The Art of Ceramics
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N. Claussen (Editor)

AUSTRALIA, ABORIGINES, ART AND CERAMICS

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Australia has one of the oldest directly identifiable human cultures on one of the politically and geologically most stable continents. Occupation of the Australian continent by Australiod peoples can be traced back more than fifty thousand years. The presentation seeks to identify the technologies, culture and art which have sustained these peoples into the 21st century. It also attempts to give a brief overview of the development and current status of ceramic activity in Australia. Since the Aboriginal population did not develop a culture incorporating fabricated ceramics, the ceramics review is limited to more contemporary times.

1. INTRODUCTION AND THE FORMATION OF A CONTINENT

At the start of the 21st Century Australia is very topical, for two main reasons: one, it hosted the first Olympiad of the new millennium (27th Olympiad or Olympics 2000), and two, its indigenous peoples are the oldest known human species whose occupation of a continent can be traced back more that 50 thousand years before the present (50kY BP) and who have seemingly not advanced technologically to any high degree of sophistication while their culture and art forms are receiving world acclaim.

The formation of Australia as a continent occurred about 25 million years ago as part of the disintegration of Gondwanaland, which commenced about 150 million years ago. Prior to its disintegration Gondwanaland existed well into the Jurassic period as a continent stable for at least 600 million years. The separation of Australia, from what is now known as Antarctica, was accompanied by a change in world ocean currents such that the equatorial warm currents no longer flowed along the coast and the circulatory polar currents were established, resulting in a dramatic cooling of the Antarctic continent. Prior to the separation the climate was temperate and the continent covered by rain forest. This explains in part the presence of Australia's fossil fuel reserves.

The Australian continent lies on what is called the Indo-Australian tectonic plate. The continental landmass laying near the center of the plate suffers no

significant earthquakes and equally has no large mountain ranges resulting from plate collisions. Australia was near the southern most part of Gondwanna Land and in comparison to the movement of the other major continents it has not moved far. The plate still proceeds north at about 1cm per year. The size of the Australian continental land mass has to some extent been determined by erosion, but far more significantly by the ocean levels which fluctuated dramatically as a function of the changes in the earth's climatic conditions during the ice ages.

The aim of the presentation is to give a brief overview of how the Australian continent first became inhabited, how the culture developed, and to look at the development of ceramic trends in contemporary Australia.

2. HABITATION OF CONTINENT

2.1. The first Australians

There are a number of theories on how people first came to populate Australia. One of the most simple and plausible, reinforced by modern archaeology, was presented by Darlington[1], who describes the movement of homosapien races across the face of the globe. The early Australians, named Australoids, were generally acknowledged to have come from the southern parts of the Asian continent through a combination of expansion and recession of the ice ages. The movement patterns indicate that these peoples were generally underdeveloped in their technologies with respect to the rest of the SE Asian continent and were thought to have been forced out by the more technologically advanced Mongolian races. The Australoids were forced south and as such had no other option but to take the land bridges ~40kY ago. These were not true "land bridges" as at least 30 km (~19 miles) of water remained, indicating the people were adept enough to make sea-going crafts. However, the narrow straits became an easy access to a very large landmass that has become known as the Australian continent.

One theory suggests Australia was occupied by three waves of immigrants. This theory has since been replaced by a two-wave theory, supported by the striking contrast of the current Aboriginals. Supporting evidence for the two-wave theory is based on different skeletal features of human remains unearthed in Lake Mungo, in the lower Murray-Darling river basin, which described them as "gracile", fine features, delicate bones, thin skulls and small jaws with no brow ridges. This can be contrasted to the Kow Swamp peoples of the upper Murray River basin, described as "robust", all big features with brow ridges, and receding foreheads. Current theory concerning the bones of the two sites is that they represent different ends of the *Homo sapien* scale, and that only one wave occurred, the bone variations being a result of local adaptations.

While the most reliable archaeological studies, using radiocarbon dates, have revealed that human occupation was established in Australia around 40kY ago, it possibly occurred as long ago as 60kY. Though most inhabitants were coastal dwellers they quickly adapted to the interior rivers and lakes. From ~28kY ago, lakes began to dry up and the people were forced to adapt to the drier environment.

At the time of European occupancy, it was estimated the continent was inhabited by ~750,000 Aboriginals comprising ~700 communities, using ~200 languages and many more dialects. Thus these Aboriginal groups were distinguished by differences in culture, language, geographical and historical features.

2.2. Premise of Aboriginal Development and Culture

Figure 1 in Prof. Petzow's paper "Relations between man and materials"[2], based on the European estimates of technology and civilization development as a function of time, gives a good estimate of the technological development expected at ~40kY BP. This figure indicates that the population of humankind in the world was probably around three million. The materials and technology in-use were based on stone, wood and bone with virtually no fired clay products. In fact this is what was basically found at the time of the first white occupation of Australia, an almost classical society of hunters and gatherers located in very well defined groups, with technology based on the utilization and shaping of natural materials.

The early Europeans did study the Aboriginal population, the best data being available for inhabitants of what is now Victorian region from a book published in 1878[3], and for Southern Australia in a book printed just after 1804, about 16 years after the arrival of the first permanent European settlement in eastern Australia[4]. The book by Brough Smythe[3], describes an aboriginal couple who were "characteristic types of natives of the eastern parts" of the Southwest, Riverine or now Victorian region of Australia. The man (Boom-bul-wa) "was rather above average height, and was a strong well-made man. Both the man and the woman were full-blooded blacks." The pair had body markings, which have clan, tribal and/or religious significance. Thus, as indicated in the previous section, almost immediately after the first white occupation of the Australian continent it was acknowledged that the indigenous peoples were part of a culture and society far more intricate than their technological development would suggest.

It is worth pointing out that, even to the present day, the lack of Aboriginal technology development is premised on the absence of the use of the wheel. It is also acknowledged that partially due to the lack of easily domesticated

animals, such as horses, cows, llamas, etc, and the culture of a wondering society, there was little need for the wheel. This position might be compared with the development of the boomerang and womerah or throwing stick. The boomerang is an aerodynamically fashioned stick used for hunting, and when it misses its target returns to the thrower. Equally the womerah is used to increase the thrust delivered to a spear by the mechanical advantage imparted through the longer contact with the spear. From these developments it might be concluded that where the use of technology was going to be of benefit to the society, discovery was often carried through to practical use.

The culture of the Aboriginal peoples was (and still is) very much associated with the land and its spirits, which are described in the "Dreaming"[5,6]. The Dreaming is a European term used by Aborigines to describe the stories about the religious or spiritual, the natural and the moral order of the universe from the beginning of creation to the present. The Dreaming provides the ideological framework by which human societies retain a harmonious equilibrium with the universe - a charter and mandate that has been sanctified over time. It focuses on the activities and epic deeds of a supernatural being and creator-ancestors such as the Rainbow Serpent, the Lightening men, the Warilag (Wawilak) Sisters, the Tingari and the Wandjina, who, in both human and non-human form travelled across the unshaped world, created everything in it and laying down laws of social and religious behaviour. Thus Aboriginal art form, very much oversimplified, often reflects the Dreaming culture and as such it can be divided into two streams, that depicted by the hunters or males and that depicted by the gatherers or females of the society.

3. ART - DOMINANT ART STYLES OF THE ABORIGINAL PEOPLES

3.1. Early Art up to 1800

At the time of first European settlement, art, other than on the body as scarring or paint, was depicted on bark, wood and stone. Four basic colours were used: white from pipe clay or gypsum, red and yellow from ochres from the earth, and black from charcoal or manganese. Pigments were ground to a powder, mixed with a natural glues and applied with fingers, sticks or "brushes" manufactured from chewed twigs, strips of bark or human hair[5].

An early picture, carved into wood, from the Southern region (Victoria-New South Wales) was created by Aborigines to be placed as a tombstone on the grave of "Bujngeleen", a reasonably well-educated native[3], see Figure 1. The artist died before giving explanation but it is assumed to be something along the lines of ref. 3: Men at the top represented friends appointed to investigate death of deceased. Animals, emus, lizards, wombat and kangaroos (in the middle layer) indicate the deceased did not die of lack of food, the

strange - somewhat obscure forms below the hollow band are those of *Mooroops,* or spirits who have caused the death of the Aboriginal by their wicked enchantment. The picture can be used to illustrate a number of features about the Aboriginal society; (1) the culture had developed an intricate mythology, (2) their art could incorporate theme, as in story line, (3) they could accurately depict scale, in this case as related to human and animal form and (4) they were capable of intricate filigree design.

Another very early example of an Aboriginal bark painting conveying messages and meaning to a large number of tribes, is shown in Figure 2. This picture depicts scenes in the life of an Aboriginal. Brough Smyth[3] comments that this picture, its detail and messages, is the mark of a very advanced peoples

FIGURE 1 - Early art image on bark, from the Southern region, see text for detail. From reference 3.

FIGURE 2 - An 1800's Aboriginal drawing depicting interaction with Europeans, possibly showing nostalgia, animals, hunting, fishing and tribal gatherings and reality, Squatters house on the best land (near river or creek) and fences (bottom at right). Note also: kangaroos communicating, man debarking tree, white hunters (pipe & gun), variety of spears, bags, nets, water in stream conveys action with almost tranquilly in the lake. From reference 3.

and much better than Europeans could do without considerable education and training, and the native appears to have a "natural talent for art and illustration".

Animals, trees, people and activities all faithfully reproduced. Art was also used to adorn weapons and tools, with fine examples found on woomeras or throwing sticks[3].

Rock engraving is the oldest and most lasting form of traditional Aboriginal art. This art form is found in most parts of Australia where suitable rock surfaces are found[5]. Typical examples are found on rock engravings, located about 100km south of Alice Springs and thought to be thousands of years old, which include circles, arcs, lines and bird and animal tracks. In the desert areas of Central and South Australia, designs and symbols used in to-days rock paintings are similar to those used in very early rock carvings.

3.2. Aboriginal Art in the 20th Century

Contemporary aboriginal art of the 20th century has been divided into two main regions of artistic activity: the Desert and the Northern region or Arnhem Land. We shall briefly describe the main attributes of each region.

The Desert art is best known for its "dot painting" style and predominantly used the symbols of the early rock carvings. The current uses of dot styles are extensions of these carvings observed more than 10kY ago and could be based on the appearance of the natural landscape in desert regions. Many modern travel books show "dotted spinifex vegetation", for example just north of Alice Springs, which is thought to be a clue to the dot style of painting[5,7]. When the modern artist began to use acrylic paints on canvas and board with brushes and sticks, many imitated the dot by dot process.

The traditional symbols used in Desert art have many different interpretations; only a few of their meanings are given to the general public as most have deep religious overtones. Hence, many ambiguous interpretations are used to hide the "true" religious significance of the paints, so that there is a duality of interpretation in some of the paintings. However, whether designs are constructed on the ground (sand), applied to the body or painted on canvas or board, as part of a contemporary movement, the religious paintings of Desert Aboriginal artists are a direct continuation of this ancient creative symbolic art tradition.

The paintings are a visual record of the Dreaming[6], and they explain the artist's relationship to the land. In the mind of the artist, the land is mapped out with Dreaming trails and the features created by the mythical ancestors. The artists dot paintings are constructed along the lines of a "journeying" experience. Through this "journeying" technique ancestral paintings are a way

FIGURE 3 - Typical modern examples of the two dominant Aboriginal painting styles. (Left) The "dot paining" found in the desert regions and (Right) the "x-ray style" used in Northern or Arnhem Land region. The paintings were by (L) Mary Dixon Nagurrayi and (R) Peter Nganjimirra. For description of the stories depicted see text. From reference 7.

in which the artist can relive past travels from one sacred place to another. The artist generally commences at one site, a concentric circle at the edge of the canvas. As painting progresses the artist fills in details of key characters and events encountered on journey, water holes, tracks - emu, possum, kangaroo, bandicoot or human foot prints. Painters seldom plan or map entire paintings, but journey across from one edge to other filling in landscape as they go.

The second major Aboriginal painting style is that of the Northern region or Arnhem Land. These paintings are often referred to as "x-ray" painting because of the very fine fill-in hatch used to decorate the figures[6,7]. The Northern Australian artists' materials generally consisted of orchid stem and human hair-brushes and ground ochre stones. Human hairbrushes enable the painting of the very fine fill-in hatching.

Favourite topics of the Northern or Arnhem Land region are paintings, that illustrate the Mimi or Namorodo Spirits. These are described as thin frail spirits easily blown about by the wind. They live in caves and crevices of the rocky western Arnhem land escarpment and emerge nocturnally to harass people, although they are not usually evil, merely mischievous. Mimi paintings on rock are ancient - 20k years old. They are generally shown in every day activities that parallel Aboriginal life and are thought to have taught the first people many hunting and gathering skills.

Typical modern examples of both painting styles are shown in Figure 3(a&b)[7]. Figure 3(a) is titled "Witchetty Grub Dreaming" by Mary Dixon Nagurrayi of Kunatjarrayi in the Northern Territory. Mary's painting depicts women gathering witchetty grubs from the roots of trees with their digging sticks and wooden bowls. As they dig one of the grubs turns into a snake and travels north towards the Granites. At a deeper level, a parallel can be drawn between the witchetty grub turning in to a moth and a boys initiation into manhood. Figure 3(b) is entitled "Mimi or Namorodo Spirits" by Peter Nganjimirra of Western Arnhem Land; a description was given in the preceding paragraph.

Thus throughout early history and to this day paintings were the "official" form of communication. This might be considered the norm in societies without written language where painting was the pretext, and hence the form of communication for the written story. It might be said that virtually all paintings, in ancient and modern times have a story to tell and are a form of communication through the ages. Thus it has to be concluded that, while Aboriginal Australians were not considered technologically advanced by western standards, their developments in painting, culture and mythology are as advanced as those in many nations.

5. CERAMIC IN CONTEMPORARY AUSTRALIA

Aboriginal Australians did not proceed to the ceramic utilisation/manufacturing stage other than shaping naturally occurring ceramic materials. It was the influence of foreigners into Australia that resulted in ceramic utilisation and development. As expected, ceramic development and utilisation is still centred around the major population concentrations. Currently Australia contains about ~19 million inhabitants or ~1.52 persons /sq km (4.2 persons/sq mile) and when this is compared with Europe ~83p/sq km (~230p/sq mile) or the USA [excl Alaska] ~36 p/sq km (~100 p/sq mile) we note that even to-day the continent appears largely uninhabited. However, that data must be contrasted with the fact that about 75% of the population live within about 50km of the coast (~32miles). It is not surprising that massive manufacturing industries did not develop. Within this context we shall now briefly review what happened to ceramics in Australia as a result of its isolation, low population and foreign influence.

While Australia had a world reputation in ceramic-oxide crystallography, the early ceramic industries were, and predominantly still are, based on imported technology. Partly as a result of this technology importation and the uniqueness, land form and climate of the Australian continent, the Federal Government established, through the *Science and Industry Research Act* 1949, the forerunner of what is now the Commonwealth Science and Industrial Research Organisation (CSIRO). This organisation was established to help Australian industry to adapt, optimise and to develop new technology in the areas of agriculture and minerals processing. Thus CSIRO has played a large part in the development of the Australian ceramic industries as they are to-day. These indigenous industries can be loosely grouped into the generic areas of Whitewares, Brick tile and pipe, Refractories, Advanced (Engineering) Ceramics, Electroceramics and Ionic conducting ceramics.

5.1. Whitewares

Australia's whitewares production is centred on table and sanitary ware. The Table ware, mainly for the hotel and catering trade has always suffered intense competition from Asian and European producers. The main company, now called Australian Fine China, manages to survive and even grow as a result of diversification of products and increased volume resulting from increase in service (tourist) numbers. It stays competitive through increased automation.

Sanitary and bathroom wares are manufactured by slip casting technology and, through significant automation, the industry also manages to stay cost competitive against, predominantly, European imports. Due to the desire for Australians to own their own home and a reasonably steady building trade,

the sanitary and bathroom ware market remains profitable.

The large number of Italian immigrants has made floor and wall tiling very popular. Johnson Tiles, Australia's largest floor and wall tile manufacturer, uses an automated Italian "turn-key" operation to produce its product range.

5.2. Brick, Tile and Pipe

The brick industry has moderate growth with the switch to more brick veneer homes from the former asbestos-cement and timber cladding. All bricks are made from local clays with the major growth occurring in "paving-stones". These have become very popular as concrete paving is replaced in such areas as domestic paving and out door shopping malls. Most manufacturing is carried out on imported brick making equipment.

Clay based tile and pipe manufacture is relative static, even though the housing market is expanding, mainly as new materials, pre-painted galvanised iron and polymer pipes, enter the market. The last new tile plant was commissioned in about 1990 by Monier and produces only for the domestic market.

5.3. Refractories

The Australian refractories industry has undergone major upheaval in the last five years, as BHP, Australia's largest steel maker, divested itself of the refractory manufacturing company, BHP Refractories, to a new company formed by Thermal Ceramics and Shinagawa Refractories – Shinagawa Thermal Ceramics (STC). This has resulted in all the major refractory manufacturing companies being foreign owned while about thirty small local companies provide installation and service requirements that are not economic for the larger companies to provide. These smaller companies concentrate on supply and manufacture of monolithic refractories of "conventional" composition such as chamottes and castables.

Australia, mainly through CSIRO, has had a long history in refractory research. This research stream has followed two paths, firstly through the use of local raw materials so that the technology of adaptation was the main driver and secondly the development of new "advanced" refractories capable of surviving the high intensity smelting operations used for the direct reduction of iron oxide.

The advanced refractories developed by CSIRO were based on the work of Garvie et al[8,9] in the area of dense-microcrack toughened refractories. The basic concept involves a highly dense ceramic matrix (alumina, zircon, magnesia-alumina spinel) in which is dispersed unstabilised - or controlled-

stabilised zirconia, and which transforms on cooling to induce a plethora of microcracks - effectively dropping the bulk modulus hence reducing the thermal shock sensitivity on cooling or non-uniform heating. "Optimised" zirconia inclusions generally comprise monoclinic zirconia polycrystals - inducing isotropic dilation rather than single crystals with large residual shear components, e.g. Baddeleyite, which has a large shear component. The concept has been applied to a number of matrices, including alumina, zircon, alumina based spinel and mullite. The last development, that of the alumina based spinel[10], has been shown to be applicable for use in high intensity smelting operations such as "HiSmelt", used by Rio Tinto. Unfortunately, because of the lack of large scale refractory manufacturers, the technology must go off-shore to be commercialised.

5.4. Advanced (Engineering) Ceramics

In the context of local manufacture, advanced ceramics are a relatively new area for Australia with general application as enabling materials in the manufacturing, mining and minerals processing industries. Before about 1980 very few advanced ceramics, e.g. high strength alumina, non-oxides or transformation toughening systems, were commercially manufactured in any large volume. In the advanced ceramic composite area, only tungsten-carbide - cobalt tools for machining and mining ground engaging tools were manufactured under license from European parents.

Currently Australia has, by world standard, four small manufacturing operations, which produce alumina, and zirconia based materials. These manufacturers generally produce to satisfy local market requirements, except for the transformation toughened zirconia supplier, Carpenter Advanced Ceramics, who export over 80% of their production.

A considerable amount of local development had been undertaken in the area of advanced ceramics and we shall briefly describe some highlights.

5.4.1. Alumina

Highest volume of the alumina consumption is for wear resistant applications in the coal and minerals processing industries. Regular shapes in the form of tiles, rods and spigots form the bulk of manufactured products of debased and up to 98% pure alumina. The bulk of the debased alumina is imported with very little high volume production capacity available in Australia.

On a smaller scale Taylor Ceramic Engineering manufacture near net complex shapes using a thixotropic casting technology, while Ceramics Oxide

Fabricators and Rojan Advanced Ceramics use extrusion, pressing and slip casting techniques to fabricate high purity-high strength alumina shapes for a variety of industrial applications.

5.4.2. Silicon non-oxide based materials

While no large scale manufacturing of thick-section high purity-silicon carbide is undertaken, pressure-less sintering technology for thick section products was developed by CSIRO[11]. This technology has produced high density 10x10x2cm (~4x4x0.75in) thick SiC tiles which were initially intended as armor protection for military applications.

Current local developments are focused on SiSiC technology for applications in the mining industry, while technology for manufacture of "Si_3N_4 bonded SiC" was brought in by Carborundum with the materials finding wide scale use in both refractory and wear resistant applications.

To this presenter's knowledge, no silicon nitride or SiAlON materials are commercially manufactured in Australia while a considerable amount of research is undertaken on the nitride variations by academic and research institutions.

5.4.3. Zirconia based and transformation toughened ceramics

Australia's ceramic research reputation was brought into world recognition by the paper published in 1975, "Ceramic Steel"[12]. This paper not only alerted the world to the exciting potential of transformation toughening in zirconia, but also pointed to new directions of how ceramics might be processed to enhance their strength and fracture properties. A number of conferences have been held and copious literature has been written on the subject with the two most recent reviewing the research historically[13] and underlying principles for the development of transformation toughening (TT) ceramic systems and their close parallels to steel[14].

The impetus for Australia to become involved in zirconia research can be traced back to its abundant zircon deposits and a 1967 Report on the Ceramic Industry in Australia[15]. This report flagged the potential of zircon for refractory applications. However zirconia extrusion dies were already being imported so it was a small step from zircon to zirconia. This step was put in place by a metallurgist, Dr. Neil McKinnon who, in about 1970, increased the size of CSIRO's ceramic skill base by encouraging researchers from North America and Europe to join his group.

Additional impetus for work on zirconia is that part of the story which starts with the unreliable behaviour of imported dies for brass extrusions and

leads onto the establishment of partially-stabilised zirconia (PSZ) and zirconia powder manufacturing plants in Australia. Ironically, or through sound economic judgement, both plants are now owned by the US based companies, Carpenter Engineered Products (trading as Carpenter Advanced Ceramics, CAC) and Millenium Performance Chemicals. Some typical products manufactured by CAC are shown in Fig. 4.

The historical development has been adequately captured in a long literature trail which can be traced back through the review[13]. It is however worth mentioning that in Australia PSZ material development successes followed the path of understanding the performance limitations of imported PSZ extrusion dies through to the development of TT Ca-PSZ which culminated in the maximum strength (MS) and thermal shock resistant (TS) Mg-PSZ product range currently produced by CAC.

Toward the end of the PSZ development saga research emphasis was switched to exploring the concept of microcrack toughening of ceramic matrices

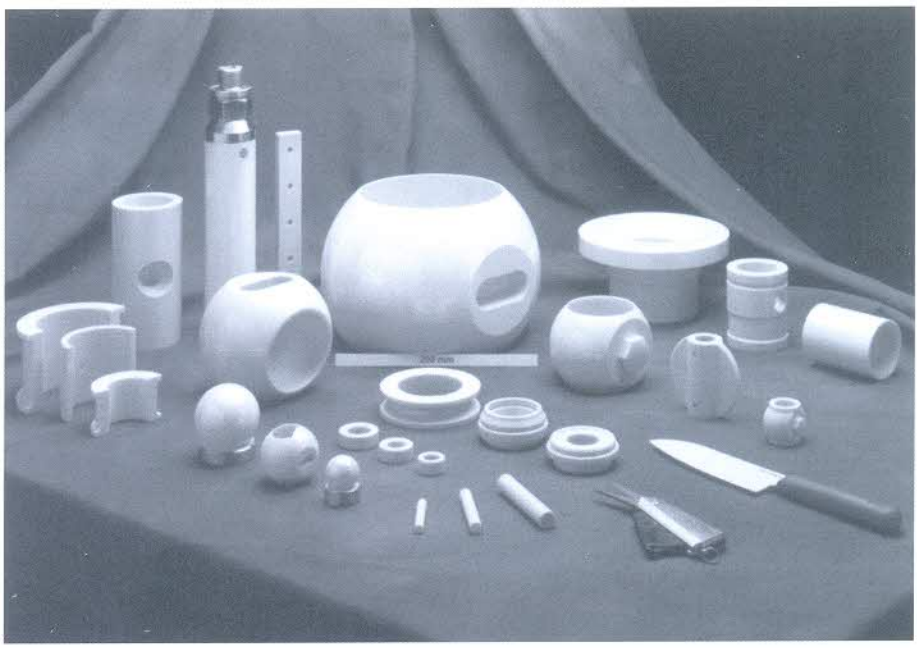

FIGURE 4 - A variety Mg-Partially Stabilised Zirconia (Mg-PSZ) commercially produced products, manufactured by Carpenter Advanced Ceramics, except for the scissors and knife which are Y-TZP. Mg-PSZ parts include ball- and butterfly-valves, bearings, shear blades, cyclone vortex finders, homoginising plunger, oil-well ball valves, glue transfer roller and metal forming tools.

with the direct aim of improving refractory performance. This concept has its genesis in the addition of 'unstabilised' zirconia to the matrices of engineering ceramics, as described previously in 5.3. The research culminated in the tailoring of a number of matrices for use in such wide scale applications as slide gates for glass fibre manufacture, slide gates and pouring nozzles for continuous steel casting[8,9] and refractories for high intensity iron smelting processes[10].

Australia's interaction with zirconia product manufacture continues on two fronts, firstly, improved manufacturing processes for PSZ and secondly for its use as the electrolyte material in solid oxide fuel cell (SOFC) (see section 5.6).

5.5. Electroceramics

Electroceramics are manufactured in Australia for defence and leisure purposes and for under water sonar applications by the European owned company GE Marconi. While some application development is carried out in Australia almost all the research is restricted to in-house use of the imported technology.

5.6. Solid state ion conducting ceramics

In parallel to the development of zirconia for its mechanical property attributes its ionic properties were also being researched. This research resulted in a range of oxygen partial pressure measuring devices being commercially manufactured through the licensing of patents, and culminated with a refocus on utilising the ionic properties of zirconia for ceramic fuel cell development.

Ceramics Fuel Cells Limited (CFCL), the company developing and commercialising the solid oxide fuel cell (SOFC) technology was established as a consortium of energy generating utilities, large Australian companies, a Government technology investment departments and CSIRO. The consortium was established about six years ago and aims to have mid-sized, 25 – 200kW, energy generating units available by 2003.

At the ceramic heart of the SOFC are the cells comprised of the PEN (positive-electrolyte-negative) structures. Two types of cells have been developed:

1. Electrolyte supported cells (70-100 μm ZrO_2 - cell to operate at 800-900 °C). The electrolyte sheets (3-YSZ) are produced by tape casting, cut to size and sintered. Sheets from 50x50 mm to 150x150 mm have been produced (100x100 mm are standard parts) - 70-100 μm thick. The anode, NiO-3YSZ, is screen printed and sintered. Finally the cathode, La-Sr-manganite

(L-S-M), is screen-printed and sintered. These cells are useful for the operational range 800-900 °C. CFCL has currently a pilot fabrication facility to produce 1000 cells (100x100 mm) per week. Since it is difficult to make larger cells, CFCL uses a windowframe array stack design as shown on the example of the 5 kW stack tested 2 years ago.

2. Anode supported cells (<20 μm thick ZrO_2 - cell to operate at 700-800 °C): In order to achieve low resistance in the electrolyte for operation at 700-800 °C electrolyte thickness of <20 μm are necessary. CFCL developed an anode-supported cell of 600 μm thick Ni-YSZ cermet, 10-20 μm thick 8YSZ electrolyte and screen-printed LSM or sputtered La-Sr-Co-Fe-oxide as cathode. The cells are produced by tape casting of the anode sheet and electrolyte sheet and further reduced by roll lamination, cutting to size and sintering.

Figure 5 shows the stacked window frames which comprise the 5kW cell. Another activity is the development of the basic operation of plant (BOP) which is also a very important part of the overall cell operation - almost as important as the cell itself.

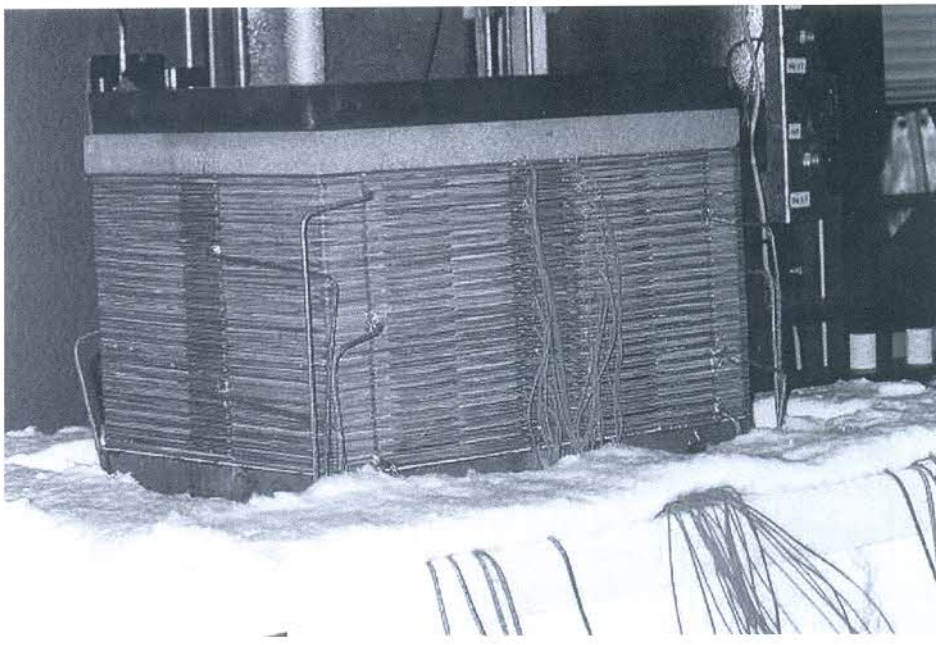

FIGURE 5 - "Heart" of 5kW Window frame-anode supported SOFC stack. (With kind permission of Ceramic Fuel Cells Limited).

6. CONCLUSIONS-COROLLARY

Aborigines are often considered to have had a stone-age technology, they manufactured no ceramic artifacts but have become serious environmentalists and guardians of the land. If one considers that they were the first culture to development of the first functioning airfoil – the boomerang – they could be considered well in advance of the culture that developed the wheel. Aborigines have a deep mystical culture, which is intertwined with their art and stories, and as such, these are used to transmit their culture on through the generations.

It took foreigners to bring and to cause development of ceramics in Australia. When ceramic development and production reaches a point where a viable industrial manufacturing base exists, the technology is exported through company acquisition by multinationals.

A scenario of global Aboriginal art, culture and environmental conscience permutation and ceramic technology exports now makes the young Australian nation truly part of the global community.

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