

GEMOLOGICAL ABSTRACTS

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COLORED STONES AND ORGANIC MATERIALS

Fossils in amber: Unlocking the secrets of the past. D. Penney
[david.penney@manchester.ac.uk], *Biologist*, Vol. 53,
No. 5, 2006, pp. 247–251.

Some of the more fascinating aspects of amber are its fossil inclusions: Many small forms of life are captured with exceptional clarity. It is also important for its ability to capture interactions between organisms and for the comparisons it offers to current evolutionary processes. This article discusses some of the factors affecting the scientific community's ability to extrapolate from the amber fossil record, and looks at the particular value of the two most significant deposits (in the Baltic region and the Dominican Republic).

As with more familiar fossils preserved in carbonate rocks and sediments, the rarity of fossils in amber means that many taxonomic studies suffer from the availability of very few specimens, and this lack of adequate data worsens the older (and thus rarer) the amber samples are. The author also mentions the uncertainty involved in applying knowledge of current life to paleocommunities that may or may not have behaved similarly, as well as how scientists must try to compensate for possible bias toward the preservation of certain groups in amber. As an example, arboreal and hunting spiders are discussed in terms of their ecological niches (body size and web building in trees vs. hunting); experiments have shown with regard to size that modern tree resins trap spiders uniformly, allowing scientists in this case to form reasonable comparisons between much older fossils and more recent ecologies.

Other topics discussed range from using fossils in amber to

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help study global climates (as biology can be a sensitive recorder of the environment) and the possibility of cloning extinct species using their fossil DNA (which is described as minimal).
DMK

Genesis and composition of lazurite in magnesian skarns.

S. M. Aleksandrov and V. G. Senin, *Geochemistry International*, Vol. 44, No. 10, 2006, pp. 976–988.

Gem-quality lazurite occurs in the Hindu Kush Mountains of Badakhshan, Afghanistan (Sar-e-Sang lapis lazuli deposits), and in the Pamir Mountains of Tajikistan (Lyadzhvardara). It is also found in several additional localities, such as the Lake Baikal region of eastern Russia (Slyudyanka and Malaya Bystritsa). At each of these locations, it is hosted by aluminosilicate rocks that are associated with Fe-poor, Mg-rich skarns. The skarns are formed by the metasomatic alteration of dolomites along their contact with igneous intrusive rocks. To produce lazurite, it is necessary for the alkaline hydrothermal or magmatic solutions that formed the skarns to contain sulfur (as both sulfate and sulfide) along with chlorine. However, the lazurite mineralization appears to postdate skarn formation. The magnesian skarns can also be sources of other gem minerals, including corundum and spinel. Chemical-composition data are provided for lazurite from a number of world deposits.
JES

Herkunftsbestimmung von Süßwasserzuchtperlen mit Laser Ablations ICP-MS [Provenance determination of freshwater cultured pearls using laser ablation ICP-MS]. D. E. Jacobi, U. Wehrmeister, T. Häger, and W. Hofmeister, *Gemmologie: Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 55, No. 1–2, 2006, pp. 51–58 [in German with English abstract].

In Japan, freshwater pearls are cultivated mainly in Lake Biwa and Lake Kasumigaura. In the latter, a crossbreed of the mussel *Hyriopsis schlegeli* with *H. cumingii* is used, and freshwater shell beads are implanted. By contrast, Chinese cultivators generally use *H. cumingii* and *Cristaria plicata* mussels, and the cultured pearls are beadless. However, as the quality of the Chinese products continually improves, it is becoming increasingly difficult to distinguish Kasumigaura cultured pearls from Chinese products by standard visual methods.

The authors performed LA-ICP-MS analyses on 41 Kasumigaura samples and a number of Chinese freshwater cultured pearls to determine the concentrations of trace elements (Li, Be, Mg, Mn, Co, Ni, Cu, Zn, Sr, Ba, and Ag). All showed high Mn contents, which clearly distinguished them from saltwater cultured pearls. Kasumigaura samples showed lower and less variable Ba/Sr ratios than their Chinese counterparts; these reflect different trace-element compositions that are typical for the waters in which they were cultivated.
RT

Mineralogy of fossil resins of northern Eurasia. M. A. Bogdasarov, *Proceedings of the Russian Mineralogical Society*, Vol. 135, No. 6, 2006, pp. 66–78 [in Russian with English abstract].

The authors investigated the diagnostic properties and genesis of fossil resins from Cretaceous, Tertiary, and Quaternary sediments of northern Eurasia on the basis of their physical and chemical characteristics (e.g., morphology, size, mass, density, optics, mechanical and thermal properties, and chemical composition). The constitution of amorphous organic minerals with a polymeric structure allows the use of IR spectroscopy and other analytical methods. A summary of results from an investigation of the amber-bearing provinces of Baltic-Dnieper, northern Siberia, and the Russian Far East showed that the resins of Baltic-Dnieper are amber (succinite). The amber-like materials from northern Siberia and from some Far Eastern areas are mainly represented by the fragile resins retinite and gedanite, which have no value for jewelry. In contrast, the widespread fossil resins from the Sakhalin coast (Russian Far East) are rumanite and have a high potential for jewelry use.
RAH

The nanostructure of fire opal. E. Fritsch, E. Gaillou [eloise.gaillou@cnrs-immn.fr], B. Rondeau, A. Barreau, D. Albertini, and M. Ostroumov, *Journal of Non-Crystalline Solids*, Vol. 352, 2006, pp. 3957–3960.

Fire opal is typically transparent and characterized by an orange bodycolor. This color is caused by the absorption of light by needle-like iron oxide nanoparticles. Fire opal forms in rhyolitic tuffs, and gem-quality material is mined around the world. The authors studied 60 fire opals from Mexico, Brazil, Ethiopia, Kazakhstan, Tanzania, Slovakia, and the United States, and found that their structure was different from other types of opal that display play-of-color.

Narrow ranges of R.I. and S.G. values suggest that fire opal is a homogeneous material. Raman spectra showed a broad band at 325 cm⁻¹ with minor shifts. Fire opals are less amorphous than most play-of-color opals, with characteristics of opal-CT. Scanning electron microscopy and atomic force microscopy revealed that the structure of fire opal consists of random aggregations of near-spherical grains with an average diameter of 20 nm—far smaller than the 150–300 nm spheres composing the majority of play-of-color opal. The authors propose that these near-spherical grains or “nanograins” are fundamental building blocks of fire opal and possibly of many other varieties of opal as well.
KSM

Vetri naturali [Natural glasses]. M. C. Venuti, *Rivista Gemmologica Italiana*, Vol. 1, No. 1, 2006, pp. 25–37 [in Italian].

Natural glasses are formed in three situations: (1) during the cooling of certain volcanic rocks (e.g., obsidian), (2) during the impact of extraterrestrial bodies (e.g., impactite and tek-

tite), and (3) from lightning strikes (fulgurite). The author explains their formation and describes the many varieties of obsidian. Obsidian is used as an ornamental stone, and some tektites (moldavite and Libyan desert glass) can be faceted. However, synthetic glass is frequently offered as natural; examples include beer bottle glass and transparent "obsidian" from Mount St. Helens. The author states "with absolute certainty" that natural facetable obsidian does not exist and that the only known facetable natural glasses of good quality are moldavite and Libyan desert glass. *RT*

DIAMONDS

Diamonds from the Udachnaya pipe, Yakutia. V. Rolandi [vanda.rolandi@unimb.it], A. Brajkovic, I. Adamo, and M. Landonio, *Australian Gemmologist*, Vol. 22, No. 10, 2006, pp. 387–397.

The authors studied 10 octahedral greenish yellow to brownish orange-yellow diamond crystals (0.07–0.62 ct) from the Udachnaya mine, Sakha Republic, Russia. The main surface features included growth layers, shield-shaped laminae, negatively oriented trigons, dislocation planes, and etch features. Inclusions of Cr-spinel and Mg-ilmenite indicated that eight of the stones were peridotitic (P-type) diamonds, while two with inclusions of rutile, chromite, and garnet were eclogitic (E-type). All were identified as type IaAB diamonds. Their cathodoluminescence (CL) color reactions, surface features, and inclusions suggest that these diamonds may have formed at a temperature of ~1200°C and pressures over 5 GPa, but were later subjected to fluctuations in temperature and pressure, leading to two or more different growth stages. Raman, FTIR, and CL spectra are presented. *RAH*

Directional chemical variations in diamonds showing octahedral following cuboid growth. D. A. Zedgenizov, B. Harte [ben.harte@ed.ac.uk], V. S. Shatsky, A. A. Politov, G. M. Rylov, and N. V. Sobolev, *Contributions to Mineralogy and Petrology*, Vol. 151, 2006, pp. 45–57.

Most natural diamonds develop with either octahedral or cuboid morphology. However, some may show a mixed growth mechanism—which usually evolves from octahedral to cuboid—resulting in so-called coated diamonds. In this study, the authors examined 16 diamonds from Siberia that showed a reversal in this growth sequence.

The samples were polished into thin plates (50–70 µm) for study of their internal growth morphologies in detail. The cuboid cores were densely populated with micro-inclusions but did not show the well-defined fibrous structures typically present in coated diamonds. Some fibrous structures could be observed in the core during the early stages of growth. However, they were modified by high-temperature annealing during subsequent octahedral growth. With photoluminescence imagery

(excited using an ultraviolet wavelength), the cuboid zones fluoresced yellow to greenish yellow while the octahedral zones fluoresced blue to dark blue. X-ray topographs showed a dark diffraction contrast of the cuboid core created by numerous dislocations. Cathodoluminescence images showed that octahedral growth on the cuboid core began with numerous small octahedral apices that evolved to larger octahedral faces.

The micro-inclusions were identified by FTIR spectroscopy as carbonates (calcite and dolomite-ankerite), water, apatite, quartz (shifted from the normal spectral position), and silicates. The spectra showed that the cubic cores had large amounts of nitrogen B-aggregates, whereas the octahedral portion had A-aggregates. The appreciable nitrogen aggregation in the core suggests that these diamonds resided in the mantle for long periods. The quantities of nitrogen, hydrogen, vacancies, dislocations, and micro-inclusions decreased from core to rim, suggesting various modes of growth kinetics, such as a slower growth rate in the octahedral zone than the cuboid core and changes in the source fluid's composition.

Photoluminescence spectra revealed H4 and N3 centers in the cuboid cores, whereas octahedral zones showed a much higher intensity of N3 centers but no H4 defects. SIMS analysis revealed a carbon isotopic composition that was "lighter" in the core and "heavier" in the octahedral zone. The concentration of nitrogen was 846–1410 ppm in the cuboid cores to 200–600 ppm in the octahedral zones. Carbonates and water in the micro-inclusions suggested that these diamonds crystallized from fluid containing C, O, H, and N. The authors also concluded that the composition of the diamond-forming fluid fell between carbonate-rich and hydrous end-members. *KSM*

Natural, untreated diamonds showing the A, B and C infrared absorptions ("ABC diamonds"), and the H2 absorption. T. Hainschwang, F. Notari, E. Fritsch, and L. Massi, *Diamond and Related Materials*, Vol. 15, 2006, pp. 1555–1564.

Natural diamonds showing a combination of types IaAB and Ib (i.e., infrared absorptions related to A aggregates, B aggregates, and isolated nitrogen [C defects]) are considered extremely rare. Such diamonds are also notable for their weak-to-strong H2 absorption. The authors studied nine brown-to-yellow diamonds (0.01–0.21 ct), six of which were so-called ABC diamonds. Most of them appeared inhomogeneous; the darker core had a phantom cloud of cuboid shape created by small particles, while the lighter rim, created by octahedral growth, showed higher clarity. FTIR spectra showed additional differences between the core and the rim: The core contained high quantities of aggregated nitrogen, while the rims had lower concentrations, most as type Ib. All the ABC diamonds were inert to long- and short-wave UV excitation, but most showed luminescence in response to 425 nm light.

The H2 center is commonly observed in treated diamonds, but it is largely unknown in natural, untreated diamonds. However, it was seen in these diamonds along with a previously undocumented absorption peak at 905 nm that was tentatively attributed to hydrogen-related defects. The authors propose that the strong H2 absorption is caused by the large amount of isolated nitrogen along with A centers and the presence of vacancies. The hydrogen-related absorptions are suggestive of rapid growth in an environment that was rich in carbon, nitrogen, and hydrogen. SE-M

Some observations on diamondiferous bedrock gully trap-sites on Late Cainozoic, marine-cut platforms of the Sperrgebiet, Namibia. J. Jacob [janajacob@namdeb.com.na], J. D. Ward, B. J. Bluck, R. A. Scholz, and H. E. Frimmel, *Ore Geology Reviews*, Vol. 28, 2006, pp. 493–506.

This article reviews the bedrock morphology underlying the diamondiferous beach placer deposits of Namibia. It has been well established, since the discovery of diamonds there in 1928, that the Orange and Vaal river systems have been transporting diamonds from the southern African interior to the Atlantic coast since at least the mid-Eocene (~40–50 Ma). Longshore drift from the prevailing winds has further transported diamonds northward along the Namibian (specifically Sperrgebiet) coast for up to 120 km from the Orange River mouth to Chemeis Bay—a zone known as Mining Area No. 1 (MA1). This zone's underlying bedrock consists of alternating hard (meta-arenite) and soft (chloritic schistose) layers of Late Proterozoic meta-sediments beveled into platforms by wave action during the Quaternary Period. Differential wave erosion of the alternating layers has created “gullies”—actually, large crevices (up to 100 m long by 4 m wide and 7 m deep)—which make superb trap sites for dense clastic material (such as diamonds) that is being transported along the beach.

The authors used air photo techniques, field mapping (of exposures from mining activity), and airborne laser topographic surveys to identify three major gully types: (1) swash-parallel, (2) strike-parallel, and (3) joint gullies. Swash-parallel gullies occur only in the southernmost section of MA1 and are perpendicular to the paleo-wave fronts. Since the sediment load in the south is both high (in volume) and coarse (in grain size), the wave action overrides local geologic structures such as joints. As this coarse bedload (highest diamond counts) decreases to the north, bedrock lithology and structure become the dominant factors in gully formation.

The central section of MA1 is dominated by strike-parallel gullies, which are directly related to the dip of bedrock foliation (bedding parallel) of 80–89°W. In the north, where the sediment load is both at its lowest and finest, only joint gullies have formed along preexisting cracks in the bedrock. Further, it was found that all the

gullies are deeper and closed (i.e., creating the best diamond trap sites) on their seaward margins, while they are shallower and somewhat open on their landward end. A specific example was measured by tacheometric survey giving detailed elevations throughout the gully. The shallow incision on the landward margins of the gullies is attributed to lower wave energy (being further from the sea) of the tidal system. A model is also presented illustrating the growth of “pot holes” in the bedrock that eventually coalesce into longer and longer gullies.

KAM

GEM LOCALITIES

Amethyst-bearing lava flows in the Paraná Basin (Rio Grande do Sul, Brazil): Cooling, vesiculation and formation of geodic cavities. D. Proust [dominique.proust@hydrasa.univ-poitiers.fr] and C. Fontaine, *Geological Magazine*, Vol. 144, No. 1, 2006, pp. 53–65.

Large amethyst geodes (up to 2.5 m) are found in tholeiitic basalt lava flows near the town of Ametista do Sul in the state of Rio Grande do Sul, Brazil. This study was undertaken to better understand the degassing and cooling history of these lava flows that permitted the formation of the large amethyst geodes. Whereas some geologists have invoked the role of surface water in geode formation, the present authors conclude that the cavities resulted from the exsolution of water and other gases from the cooling lava. They attribute the elongate shape and abnormal size of some geodes to rapid cooling and the coalescing of multiple exsolving gas bubbles, respectively. JES

Ar-Ar and U-Pb ages of marble-hosted ruby deposits from central and southeast Asia. V. Garnier, H. Maluski, G. Giuliani [giuliani@crpg.cnrs-nancy.fr], D. Ohnenstetter, and D. Schwarz, *Canadian Journal of Earth Sciences*, Vol. 43, No. 4, 2006, pp. 509–532.

Ruby deposits hosted by marbles are distributed along the Himalayan mountain fold belt that formed during the Tertiary collision of the Indian plate with Asia, as well as in the Indochina crustal block extruded along shear zones during this collision. These metamorphic deposits are found in Tajikistan, Afghanistan, Pakistan, Nepal, Myanmar, and Vietnam. This study was undertaken to relate the age of their formation to the geologic events associated with the continental collision. Ruby itself is not suitable for age dating, but inclusions in ruby, and certain associated minerals, can both be dated by certain techniques.

Ar-Ar age dates of between 25 and 4.6 Ma document Oligocene-Miocene cooling ages for the ruby-bearing metamorphic belts, which in turn represent minimum ages for ruby formation. These ages are in agreement with published data on the tectonic-metamorphic history of the marbles hosting the rubies. U-Pb age dates of 54–36

Ma for zircon inclusions give a maximum Eocene age for ruby mineralization in Vietnam. The specific time of formation of each ruby deposit depended on its location within the fold belt. JES

Contrasts in gem corundum characteristics, eastern Australian basaltic fields: Trace elements, fluid/melt inclusions and oxygen isotopes. K. Zaw [khin.zaw@utas.edu.au], F. L. Sutherland, F. Dellapasqua, C. G. Ryan, T.-F. Yui, T. P. Memagh, and D. Duncan, *Mineralogical Magazine*, Vol. 70, No. 6, 2006, pp. 669–687.

Corundum xenocrysts from alkali basalt fields differ in their lithospheric origins (magmatic vs. metamorphic) and hence in their characteristics. Detailed comparisons are made between sapphires from Weldborough in northeastern Tasmania and those from Barrington in New South Wales. The Tasmanian sapphires had a magmatic signature (high Ga, average 200 ppm), and were dominated by Fe (avg. 3300 ppm) and variable Ti (avg. 400 ppm) as chromophores. They contained Cl, Fe, Ga, Ti, and CO₂-rich fluid inclusions, and yielded $\delta^{18}\text{O}$ values (5.1–6.2‰) in the mantle range. Geochronology on coexisting zircons suggested several sources (200–47 Ma) that were disrupted by the basaltic melts (47 $\pm$ 0.6 Ma). Corundum from Barrington included magmatic sapphires (avg. 170 ppm Ga; $\delta^{18}\text{O}$ 4.6–5.8‰) with relatively more Fe (avg. 9000 ppm) and less Ti (avg. 300 ppm). Zircon dating suggested that gem formation preceded and overlapped Cenozoic basaltic melt generation (59–4 Ma). The Barrington samples also consisted of a metamorphic sapphire-ruby suite (low Ga, avg. 30 ppm), with Cr as an important chromophore (up to 2250 ppm). Fluid inclusions were CO₂-poor, but melt inclusions suggested some alkaline melt interaction. The $\delta^{18}\text{O}$ values (5.1–6.2‰) overlapped magmatic sapphire values. The formation of the metamorphic suite may be attributed to interactions at contact zones between Permian ultramafic bodies and later alkaline fluids. RAH

Famous mineral localities: The Erongo Mountains, Namibia. B. Cairncross [bc@rau.ac.za] and U. Bahmann, *Mineralogical Record*, Vol. 37, No. 5, 2006, pp. 361–470.

This article provides a detailed review of the mineral wealth of the Erongo Mountains in Namibia. Originally mined for tin by German settlers in the early 1900s, this region was found to contain abundant pegmatites and their accompanying wealth of minerals. Fine crystals of aquamarine, schorl, and jeremejevite are known from various areas of the mountain complex. One of Erongo's most important finds happened in April 2000, when the first major pocket of aquamarine was discovered on the farm Bergsig 167. Various localities and their geology are discussed along with the types of minerals that come from each. Vast areas have yet to be explored because much of the land is privately owned and large northern and western

sections form part of the Erongo Mountain Nature Conservancy. Numerous maps, diagrams, and photographs of the region and its minerals are provided. JEC

Formation of emeralds at pegmatite-ultramafic contacts based on fluid inclusions in Kianjavato emerald, Mananjary deposits, Madagascar. Ye. Vapnik [vapnik@bgu.ac.il], I. Moroz, M. Roth, and I. Eliezri, *Mineralogical Magazine*, Vol. 70, No. 2, 2006, pp. 141–158.

Emeralds from Kianjavato on the eastern coast of Madagascar are hosted by the Ifanadiana-Angavo shear zone and formed via metasomatic processes near the contact between pegmatite and hornblende. Fluid inclusions in emerald and quartz samples were studied by microthermometry and Raman analysis. Three main populations of inclusions were found: CO₂-rich, CH₄-rich, and H₂O-rich with a salinity of ~2 wt.% NaCl. Based on fluid-inclusion data, the emeralds crystallized at 250–450°C and 1.5 kbar.

Fluid inclusions were also studied in emeralds from Ianapera in southern Madagascar. Those emeralds are hosted by the Ampanihy shear zone and formed in the absence of pegmatites; they were found to contain mostly CO₂-related fluid inclusions.

Both shear zones resulted from collisional forces related to the formation of the early supercontinent Gondwana. At Kianjavato, the intrusion of granitic pegmatites shortly after this collisional event contributed the bulk of the fluids to the metasomatism. The regional deformation event is thought to have taken place at 530–500 Ma, and phlogopite related to the emerald-bearing veins has been dated by ⁴⁰Ar/³⁹Ar at 490 $\pm$ 8 Ma. Mantle-derived CO₂-rich fluids were channeled by the shear zones, while H₂O-rich fluids of crustal origin are related to pegmatite emplacement. The introduction of CO₂-rich fluids into graphite-bearing host rocks created a reducing environment that generated the CH₄-rich fluids. While pegmatite–host rock interactions were the main driving force behind the metasomatic formation of the Kianjavato emerald deposits, the presence of CO₂-rich fluid inclusions suggests that fluids from the shear zone also played a role. EAF

The variation of gemmological properties and chemical composition of gem-quality taaffeites and musgravites from Sri Lanka. K. Schmetzer [schmetzerkarl@hotmail.com], L. Kiefert, H.-J. Bernhardt, and M. Burford, *Australian Gemmologist*, Vol. 22, No. 10, 2006, pp. 485–492.

The gemological, chemical, and spectroscopic properties of two transparent faceted taaffeites, a semitransparent taaffeite crystal, and a faceted transparent musgravite from Sri Lanka were determined. The grayish violet color of two taaffeites and the musgravite was caused by various amounts of iron, and the purplish red taaffeite contained traces of chromium in addition to moderate iron.

Variations in the RI and SG values of these specimens were correlated to their chemical composition, and in particular the sum of the concentrations of transition elements based on electron-microprobe analysis. The RI and SG values of taaffeite and musgravite overlap, so for an unequivocal determination a combination of X-ray diffraction analysis, quantitative chemical analysis, and/or Raman spectroscopy may be necessary. RAH

INSTRUMENTS AND TECHNIQUES

Gemmologia a basso costo. Costruirsi una bilancia per il peso specifico delle gemme [Gemology at low cost. How to construct a specific gravity scale for gems]. P. F. Moretti, *Rivista Gemmologica Italiana*, Vol. 1, No. 1, 2006, pp. 61–64 [in Italian].

The author describes how to set up a simple specific gravity apparatus using low-cost materials (<€50). He discusses the problems and pitfalls of its construction, the measurement procedure, and possible errors (and how to reduce them). He also explains the difference between SG and density and why this difference can be ignored. RT

JEWELRY HISTORY

Italian gemology during the Renaissance: A step toward modern mineralogy. A. Mottana [mottana@uniroma3.it], *Geological Society of America Special Paper* 411, 2006, pp. 1–21.

Significant advances in the study of gems and minerals occurred in Italy during the height of the Renaissance in the 16th century. Italy hosted the superior universities in Europe at the time (such as Ferrara and Padua) and these academic centers, together with the rediscovery of ancient knowledge from the Greeks, Romans, and Arabs, led to the publication of a number of works on minerals and gems. Around 1469, the first of what became numerous editions (over the next 150 years) of Pliny's 37-volume encyclopedia *Naturalis historia* was printed in Venice. These and other books served to transfer historical knowledge of gems from Italy to the other countries of Europe. The book *Speculum lapidum* by Leonardi (1502) serves as a marker between the speculations about gems prevalent during the Middle Ages and early scientific studies that commenced during the Renaissance. The writer Agricola, a native of Saxony who spent 1522–1526 as an apprentice in Italy, went on to publish information (both accurate and inaccurate) on minerals and gems in his *De natura fossilium* in 1546.

In the book *De la pirotechnia*, written primarily on metallurgy by Biringuccio and published in Venice in 1540, the author describes gems as stones having a special color, and divides them into transparent and translucent

categories. This was followed in 1544 by Mattioli's *I discorsi*, a book describing the (primarily medicinal) uses of minerals, gems, and other materials. A 1565 Italian translation of *Speculum lapidum* helped spread gemological knowledge among the general population, who were largely ignorant of Latin. During this same period, another book appeared in Italy that described the relationship between weight and value of 10 important gems, including diamond.

The growth of the arts in Italy during the Renaissance contributed indirectly to the development of gemology, because gems were used to decorate art objects (e.g., book covers and crucifixes) as well as for jewelry, carvings, cameos, and intaglios. The book *De subtilitate* by Cardano summarized an enormous amount of information on gems when it appeared in 1560. He ranked the key properties of gems as brightness, hardness, murkiness, and color. In order of commercial value, he listed the important stones as emerald, opal, ruby, diamond, pearl, sapphire, chrysolite (peridot), hyacinth (zircon), and smoky quartz. In a book published in 1568, the artist Cellini described the four main gems, in their order of value at the time, as ruby, emerald, diamond, and sapphire.

Published in 1587, the book *Questo è 'l libro lapidario* (compiled by Costanti) discussed how Renaissance merchants evaluated gems. For example, a good diamond should be well pointed and possess a square outline, equal faces, sharp edges, transparency, and good reflectivity. The book provided detailed tables of price vs. weight for diamond, ruby, emerald, and spinel. It also showed how gem merchants at the time were interested in learning the sources of gems and where they could be obtained at the best prices.

This period also witnessed the establishment in Italy of several museums with collections of materials from the natural world, including minerals and gems. Finally, improvements in the cutting of gemstones also took place; for example, Peruzzi is credited with introducing a four-fold symmetrical diamond cut with 58 facets, which became a precursor of the modern brilliant cut.

Near the end of the 1500s, Italy began to lose its position in culture and trade, and gemological knowledge shifted northward to Antwerp, which then became the center of diamond cutting. JES

SYNTHETICS AND SIMULANTS

Distribution of nitrogen-related defects in diamond single crystals grown under nonisothermal conditions. Y. V. Babich [babichyv@uiggm.nsc.ru] and B. N. Feigelson, *Inorganic Materials*, Vol. 42, No. 9, 2006, pp. 971–975.

Nitrogen impurity-related defects are important in both natural and synthetic diamonds. Experimental data on their distribution in internal growth sectors are presented

for yellow-brown synthetic diamonds grown from an iron-nickel solvent at 6 GPa and 1370–1550°C for 80–126 hours. At each of the selected conditions, the exact growth temperature of a crystal was varied upward and downward in a stepwise manner, with several slightly higher and lower isothermal periods lasting from 6 to 22 hours and with temperature differences of up to 110°C between periods (relative to the nominal growth temperature). The crystals were then cut into flat plates for examination.

The total nitrogen concentration in a plate ranged from 100 to 250 ppm. Nitrogen was present as C defects (≤ 150 ppm), A defects (≤ 245 ppm), and N^+ centers (≤ 25 ppm). Within a crystal, C defects prevailed at the periphery, while A defects prevailed around the seed. The A defects predominated in material grown during lower-temperature periods, while C defects predominated in synthetic diamond grown at higher temperatures. A reduction in growth temperature was also accompanied by a rise in N^+ concentration. The lower-temperature growth regions displayed yellow-green luminescence, which is a result of their higher nickel content (and increased concentration of nickel-nitrogen centers). The degree of nitrogen aggregation was influenced by nickel incorporation into the diamond structure on changes in growth temperature. The N^+ concentration increased in response to cooling steps in growth conditions, indicating that the concentration of substitutional nickel increases with carbon supersaturation and with growth rate. Thus, temperature plays a key role in determining the rate of nitrogen incorporation into the diamond structure and subsequent transformation of nitrogen-related defects.

JES

High-pressure and high-temperature annealing affects on CVD homoepitaxial diamond films. K. Ueda [kueda@will.brl.ntt.co.jp], M. Kasu, A. Tallaire, and T. Makimoto, *Diamond and Related Materials*, Vol. 15, 2006, pp. 1789–1791.

High-pressure, high-temperature (HPHT) annealing of homoepitaxial synthetic diamond films of 1 μm thickness grown via chemical vapor deposition (CVD) is reported. HPHT annealing proved advantageous for optical and electronic applications in that it improved the crystalline quality by decreasing the crystalline defects. A cubic-anvil-type high-pressure apparatus and a graphite heater were used to anneal the films at 1200°C and 6 GPa for one hour in NaCl. The samples were studied before and after annealing using cathodoluminescence (CL) spectroscopy and Hall-effect measurements. CL spectroscopy revealed improved crystalline quality and improved optical characteristics after HPHT annealing, through both a decrease in nonradiation centers and a decrease in emission bands due to interstitial carbon atoms and boron-related defects. The Hall-effect measurements showed an increase in hole mobility (the synthetic diamond films showed p-type

semiconductivity due to unintentional boron doping) with HPHT annealing, indicating a decrease in crystalline defects. The authors also observed changes in nitrogen-vacancy states as a result of HPHT annealing. JS-S

Inclusions of metal-solvent and color in B-containing monocrystals of artificial diamond. A. I. Chepurov, E. I. Zhimulev, I. K. Federov, and V. M. Sonin, *Proceedings of the Russian Mineralogical Society*, Vol. 6, No. 135, 2006, pp. 97–101 [in Russian with English abstract].

Crystals of type IIb synthetic diamond (0.1–2 ct) were grown with a cuboctohedral habit along with minor faces of {110}, {311}, and {511}. The crystals varied from blue to dark blue depending on the amount of boron; a characteristic feature was a sectorial structure expressed in a nonuniform distribution of color. Metal inclusions corresponded in composition to that of the metal solvent. The IR spectrum of a boron-bearing diamond crystal is presented together with figures showing the dependence of the a cell parameter of the metallic inclusions on the iron content of the Fe-Ni alloy. RAH

The nature of Ti-rich inclusions responsible for asterism in Verneuil-grown corundum. C. Viti [vatic@unisi.it] and M. Ferrari, *European Journal of Mineralogy*, Vol. 18, No. 6, 2006, pp. 823–834.

Verneuil-grown star corundum with variable zoning and coloration hosts three sets of acicular inclusions at 120°. The inclusions are up to 20–30 μm long and 0.1–0.4 μm wide; they are elongated parallel to the {110} faces and are polysynthetically twinned on {110}. Electron diffraction and high-resolution transmission electron microscopy (TEM) show that the inclusions are almost isostructural with the corundum matrix, even if slightly distorted to a monoclinic lattice. Chemical data obtained by TEM suggest a possible TiO_2 stoichiometry, thus indicating the presence of Ti^{4+} cations, coupled with vacancies, within the distorted corundum-like structure. Close to the ends of the TiO_2 needles, local stoichiometry is consistent with the presence of Ti^{2+} cations, possibly formed during post-growth annealing. RAH

The state of the art in the growth of diamond crystals and films. V. P. Varnin, V. A. Laptev, and V. G. Ralchenko [ralchenko@nsc.gpi.ru], *Inorganic Materials*, Vol. 42, Supp. 1, 2006, pp. S1–S18.

This article reviews the history and current status of the high-pressure synthesis of diamond single crystals and the more recent development of the low-pressure growth of polycrystalline and single-crystal synthetic diamond thin films. Synthesis methods include so-called static processes, such as the temperature-gradient technique in which diamond growth takes place on a seed in the presence of a molten metal solvent-catalyst. Lower-quality crystals up to 25 ct, and gem-quality crystals up to 5 ct, have been pro-

duced in small quantities by this method using belt, multi-piston, and multi-anvil equipment. High-pressure growth methods also include "dynamic" processes, where diamond synthesis occurs in a graphite-metal mixture subjected to the pulsed action of very high pressures generated by a shock wave, and explosive detonation of a graphite mixture, with tiny diamond crystallites being produced in both cases. Metastable low-pressure growth of diamond thin films has been perfected by using several variations of the chemical vapor deposition (CVD) technique. Here, the presence of hydrogen in the growth chamber is important to prevent the nucleation and growth of nondiamond carbon phases. Production of synthetic diamond by all of these methods has led to its increased use in numerous technological applications. JES

TREATMENTS

High pressure–high temperature (HPHT) natural diamond enhancement. M. A. Viktorov and M. B. Kopchikov, *Moscow University Geology Bulletin*, Vol. 61, No. 3, 2006, pp. 61–68.

The authors examined two brown diamond crystals, both before and after HPHT treatment, to document changes in their gemological properties. Annealing conditions employed temperatures of 1973–2073 K and a pressure ~6 GPa for five hours.

After treatment, the color of one crystal changed to yellow-green, and its UV fluorescence (long- and short-wave) became a more intense yellowish green. Its absorption spectrum displayed strong 415 and weak 503 nm bands, and an increase in overall absorption across the spectrum. The photoluminescence spectrum showed a pronounced 503 nm band. The color and UV fluorescence of the other crystal remained basically unchanged, although yellow phosphorescence that was present before the treatment was removed. Its absorption and PL spectra exhibited similar changes to those of the first crystal. Both samples displayed a change in cathodoluminescence colors from blue to yellowish green after treatment.

The authors discuss the changes in optical defects that occur during HPHT annealing, and conclude that a careful selection of diamonds for this type of treatment is necessary to achieve particular color changes. JES

Optical study of the annealing behaviour of the 3107 cm⁻¹ defect in natural diamonds. F. De Weerd [fdw@hrd.be] and A. T. Collins, *Diamond and Related Materials*, Vol. 15, 2006, pp. 593–596.

Hydrogen is a common impurity in diamond, and may be observed in the mid-infrared spectral range as the bend (1405 cm⁻¹) and stretch (3107 cm⁻¹) modes of the C-H vibration; however, hydrogen concentration and the intensity of the 3107 cm⁻¹ absorption are not proportional in diamond. The authors monitored the effect of HPHT

annealing on the 3107 cm⁻¹ defect in 14 natural type Ia diamonds. One set of diamonds was annealed at 2100°C and 7.0 GPa, and the other set at 2200°C and 7.5 GPa. In most diamonds, the 3107 cm⁻¹ absorption consistently decreased with increased annealing time, while some showed an initial increase and then a decrease thereafter. This general decrease was not surprising, as the 3107 cm⁻¹ defect is not stable at the high temperatures used in HPHT annealing and may be destroyed.

Assuming first-order kinetics and an infrared-inactive reservoir of available hydrogen in the diamond, the authors created a simple model of the 3107 cm⁻¹ defect's concentration. For the samples that showed a continual decrease in absorption, the calculations indicate that the dissociation rate is higher than the aggregation rate. In the diamonds showing an initial increase, the aggregation and dissociation rates are approximately equal. Using this model, the total hydrogen concentration in the diamond may be considered proportional to one of the calculated parameters. However, these calculated results for total hydrogen concentration did not show a correlation with nitrogen, so a relationship between nitrogen and hydrogen concentrations in diamond could not be inferred from the data. SE-M

Study on the wax enhancement for the unearthed jade wares by FTIR technique from ancient tombs of Shang-Zhou period in Henglingshan site of Boluo County, Guangdong Province. Z. Qiu, M. Wu, and Q. Wei, *Spectroscopy and Spectral Analysis*, Vol. 26, No. 6, 2006, pp. 1042–1045 [in Chinese with English abstract].

Jade (nephrite and jadeite) and jade-like materials (such as serpentine and fine-grained quartzite) have played an important role in Chinese culture since ancient times. Waxing has long been used by Chinese artisans to enhance the luster of polished jade. However, the early history of this treatment is unknown. In this article, the authors used FTIR techniques to study various jade and jade-like materials from the famous tombs of Henglingshan (1600–221 BC) in Guangdong Province. In addition to these 95 pieces (13 nephrite, 82 quartz and fine-grained quartzite), two modern wax-treated jadeite samples, two wax-treated quartzite "jade" pieces, and pure wax samples were analyzed for comparison.

Two or three characteristic absorption bands at 2960, 2920, and 2850 cm⁻¹ were found in the IR spectra of the ancient quartzite materials, resembling those of the pure waxes at 2956, 2918, and 2850 cm⁻¹. Absorption bands located at 2960 (very weak), 2925, and 2855 cm⁻¹ were detected in the modern jadeite pieces. These results suggest that the ancient wares were enhanced with wax, and that the wax materials were very similar to those used on modern jadeite. Thus, it appears that wax enhancement of jade and jade-like materials in China can be traced back more than 2,000 years. TL

MISCELLANEOUS

Angola: The new blood diamonds. R. Marques, address to the School of Oriental and African Studies, London University, Nov. 28, 2006, www.business-humanrights.org/Links/Repository/606731.

Although the civil war in Angola is long over, the government has recently enacted highly restrictive laws in the diamond-bearing provinces of Lunda Norte and Lunda Sud that deprive the local population of livelihoods outside of diamonds, reports Angolan journalist Rafael Marques. The laws prohibit all non-diamond-related economic activity, including fishing, farming, and traditional industries.

Often, with the knowledge and cooperation of mining companies, private security forces commit human rights abuses in these areas in the name of security. In addition, conflicting and confusing regulations allow many loopholes through which mining companies can exploit the independent diamond diggers. Because the activities of the independent diggers are officially prohibited, they are denied rights and protection. Yet they routinely supply the licensed buying offices with diamonds. The article concludes that the top officials of the Angolan government benefit from this situation, and thus do not want to change it.

RS

A cartel's response to cheating: An empirical investigation of the De Beers diamond empire. D. J. Bergenstock [bergebst@muhllberg.edu], M. E. Deily, and L. W. Taylor, *Southern Economic Journal*, Vol. 73, No. 1, 2006, pp. 173–189.

This paper examines how De Beers reacted to massive Russian rough diamond sales during the 1990s, when it still controlled a majority of the rough diamond market. The authors found a correlation between rising Russian state budget deficits after the Soviet era and increased diamond “leaks”—sales outside the country’s contract with De Beers. They believe that, in contrast to traditional cartel behavior of aggressive discounting to chasten entities that “cheat” by dealing independently, De Beers facilitated the Russians in nontraditional ways to maintain diamond price stability. These included both negotiation and accommodation (by going against its stated policy of refusing to buy leaked Russian diamonds from the open market, and actually absorbing large quantities of such goods under the guise of “Zairian” origin).

Although the strategy was successful in the short term by protecting diamond prices, it came at a high cost in the form of accumulating inventories, which contributed to the firm’s decision in 2000 to end its custodial role of the diamond market and change its direction to a company selling branded diamonds.

RS

Conflict diamonds and the Kimberley process: Mission accomplished or mission impossible? T. Hughes. *South African Journal of International Affairs*, Vol. 13, No. 2, 2006, pp. 115–130.

The Kimberley Process (KP), fully ratified in 2003, is a mechanism designed to stop the entry of conflict diamonds into the legitimate market by requiring all rough diamond imports to carry certificates stating that they were mined and exported in accordance with local laws. Claims that the KP has helped dramatically reduce the flow of such stones are tempered by criticism that it is not airtight, although it has been credited with preventing the re-ignition of civil wars in Angola and Sierra Leone and with keeping new wars from getting worse in the Ivory Coast and Democratic Republic of the Congo. All these countries have reported substantial increases in legitimate diamond exports since the inception of the KP.

However, the system is subject to abuse, with several countries issuing KP certificates without adequate paperwork to back claims they were legitimately mined or imported. Additionally, the KP fails to address the situation of artisanal diggers who often work in unacceptable conditions. Several programs such as the Diamond Development Initiative are a step in that direction. However, as long as artisanal mining continues unregulated, dependent on warlords and powerful middlemen, the KP will be difficult to enforce.

RS

Diamonds by Linares, Gemesis may cut De Beers, Rio Tinto sales. D. Rossingh, Bloomberg.com, June 11, 2007, www.bloomberg.com.

This article provides an update on the commercial production of synthetic diamonds, noting that current output from all producers (largely Gemesis of Sarasota, Florida) is about 100,000 carats per year, compared to 155 million carats of natural diamonds. The report quotes market analysts stating that the output of synthetics will increase to about one million carats per year when other sources, including Boston-based Apollo Diamond Co., begin production. The analysts maintained that the average price of synthetic diamonds was \$2,500 per carat against an average of \$8,000 per carat for a natural diamond of similar weight.

The article also traces the history of Gemesis and Apollo. Apollo has produced about 1,000 stones since its beginnings in 1990 but plans to expand to hundreds of thousands of carats by 2012. Gemesis executives claim that synthetic diamonds will comprise 10% of the rough diamond market within five years.

Some analysts quoted believed synthetics would dent sales of the large diamond mining companies, while others said that synthetics would help meet predicted shortages of natural diamonds.

RS