Diamonds

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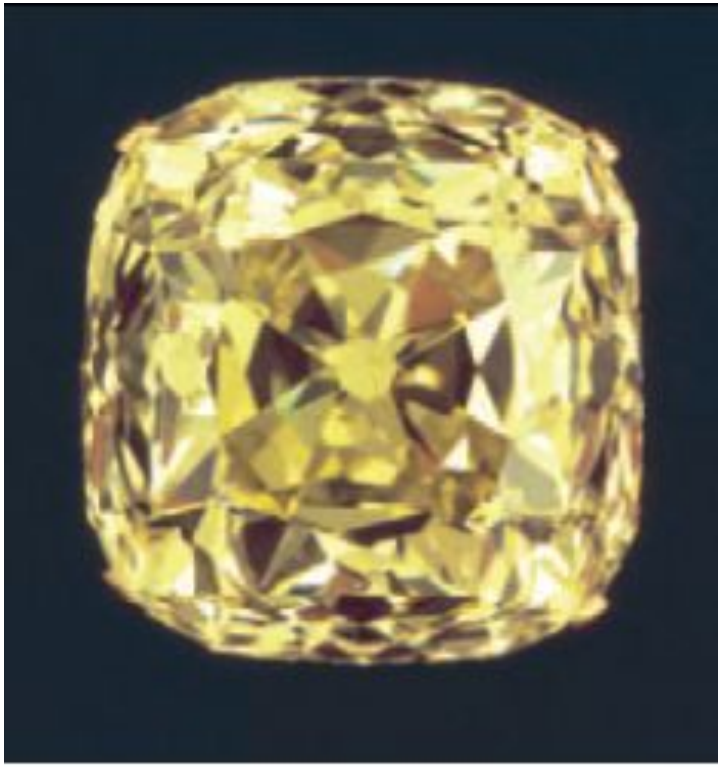
Diamond, the ultrahard cubic form of carbon, is a mineral requiring a long string of superlatives to describe its properties, its technological and commercial importance.
Diamond, the king of gems, is at the heart of the most lucrative part of the gem industry,
with an unmatched combination of brilliance, fire, Hardness. Natural diamonds are probably the oldest and deepest-sourced objects we will ever touch, and provide direct information about the mantle.



Tiffany diamond, 287.42 ct, canary, from Kimberley, South Africa. PHOTO COURTESY OF TIFFANY & CO. ARCHIVES

Diamond is a beautiful substance in many ways. Its simple but elegant crystal structure (FIG. 1), in which each carbon atom is bonded to four other atoms in a tetrahedral arrangement, yields a strong rigid framework. Combining this structural arrangement, which coincides with the hybrid *sp3* orbitals of carbon, with the unmatched strength of the C–C bond, explains most of diamond’s properties.

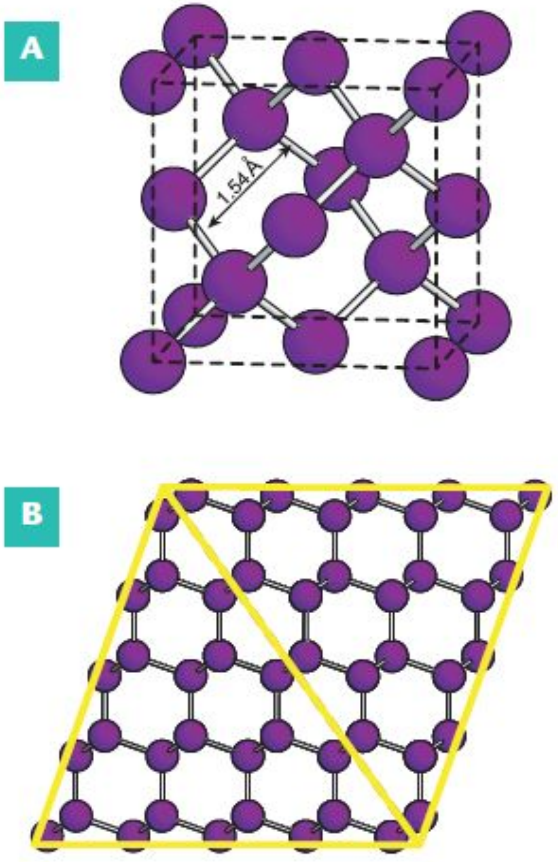


FIGURE 1 Ball and stick models of the diamond structure showing (**A**) the unit cell with the C–C distance indicated and (**B**) a projection with the boundaries of an octahedron, the archetypal “diamond” shape.

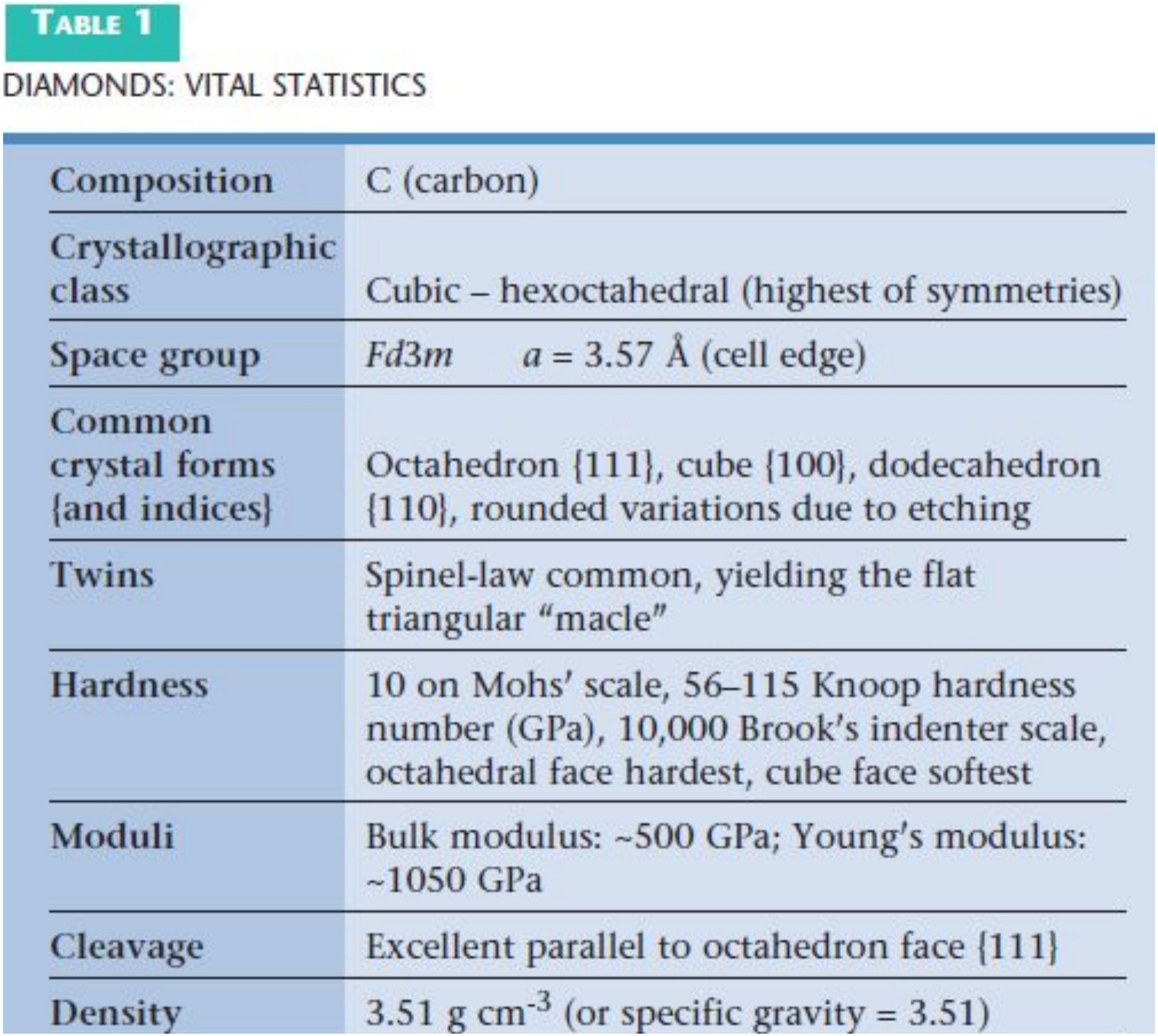
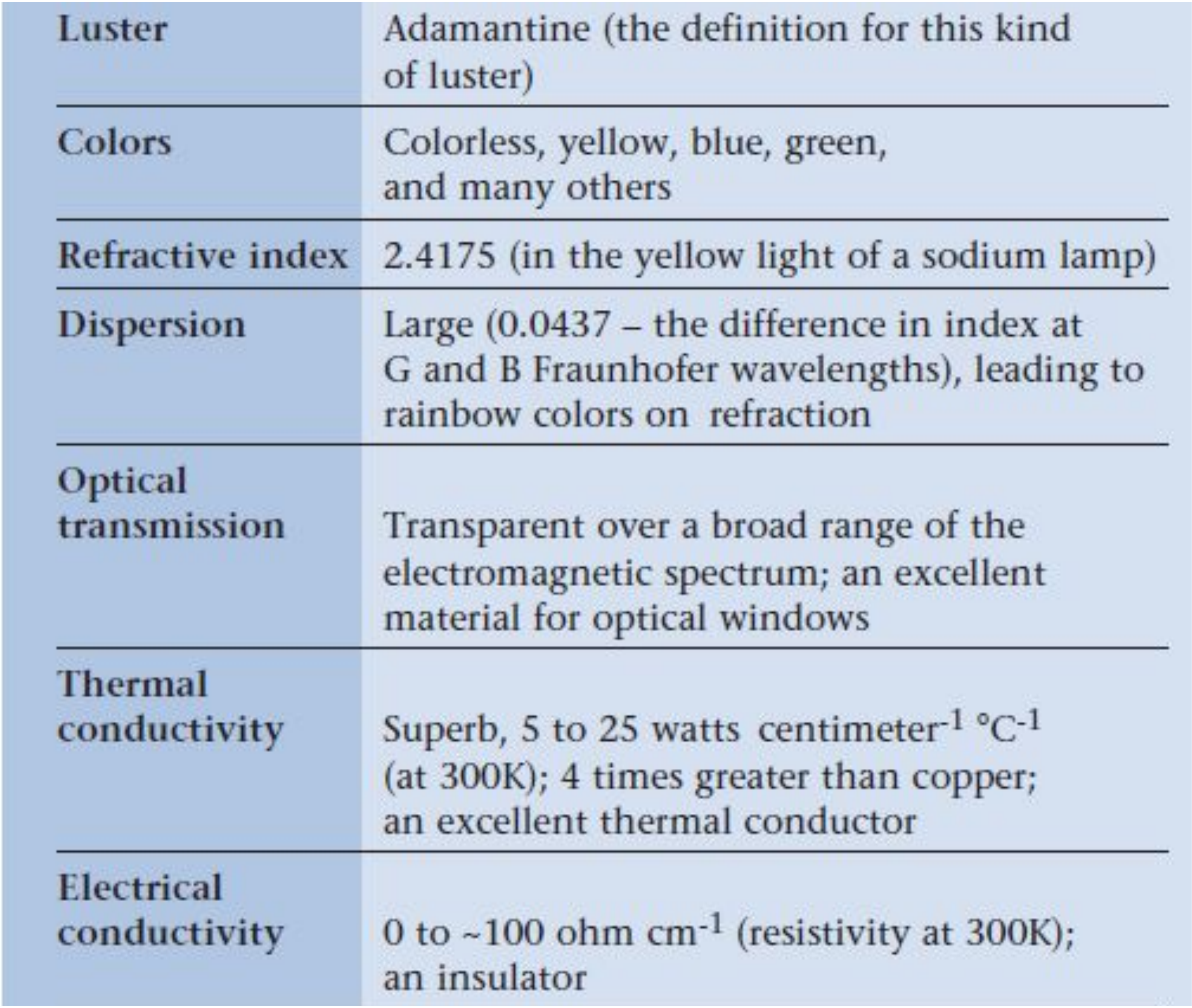


TABLE 1

DIAMONDS: VITAL STATISTICS

Composition	C (carbon)
Crystallographic class	Cubic – hexoctahedral (highest of symmetries)
Space group	*Fd3m* *a* = 3.57 Å (cell edge)
Common crystal forms {and indices}	Octahedron {111}, cube {100}, dodecahedron {110}, rounded variations due to etching
Twins	Spinel-law common, yielding the flat triangular “macle”
Hardness	10 on Mohs′ scale, 56–115 Knoop hardness number (GPa), 10,000 Brook′s indenter scale, octahedral face hardest, cube face softest
Moduli	Bulk modulus: ~500 GPa; Young′s modulus: ~1050 GPa
Cleavage	Excellent parallel to octahedron face {111}
Density	3.51 g cm^{-3} (or specific gravity = 3.51)

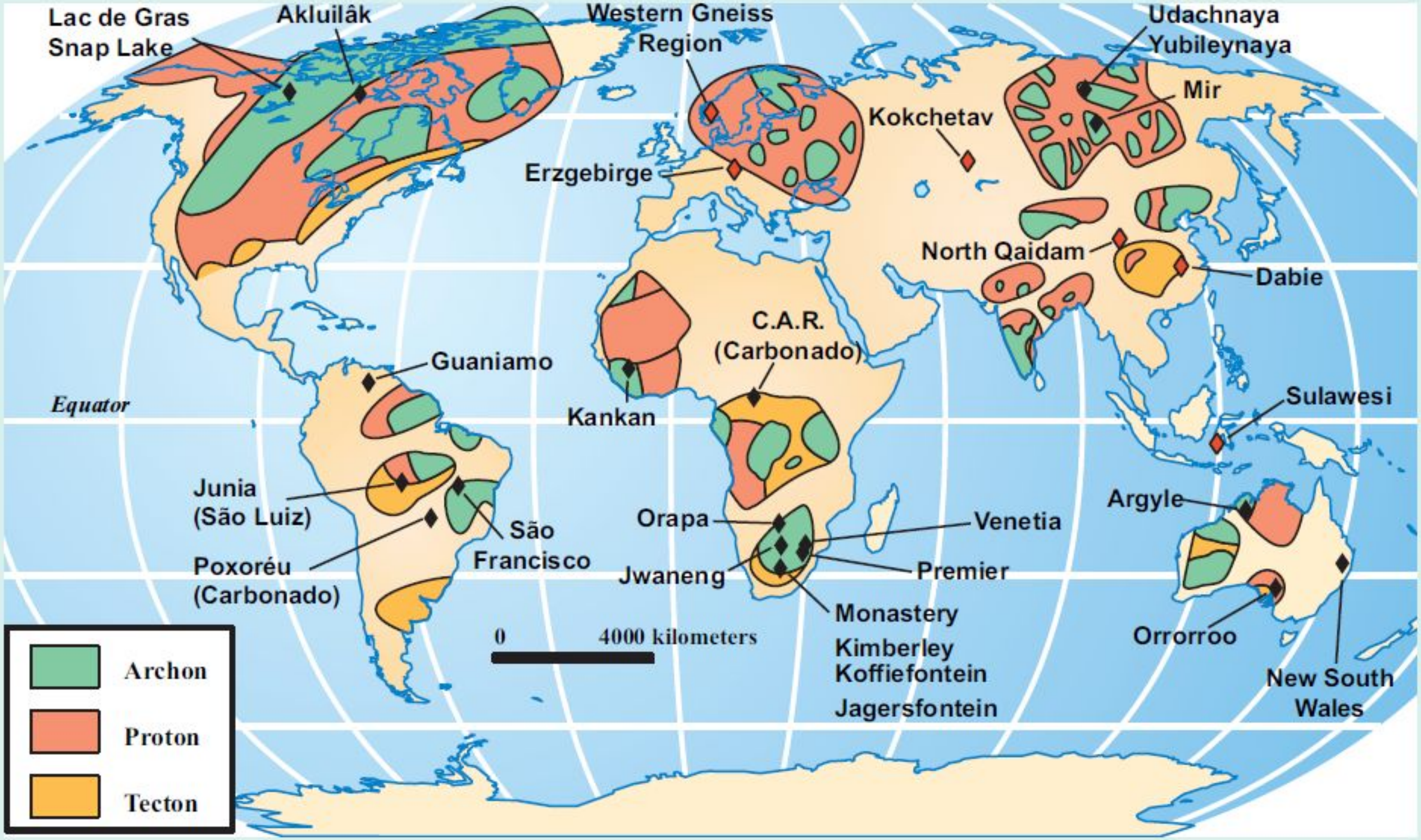


Luster	Adamantine (the definition for this kind of luster)
Colors	Colorless, yellow, blue, green, and many others
Refractive index	2.4175 (in the yellow light of a sodium lamp)
Dispersion	Large (0.0437 – the difference in index at G and B Fraunhofer wavelengths), leading to rainbow colors on refraction
Optical transmission	Transparent over a broad range of the electromagnetic spectrum; an excellent material for optical windows
Thermal conductivity	Superb, 5 to 25 watts centimeter^{-1} °C^{-1} (at 300K); 4 times greater than copper; an excellent thermal conductor
Electrical conductivity	0 to ~100 ohm cm^{-1} (resistivity at 300K); an insulator

The high density of diamond (3.51 g cm-3) as compared to that of graphite (2.20 g cm-3), the other common polymorph of carbon, is a clear indication that diamond is a high-pressure mineral, formed mostly in Earth’s interior. Thus, diamond is a key indicator and recorder of events deep within our planet, in part because its extreme strength and refractory nature permits it to survive exhumation to Earth’s surface and subsequent weathering (another aspect is the extraordinary volcanic style of kimberlites and lamproites, which act as express elevators to raise diamonds quickly from depth, but that is a different story). Moreover, inclusions captured in a diamond growing in the mantle are protected by its adamantine embrace, so diamonds have become our “space missions” to inner Earth, providing our most important samples for understanding the chemistry of the deep mantle.

By extracting inclusions (yes, diamonds get busted, burned, and ground away) and analyzing them, researchers have discovered the association of diamond with peridotite and eclogite assemblages from the roots of ancient cratons. More recently, transition-zone and lower-mantle signature minerals have been identified. The contribution by Stachel, Brey, and Harris reviews the status of these, the deepest samples of Earth that we have at our finger tips. Diamonds, while essentially pure carbon, allow us to investigate their carbon source through isotopic analysis of C and the minor contained N. Cartigny presents the available isotopic data and shows how diamonds reveal the hallmarks of primitive Earth, recycled crustal sources, and crystallization processes.

One of the most remarkable diamond discoveries in the last decades is that of the nanometer-sized diamonds in meteorites. Meteoritic diamonds are hardly new, since they were described in the Canyon Diablo iron meteorite in 1891. On the other hand, diamonds in the Nova Urei (Ringwood 1960; Carter et al. 1964) and Kenna (Berkley et al. 1976) ureilites formed by shock on the meteorite parent body. Searching for the most primitive materials and reservoirs of noble gases in primitive meteorites, led Ed Anders and colleagues to seek the last moieties in meteorites that could not be dissolved by aggressive acid or base—diamond, graphite, and silicon carbide. Huss reviews the results of research on these “nanodiamonds” and their possible origin in supernovae prior to the formation of our solar system.



World map showing diamond sources cited in this issue. Colored areas demark "Archons"–cratons older than 2.5 Ga, "Protons"–cratons 1.6-2.5 Ga, and "Tectons"–0.8-1.6 Ga, important in prospecting for mantle-derived diamonds (see Stachel et al., this issue). Black diamond symbols are used for mantle-derived sources and red diamonds for ultrahigh-pressure (UHP) metamorphic sources. (Adapted from Levinson 1998)

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