MINING BURIED RESIN (KAURI GUM) – AN ENGINEERING PERSPECTIVE

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ABSTRACT

Mining buried copal (the sap of the kauri tree known as “Kauri gum”) is an important part of New Zealand’s heritage. Kauri trees are ancient and are unique to New Zealand. Over geologic time, as the trees died and decomposed, the copal (resin) became buried. In the 1860s, the commercial value was recognized and mining was initiated. Initially the resin was used to produce the best varnish available at that time. However, this use required a purity of 97% and in 1910 a use for gum with purity as low as 70% was found in linoleum production. Kauri gum became one of New Zealand’s leading exports. Mining of the resin has ceased. Little has been published on the engineering-related challenges involved in the mining operations, development of mechanical equipment, field processing and reclamation. The challenges were successfully met by the “Gumdiggers” without formal geological or engineering training. The paper is a tribute to pioneers in the Kauri gum industry in recognition of their contribution to one of New Zealand’s important heritage events. It is presented from an engineering perspective by Engineers with first-hand knowledge of the industry.

Key words: Kauri gum; pioneers; mining operations; engineering perspective.

1 INTRODUCTION

The mining of buried resin (the dried solidified aromatic sap extruded copiously by the Kauri tree and known as Kauri Gum) spanned a period of about 100 years beginning in the mid-1880s. The industry contributed significantly to the economy and is an important part of New Zealand’s heritage. Miners (known as “Gumdiggers”) included mostly people of Maori, Croatian (Dalmatian) or British background. There are a number of excellent publications such as Bruce Hayward, 1989; Bert Hingley, 1980; Brown & Spoelstra, 1997; Senka Bozic-Vrhancic, 2008; Jelicich, 2008 and Wagner, 1977 (to name a few) that describe life of the early miners on the often remote forested mining areas (“gumfields”). There has however, to the Authors’ knowledge, been no account of gumdigging from an engineering perspective. This paper focuses, in particular, on the evolution of mining techniques and equipment to improve efficiency and meet market demands.

In a mining context the resin constitutes the ore. (Brewer, 1944). Kauri trees are believed to have originated 150 million years ago. Relatives are found widely throughout the Western Pacific Region, and are known to science as Agathis Australis. (Gordon Ell, 2008). Only the Kauri is resinous. The trees referred to in this paper are, however, unique to New Zealand and grow only in the region extending from the Coromandel peninsula to the northern tip of Auckland Province. The Kauri is one of the largest tree types in the world. There is evidence that some have lived more than 1000 years. (Erne Adams, 1986).

Kauri gum was first mentioned in the literature in the November 16, 1769 Journal of Captain Cook. About 70 years later its potential commercial uses began to be recognized. (Firth, 1922). Winning (or “digging”) of the Kauri gum became a significant industry which has ceased at this time. Locations of gumfields are shown on Figure 1. (Hayward, 1989). The majority was recovered from excavations in areas where the gum had become buried over geologic time. There was exploitation of natural resins commercially elsewhere, such as in the Congo. Good quality Kauri copal resembles amber found in many parts of the world, including the Baltic Region and especially Russia. (World of Amber, 2010).

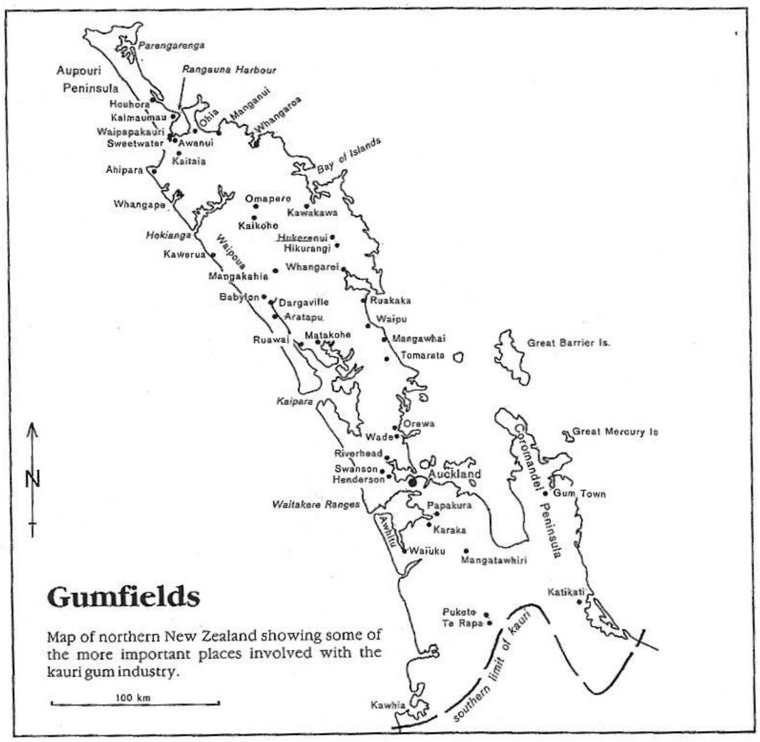

Figure 1. Gumfields in Northland (Hayward, 1989)

2 ECONOMIC IMPORTANCE

Beginning about the mid 1800s, winning (digging) of Kauri gum became the basis of a significant mining industry. Kauri gum was a major export of Auckland Province in the nineteenth century. In the 1890s there were some 20,000 people involved in the industry, 7000 of them full time. Up to the beginning of the First World War, Kauri gum yielded more in oversees funds for New Zealand than any mineral. (Erne Adams, 1986). Peak production was achieved in 1896-1900 with 44,900 tons exported. Production progressively declined and by 1951-55 had reduced to 2,700 tons. Total production in the period 1861 to 1960 was about 443,000 tons with an export value of NZ£ 25,000,000.

Kauri gum was not used for manufacture in New Zealand so the bulk of the funds generated by its export were available for use locally. There were also secondary benefits, including providing the "seed money" for many successor enterprises such as farming.

3 THE OREBODIES (GUMFIELDS)

(i) Geological Setting: According to Smith, 1952, approximately one-fourth of Northland's six thousand square miles are gumlands. Evidence for Kauri trees has been observed in the South Island indicating that the forests were much more extensive prior to the Pleistocene glaciation than at present. During the Ice Age, the Kauri pine was restricted to the peninsular north where relatively mild climatic conditions enabled it to survive. Some swamp Kauri is believed to be the product of a massive die-back of the trees in cycles of climate change. (Gordon Ell, 2008).

The resin was found either as "Hill" gum in hilly or flat ground areas, or as "swamp" gum concentrated and buried in swampy terrain by water erosion from higher ground to augment resin already there from dead trees. Much of the gum was found within a depth of 10 feet (3m). However, it reportedly occurred as deep as 30 feet (9m) in places, and sometimes was concentrated in two or three levels over this total depth. Below the groundwater table, the resin underwent considerable physical and chemical alteration, and became fossilized. (Smith, 1952).

The buried dead-fall from the ancient forests, as well as the more recent growth of scrub, peat and rushes, are impurities which posed special problems to the mining and processing of the resin.

At the end of the nineteenth century mining was being carried out on both Crown and private lands. Gumfields covered some 800,000 acres (nearly 325,000 hectares). Individual gumfields could extend over several hundreds of hectares. There were maps e.g. (Boleyn, 1961) which showed land ownership and utilization as early as 1901. Shown also are areas of Clay Gumlands (subdivided into little, moderate and large amounts of gum, and Peat Gumlands, similarly subdivided into large and small amounts of gum. More recent mapping of the surface features of the Aupouri Peninsula are provided by Northland Regional Council (1991), which identifies various unconsolidated overburden materials. The formations of particular interest to gumdigging are swamp and lagoon deposits.

(ii) Climate: The gumfields area enjoys a sub-tropical climate of long hot summers and relatively mild but rainy winters. For the Kaitaia area, for example, the Northland Regional Council, 1991, notes that the average daily temperatures for July and February are 7.2 degrees C and 25.6 degrees C, respectively. On a mean annual basis, the rainfall and pan evaporation are about 1400mm and 1250mm, respectively.

(iii) Seismicity: According to the Seismic Zoning Map of New Zealand (NZS3604), the gumfields are mostly in Zone C (low risk) with some in Zone B, a moderate risk area.

(iv) Environmental Aspects: Constraints were sometimes placed on operations to ensure that “potholes” were backfilled. Permits to take water from natural sources were also required, albeit late in the period of gum mining activity. The resin, for all practical purposes, contained no toxic elements. Environmentally, the main impact of the gumdigging was land disturbance.

(v) Hydrology: This was important given the generally swamp environment of the higher yield gumfields and the climate with its rainy winters. There were some notable drainage works constructed, as discussed later.

(vi) Hydrogeology: The pertinent hydrogeology was mainly that of the swamp overburden, which generally comprised surficial organics (topsoil and peat) over mineral soil. Both pond removal and groundwater lowering had to be contended with. The severity of groundwater inflow often determined which locations in a given gumfield were exploited.

(vii) Waste Disposal: As discussed later, the overburden waste was able to be left in the mined-out area. “Tailings” were limited in volume and generally able to be left in place without special retaining structures.

4 EXPLORATION TECHNIQUES

Methods used were based primarily on judgment or use of manually-operated equipment.

(i) Visual reconnaissance and general appraisal of the local surficial geology by the more experienced Gumdiggers who developed a good understanding of the geological factors associated with the orebodies.

(ii) Exploration by special small diameter high strength steel rods attached to a spade handle (“gum spears”) usually about 2m long but up to 8m long (Hayward, 1989). The spear was pushed or driven into the ground until it encountered a pronounced increase in resistance or was stopped abruptly on something hard. It was discovered (by John Botica in the mid-1890s) that a small “foot” near the tip, reduced shaft resistance and also assisted in bringing back traces of what had been encountered (Brown and Poelstra, 1997). The Mataga Family patented a steel spear with an upheaved hook for recovering the resin without excavation, in 1894. This procedure has modern parallels in shallow geotechnical exploration by dynamic cone penetration tests, and probing manually by earth augers.

(iii) Exploratory test pits were also used particularly where there were accumulations of finer sizes of resin, (chips). The approach has its parallel in modern investigations of residual soil type ores, such as lateritic nickel and aluminium-bearing bauxite overburden, and in the evaluation of diamond-bearing alluvial gravel.

5 MINING METHODS

Developments in the extraction, processing, and refining of Kauri resin were largely indigenous to New Zealand. (Smith, 1952). Similarities can however be identified with aspects of other current mining operations world-wide, as alluded to elsewhere herein.

(i) Regulatory and Safety Requirements: Gumdigging was finished, for all practical purposes, at about the time when it became a requirement to submit designs, operating and closure plans, and environmental impact statements, for regulatory approval. In terms of safety, protective personal equipment or shoring to support sides of excavations were rarely used. Precautions taken by the Gumdiggers included systems for warning of imminent collapse of sides of typically unsupported vertical-sided excavations. One warning system included a rope run down to the bottom. A man would be on duty at the top at all times. If he saw the ground start to crack he would warn his workmates who would grab the rope and climb out. (Hingley, 1980). This has a parallel in warning systems used in some current mine waste dumps, based on observations of cracks near an active dumping face.

(ii) Site Preparation and Operations: In the main gumfield areas, Kauri trees had long vanished. Vegetation was largely of the scrub type, and associated ground cover of ferns, grasses and rushes. An important aspect of site preparation included construction of “drains” (open ditches) to remove ponded water and lower the groundwater table. Some such drains have provided service for about 100 years. Two drains (Omamari and Aoroa) in the Dargaville area, as described in Martinovich, 1998, involved excavation depths up to 10m and expedients such as timber shoring for side support, and sloping sides with horizontal benches at intervals vertically. A party of Gumdiggers worked for nine months without pay to drain the Omamari Swamp. (Martinovich, 1998). A photo of a group of Gumdiggers working on the so-called Notorious Aoroa Drain taken by Aubry Cook (Brown and Poelstra, 1997) has deservedly appeared in a variety of publications. It deserves recognition also in an engineering context and is reproduced herein as Figure 2. A tunnel excavated through a sandstone ridge at Sweetwater, (inspected recently by the senior author and found to be still functioning effectively) and a major private drain extending from Sweetwater to Waipapakauri are described in Ramsay, 2007. These works were excavated manually by Gumdiggers working cooperatively. Local groundwater lowering was carried out in the early days using manually-operated improvised piston-type pumps.

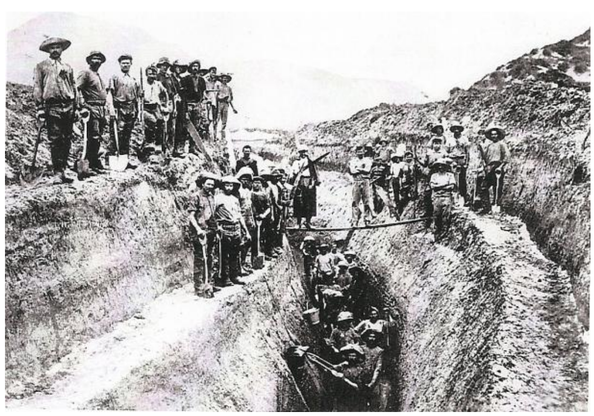

Figure 2. Excavation of the Notorious Drain at Aoroa (Brown and Spoelstra, 1997)

Mining was initially based on manual excavation of “potholes”. The main hand tool was a spade of the Skelton brand which was far superior to ordinary spades. When “gum washing” machines were introduced (employing hydraulic separation of the gum from the soil), superior variants of conventional hand shovels were also developed. An important step in the evolution from “pothole” mining was development of the face-digging technique. Operating cooperatively, Gumdiggers systematically spaded large areas when good gum-yielding ground was located. This step improved the efficiency of recovery of gum and also enabled buried timber to be salvaged. The technique is illustrated in Hayward, 1989 and Brown & Spoelstra, 1997 and in Figure 3 herein.

Figure 3 Illustration of mining on a continuous face (Hayward, 1989)

Strip mining (or open cast mining) was introduced next. This involved placing resin-bearing soil manually in mounds (windrows) and then systematically shoveling such soil into gum “washing” machines to hydraulically separate the resin from the bulk of the soil. Obstructions such as buried logs virtually precluded the effective use of mechanical excavators. Attempts at mechanization included a tractor-mounted backhoe and a disused Otago gold dredge (Hayward, 1989). At Parengarenga Harbour about 1920, high pressure sea water was used to sluice gum-bearing soil for delivery to the steam processing plant of Parenga Oil Fields Ltd. which separated out and refined the gum”. (Hayward, 1989)

Preparatory work typically entailed excavating (in the summer) a series of parallel trenches about four to six yards wide and one hundred and fifty to two hundred yards long. The resin-bearing soil excavated from the trenches was heaped in the intervening spaces and freed of large roots and refuse. The heaps were processed systematically (by use of moveable gum washing machines) in the winter season after fall rains had flooded the trenches thus ensuring a water supply. After separation of the gum, waste soil (tailings) was discharged into the trench excavated the previous summer. In the following summer, the intervening spaces were trenched and the process repeated. A gum washing machine operating at one of the windrows of resin-bearing soil is shown in Figure 6.

A limited amount of mining was carried out using high pressure jetting to loosen gum bearing soil which had been placed in windrows (mounds). Separation of the gum from the soil was done by the sorting action of fast flowing water in special sluices (trenches with corrugated bottoms).

(iii) Stability of Excavations: In comparison with other modern strip mining ventures within the Authors’ experience, excavations involved in preparatory work and gum digging were comparatively shallow, (2 to 3m maximum depth). They did not involve the extreme depths of up to 8m of some of the early “potholes”

(iv) Water Supply: The advent of gum washing machines brought with it the need for a reliable water supply. Sources were either natural water courses or springs. Operations were also scheduled during the winter season, as noted earlier. Water used to transport the soil discharged from a gum washing machine was recirculated after clarification by settling of sediments.

(v) Gum Washing Equipment: This went through a number of stages of development. A key event was the introduction of hydraulic separation of the gum from the host soil. Pioneer George Sulenta featured prominently in this event at Awanui in 1912, placing resin-bearing soil on a sieve and pouring water on it manually, as shown in Figure 4. This led to the drum-shaped sieve-bottomed “Hurdy Gurdy” illustrated in Figure 5 where the “washing” action was facilitated by a blade (impeller) rotated manually while water was poured in.

Figure 4. Pioneering experiments of sluicing gum-bearing soil by Mr. George Sulenta (Mitcalfe. 1984)

Figure 5. Photo of Manually-Operated "Hurdy Gurdy" (Hayward, 1989)

Gum washing machines are essentially mechanically powered sluice boxes. They are skid-mounted and comprise a sieve-bottomed barrel-shaped "tub" equipped with an impeller, a motor to drive both the impeller and a centrifugal pump which supplies water to the tub (and in some cases, to power a winch to move the machine). The machines are fed manually with resin-bearing soil. The resin and any foreign material retained are removed through a small trapdoor in the side of the tub while the soil and water passes through a steel sieve (screen) in the tub's bottom. Successive stages of development included a two-man version with a steel tub, a four-man version with wood barrel-type construction for the tub, illustrated in Figure 6. The version requiring a 6-man operating crew, shown as Figure 7, is representative of the last stage of development of this type. As noted, in Gordon Ell (2008), this machine (with which the Authors have first-hand knowledge) was last used in 1952, *"(i) it washed ½ acre of heaped soil and gum in 10 days, (ii) it was capable of taking 3 yards of gumsoil mixture at each refill. This took 5 minutes to wash, (iii) large quantities of water were needed and this was drawn from drains or specially built ponding areas, and (iv) gum from this machine was placed in large heaps to be sieved and graded for sale"*. It is powered by a 2 cylinder diesel engine. The ultimate stage of development was a different type of machine, illustrated in Figure 8 was invented by F.S. Petrie & Co. in the late 1930s, in which washing is accomplished in two horizontal cylinders. There is no evidence that it was ever used in practice. The mechanical gum washing machines have parallels in the feeder-breakers used in Canadian oils and mining.

Figure 6. Intermediate Stage of Gum Washing Plant Development. Four Man Crew Model (The Kauri Museum, Matakohe, A.1992.915.191)

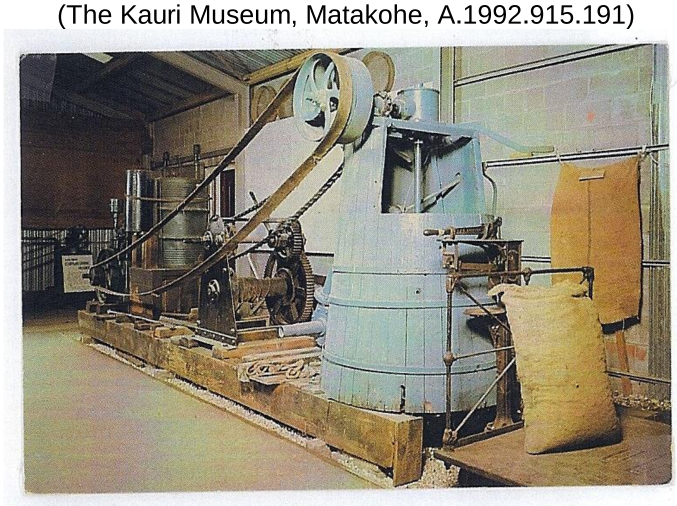

Figure 7. Latest Development of 6-man Gum Washing Plant (Gordon Ell, 2008)

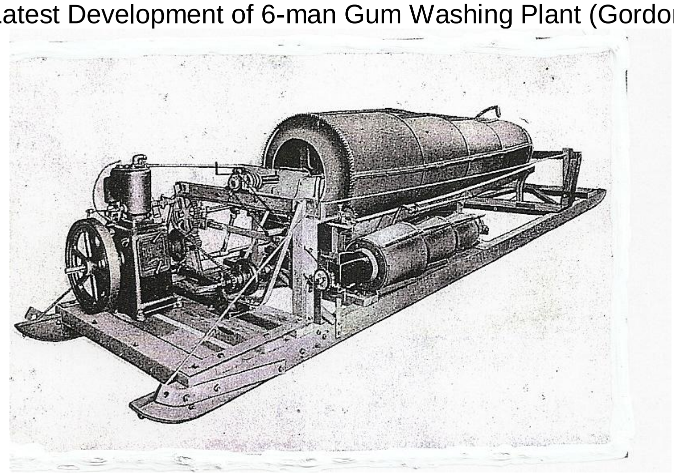

Figure 8. Rotary Double Cylinder Kauri Gum Washing Machine (F.S. Petrie & Co. Engineers)

6 FIELD PROCESSING OF THE ORE

After recovery from the gum washing machine, the “raw ore” (resin together with impurities such as roots, pieces of wood, hardsoil, etc), was transported to a work pad, an area adjacent to the gumfield (preferably located on higher ground with good exposure to prevailing winds) which had been stripped and the exposed ground surface well compacted. A typical layout of a work pad showing mechanical winnowing and size grading of gum, is reproduced herein from Gordon Ell, 2008 and shown on Figure 9. The raw “ore” was spread on the work pad in layers generally less than 6 inches thick and systematically raked or turned until virtually complete drying was achieved by solar drying. Solar drying has a parallel in the use of this natural resource (instead of artificial drying in oil-fired dryers), to reduce the moisture content of lateritic nickel ore so that it can be fed directly into reduction kilns.

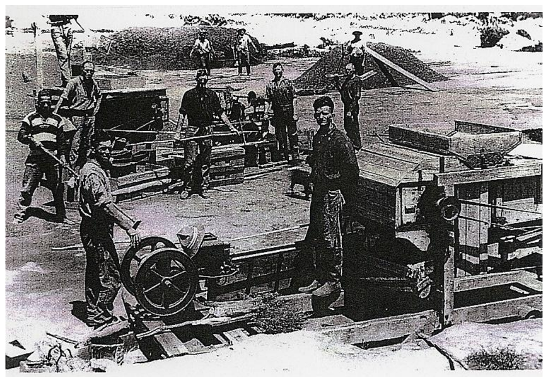

Figure 9. View of Work Area for field processing of Kauri gum (Gordon Ell, 2008, Hayward, 1989)

In the early days, the dried raw ore was repeatedly thrown manually onto sloping perforated screens (sieves) against the wind on bright windy days. This process produced a crude separation between the light dry fibrous vegetal matter, and the heavier resin and soil or rock fragments. Around 1920, portable engine powered winnowing machines were introduced, known locally as “Blowers”. These machines (an early model shown in the foreground on Figure 9) generated wind by a fan which blew away the light impurities in the “ore” while the latter was conveyed from a vibrating feeder hopper over perforated screens. Mechanical winnowing usually resulted in a product consisting of 70 to 80% gum “chips” (Hayward, 1989 and Wagner, 1977). This quality of the product was acceptable for marketing. Smith (1952) indicates that the use of Blowers enabled separation of about 200 sacks of gum per day. Two of the Authors working as crew of a Blower in 1950, are shown in Figure 10. After winnowing, further purification of “chips” was sometimes done by the “sinking” method, which involved immersion and agitation in a strong brine of salt and water to float off progressively (with vacuum assistance) the light vegetal matter, charcoal, etc. and the gum, while dirt sank and was bled off. Hayward (1989). This process of differential floatation was invented by Dr. J.S. Maclaurin (Hosking, 1935).

Figure 10. Late model of “Blower” operating in 1950.

7 CLASSIFICATION AND ENGINEERING PROPERTIES

Engineering properties of Kauri resin are important from mining, processing and refining standpoints. Specific properties, primarily relating to mining, are described in summary below.

In respect to terminology, the term Kauri gum, accepted through usage, is a misnomer because gum is soluble in water and resin is not. Exporters used the general classification "range gum" for the better quality found in upland areas, and "swamp gum" for the more prolific lower quality gum recovered from swamps (Smith, 1952). The largest sizes were called "nuggets" (comparable to boulders). Intermediate sizes "nuts" (compared with gravel). Finer sizes "chips" were in the size range of natural fine gravel to fine sand. Hosking (1935) cites the terms "dust", "seeds", "chips" and "nubs" for the fine end of the size range. Other terms based on colour and quality, respectively, are also in common use. No standard classification was ever developed, however. The lack of standardization is recognized in a number of references, e.g. (Hosking, 1935) as an important factor in the decline in the demand for Kauri gum. A given product needed to be entirely homogenous and have definite reproducible properties such as colour, acid value and melting points, and resin content.

Gum is soft and sticky when extruded from the tree and dries to an uncrystallized mass. Colour varies from yellow and brown to black. Good quality gum is hard and has a clear, amber-like appearance, and is often translucent. Poor quality gum is soft, black or chalky and "sugary" in character. (The term "sugar" was applied by Gumdiggers to soft crystalline gum which could be crumbled by finger pressure). Gum weathers under prolonged exposure to the atmosphere to produce an oxidized "crust", and also undergoes chemical deterioration in swamp water, both over the very long term. It is soluble in alcohols and ketones. Photos of different types of Kauri resin are given in Figure 11.

Figure 11. Photos of Different types of Kauri Gum (Author's Collection)
(a) Unscraped (b) Polished (c) Chips. Scale: Knife length 4.5cms

Engineering properties include:
(a) **Angle of Repose:** In a dry state. Coarse sizes ("Nuggets" and "Nuts") about 38°. Fine sizes ("chips") about 30°
(b) **Specific Gravity:** According to (Firth, 1922) this can vary from about 1.08 for high quality clear resin to less than 1.0 for very poor quality resin.
(c) **Strength:** Comparable to soft rocks such as sandstone. Brittle failure in a solid state. Good quality resin polishes easily. It tends to shatter on impact,
(d) **Thermal Characteristics:** Melting point varies from 380°F to 450°F (Brown & Spoelstra, 1997). Tends to soften with temperature (e.g. in hot water). It is highly flammable, (e) Specific Heat. Value of 0.458 quoted by Burbidge and Macky (1927).

No specific data on geochemical characteristics could be located. It is known to be easily fused and “run” with a dry oil, which made it suitable for high quality varnishes. After thermal processing, it shows compatibility with all animal and vegetable oils (Natural Resins Handbook, 1939). There is no evidence of adverse toxicity from an environmental standpoint.

8 REFINING METHODS AND COMMERCIAL APPLICATIONS

Although the focus of this paper is on mining of the resin, reference to refining is also made for completeness. Refining for commercial end-uses involved a number of specialized processes.

For varnish products, the necessary purity (97%) was achieved by removing any weathered exterior of selected large pieces of gum by hand scraping. Linoleum manufacture accepted gum with a purity as low as 70%. Sorting was confined to the larger pieces and done manually. One of the methods used to improve the quality of the finer fractions of the raw gum was the Maclaurin Process mentioned earlier.

By the late 1920s the scarcity of varnish grade gum led to investigations to improve purity using solvent extraction. In the 1930s, the Department of Scientific and Industrial Research developed a process which produced resin with 99% purity. Its use in practice was limited, however, due to the depression and competition from synthetic resins. For a very informative account of the purification of Kauri gum, the interested Reader is referred to Burbidge and Macky (1927).

For the first 70 years Kauri Gum’s use was in the manufacture of varnish initially in the USA, the UK and later in Germany. It had the necessary purity and could be converted to a durable varnish of the highest quality by the simple process of heating it and mixing with a suitable oil. The Natural Resins Handbook of the American Gum Importers Association, (1939) regarded Kauri varnishes as the standard of quality. In 1910 a new market in production of linoleum was opened up. (Smith,1952). Initially linoleum makers sourced their kauri gum component by using the dregs of the varnish makers. When low price “chips” became available linoleum makers quickly made the change to it. According to Wagener (1977) linoleum manufacturers would accept gum with 70-80% purity.

Kauri gum was also used in the manufacture of explosive (pers. comm. A.J. Routley, B.E.) and also as a gloss and hardening ingredient in paints.

9 RECLAMATION OF MINED-OUT AREAS

Mined-out areas were reclaimed for a variety of end-uses the majority being, pasture lands for dairy farming and raising beef cattle. Other uses include plant nurseries, orchards, and market gardens. Reclamation was often driven by the need for an alternative source of income after extraction of the Kauri gum. In many cases, gum digging and farming were active simultaneously on the same property for a number of years. A significant post-mining feature of the early gumfields was the presence of numerous randomly spaced open pits or “potholes”. Gumfields worked systematically by mechanical “washing” left a reasonably level surface because excavations were progressively backfilled with “tailings”. Drainage of gumfields assisted future reclamation, although it also caused consolidation-related settlement of peat. Peat deposits were also acidic requiring addition of lime and fertilizer for pasture or agricultural use. Fortunately, no unacceptable toxic elements resulted from gumdigging.

Tailings consisting of impurities excavated with the gum bearing soil, were generally deposited in the excavations between mounds of gum-bearing soil during strip mining. Vegetal matter resulting from winnowing was easily disposed of separately. The original indigenous growth of scrub, rushes, ferns, etc. quickly re-established itself as a thick cover over mined-out gumfields often obscuring evidence of the workings. The exceptions are the few cases such as at Ahipara Hill, where some mining was done by high pressure jetting hydraulically, as noted earlier.

10 ACKNOWLEDGEMENTS

This paper is a tribute to all of the pioneers in the Kauri gum industry, and particularly the Gumdiggers. The Authors acknowledge gratefully first-hand assistance received from the Otamatea and Dargaville Museums, and also from a number of individuals, who have provided material from their archives. Also acknowledged are the various Authors identified in the List of References hereto, whose writings about the gumdigging industry have been drawn upon heavily in preparing this paper. Above all, we have been privileged to know personally, some of the "Old-timers" in this industry and to be inspired by their example and significant achievements without the technical tools presently available to the mining industry.

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