon is consistent and provides superior gold loading. This consistency will improve a site's gold adsorption and ability to regenerate the carbon effectively.

WHY CHOOSE GOLD PLUS?

Equivalent performance to DG family and **superior performance** to GRC family

Provides **significant cost savings** over DG and GRC products

Reduces risk of being dependent on one region prone to severe weather conditions

Calgon Carbon historically offered two products lines – DG-11 and GRC-20. DG-11 was exclusively produced in Sri Lanka. While it performed better than GRC-20, that increased performance was a result of the extra processing steps taken in production, which, in addition to Sri Lanka's labor costs, made it more expensive. GRC provided sufficient performance, but the recycle yield was reduced and the gold losses were high due to more fines created, as compared to DG-11.

Gold Plus was developed as a product with equal performance to DG-11 at a lower cost. By optimizing the process, we were able not only to reduce the cost, but also to introduce coconut feedstock from different regions. These factors serve to reduce the price and supply volatility of Gold Plus. Studies and field trials confirm that Gold Plus has equal performance to DG-11 but at a significantly lower cost. Additionally, Gold Plus has superior performance compared to GRC-20 and is available at an even lower cost.

About Calgon Carbon

Calgon Carbon Corporation is an industry leader through unmatched innovations in the purification, separation, and concentration of liquids and gases. Throughout our history, Calgon Carbon has been a pioneer in creating new products, systems, and services from infancy stages to global commercialization. As an industry forerunner in activated carbon, Calgon Carbon provides cutting-edge purification solutions in more than 700 distinct market applications, from purifying sweeteners and pharmaceuticals, air, and water, to separating gases and removing mercury emissions from coal-fired power plants.

Each year, hundreds of customers turn to Calgon Carbon to solve their purification and separation challenges. Our technical experts frequently help customers choose the most cost-effective solutions, and our laboratories are fully equipped to perform a variety of carbon characterization and performance tests.

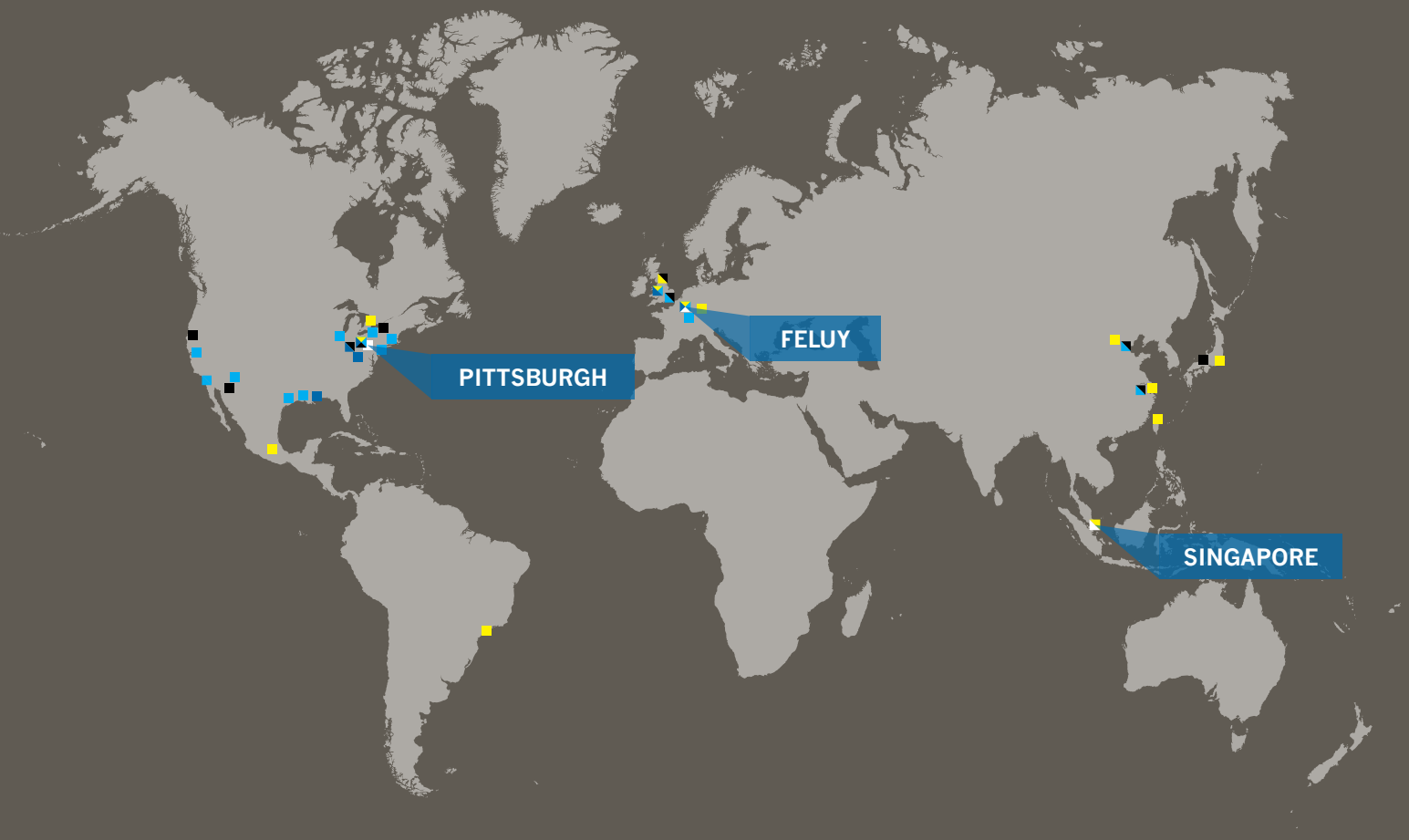
For more information, please contact us at **1-800-422-7266** or **info@calgoncarbon-us.com**.

Pure Water. Clean Air. Better World.

Calgon Carbon's technical expertise and capabilities will help provide the most economical and efficient solution for your application.

GLOBAL LOCATIONS

FACILITY SERVICE SALES REACTIVATION HEADQUARTERS



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