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AMBER IN BRITISH COLUMBIA

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INTRODUCTION

Amber is best known for the excellent preservation of fossil life. The public interest in amber is heightened by the success of the movie Jurassic Park. In the movie dinosaurs were cloned from dinosaur DNA extracted from the blood of mosquitoes which had become trapped in tree resin. Though this degree of preservation is unlikely, fragments of fossil DNA have in fact been successfully recovered from insect remains in amber. These remains up to 125 million years old attest to some of the unique qualities of this substance.

Amber resin represents fossil resins and waxy substances secreted by paleoflora (Broughton, 1974). Recent to modern resins are termed gums and copals. For example Kauri gum is a type of copal found in New Zealand. The gum is the hardened resin of the Kauri pine, Agathis australis.

Historically amber was collected and valued as an organic gemstone. Today amber in Europe is often heated, melted and pressed, or even mixed with synthetic material as a precursor to jewelry making. Copal was collected in New Zealand by the Maori and used for fuel, insecticide, tattooing, teeth cleaning, and as an antiseptic. Later immigrants mined it as a base for varnish. Today both amber and copal have potential to be used in an expanded specialty market within the ink, rubber, paint and thermoplastic industries.

Plant remains and pollen are associated with amber. These remains include fossil leaves and pollen of the resin-producing trees. In B.C. due to climatic changes most of these resin- producing trees no longer grow here (see Appendix).

Amber is associated with coal. In the United States approximately 180000 tonnes of resin in coal with a value of 200 million U.S. dollars is combusted yearly in electric power generation. The potential value of the resin is much greater than that of the associated coal (Yu *et al.,* 1991).

Descriptions of the geologic setting and occurrences of amber in B.C. are scattered in numerous publications. The following notes attempt to summarise some of this data and put it in context.

Amber resin and Coal Resinite

Amber resin should be distinguished from resinite described in higher rank bituminous coal. Resinite is chemically and physically distinct from amber resin. It is dark, like its opaque coal host, and not easily distinguished with the naked eye. It is a secondary product resulting from geochemical changes in the coal, and is intimately associated with other coal macerals.

OCCURRENCE

Amber resin in British Columbia is most commonly found as small nodules and beads in low rank coals (brown coal and lignite) within limnic Tertiary basins. It has also been reported in carbonaceous shales, paleosols and siltstones associated with these coals. Amber in Alberta is collected from tailings from coals of the Late Cretaceous Foremost Formation (Brown and Pike, 1990). The Alberta coal swamps developed in a delta-lagoonal environment behind a barrier bar. Interestingly this amber is associated with dinosaur remains (Poinar & Poinar, 1994).

Amber is often retrieved from both fresh water and marine beach placers. In Manitoba Late Cretaceous amber was found in beach sediments of Cedar Lake, opposite the mouth of the Saskatchewan River. It extended along two kilometres of shoreline and to a depth of a metre. The locality is now flooded. The most famous and abundant amber placers are along the Baltic coast where amber of Eocene age is found (see Baltic amber below).

In the Dominican republic amber of Oligocene to Eocene age is mined from "veins" in sediment and blue soil. The geologic setting of these "veins" is not clear in Poinar & Poinar (ibid.). Amber there can occur in a variety of colors, even pink and blue, but commonly is yellow to red.

In New Zealand Kauri gum was found as lumps in soil, in swampy depressions, and in peat basins. Lumps (the largest found was 185 pounds) were dug out by hand. Dating of kauri wood associated with copal provides a range of 850 to 45000 BP for these deposits (Poinar & Poinar, 1994).

CHEMICAL PROPERTIES

Resins are very complex mixtures of mono-, sequi-, di- and tri-terpenoids. The carbon skeleton unit of these terpenoids is called isoprene. Different forms of terpenes may result from the polymerisation of isoprene (3,4, or 6 unit). Most fossil and recent resins discussed in the literature are dominated by diterpenoids (C20). In addition to terpenoids, alcohols, aldehydes, esters, and resenes may be present to a lesser degree (Broughton, 1974). During diagenesis the more volatile fraction is liberated and the non-volatile fraction becomes fossilised. Relatively modern resins like the New Zealand Kauri gums, retain appreciable volatiles.

PHYSICAL PROPERTIES

Over 2500 years ago, Thales of Miletos discovered that when amber was rubbed against cloth, sparks were produced and then the amber attracted husks and small wooden splinters. This force was given the name electricity after the Greek word electron which means amber. Amber resin is recognised by its hardness, brittleness, amorphous nature, conchoidal fracture, and lustrous translucent color.

Amber is very close to the density of seawater. In saturated salt water it floats, and this method has been used to separate amber in some deposits.

Amber from coastal erosion is transported along the shores of all the countries around the southern Baltic sea. When the storms begin in the autumn, the local people head for the beach to search for the "Gold of the North". Amber drifts on the bottom of the shallow sea, following the currents, until it comes up on the shore. It is easy to find a pebble, but rare pieces can be more than one kilogram.

Baltic amber occurs naturally in a variety of colors: white, yellow, brown, black, red, green and blue. The most common are honey-colored and milky. A small percentage is bone white, due to microscopic gas bubbles. Some amber shows layers from successive flows on already dried resin. The black and dirty brown colors are caused by a mix of resin, soil and plant fragments. The most uncommon have a tone of green or blue caused by gas or inclusions. Most true Baltic amber is milky and pale under the crust. The warm amber color occurs after it has been exposed to oxygen for about a hundred years.

Copal differs in properties from amber resin. It is a transparent champagne color and very brittle. It has a lower melting point and turns sticky if heated (and smells like fresh resin). It does not take a good polish and the crust comes back in a few years.

Copal and amber resin may or may not contain inclusions. There are almost no inclusions in the New Zealand Kauri gum or copal; unlike the very fossil-rich copal from East Africa and Columbia. Whether resin contains inclusions is dependent in part on the source of the resin. For example resin that forms below the bark of the tree is unlikely to contain inclusions.

A remarkable variety of organisms have been found embedded in amber. For example well preserved remains of wasps, termites, ants, midges, are found in deposits of Dominican amber. Inclusions in amber have included a gecko, a frog, a feather and fragments of flowers and mushrooms. The variety of inclusions and their significance is colorfully described in a recent issue of Scientific American (Grimaldi, 1996). Grimaldi notes amber resin somehow fixes tissue so that it retains its original size in spite of dehydration.

Amber Jewelry: Enhancements and Deceptions

To make amber more attractive to purchasers, today's industrial amber jewelry producers manipulate the raw amber to get the warm brown-reddish amber color, which often includes discs, called sunspangles. First the amber is made clear by putting it under pressure and heat in an autoclave together with nitrogen. After this procedure, it is put into an oven to obtain the sunspangles and the characteristic cognac color.

It is possible to melt amber pebbles and press them to bigger lumps. It then becomes harder, and less brilliant when cut. Any color can be added in this procedure. This pressed amber is still considered to be natural amber by some producers.

Since the bakelite and plastic era began early this century, fake amber jewelry has appeared in the commercial market. For example bakelite necklaces were sold in Europe in the early twenties, when amber was in fashion.

In the markets in Morocco, North and East Africa, as well as in the Middle East and India, amber-colored plastic necklaces are very common. They are often sold as antique trade beads. Sometimes they are old, very beautiful, large egg-yolk colored strands, but they are still plastic, and tend to be heavier than amber.

The original trade beads, which were distributed from northern Europe around 300 years ago, are rare. It is difficult to see the difference with fake amber but there are easy tests to distinguish amber and plastic beads. If a heated needle is put into the hole of a bead, the smell of burned plastic immediately appears. Baltic amber smells like pine resin. Also plastic is elastic, and the needle will get stuck in the material, but true amber is brittle and small pieces will chip off under the pressure.

BRITISH COLUMBIA AMBER OCCURRENCES BY AGE

Late Eocene

BOWRON

The Bowron basin, about 20 km long and 2.5 km. wide, extends along the Bowron River, 50 km. east of Prince George. It contains coal measures toward the base of 700 metres of a poorly exposed unnamed unit comprising sandstone, conglomerate, carbonaceous shale, siltstone and mudstone. The sequence is interpreted as a lacustrine mudstone facies overlain by coarser sediments representing alluvial fans prograding (upward coarsening) into the basin. Drilling has delineated two coal seams of which the lower generally consists of up to 15 metres of interbedded coal and rock, occasionally represented by a single seam to 5 metres thick. This seam lies 50 to 100 metres above basement. The upper coal zone is within 50 metres of the lower. It is thinner and discontinuous. The coal is high volatile B and C bituminous. A high content of amber occurs in the seams, both in outcrop along the Bowron River and in drill core. An average content of 1.2% amber resin is reported in coal assessment report 787 (Norco Resources, 1982) with values to 2.5% in the commercial (i.e. lower?)seam. Values to 4% are reported by Versoza (1981). Matheson and Sadre (1991) noted that amber occurs not only in the coal but also in adjacent podzols and carbonaceous shales.

The clear amber colored resin which is up to 1.5 cm. in diameter, is normally elongate and occurs as flattened blebs. *It is reported to have a high melting point but its* chemical characteristics are not well known.

According to Sweet (personal communication 1996) a late Eocene age is indicated by palynomorphs within the coal measures.

Poorly preserved plant remains include Pinus and Metasequoia (Holland, 1949).

QUESNEL BASIN

The narrow Quesnel basin, about 40 km. long and 4 km. wide extends along the Fraser River near the town of Quesnel. It contains about 560 metres of poorly consolidated sediments within a fault trough. The Lower Fraser River Formation consists of 360 metres of mudstone, silty mudstone, with minor sandstone, conglomerate and coal ascribed to a fluvial-limnic-peat swamp environment.

The 1930 report of the Minister of Mines notes that seams in the area have a high resin content. Subsequent reporting provides little detail. Two rock core logs from British Columbia Ministry of Highways cable tool drilling (in McCullough, 1980) indicate inclusions of amber with lignite fragments in dark brown shale (particularly RMH6). Amber beads are noted in coal intersections (graphic log of G.S.C. BH Q1, Long and Graham, 1993). Goodarzi and MacFarlane (1991) apparently collected relatively large pieces of pale-yellow transparent resin from this formation.

The lower Fraser Creek Formation is dated as Late Eocene based on a reassignment of mammal data previously considered to be Oligocene (Art Sweet, 1996, personal communication). The spore and pollen assemblage indicates a flora and climate comparable to central China and southeastern United States (Rouse and Matthews, 1979).

HAT CREEK

Hat Creek valley, located 20 km. west of Cache Creek, is underlain by Cretaceous and Eocene sediments. Eocene Kamloops Group rocks consist of a basal volcanic sequence overlain by 1600 metres of fluvial-lacustrine sediments. The coal-bearing Hat Creek member lies 400 metres above the base of the fluvio-lacustrine sequence. It consists of coal, mudstone, minor siltstone and coarser beds. On average 65% of the formation is coal, *representing a vast accumulation of organic material* within a long lived shallow lake in a subsiding basin. About 350-550 m. of sub bituminous to lignitic coal have been defined in A zone of Deposit One by B.C. Hydro. Within 'A' zone amber occurs in at least 3 coal layers and in associated carbonaceous shale.

Hand-picked samples of the resin were studied to determine the influence of weathering by Goodarzi & MacFarlane (1991). They are described as yellow to yellow-orange to black and white lumps (table 1, p.286). Campbell *et al.* (1977) noted that "relatively continuous horizons of resin beads and petrified wood fragments are common in the coal". McKay (1926) also noted "Parts of the coal are characterised by small lenses, globules and irregularly shaped masses of light yellow, semi-transparent, fossilised amber". The percentage of amber in the coal interval is unknown.

Dominant plant remains in Hat Creek coal are of Metasequoia and Glytostrobus (Goodarzi and Gentzis, 1987). Hat Creek is provisionally dated as Late Eocene based on 82 palynology samples (Read, 1990).

Early to Middle Eocene

TULAMEEN (COALMONT)

The Tulameen basin, 20 kilometres northwest of Princeton, is approximately 15 square kilometres in surface area and oval shaped. A truncated synclinal structure preserves 790 metres of interbedded sandstone, siltstone, mudstone, coal and local tuff layers. These beds are assigned to the fluvial-lacustrine Allenby Formation. The lower member consists of 110 metres of basal sedimentary breccia, sandstone and shale, and the upper unit consists of 590 metres of quartzose sandstone and conglomerate with minor shale. The 90 metre medial section is dominated by interbedded mudstone and coal.

rock that may have a pegmatitic affinity. Work is in progress to better evaluate the potential of the 76 zone of the Empress deposit and overlying overburden as a source of sapphire and to explain the origin of the corundum.

Andalusite-pyrophyllite

The andalusite crystals from the Empress deposit have relatively low iron content (Table 2) and could satisfy current refractory specifications. However the andalusite-bearing rocks are generally too fine-grained to be processed into high-grade concentrates that could compete with South African material.

A large number of drill core samples were analyzed for metallic elements (Lambert, 1988, 1989, 1991a and b), but little major element data is available from the property. Table 3 shows the composition of andalusite-pyrophyllite-muscovite-bearing rocks compiled from Madeisky (1994). Unfortunately, these analyses are not supported by detailed petrographic or X-ray diffraction studies. The table indicates that these rocks are relatively rich in alumina, low in silica and that there are large variations in the concentrations of other major oxides. Typical properties of American and South Korean refractory and whiteware grade pyrophyllite are given in Table 4 for comparison. Most of the rocks from the Empress deposit appear to be high in Fe_2O_3, CaO, Na_2O and K_2O. Unfortunately, detailed sample and petrographic descriptions were not done, so it is not known if the high Fe_2O_3 content is due to the presence of sulphides and iron oxides or other sources. It is assumed that the relatively high CaO, Na_2O and K_2O contents are due to the presence of feldspar and mica. Although the andalusite-pyrophyllite bearing rocks from the Empress deposit do not meet current specifications for traditional North American refractory or ceramic applications, they may have industrial applications in domains with less stringent specifications. Two samples analysed by McMillan (1976) (Table 3) have similar compositions to andalusite-pyrophyllite products currently in the market place but are slightly high in TiO_2. Because pyrophyllite has a low unit value, \$20.00 to \$300.00 per tonne FOB depending on grade and degree of processing, it is important to consider transportation costs to markets.

Rare Earth Minerals

A rare reddish brown, rare earth element (REE) - bearing mineral, with brownish irradiation halos up to 0.5 centimetres in radius occurs within plagioclase-pyrophyllite-andalusite-bearing lithologies. Its distribution is erratic and it is present in trace amounts. This mineral was tentatively identified as bastnaesite ((Ca, La) CO_3F). A carbonate-phosphate-sulphide boulder, 30 by 30 by 25 centimetres was found by Westpine geologists near the corundum-bearing zone and probably contains rare earth elements. Furthermore, REE-bearing phosphate was described in concentrations of up to five percent with tennantite, energite, chalcopyrite and sphalerite in two main veins at the nearby Taylor-Windfall gold deposit (Price, 1986). These occurrences indicate that the area may have some exploration potential for REE's.

SUMMARY

The copper, gold and molybdenum potential of the Empress deposit was discussed by Osborne and Allen (1995). The non-metallic mineral potential of this deposit remains to be established. Corundum crystals from the Empress deposit are typically dark blue, subhedral to euhedral and a fraction of a millimetre to one centimetre in cross section. Some transparent, colourless crystals were found in overlying sediments. Coarse crystals contain numerous inclusions of pyrophyllite, but parts of them, up to several millimetres in size, are fracture and inclusion-free. The potential of this deposit as a source of corundum depends on the proportion and quality of coarse corundum crystals, their abundance and distribution either in residual soils, placers or primary host rock. Andalusite-pyrophyllite rocks may have industrial applications if produced as a by-product of metal mining, although the cost of transportation to markets may be prohibitive. Andalusite crystals within the Empress deposit area are too fine grained to be economically upgraded to compete with South African and French concentrates currently on the market. The area might also have Rare Earth element exploration potential.

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CONCLUDING REMARKS

Amber in British Columbia is more common than surmised by Mustoe (1985), both in age and location. It is doubtful however that amber of the size and quality found in the Baltic coast or Dominican Republic will be found. On the other hand the geologic setting of amber producing deposits is not well understood or documented.

No insect fossils have been observed in British Columbia amber. However insect remains are known from a number of Eocene sediments associated with plant remains, for example in the Princeton area (Handlirisch, 1910), Horsefly area: (Wilson, 1977), and Driftwood Creek: (Rouse et al., 1970). A diligent examination of known occurrences could reveal fossil bearing amber in British Columbia.

Placer amber, while unknown in British Columbia, may yet be found in beach sediments representing the margins of Eocene Lakes.

Some opportunity presents itself for small scale production of amber jewelry from pressed amber. The Tulameen amber appears to show some natural color variation that might be attractively marketed. Small scale extraction of coal and separation of amber resin for a cottage jewelry industry might be considered.

Larger scale industrial applications of amber await further studies. The amber content of Hat Creek coal should be assessed. Amber in specific basins may have particular properties that would be advantageous for specific purposes. For example the high melting point of Bowron amber may be applicable for high speed printing inks or heat resistant plastic coating. Further studies could be done on some of the traditional uses of resin and its naturopathic qualities.

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APPENDIX

Trees Associated with Resins

In B.C. the following plant remains are typically associated with amber resin.

- Glyptostrobus: Glyptostrobus, related to the bald cypress of SE United States, is confined to China in its natural habitat. Also known as the water pine, it grows in well drained areas by lakes and rivers.
- Metasequoia: Metasequoia, the dawn redwood, was considered extinct until about 1945 when it was discovered growing in isolation in China. It is a deciduous conifer, anually shedding its needles.

In New Zealand the tree associated with Kauri gum is Agathus Australis. This tree belongs to the family Araucariaceae which today comprises two living genera Agathis and Araucaria. The well known species of the latter are the Norfolk Island pine and the monkey puzzle tree. The genus Agathis dates back to the Jurassic (175 million years) from remains in Australia. Pionar and Pionar (1994) note Agathis Australis or Kauri pine 'bears no resemblance to the pines we are used to seeing in North American forests. Kauri pines don't have needles, but thick broad leaves shaped similar to those of acacias.

Dominican amber is associated with Hymenaea protera. This fossil tree closely resembles Hymenaea verucosa now found in East Africa. These flowering trees are members of the legume family.