AK Milroy

Epistêmê, technê & poïesis

Visualisations of evolution & extinction in Queensland flora

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Epistêmê, technê and poïesis

visualisations of evolution and extinction in Queensland flora

An exegesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy at CQUniversity, School of Education and the Arts.

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Abstract

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Experimental intra-disciplinary praxis forms the basis of this research, specifically bridging the domains of art-science and utilising innovative imaging technologies. The research addresses the following questions:

> In what ways, if any, can the outcomes of a practice-based visual arts researcher significantly contribute to the development and communication of knowledges in scientific practice?
>
> And conversely:
>
> In what ways, if any, can scientific research practices significantly contribute to the development and communication of knowledges in artistic practice?

Significance is measured through contributions to knowledge including, but not limited to, the development of: new concepts, methodologies, inventions and understandings.

Over a period of four years, the researcher, a professional practising artist, documents and creates intra-actively with scientific practitioners in the fields of fine art, palaeontology and physics. This emergent inquiry results in outcomes significant to both art and science domains as it provides a critical examination of each discipline's standard research practices and knowledge making paradigms. It subsequently proposes a paradigm shift, as a direct result of working collaboratively within disciplines and sparked by creative and innovative methods of knowledge production.

In responding to the questions posed, the researcher applies a Bohrian philosophy of physics and this is strongly influenced by Karen Barad's interpretation of it. Quantum theory provides a rich source for rethinking knowledge creation in both artistic and scientific domains. It also suggests the application of a diffractive, rather than reflective, methodology as the research investigates Bohr's notion that *we are a part of that nature we seek to understand*.

The art-science experimental procedures and outcomes are additionally theorised by integrating and supplementing them with ideas about agency, epistemology, ontology, and praxis from theorists such as Donna Haraway, Estelle Barrett, Barbara Bolt, Andrew Pickering and Bruno Latour.

This thesis comprises visual and textual components inspired by the researcher's scholarly engagement with the palaeobotanic type collection at the Queensland Museum.

For the first time ever, the exhibited visual outcomes utilise and interpret type collection data using state-of-the-art imaging technologies from the Imaging and Medical Beamline (IMBL) at the Australian Synchrotron. The thesis exhibition, *Aletheia*, provides visualisations of seeds and fruits at a previously unseen evolutionary stage because the technique proposed by the researcher non-destructively reveals detailed internal morphologies and key taxonomic features of previously unclassifiable fossils.

The significance of the research outcomes to date, for communicating in visually creative and innovative ways, to share new artistic and scientific knowledges across and through disciplines and the wider global community have already been recognised through the research being extended beyond the current candidature period. A competitive, collaborative proposal for future work, scanning at ANSTO's advanced DINGO neutron beamline at the Lucas Heights facility has been accepted. This technology provides capability for neutron scanning, a complementary technique to the synchrotron x-ray radiation of the IMBL. It is anticipated that the ongoing work will continue to provide a platform for synergistic national and international intra-disciplinary research linkages.

Documentation of the culminating exhibition, which was held in April 2016, together with evidence of other significant exhibitions, international collaborative artefactual outcomes, and published articles is presented for examination for the award of Doctor of Philosophy.

Acknowledgements

I would like to acknowledge the people who have assisted with this research: my supervisors, Dr Ashley Holmes, Professor Donna Lee Brien and Dr Andrew Rozefelds; text editing by Sue Bond and Julie Koest; document layout assistance by Rachael King; the staff of the Queensland Museum Geosciences Department – Kristen Spring, Dr Mary Dettmann, Prof Trevor Clifford, Dr Scott Hocknull, Jo Wilkinson, Deb Lewis and Brian Flynn; Studio West End – Wim de Vos for curating the Aletheia exhibition and Adele Outteridge assisting with hand binding of seven copies for examination; Serena Coghlan, Sue and Elmar Rothbrust, Heather Raines, Scott Turner, Lachlan and Simon Milroy for technical and support. I would also like to acknowledge my scientific collaborators, Dr Margaret Wegener, Dr Anton Maksimenko and Saeed Dadvar; and artist-in-residencies as facilitated by: Halina Rubinzstein-Dunlop @ APPC–AIP 2016 physics conference, Brad Freeman @ The Centre for Book and Paper, Columbia College Chicago, and Robyn and Stuart Mackenzie @ Plevna Downs Station, Eromanga. This research was made possible by Research Training Scheme funding by the Australian Government and through grants from the School of Education and the Arts, CQUniversity, and from access to ANSTO's Australian Synchrotron and Lucas Heights Dingo facility.

Certificate of Authorship and originality of thesis

The work contained in this thesis has not been previously submitted wither in whole or part for a degree at CQUniversity or any other tertiary institution. To the best of my knowledge and belief, the material presented in this thesis is original except where due reference is made in text.

Signed:

Date:18th June 2017

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Signed:

Date:18th June 2017

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Table of publications and presentations arising from the thesis work

Publications during candidature (TOs)

I. Milroy, AK and Freeman, B 2017, 'Diffract', *Journal of Artists' Books*, JAB 41, Spring, in press.

II. Rozefelds, AC, Milroy AK, Dettmann ME, Clifford, HT and Maksimenko, A in press, 'Synchrotron computer tomographic (CT) scans complement traditional techniques in understanding the internal anatomy of permineralised *Fontainocarpa* (Crotonoideae, Euphorbiaceae) fruits from the Oligo-Miocene of eastern Australia', *Review of Palaebotany and Palynology.*

III. Milroy, A, Wegener M, and Holmes, A 2015, '*Labpunk* – curiosity, intra-action and creativeness in a physics-art collaboration', *Transformations*, issue 26.

IV. Milroy, AK and Rozefelds, AC 2015, 'Democratizing the collection: paradigm shifts in and through museum culture', *Australasian Journal of Popular Culture*, 4: 2+3, pp. 115–130.

V. Milroy AK 2015, 'Talking through jewellery with Laura Bradshaw-Heap and AK Milroy, 'Was and is to be', *Paillon*, Jewellery and Metalsmiths Group of Australia (Queensland Chapter).

VI. Milroy, AK and Wegener, M 2015, 'Network nodes – jewellery at the edges, gaps, borders of Art and Science :Introducing the Labpunk collaboration', *Paillon*, Jewellery and Metalsmiths Group of Australia (Queensland Chapter).

VII. Milroy, AK, Rozefelds, AC, Coghlan, S, Holmes, MA and Hocknull, S, 2015, Digitising the collection: Evaluating photogrammetry as a means of producing a digital, three dimensional model', *Journal of Natural Science Illustration*, vol 47, no. 3, pp. 3–10.

VIII. Milroy, AK and Wegener, MJ 2014, *Labpunk* – The Art in Physics, Poster, Australian Physics Congress.

IX. Wegener, MJ and Milroy, AK 2014, 'The Art in Physics - Creating *Labpunk*, *Australian Physics*, Mar-Apr, vol. 51, no. 2, pp. 53–56.

Posters

I. Milroy, AK , Dadvar, S, Rozefelds, AC, Holmes, MA, Brien DL, Rajkhowa, R and Wang, X 2016, 'Carbon copies – fossil inspired wearable art 3D printed in new material', presented at the APPC–AIP 2016 conference and congress in Brisbane, Australia.

II. Milroy, AK and Wegener, MJ 2104, '*Labpunk* – the art in physics', presented at AIP 2014 congress at ANU, Canberra, Australia.

Conference presentations

1. APPC–AIP 2016: *Aletheia* performance and speech at welcome function, Sunday 4th December, 2016.
2. Palaeo Down Under 2 PDU2. Adelaide.
   - Presentation: *Visualising Evolution and Extinction using Synchrotron Radiation.*
   - Workshop chair and facilitator: *Computed Tomography at the Australian Synchrotron: a palaeontological user's perspective.* Co-chair Dr Anton Maksimenko, Australian Synchrotron.
3. AOFSRR 2015 Asia Oceania Forum for Synchrotron Radiation Research. *Visualising evolution and extinction through silicified fossil fruits from Queensland* (Milroy, Maksimenko, Rozefelds, Holmes).

- *abbe*: Artists Book Brisbane Event. Griffith University, Brisbane. Biography of a physicist .

4. Creative Labs. Queensland Museum. Keynote : 'deep time' presentation and workshop faciliatator.
5. SEDUA:School of Education and the Arts annual conference. Central Queensland University, Brisbane. 'deep time' Presentation.
6. POPCAANZ 2014. Popular Culture Association Australia and New Zealand.
   - Presentation: *What's my holotype?* AK Milroy
   - Presentation: *Reconciling the two cultures.* MJ Wegener & AK Milroy.
   - Presentation: *Democratising the collection*. AC Rozefelds and AK Milroy

Books

VII. Image in books: *'Spondylostrobus rozefeldsii', In search of ancient Queensland* (Cook & Rozefelds 2015), p. 228. (Figure 6.3)

Exhibitions (NTROs)

The following exhibitions have featured work inspired by this research project:

2016

- Manifest Printmaking Exhibition (Curated by Studio West End: Impress Art Gallery Brisbane | Firestation Gallery Melbourne)
- 'Aletheia' - Green Vale Gallery (Brisbane)
- CQU Creates - Central Queensland University, Rockhampton
- Creative non-fictions I & II acquired for CQUniversity Collection.
- 'Aletheia' - APPC–AIP 2016 Congress (Brisbane, December 4-8)

2015

- Lux Lumens (Jeweller & Metalsmiths Group of Queensland, Sydney)
- abbe (Artists' books Brisbane Event - Griffith University)
- Stories in Small Spaces (Curated by Studio West End: Impress Art Gallery Brisbane | Gympie Regional Gallery)
- Advanced Certificate of Excellence (ACE) Exhibition (The Goldsmiths' School, Brisbane)

2014

- Labpunk (AIP 2014: Australian National University, Canberra)
- Draw Me a Discovery—Cafe Scientifique (University of Queensland, Brisbane)

2013

- Confluence/influence (Jewellery & Metalsmiths' Group of Queensland: Brisbane City Library)
- Talking through jewellery with Laura Bradshaw Heap (Queensland College of the Arts: Griffith University, Brisbane)
- Addition/subtraction (Studio West End, Brisbane)

2012

- The extant landscape, Eromanga Basin (Brisbane)
- Bookplates unbound (Curated by Studio West End: Brisbane)
- 100 % recycled (Jewellery and Metalsmiths' Group of Queensland: Brisbane City Library)

Post doctorate 2017

- Salon – World Science Festival, Queensland Museum
- *'Aletheia'* – Australian Synchrotron
- 'deep time' – *The Planting*, Woodford folk festival

Art residencies during candidature (NTRO & TO)

- Joint 13th Asia Pacific Physics Conference – and 22nd Australian Institute of Physics Congress, APPC–AIP 2016, *Artist-in-residence.* December 4th to 8th, 2016.
- Columbia College Chicago, *Artist in Residence*. June/July 2016. Collaboration with Brad Freeman, editor of JAB (Journal of Artists' Books). Production of *Diffract*.
- Australian Institute of Physics Conference. *The Art of Physics.* ANU, Canberra. Labpunk exhibition and co-creator of Plenary speaker gifts.
- Artist In Residence. Eromanga Dinosaur Dig.

Grants (TOs)

- SEDUA Seed Grant Application: Value $3,900. *AK Milroys' Aletheia Exhibition at the APPC-AIP 2016 conference and congress 2016.* Collaborator: Saeed Dadvar, Deakin University.
- ANSTO, Lucas Heights DINGO facility, proposal ID 5346: Value $21,000. *Evolution of the Australian flora: visualisations of the internal anatomy of*

permineralised fossil fruits and cones. October 2016. Collaborators: Anton Maksimenko, Andrew Rozefelds, Joseph Bevitt, Floriana Salvemini, Ashley Holmes.

- ANSTO, Australian Synchrotron IMBL facility, proposal ID 9722: Approximate value $50,000 (approximate for five days of beam time). *Evolution of the Australian flora: visualisations of the internal anatomy of permineralised fossil fruits and cones using the Imaging and Medical Beamline (IMBL) at the Australian Synchrotron, Melbourne.* 21 October – 25 October, 2015. Collaborators: Anton Maksimenko, Andrew Rozefelds, Ashley Holmes, Gary Pattemore, Ashley Holmes.

Chapter one

a research opportunity

Seeing comes before words. The child looks and recognizes before it can speak. But there is another sense in which seeing comes before words. It is seeing which establishes our place in the surrounding world; we explain that world with words, but the words can never undo the fact that we are surrounded by it. The relationship between what we see and what we know is never settled. The way we see things is affected by what we know or what we believe. (Berger 1977, p. 7)

Figure 1.1: Pilot Scott Turner and the *Yellow Peril* (AK Milroy 2010)

Figure 1.2 (opposite): Seeing further — flight over Cooper country (AK Milroy 2010)

Background

Seeing and not knowing

A chance discovery of a deposit of fossilised leaves, whilst working as a volunteer on Queensland Museum Dig near Eromanga in the South West corner of Queensland, was the catalyst for a series of events which have led to this artistic practice-based research project, situated within palaeo-botanic scientific practice.

This unique landscape, with its conglomerate of fossilised and living plants, triggered an avid curiosity to know more. The sediments, identified as part of the Winton Formation[i] are deemed approximately ninety-five million years old (Jell 2013). This in turn meant that these newly found fossilised leaves had been entombed for a vast period of time. It seemed that I was the first sentient being to see them in millions of years, and with this realisation, my concept of time was challenged.

Figure 1.3: Time travel - Brisbane to the Cretaceous Digitally altered HEMA map (AK Milroy 2010)

Initial discussions with palaeo-botanists indicated that the fossils were impressions of fern leaves, possibly of the extinct *Phyllopteroides* genus (Mc Loughlin 2010, pers. comm.), family Osmundaceae, and related to the extant austral king ferns of *Todea* and *Leptopteris* (Rozefelds 2014, pers. comm.). These fossil forms of delicate, water-loving, sun-avoiding ferns are completely out of place in the current arid environment and prompted me to wonder what the environment had looked like during the Cretaceous period. Today, the landscape is characterised by extremes in temperature from scorching heat in summer to less than zero degrees centigrade in winter, and season-wise drought or flood, and not much in between. Extant fern species in the area at the time of the dig were not obvious. Subsequent searches of Queensland Herbarium surveys (Herbrecs 2015), revealed a distinct lack of pteridophytes (ferns) – notwithstanding records of Marsileaceae (Nardoo) and Adiantaceae (Rock Fern) families near Quilpie and Barcoo. A few months prior to

i A geologic unit comprising interbedded labile volcanic lithic-crystal sandstone, sandy siltstone, mudstone, intraformational conglomerate and coal (Jell 2013, p. 531).

the dig, drought-breaking rains, a long and dusty decade in coming, had transformed the flat, brown, desolate environment to a verdant sea, resplendent in delicate green foliage and beautiful flowers. Incredible that such variety had survived one of the area's worst droughts and could then regenerate, grow, flower and re-seed in such a short space of time.

Figure 1.4: Bloom after the dust – *Swainsona murranyana* (AK Milroy 2013)

A narrative of deep time

This juxtaposition of extinct and extant emphasised two very different environments, and led to ruminations on the 'deep time' narrative. McPhee (1981), attributes the term to Scottish geologist James Hutton's (1785–88) observations of geological time, akin to deep space, an almost incomprehensible infinitude. In Hutton's day, such geological observations were highly controversial as they challenged the established biblical diluvian (the great flood) theory, and were particularly challenging to established theories on the age of the earth. The Reverend Archbishop Ussher, for example, in his 1658 publication *Annals of the World* (translated by Pierce 2003) gave a confident calculation of the birth and thus age of the earth:

Figure 1.5: Time lapse - juxtaposing extinct and extant (AK Milroy 2014)

> In the beginning God created the heaven and the earth. The beginning of time, according to our chronology, happened at the start of the evening preceding the 23rd day of October (on the Julian calendar), 4004 BC or 710 JP. (in Pierce 2003, p. 17)

This narrative of time influenced many early naturalists. Noteably, physician Johann Jacob Scheuchzer (1672–1733) believed, as did most, that fossils were relics of the *Deluge*. This was gloriously illustrated in many of his publications, including the *Herbarium Diluvianum Collectum* (1723) and also in his magnum opus *Physica Sacra* (1731–33).

Historian Martin J S Rudwick (1992, p. 5), in *Scenes from Deep Time,* commented that this early naturalist/geological work was considered to be sacred as it sought to

Figure 1.6: Frontispiece - *Herbarium diluvianum collectum* (Scheuchzer 1723)

illustrate the biblical narrative as evidenced from the science of the day. The first book on palaeontology (as credited by Mantell in 1830) was written by Hutton's contemporary, physician and polymath James Parkinson[ii] (1755–1824). Interestingly, and as the frontispiece shows (from the 1811 edition of *Organic remains of a former world*), he too continued the biblical, diluvian narrative, although the ark in this image is only just visible in the distance.

Figure 1.7: *Organic remains of a former world*. Drawn by Richard Corbould, engraved by Samuel Springsguth (Parkinson 1811)

The narrative today

As the science of geology gained momentum, and empirical methodologies

ii The condition of Parkinson's disease is named after him, in deference to his research and 1817 essay on the 'Shaking Palsy' describing 'paralysis agitans'.

developed, the narrative of deep time today has reached an interesting chapter. Currently, the age of the earth is estimated to be 4.55 billion years[iii] and our known universe, 13.8 billion years[iv] (Randall 2015, p. 40). However, I wonder if future generations will express the same surprise at these estimates as we today have to the Reverend Ussher's calculation.

Changes in the fossils (flora and fauna) contained in sediments are the basis for most GSSPs[v] (Global Boundary Stratotype Section and Points).These are internationally agreed upon points that define the lower boundary of a stage in the geologic time scale. They are often marked with a 'golden spike' — a circular brass plate affixed to a stratigraphic layer with the name of the epoch, the date and the letters *GSSP*. In my own work I consider the concept of the Anthropocene epoch using the medium of the Artists' book and a miniature 'golden spike' brass plate (Figure 8).

Figure 1.8: Living in the Anthropocene - Artists' book (AK Milroy 2016)

The Anthropocene – a geological perspective

The current epoch of the Anthropocene is a controversial proposition to some groups. The term appeared with its current meaning in the 1980s and was formalised in an article by Crutzen and Stoermer in 2000, who claim that the influence of human behaviour on the Earth's atmosphere is significant enough to warrant a new geological epoch for the lithosphere[vi].

iii http://www.scientificamerican.com/article/how-science-figured-out-the-age-of-the-earth/

iv This figure could be much higher, as some stars are estimated to be 18 billion years old. See http://www.scientificamerican.com/article/how-do-scientists-determi/?print=true & http://www.space.com/24054-how-old-is-the-universe.html

v International Union of Geological Sciences http://www.iugs.org/

vi The part of the earth that encompasses the crust and the upper mantle.

> Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term 'anthropocene' for the current geological epoch. The impacts of current human activities will continue over long periods. According to a study by Berger and Loutre (14), because of the anthropogenic emissions of CO_2, climate may depart significantly from natural behaviour over the next 50,000 years. To assign a more specific date to the onset of the 'anthropocene' seems somewhat arbitrary, but we propose the latter part of the 18th century, although we are aware that alternative proposals can be made (some may even want to include the entire Holocene). (Crutzen and Stoermer 2000, p. 17)

Recent articles in the International Union of Geological Sciences (IUGS) publication—*Episodes,* by Klein (2015) 'The Anthropocene: What is its geological utility? (Answer: It has none!)' and Matteucci *et alia* (2014) 'The Geoethical Promise: A Proposal'—illustrate the degree of dissention within geological circles. More recently, however, Waters et al (2016) have put forward a convincing case to defend their position that the Anthropocene is functionally and stratigraphically distinct from the Holocene. These concepts will be discussed at greater length during this exegesis but, for now, we need to return to the dig site.

Figure 1.9: Journal entry – Zac site Watercolour pencil on paper (AK Milroy 2010)

Taxonomic gaps – lost time

Ruminations of these newly discovered fossil plants generated more questions than answers. Which families do they belong to? Are their species represented in the stratigraphy extinct or do they having living relatives? And if so, where are these species located today? Which part of the life cycle of the plants is recorded in these fossils? Were

they evergreen[vii] or ephemeral[viii]? And, what could have caused the fossilisation event and subsequent change in botanical environment: rapid or gradual changes in climate, extreme weather events or geological or cosmic catastrophes?

At the dig site, Winton Formation sediments are closer to the surface than in other areas due to a geological structure called the Mt Howitt anticline[ix]. The clay sediments are gradually moving upwards, pushed up by alternating periods of flood and drought, and repeated swelling and shrinking, pushing entombed, fossilised flora and fauna to the surface. The presence of fossils on the surface is usually a good indicator of fossil beds below, and indeed this was how the first fossil site[x] in the area was discovered.

I initiated a search to find visual records, images which would facilitate comparison and identification of both extinct and extant species. However, and despite the considerable amount of taxonomic research by scientists in Australia, investigations revealed that floras of this particular south-west region of Queensland, are, in general, not well recorded, and hence not well known (White 1986; Hill 1994). White (1988, p. 7) makes the comment that 'the rich and diverse nature of the continent's plant record, particularly the extinct species, is inaccessible'.

It is possibly even more inaccessible for the non-scientist: specimens are either entombed in sediment on a remote site, obfuscated by a specialist language in scientific papers or lodged in museum collections (where they are overshadowed by the co-occurring dinosaurs and marine reptiles) and hence are rarely on display. The most important of these, the botanical holotype specimens, are considered a part of the museum's 'crown jewels'[xi] but are rarely on view or otherwise accessible to the public.

For the extant varieties of this region of South-East Queensland on this particular site, the most comprehensive non-digital publication for reference was *Plants of Western New South Wales* (Cunningham et al 1992). Despite a plethora of more recent publications, none match this text for visual detail and comprehensiveness. Investigations also revealed that the Queensland Herbarium has performed a recent survey of the area and, as I write, a 2015 survey has appeared online. This spreadsheet has a wealth of quantitative data. However, no images. *Australia's Virtual Herbarium* (AVH) is mute on the extant flora of this remote outback dig site due to the lack of telecommunications and power. This meant that visual identification of extinct and extant flora continued to be challenging.

For the extinct species, *History of the Australian Vegetation—From the Cretaceous to Recent* by Hill (1994) provides a survey of palaeobotanical data. However, once again, the sparse visuals did not reveal exact matches for the enigmatic fossils. These fossilised

vii One that has green leaves throughout the year and does not lose foliage during seasonal changes.
viii Those which are short lived.
ix Type of geological fold that is an arch like shape and has the oldest beds at the core, typically convex up
x In 2004, the first piece of dinosaur bone was discovered at Plevna Downs by 14 year old Sandy Mackenzie (Jnr) marking the first discovery of dinosaur evidence in south-western Queensland http://ogf.org.au/uncategorized/latest-news/
xi http://www.qm.qld.gov.au/Collections/Biodiversity+and+Geosciences#.Vzetv_l96Uk

ferns are significant, as they are a record of a palaeoclimate and potentially new species, or genus.

In *Geology of Queensland,* Jell (2013) provides a brief summary of botanical fossils found in the Winton Formation. The recent *In search of ancient Queensland* (Cook & Rozefelds 2015) delivers an accessible history of Queensland over the past 250 million years, including visualisations of the Queensland Museum's palaeobotanical holotypes. However, at the time of the 2010 dig, *The greening of Gondwana* by Dr Mary White (1986), with photographs by Jim Frazier, was the most accessible resource. Whilst some of the information is now outdated due to recent discoveries and revisions, this remains a remarkable publication, and delivers a comprehensive overview of the changing vegetation of the Australian continent over time. It succinctly summarises Australia's epic tectonic journey from super continent Gondwana to its present global position, as well as current names for, and evolution of, endemic species.

Continuing the search for information on Australia's palaeobotanical past, I contacted Dr White[xii] in 2013, and, with fellow artist-scientist Adele Outteridge[xiii], visited her Forest Falls Retreat (Figure 1.11). Over three days, we spoke at length about art and science and how they could interconnect to produce new knowledge. As she had not been actively working as a palaeobotanist in recent years, Dr White declined to identify the fossil specimens I had brought with me. She did, however, support continued intra-disciplinary investigations. Dr White's most recent book *Earth Alive* (2003) focuses on climate change education and theories of Gaia, as described by James Lovelock in 1988, and suggests ways to reverse current global warming trends. Our meeting and discussions inspired a small wearable work of art, below. Dr White was very generous with her knowledge, and shared many anecdotes and her method for writing in a style that is both scientific and rigorously researched, but also accessible to the non-specialist.

Figure 1.10: *Gaia* Sterling silver, *plique-à-jour* enamel (AK Milroy 2012)

xii For a recent interview with Dr Mary White https://vimeo.com/77669670
xiii www.studiowestend.com

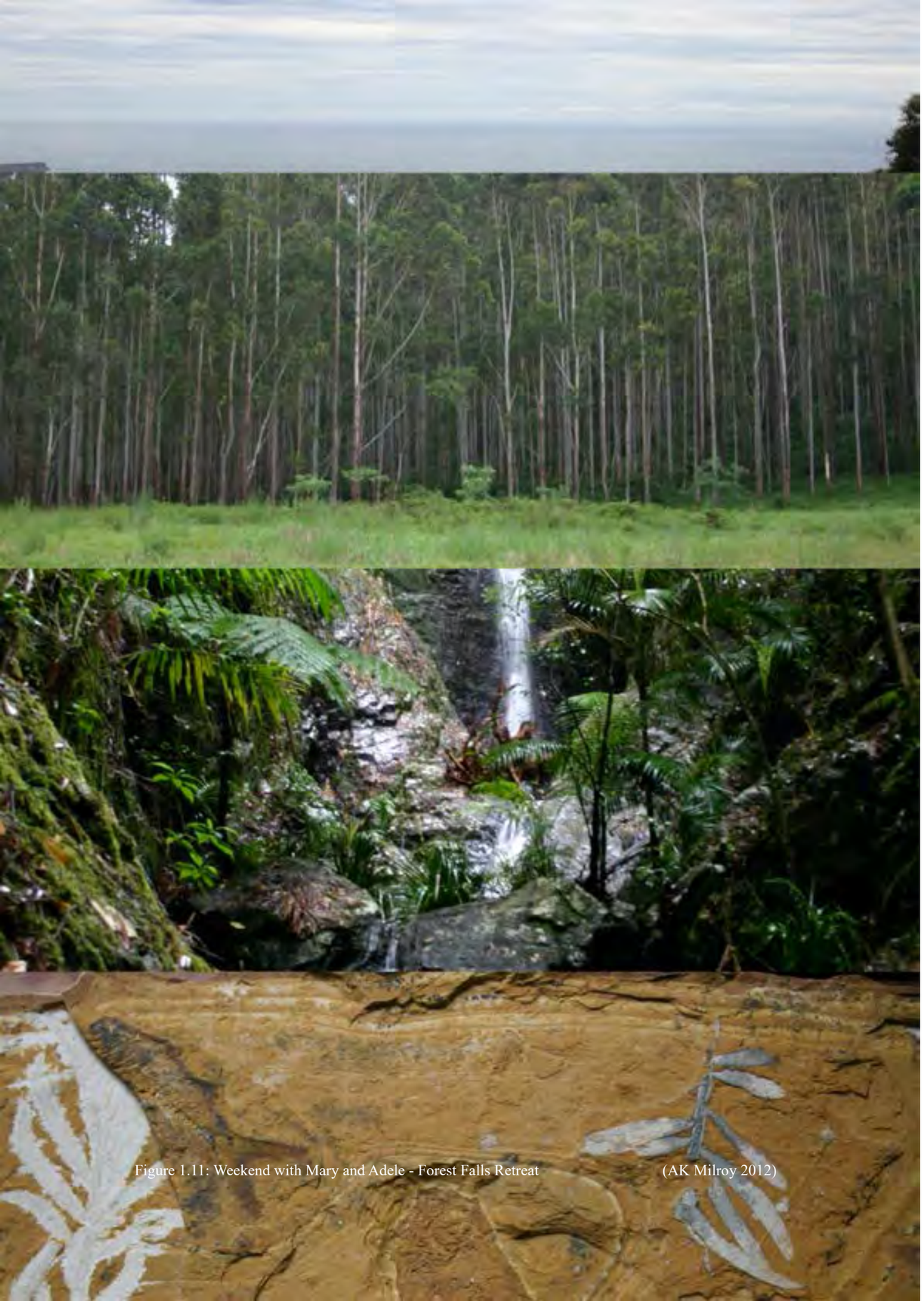

Figure 1.11: Weekend with Mary and Adele - Forest Falls Retreat (AK Milroy 2012)

Introduction

A research opportunity

In the quest to contribute knowledge to Queensland's botanical heritage, an experimental, investigative research proposal was submitted for peer review. A key point of difference to previous botanical research projects was that the project would be focused through an established artistic practice. The aim, to facilitate a more democratic process of knowledge acquisition and dissemination about botany was planned to be achieved through (physical and/or virtual) access to localities, specimens, information and images. It was anticipated that this could generate novel and perhaps innovative methods for accessing and communicating research results, and would contribute to the deep time narrative via concepts of evolution and extinction. This led to the development of the research question.

During the course of the research, themes such as genesis, deep time, black boxes, knowing, diffraction, agency and the Anthropocene have entangled and manifested in a body of creative works. The research is thus positioned firmly in the *post* postmodern era. The term *metamodern* (Vermeulen & van den Akker 2010) will be used to describe this philosophical orientation, which seeks to resist a modernist urge to dichotomise phenomena. The art-science divide, as a modern social construction, is a case in point here. In a very general way, one may think of modern science as following a modernist (realist/positivist) paradigm, and the arts leaning towards a postmodernist (constructivist) mode of thought. Recent discussions, however, contradict or make incomprehensible, this postmodern manifesto. The metamodern[xiv] as proposed by Vermeulen and van den Akker:

> ...we contend that metamodernism should be situated epistemologically with (post) modernism, ontologically between (post) modernism, and historically beyond (post) modernism...We do not seek to impose a predetermined system of thought on a rather particular range of cultural practices. Our description and interpretation of the metamodern sensibility is therefore essayistic rather than scientific, rhizomatic rather than linear, and open-ended instead of closed. It should be read as an invitation for debate rather than an extending of a dogma. (Vermeulen and van den Akker 2010, p. 2)

The research questions

The research opportunity evolved into a research question, and then into questions, during the course of candidature. These are:

> In what ways, if any, can the outcomes of a practice-based visual arts researcher significantly contribute to the development and communication of knowledge/s in traditionally scientific disciplines?

xiv Huff Post Blog. http://www.huffingtonpost.com/seth-abramson/the-metamodernist-manifes_2_b_5678854.html

and conversely:

In what ways, if any, can scientific research practices significantly contribute to the development and communication of knowledge/s in an artistic practice?

The theoretical construct, or mode of operation, is *practice-based research.* It was anticipated that by analysing the knowledge development and communication of two (arguably) disparate disciplines, or practices, might suggest ways for the arts to contribute in the sciences, and the sciences to the arts, and assess the significance of these contributions. The outcomes subject to examination are Non-traditional Research Outputs (NTROs) in the form of literal and figurative art works produced during the research, and also Traditional Research Outputs (TOs) in the form of published works (journal articles, conference presentations, posters etc). The main challenge, however, is to contribute to the conversation on practice-based visual arts research within specific fields of science and vice versa. Whilst there are pre-existing personal philosophies of how this might work out, it was not clear at the outset how and what this arts practice could contribute significantly to scientific knowledge, nor how and what the science practice could contribute to artistic knowledge. The potential for serendipitous or surprising results is inherent in this type of research. By recording, diffracting (Barad 2007) and analysing the research outcomes, works of art, and the work of the art (Bolt 2014), insights into practice-based artistic research, scientific research, and research paradigms in general are made available for critical discussion. Rozefelds (2015, pers. comm.) notes that 'most field specific researchers are keen for their research to be visual/or see a visual rendering of their ideas. The best science research is arguably visual in nature'.

The thesis title

Epistêmê, technê and poïesis : visualisations of evolution and extinction in Queensland flora

Some of the most basic questions seem to defy answers. What is art? What is science? What is knowledge? What is research? In an attempt to answer the research questions, a conceptual map was made using three key philosophical concepts of *epistêmê, technê* and *poïesis*, as themes. These are specifically applied to my visualisations/artworks, as valid outcomes of this research project. The artworks have been inspired by extinct and extant botanical specimens, both from the Queensland Museum Type collection, and from those collected in the field. The title suggests that for a work of art (or indeed science) to be considered as new/novel, and a contribution to knowledge, it should have as a minimal *a priori* condition, the three qualities of *epistêmê, technê* and *poïesis*. The following definitions are simplifications of those found in the *Stanford Encyclopedia of Philosophy* (2007).

Epistêmê, from the Greek ἐπιστήμη, may be translated as 'knowledge'. For this inquiry it is used to signify the explicit knowledge/s the researcher has and imparts when producing a work of art (or science): this is what they know about the world, as a human agent. For sentient beings, knowledge/s are comprised both of learnt information (from school, trade, work and university) and confirmed through direct and indirect experience and/or observation. *Technê*, from the Greek *τέχνη,* is often translated as craftsmanship, craft or art. Here it is used to signify the technical aspect inherent in art works, specifically the researcher's technical skills. In this thesis specifically, the definition is extended to include the agency of *both* the human and the non-human (materiality) as agents in practice. To create works of art, or other works of research, a certain level of technical ability is required in the medium of choice (art, science, language etc). A craftsperson traditionally has a high level of technical skill gained from sustained practice in using specific media or materials, over an extended period of time. The work of craft is thus associated with both high aesthetic and utilitarian qualities. This definition could be extended to include objects which have potential to be multiples and made by a number of different craftspeople. Specifically, a recipe, a brief, or a formula is followed to give a predicted or predictable result. Craft and art share contiguous borders, and it is conceptually easy to move from one to the other. A proposed differential, *poïesis*, is a quality that moves a work from craft to art, and it is the absence of this element that moves art back to craft. *Poïesis*, from the Greek *ποιέω,* is defined as 'to make' and is the root of the modern word *poetry.* It was first used as a verb, an action that transforms and continues the world. Heidegger (1977, pp. 4–5) referred to poïesis as a 'bringing forth, a threshold occasion; a moment when something moves away from its standing as one thing to become another'. Barbara Bolt (2004, p. 9) in *Art Beyond Representation* considers art is a 'poïetic revealing'. Thus it is an act of creativeness, initiated by curiosity, which brings into being something which has not been seen before. So here is a starting point for developing a method of critical analysis to assess research outcomes *a priori* as art, and available *a posteriori* for analysis as viable contributions to knowledge.

The thesis sets the scene for the production of original works (in art or science), which in order to satisfy the *a priori* condition, should embody a combination of knowledge, technical skill and novelty or inventiveness. It is the role of subsequent analysis to test for significance, the work's contribution to knowledge/s. Visualisations, in two and three dimensions, are the outputs of this artistic/scientific practice. They are associated with revealing, unconcealedness (Heidegger 1996)—and knowing in being (Barad 2007).

The significance of the study

Many milestones in human history, in both the arts and sciences, provide examples of innovation which began, in retrospect with:

> … a grumble or an irritation – not a well defined and elegantly phrased question – that sets the work in process and that implicates both matter and meaning. (Bolt 2014, p. 35)

The term 'blue skies research' is derived from such a phenomenon. John Tyndall's curiosity-driven study of Alpine sunsets (or why the sky changed colour from blue to orange, and red) inadvertently led to the discovery of the roots of disease transmission via airborne microbes (Cox 2013). Webb and Brien (2010) confirm this *blue skies* approach as one of the hallmarks of creative (writing) research. They quote Kundera:

> … the novelist's [researcher's] ambition is not to do something better than his predecessors but to see what they did not see, say what they did not say. (Kundera 2006, p. 15 in Webb and Brien 2010, p. 195)

If one agrees that curiosity and inventiveness are characteristics essential to the human condition and for humanity's continued evolution and development, then the study is significant in those terms. As per the Organisation for Economic Development (OECD) criteria: it is *novel* and is aimed at new findings in intra-disciplinary research; it is *creative* in its use of new paradigms, methodologies and research outputs; it is *uncertain*, the knowledge outcomes were not pre-known; it is *systematic*, being undertaken within the university's research protocols and systems and; it is *transferrable*, not only as practice-based outcomes but as knowledge revealed.

Artistic Practice as Research

Candidature was confirmed in 2012. The proposal was a hybrid, entangling artistic and scientific practice within its framework. This was new territory and not without academic risk, but the commitment was to see where the investigation would lead. The challenge was to frame the research opportunity, without being overly prescriptive or defining from the outset, whilst concomitantly meeting the criteria for academic research, specifically the production of new knowledge.

> Artistic research as a rule does not start off with clearly defined research questions, topics or hypotheses whose relevance to the research context or to art practice has been established beforehand […] it is not 'hypothesis-led' but 'discovery-led' research. (Borgdorff 2012, p. 80)

To gain inspiration and source data, immersion in the associated scientific practice was proposed. This was achieved by working as an honorary within the Queensland Museum (from 2010 to the present), participating on fossil digs and assisting with palaeobotanical audits and research projects. An associate supervisor from the museum was appointed. The result: a hybrid practice-based research methodology which might be characterised as emergent, diffractive, iterative and responsive (Harraway 1991,1997; Barad 2007).

My initial proposal was met with polarised critique: the hybrid form did not fit neatly into traditional scientific or (fine) artistic format. A comment 'art per se does not contribute knowledge to or about other disciplines' was particularly challenging to my personal world view (that all things in the world are entangled and thus capable of affecting the other in some way). Fellow scholar Barker (2015) likened my personal paradigm to the original concept of *Wissenschaft*[xv]— a German term which may be translated as 'any study that involves a systematic pursuit of knowledge, learning and scholarship'. Botany, in particular, has had a very long and entangled connection with the arts. Botanist Agnes Arber explained this succinctly in 1950:

> In the physico-chemical sciences interpretations are conveyed through the medium of words, supplemented by symbolism of a mathematical kind. In morphology, on the other hand, the second medium, added to words, is expression directed to the visual sense. The necessity for these two media is tacitly recognised by every botanist who illustrates his text with pictures of plants.
>
> As Turpin wrote more than one hundred years ago, '*la plume and le pinceau sont les deux principaux moyen dont nous puissions nous server pour le signalement des êtres*[xvi]', and he added that, of the two instruments, pen and brush, the brush was perhaps '*le plus signifcatif*[xvii]'.

As an exemplar see Figure 1.12, Turpin's '*Organographie vegetale*' on the following page.

> There is, indeed, a certain correlation between artistic power and morphological insight. This may well be why the study of plant form was initiated and carried to so advanced a point in the classical period, for the visual capacity of the Greeks reached a peculiarly high level. It is not mere chance that in their language the word 'knowing' (*εἴδέμαι*) and 'seeing' (*ἴσεϊν*) came from the same stem, and that one term, *Θεωρα*, was used both for scientific investigation and also for beholding. The Greeks understood how to think with the mind's eye. (Arber 1950, p. 210)

Notwithstanding this historical precedent, the question concerning the ability of art to contribute to other disciplines was regarded as significant and subsequently incorporated into this investigation. Specifically, it is addressed in the research question and I have sought to identify and explain how artistic practice *can* contribute to other disciplines and vice versa. In Chapter four I submit evidence to the affirmative, illustrating how these two practices in the disciplines of art and science have become very much entangled and that the research results have been served well by the use of intra-disciplinary knowledges and methodologies; specifically, the intra-twining of practices is successful as a method

xv www.oxforddictionaries.com/definition/english/wissenschaft
xvi 'the pen and the brush are the two main ways in which we can serve for reporting reality'.
xvii 'the most significant'

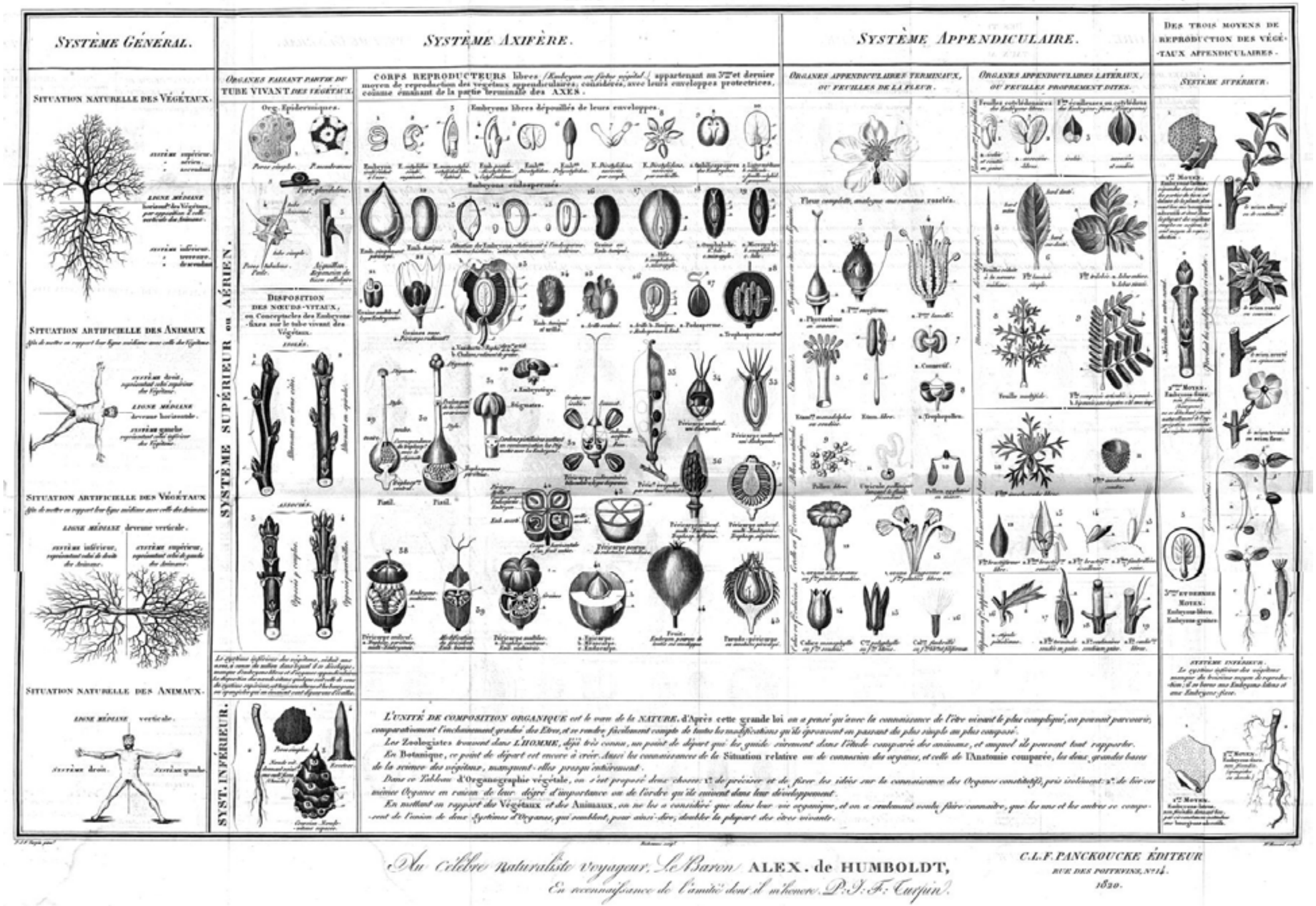

Figure 1.12: *Organographe vegetal* (Turpin 1820)

of encouraging innovation and positively challenged disciplinary specific black-box[xviii] thinking (Milroy, Wegener and Holmes 2015).

Heterogeneous literacies

Language, and text-based theses, are the traditional academic agents of scholarly communication. One of the challenges facing artistic research practitioners in general is the establishment of the *artwork* as research without losing the *work* of art in the process (Barrett & Bolt 2014; Borgdorff 2009; Schwab & Borgdorff 2014). Many artistic research scholars are challenged by an academic (writing) paradox: the provision of an explicit verbal account of the implicit knowledge and understanding embodied in artistic practices and products. Many argue that this is at odds with the ability (or the work) of art to go beyond, or reveal, that which cannot be expressed by words or accounted for by academic convention (Borgdorff 2009). Ian Heywood, in *The Handbook of Visual Culture* (2014) notes that:

> The rise of the new media and globalized visual culture in particular—we might also say hybridized and diasporic cultures—has become one of the driving force-fields of contemporary knowledge production and cultural change. (Heywood 2014, locn 356 of 21212)

Whilst I acknowledge that writing is in itself a practice, I am using it as a type of translation device, in an attempt to express the visual results of the research in words. Despite the fact that peer-reviewed publications have been produced during this project as a means of validating knowledge claims, there is an acute awareness that readers may not have had the opportunity to experience, to physically view and handle, the resolved artworks in professionally curated exhibition spaces or as hybrid performance pieces at academic conferences. Can the work of art in the world be determined *in absentia* by an explanatory text and accompanying photograph—which are arguably different and artefacts in their own right?

Thus, the physical production of this exegesis simultaneously reinforces and reduces this bias by its submission as an artefact of artistic practice, one that may stand as such in its own right. Importantly, it is presented in a creative academic manner, as both an Artists' Book[xix] — an output of artistic research practice, and as a scholarly document, thus providing discursive and non-discursive evidence of academic knowledge production in art and science. Heywood (2014) writes:

> We are reminded that the concern for modes of signification and signifying practices is not a recent intellectual invention. John Berger in his path breaking lectures Ways of Seeing had already pointed the way to more concrete studies of gendered power in understanding the visual field. Being 'shocked' by past theories of meaning and signification might help loosen the overwhelming textual orientation of critical studies. (Heywood 2014, locn 508 of 21212)

xviii https://en.wikipedia.org/wiki/Blackboxing
xix http://www.slq.qld.gov.au/resources/art-design/artists-books

The multiple disciplinary audiences provide another challenge, as each has its own language and writing style. To facilitate this, the aim has been to write in a clear manner, and to avoid where possible, discipline specific 'jargon'. Links to discipline specific concepts are provided throughout the document as footnotes. I have deliberately avoided over paraphrasing authors, preferring instead to keep the integrity of their original words and to allow the reader to interpret these from their own field of experience.

However, whilst acknowledging this work's metamodern orientation and subsequent production, it is also written with consideration to accepted standards and definitions. Academically speaking, these are derived from the Organisation for Economic Co-operation and Development's (OECD) Frascati Manual and the Australian Research Council's (ARC) Excellence in Research Activities (ERA) guidelines. I also realised, through conversations with colleagues from other disciplines, that we did not share the same definitions of research. I have thus included the following summary, to clarify my position and to assist in establishing a framework for this entangled, intra-disciplinary (art-science-technology) academic research practice.

Research frameworks

Internationally – Frascati Manual

As prepared by the OECD and officially known as 'The Proposed Standard Practice for Surveys of Research and Experimental Development'. The 2015 Frascati Manual's foreword states:

> Understanding how knowledge creation and dissemination contributes to economic growth and societal wellbeing requires a sound evidence base. Throughout history, the outcomes from research and development (R&D) have transformed people's lives and societies in multiple ways, as well as the natural environment we are part of. This realisation has created a sustained demand among policy analysts and decision makers for documenting the level and nature of both human and financial resources that countries, regions, firms and institutions devote to such endeavour, as a first step towards learning how to direct them towards desired objectives. Supporting this evidence need through international comparable statistics and a common language is the main objective of this manual … (Frascati 2015, p. 3)

Research and experimental Development (R&D)

Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge. (Frascati Manual 2015, p. 44)

Core criteria and research types

For a research activity to be considered R&D it must satisfy five core criteria and be:

- novel (aimed at new findings)
- creative (based on original, not obvious, concepts and hypotheses)
- uncertain (uncertain about the final outcome)
- systematic (planned and budgeted)
- transferable and/ or reproducible (to lead to results that could be possibly reproduced)

(Frascati Manual 2015, p. 45)

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.

Oriented basic research is carried out with the expectation that it will produce a broad base of knowledge likely to form the basis of the solution to recognised or expected current or future problems or possibilities.

Applied research is original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.

Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving products or processes.

(Frascati 2015, pp. 50–51)

The manual notes that it is not unusual to find multiple research activities occurring within the one research project. Specifically, an example is given in how to differentiate between different types of R&D:

> The study of sources of all kinds (manuscripts, documents, monuments, works of art, buildings, etc) in order to better comprehend historical phenomena (the political, social, cultural development of a country, the biography of an individual etc) is basic research. Comparative analysis of archaeological sites and/or monuments displaying similarities and other common characteristics (eg geographic, architectural etc) to understand interconnections of potential relevance to teaching material and museum displays is applied research. The development of new instruments and methods for studying artefacts and natural objects recovered through archaeological endeavours (eg for the age dating of bones or botanic remains) is experimental development. (Frascati 2015, p. 54)

This research project is no exception to this, with origins in basic research and results which may be retrospectively categorised as applied research and experimental development. This multiplicity will become more apparent in later chapters.

Nationally – ARC and ERA

The Australia Research Council (ARC) definition of Research for the purposes of Excellence of Research in Australia (ERA 2015) has a similar definition:

> … the creation of new knowledge and /or the use of existing knowledge in a new and creative way so as to generate new concepts, methodologies, inventions and understandings. This could include synthesis and analysis of previous research to the extent that it is new and creative. (ERA 2015, p. 12)

Bolt (2014) noted that the ARC committee did not agree that 'all art is research' and suggests that in order to establish the research in their art, creative arts researchers need to prepare and submit a discursive research statement to accompany each artistic output submitted to the assessment exercise. This has been incorporated into the 2015 submissions guidelines. See hyperlink in reference section. The primary Unit of Evaluation (UoE) for ERA is the field of research at each institution. Fields of Research (FoR) are a hierarchical classification of research disciplines as set out in the Australian Bureau of Statistics Australian and New Zealand Standard Research Classification (ANZSRC) 2008. For more information please see hyperlink in reference section. The results of this research project fall into several FoR categories, and these include:

FoR 19 Studies in Creative Arts and Writing
FoR 04 Earth Sciences
FoR 06 Biological Sciences and
FoR 02 Physical Sciences.

Multidisciplinary, intra-disciplinary, transdisciplinary research

This intra-disciplinary research project, with its inherent hybridity, may also be considered as *Multidisciplinary research*, identified by the ARC 2012 ERA Report as an emerging discipline.

> Multi-disciplinary research relates to, or involves two or more academic disciplines that are usually considered distinct. Knowledge flows between disciplines have attracted interest because advances in science often involve collaboration across discipline boundaries. (ERA 2012, p. 41)

> Increasingly, government, industry and the research sector are looking towards multi–disciplinary research to solve complex problems. Knowledge flows between usually distinct disciplines attract interest because major advances in innovation often involve collaboration across disciplinary boundaries. (ERA 2015, p. 47)

Interdisciplinary and multidisciplinary research is assessed in its component fields of research. In the 2012 ERA report, the percentage of multidisciplinary research between the Visual Arts (FoR 19) and Earth Sciences (FoR 04) or the Biological Sciences (FoR 06), were reported as 0.0% and 0.1% in respectively.

Traditional and Non-traditional Research Outputs

Under ERA 2015 guidelines, eligible research outputs include traditional types,

such as published research books, book chapters, journal articles or conference papers. Non-traditional research outputs (NTROs) are defined as:

- Original Creative Works;
- Live Performance of Creative Works;
- Recorded/Rendered Creative Works;
- Curated or Produced Substantial Public Exhibitions and Events; and
- Research Reports for an External Body.

Where institutions have nominated non-traditional research outputs for ERA peer review, institutions must provide a statement identifying the research component of the output, known as a 'Research Statement for ERA Peer Review of Non-Traditional Research Outputs'. Multiple exhibitions/performances of non-traditional research output types may be counted as separate outputs where each subsequent exhibition/performance introduces a new research component to the work that builds upon the initial research component of the output. Institutions may also submit a portfolio of items as a single non-traditional research output. A portfolio is a collection of individual items that are derived from the same underlying research endeavour but which do not in themselves constitute a research output. The portfolio must be able to demonstrate coherent research content.

> Non–traditional research outputs provide an important insight into applied research, and creative and practitioner–based research in the Humanities, Creative Arts and Social Sciences. The provision within the ERA framework for portfolios allows for related works that demonstrate coherent research content to be submitted and reviewed as a single output. This is particularly important in the case of applied, creative and practitioner-based research, where a body of work needs to be viewed as a whole so that the full significance of the research involved can be considered. (ARC 2015, p. 66)

Research outputs from this project are also available via University databases.

Practice-based research

For the purposes of this inquiry, I suggest that this artistic research project sits within the category of *practice-based research*. Gray and Malins (2004, p. 202) put forward the following definition of practice-based research, within the doctoral framework as:

> A doctorate where the primary research is done through producing artefacts, designs, performances, films etc. It implies that the practice is an intelligent discourse in the 'language' of the medium or art [science] form and that this is a dialogue already with the history and other contemporary work in the field. The practice or its adequate documentation will form a significant part of the submitted thesis.

Feedback from the confirmation of candidature process and observations of practice in the wider research community in Australia and overseas has re-framed and contextualised the research opportunity within contemporary practice-based research. This, in turn, has directly influenced the evolution of the research questions, by directing the focus to the nature of the practice and how working within each one changes/affects the other.

Conclusions

With its *blue skies* genesis, this inquiry investigates multiple methods of researching phenomena within art and science. It is anticipated that the outcomes demonstrate significant research benefits using a hybrid art-science practice approach, through the incorporation of heterogeneous perspectives and insights. Inherent within this is the knowledge transfer between disciplines, co-authorships among artists and scientists and in new media, publications and exhibitions. An added outcome is an expanded peer group, and cross-institutional collaborations. In Chapter two: *epistêmê*, I examine research paradigms and suggest, as a successor science (Barrett 2014) 'Quantum-ivism' with origins in creative arts research and quantum physics (Barad 2007), but applicable across all disciplines. Chapter three: *technê*, builds on this paradigmatic research to put forward a modifications to practice-based research methods and focuses on a diffractive (Haraway 1991, 1995; Barad 2007) rather than a reflexive (Schon 1983) methodology. The outcomes and data analysis are presented in Chapter four: *poïesis* and the NTROs are contextualised by accompanying research statements. Copies of TOs are available through Academia.ed.au and are included as PDF files in the accompanying CD. (Appendix A). Each outcome evaluated as contributing to knowledge is available via the internet, democratically accessible by all for further dissemination and discussion[xx]. The research illustrates serendipitous meetings and unexpected results. It recognises the nonhuman turn in practice, considers the Anthropocene and the concept of the collective in research. The thesis exhibition highlighted the work of art in the world as a process of *Aletheia,* or unconcealedness (Heidegger, 1966). Chapter five: *evolution and extinction*, briefly analyses these terms and considers how they relate to space, time and matter. Finally, in Chapter six: *conclusions and future work*, the research findings within the disciplines of art and science are summarised and a list of future publications and public exhibitions/performances to be developed from this work is provided. I now turn to the next chapters which continue the literature review. The content of the Chapter two may be unexpected as it does not focus on the botanical art-science works but has evolved in response to this project, to resolve paradigm conflicts and defintions of knowledge between art and science. Here I discuss the construct of practice based research and develop an intra-disciplinary research paradigm.

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Chapter two

epistêmê

Leonardo da Vinci's codexes were not 'art objects' for him, but lab books; they were recordings of scientific investigations and technological studies. The sketches in those workbooks operate as art in that they concretized and reflected back to him his mind's almost unconscious exploration of observed phenomena, and they served as scientific laboratory notes in that they were illustrations of his focused analysis, a working out of what he was observing. In Renaissance Italy the greatest technological, scientific and artistic minds worked in studios and ateliers that did not separate the engineering from the aesthetic, the examination of materials properties from the social implications of their application, the contributions to scientific knowledge from the conceptual border-breaking artistic investigations. Art and science were interwoven systems of knowledge production that together allowed for not just the factual addition of understandings but also the conceptual agility to step out of the 'known' and explore the world meticulously and fantastically. Since the Renaissance a lot has been gained by the precision and specialisation of the sciences, but the cost of intense specialisation has been a loss of agile, intuitive connection-making, the capacity to imagine the invisible visible, the possibility of unabashedly examining the future and, perhaps most gravely, the ability to address massively complex problems that can be understood only through a combination of the material sciences, the biological sciences and social, cultural and human variables. (Knox 2016, p. 8)

(opposite) Figure 2.1: From Leonardo da Vinci's codex, *The flight of birds* (1505–6)

Epistêmê

As defined in Chapter One, *epistêmê*[i], is an ancient term for knowledge. In this chapter, I explore the term's historical and contemporary meanings, to clarify what knowledge is and how a researcher may create new knowledge. I do this because I work in a hybrid practice-based space of art-science, or science-art, where established paradigms of knowledge production clash and, at times, contradict each other. In this chapter I present a literature review on this topic and suggest a new paradigm, which I term 'Quantum|ivism' to account for and resolve these disciplinary 'divides'.

O'Farrell (2010) describes Foucault's (1966) introduction of *epistêmê*, from *The Order of Things*, as 'orderly unconscious structures which underlie the production of knowledge in a particular time and place'. O'Farrell compares Foucault's *epistêmê* to Thomas Kuhn's concept of a paradigm[ii] as a shared worldview. Kuhn (2012, p. 42) himself suggests that 'rules derive from paradigms, but paradigms can guide research even in the absence of rules.' However, whilst Kuhn's paradigms deal specifically with scientific disciplines, Foucault's *epistêmê* may be read as applicable to a wider range of discourse including, though not limited to, scientific worldviews and practices. Schirato, Danaher and Webb translate *epistêmê* as:

> the organising, categorising and evaluating of the discursive and material phenomena of a time/place; and by doing so, effectively producing ideas, values and narratives as natural, doxi[iii], normal or universal, and others as unthinkable. (Schirato, Danaher and Webb 2012, p. 18)

For any researcher, the quest to add to knowledge is a given and the reader may be surprised at this chapter's aspirations. Naturally, during the course of candidature I have had my own philosophical assumptions of knowledge challenged constantly. However, I do not think there has to be a compromise; Massumi expresses this eloquently:

> Thinking art [science] is not about imposing a general overlay on its practice. The last thing it should be about is forcing art [science] to fit into another discipline's categories, and holding it to them. It's about putting art [science] and philosophy, theory and practice, on the same creative plane, in the same ripple pool. Thinking–feeling art [science] philosophically can intensify art's [science's] speculative edge. It's totally unnecessary to put theory and practice at odds with each other. (Massumi 2011, p. 83)

I have thus come to re-define my research as an intra-disciplinary practice but in doing so, found that this did not fit into established research paradigms. My conundrum: which paradigm should I follow to answer my research questions whilst remaining credible

i It is distinguished from technê - applied knowledge – which will be discussed in greater depth in the next chapter.
ii Kuhn's definition of a paradigm changes throughout his text and is used also to designate a 'model in practice', rather than a world view. (Kuhn 2012, p. 11)
iii Doxa may also be understood as ideology. Bourdieu and Eagleton (1994, p. 268) cited in Shirato et al (2012, p. x).

across the academic disciplines of art and science? Could intra-disciplinary practices, specifically those involving an artistic research practice, contribute to what Kuhn (2012, p. 67) would describe as a 'paradigm shift' in research practice?

Table 1 summarises my early investigations into the paradigm dialogue, from positivism to constructivism, and from there I began to examine how accepted disciplinary specific paradigms capture both tacit (implicit) and explicit knowledge. I then explain how I have used this to produce a 'new' or modified paradigm, and one that I think could work for research practice, across all disciplines.

Tacit knowledge/s

The term 'tacit knowing' or 'tacit knowledge' was first introduced into philosophy by Michael Polyani in his book *Personal Knowledge* (1958). Polyani famously summarized the idea in his later work *The Tacit Dimension* with the assertion that 'we can know more than we can tell' (Polyani 1966, p. 4). In this, he identified knowledge that cannot be adequately articulated by verbal means, and also that all knowledge is rooted in tacit[iv] knowledge. Tacit knowledge is that which is difficult to transfer to another person by means of writing it down or verbalising it. Although it is possible to distinguish conceptually between explicit and tacit knowledge, Polyani emphasises they are not separate and discrete in practice and that the active interaction between these two modes of knowing is vital for the creation of new knowledge.

Such epistemological debates build upon the dialogues of the past: from Protagoras' (490–420 BC) relativist theory of knowledge, Plato's rebuttal of the same (428–348 BC), the telescopic de-centring of the world by Galileo (1564–1642), the rationalism of Descartes (1596–1650), the empiricism (observation and experience) of John Locke (1632–1704), and the scepticism of GE Moore (1873–1958), to the pragmatism of William James (1842–1910). Contemporaneous scholars, also contemplate the speculative realism of Alfred North Whitehead (1978), Andrew Pickering's (1995) mangle of practice, Hawking and Mdlodinows' (2011) multiple-theory, Bruno Latour and Steve Woolgar's (1979) actor network theory, and the ethico-onto-epistemologies of feminist scholars such as Isabelle Stengers (1997), Donna Haraway (1997) and Karen Barad (1995, 2007). An important characteristic of many of these paradigms is how they articulate the relationship between knowledge, the human and the non-human/other. For example, Nagel's (2014) humanist view states that:

> …knowledge has a closer connection to [the human] than [non-human] like water or gold. [The non-human] would continue to exist even if [humankind] were wiped out in a catastrophe; the continued existence of knowledge, on the other hand, depends on the existence of someone who knows…Everything known must be linked to a knower. Knowledge always belongs to some individual or group; the knowledge of the group may go beyond the knowledge of its individual members. (Nagel 2014, pp. 2–4)

iv understood or implied without being stated

Table 2.1: Paradigms of inquiry

Sourced and adapted from Guba 1990; Guba and Lincoln 1994; Haraway 1997 ; Latour 1998; Gray and Malins 2004; Guba and Lincoln 2005; Barad 2007; Mertens 2009; Killam 2013)

PARADIGM	**Ontology** The nature of the "knowable". The nature of reality.	**Epistemology** The relationship between the knower (inquirer) and the known (or knowable).	**Methodology** Techne & Praxis How should the inquirer find knowledge.	**Axiology** Beliefs about the role of values or ethics in conducting research.
	Time, Space, Human, Non-Human		**Research Practice**	**Ethics, Aesthetics, Religion**
POSITIVISM (MODERNISM)	**Realist** **Precedent** Reality exists and is driven by immutable natural laws and mechanisms. Foundation for traditional science. Time and context free generalisations. Universal. In the traditional sciences dynamics are concerned with how the values of particular variables change over time as a result of the action of external forces where time is presumed to march along as an external parameter. Barad 2007) A metaphysics of *things* (Barad 2007, p. 33)	**Dualist/ objectivist** It is both possible and essential for the inquirer to have a distant and non- interactive position. Values and other biasing and confounding factors are automatically excluded from influencing outcomes. Linguistic representations (Barad 2007, p. 141)	**Experimental/ manipulative** Questions, problems and hypotheses are stated in advance in propositional form and subjected to empirical tests under carefully controlled conditions. Deductive reasoning.	Honesty, integrity and trust (Killam 2013) Researcher maintains an etic (outsider's) perspective through objectivity and distance from subjects. Search for the truth.
POST-POSITIVISM	**Critical realist** Reality exists but can never be fully apprehended by humans with their imperfect sensory and intellective mechanisms. It is driven by natural laws that can only be incompletely understood.	**Modified objectivist** Objectivity remains a regulatory ideal, but can only be approximated with emphasis placed on external guardians such as the critical tradition and the critical community. Eg Heisenberg Uncertainty Principle & Bohr complementary Principle	**Modified experimental/manipulative** Critical multiplism is emphasized. Imbalances are redressed by doing inquiry in more natural settings, using more qualitative methods, depending more on grounded theory and reintroducing discovery into the enquiry process. Critical multiplism Elaborated triangulation (Denzin 2010)	Respect, beneficence and justice (Killam 2013) Intellectual honesty, suppression of bias, careful data collection, accurate data reporting, admission of limitations. Open to being proven wrong.
CRITICAL THEORY (POST MODERN) (TRANSFORMATIVE, NEO-MARXIST, FEMINIST OR PARTICIPATORY)	**Critical realist** As in the case of post-positivism. Ideologist. Ontology and epistemology overlap, difficult to distinguish between them (Guba and Lincoln, 1994)	**Subjectivist** Values mediate inquiry. Inquiry becomes a political act.	**Dialogic, transformative, logic** Based on dialogue that leads to the discovery of findings through logical arguments (Guba and Lincoln 1994, 2005) Eliminate false consciousness and energize and facilitate transformation.	Respect, culture, beneficence, social justice and reciprocity. Particular attention is paid to ensure that the voices of marginalised groups are heard (Mertens 2009).
CONSTRUCTIVISM (POST MODERN)	**Relativist** Realities exist in the form of multiple mental constructions, socially and experientially based, local and specific, dependent for their form and content on the persons who hold them. Search for meaning rather than truth. Multiple truths. Reality cannot exist without context. . Ontology and epistemology overlap, difficult to distinguish between them (Guba and Lincoln, 1994)	**Subjectivist** Inquirer and inquired as fused into a single (monistic) entity. Findings are literally the creation of the process of interaction between the two. (*)	**Hermeneutic, dialectic** Individual constructions are elicited and refined hermeneutically and compared and contrasted dialectically with the aim of generating one (or a few) constructions on which there is substantial consensus. Phenomenology, ethnography, grounded theory. Constructed, interpretive or natural inquiry. Inductive reasoning.	Balance viewpoints, raise awareness, develop community rapport (Killam 2013) Authenticity, trustworthiness, balanced viewpoints, reflexivity, rapport, reciprocity. Researcher adopts an emic (or insider's) view of phenomena.
Mixed Method Research – MMR (Teddlie & Tashakkori 2003)	**Critical realist** Critical realist (Teddlie and Tashakkori 2003) Combination of realist ontology (a 'real' world exists independent of our perceptions) with a constructivist epistemology (our understanding of this 'real' world is a construction based on our own perspectives and points of view).	**Intersubjectivist** (Biesta in Teddlie and Tashakkori) – a common world that we create from our individual subjective worlds) Rejects objectivist norms Multiple epistemologies	**Methodological eclecticism** (quantitative and qualitative) Pracitioners select and then synergistically integrate the most appropriate techniques from a myriad of quantitative and qualitative and mixed strategies to thoroughly investigate a phenomenon of interest. Methodologies are hybrids, emergent and interactive productions. Bricolage (Denzin and Lincoln 2011) Begins with Research Question that drives all later stages, may be modified during the process. Triangulation Use of two or more methods and media for gathering and reporting information on an issue. Also known as bricolage, collage and metissage. Use of that which is appropriate to the inquiry.	**Sociopolitical commitment** Individual axiological orientation of researchers are applied to the concerns and problems of the real world contexts within which they work (Teddlie and Tashakkori 2003)

A similar view is confirmed by Hawking and Mdlodinow:

> There is no way to remove the observer, us, from our perception of the world, which is created through our sensory processing and the way we think and act. Our perception - and hence the observations upon which our theories are based - is not direct, but rather is shaped by a kind of lens, the interpretive structure of our human brains. (Hawking and Mdlodinow 2011, p. 62)

Arguably, this interpretive structure is more than a passive lens as it also actively filters and modifies external and internal content. For example, we may consider 'filters' such as age, race, education, religion, gender and culture all affect the brain's perception of the world. Haraway's definition of the 'modest witness' is an example of filtering in practice:

> This is the culture within which contingent facts – the real case about the world – can be established with all the authority, but none of the considerable problems of transcendental truth. This self invisibility is the specifically modern, European, masculine, scientific form of the virtue of modesty. This is the form of modesty that pays off its practitioners in the coin of epistemological and social power. This kind of modesty is one of the founding virtues of what we call modernity. This is the virtue that guarantees that the modest witness is the legitimate and authorized ventriloquist for the object world, adding nothing from his mere opinions, from his biasing embodiment. (Haraway 1997, p. 23)

If one agrees, for the moment, that human knowledge and definitions of reality originate through the senses, we could think of knowledge as embodied, a tangible expression of sensory perceptions and the brain's subsequent interpretations. Berger (1977, p. 7) states that knowledge is not only what we make of things with our senses, but is also affected by 'what we know or believe'. Figure 1, the iconic *La trahison des images*—the treachery of images—by Rene Magritte (1898–1967) illustrates that the image, despite looking like a pipe, is, in fact, not a pipe but an image of one.

Figure 2.2: *La trahison des images*. (Magritte 1928–29)

The gap between words and seeing

Figure 3 continues Magritte's theme and is an artistic appropriation of 'The Key of Dreams' a Hindu fable of six blind men, and related poem[v] by John Godfrey Saxe. It is a comment on knowledge acquisition and how there is always a gap between words and 'seeing' such that we each agentially intra-act within the collective and subsequently interpret this intra-action based on our sensory input and information from past experience/accumulated knowledge. Each of the six men in the poem are blind and cannot 'see' the 'thing' in front of them. Thus they come to their individual conclusions, by touching and sensing different parts of an elephant, subsequently claim what they 'see' and this reflects what they have previously experienced. In this instance, a *wall* (hide); *a spear* (tusk); *a snake* (trunk); *a tree* (leg); *fan* (ear) and *rope* (tail):

> It was six men of Indostan
> To learning much inclined,
> Who went to see the Elephant
> (Though all of them were blind),
> That each by observation
> Might satisfy his mind.
>
> And so these men of Indostan
> Disputed loud and long,
> Each in his own opinion
> Exceeding stiff and strong,
> Though each was partly in the right,
> And all were in the wrong!(Saxe 1873, pp. 259–60)

McPhee (1981) in *Basin and Range* also cites the poem and notes that it was often included in early books on geology—presumably as a warning to be vigilant to one's own biases. He makes the point that 'geologists are famous for picking up two or three bones and sketching an entire and previously unheard-of creature into a landscape long established in the picture' (McPhee 1981, p. 85). A similar tale about the mastodon, a distant relative of the elephant in the order proboscidea, enabled Georges Cuvier to describe the concept of 'extinction' and will be discussed in Chapter 5. These theories also reflect an anthropocentric view of the world with humanity at the core of knowledge production. Increasingly, however, the nonhuman are being considered as agential (Latour and Woolgar 1979; Barad 2007; Pickering in press) or lively (Bennett 2010) contributors to knowledge. This translates to a progressive de-centering of the human in contemporary theory, and a democratizing move to include all actants, human and nonhuman, in the production of knowledge (Latour and Woolgar 1979; Pickering 1995, in press). Schirato, Danaher and Webb (2012) and O'Farrell (2010) note that such a de-centering is reflected in Foucault's non-reductionist position; where he concedes that there is no single

v Mentioned by McPhee (in Basin and Range) as often being cited in early geology textbooks. https://archive.org/details/poemsjohngodfre02saxegoog

Figure 2.3: *Ce n'est pas un éléphant*—making sense of knowledge (AK Milroy 2015)

foundation for knowledge, no one principle to explain everything else; but instead that the production of knowledge is an interrelation of a complex and multilayered range of elements.

The mangle of practice

In 1995, sociologist, philosopher and historian of science, Andrew Pickering published a post-humanist manifesto, 'The Mangle of Practice'. He explains disciplinary divides:

> These humanist and anti-humanist discourses run deeply through everyday thought, though they do not exhaust it. They are also the very stuff from which the traditional academic disciplines are created and that holds them apart. To be a traditional sociologist is to be a humanist; to be a physicist is to be an anti-humanist (in technical practice, I mean). (Pickering 1995, p. 25)

This constructivist – positivist sentiment resonates today in a recent collaboration (Milroy, Wegener & Holmes, 2015) in which physicist Wegener, in response to a question about Pickering's mangle of practice, stated that:

> Both art and science search for meaning, but they situate the human differently. Art puts human experience at the centre...relevant to the Labpunk project...and also the laws of physics which exist regardless of humans. (Wegener 2015, p. 14)

Our collaboration involved making wearable art from defunct equipment from the physics lab for the Australian Institute of Physics (AIP) Congress in 2014 (see Appendix A). Working within an artistic practice with a scientist emphasised the disciplinary differences in worldview/research paradigms and thus contributes to this chapter's discussion on knowlege creation. To continue Pickering's dialogue:

> But the mangle, like the actor-network approach, corrodes the distinctions between these discourses and disciplines enforce... The performative idiom that I seek to develop thus subverts the black and white distinctions of humanism/antihumanism and moves into a posthumanist space, a space in which the human actors are still there but now inextricably entangled with the nonhuman, no longer the centre of the action and calling the shots. The world makes us in one and the same process as we make the world. (Pickering 1995, pp. 25–26)

Pickering (in press) refers to 'the dance of agency' — describing this as an analysis of how lively human beings (agents) are coupled with lively nonhuman (agents) in a vitalism[vi] (Bennett 2010) which brings about a co-evolution in time and space of related phenomena. These additions to his original notion of a 'dialectic of resistance and accommodation' (Pickering 1995) highlight its evolution. However, I prefer to re-imagine

vi The capacity of things not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories, propensities or tendencies of their own. Runs alongside and inside humans. Socio-political - being accountable. locn 16 of 2417. Kindle edition (Jane Bennett 2010)

it as a multi-lectic, to include other factors such as creativity, innovation and more, thus extending the binary focus on resistance and accommodation. Pickering himself hints at this extension by emphasising that he would like to highlight a 'productive latching onto emergent nonhuman agency, rather than simply implying friction.' (in press, p. 6) However, in *Meeting the Universe Halfway* (2007) philosopher and physicist Karen Barad[vii] challenged Pickering's view as being separatist—supporting a dichotomy between the human and nonhuman—and described Pickering's de-centering of the human as explicitly epistemological, not ontological. Pickering, today, however, counters that the difference he has with Barad is that his performative analysis describes a 'temporal evolution of relational entities' (Pickering in press, p. 6). This seems to approach Barad's (2007) 'spacetimemattering' and 'knowing in being', and the entanglement of ontology and epistemology. The differences perhaps entwined in the concept of temporality. This will be discussed in greater detail in Chapter 5. Barad follows Neils Bohr's[viii] 'philosophy physics' and recognises:

> that we are part of the nature that we seek to understand.

Barad explains:

> ...knowledge making is not a mediated activity, despite the common refrain to the contrary. Knowing is a direct material engagement, a practice of intra-acting with the world in its dynamic material configuring, its ongoing articulation. The entangled practices of knowing and being are material practices. The world is not merely an idea that exists in the human mind. To the contrary, the 'mind' is a specific material configuration of the world, not necessarily coincident with a brain. Brain cells are not the only ones that hold memories, respond to stimuli or think thoughts. (Barad 2007, p. 379)

Barad gives as an example, an account of a brittlestar (a marine animal, without a brain, but with a body that acts as an eye) and uses it as evidence of the 'inseparability of knowing, being and doing' (2007, p. 380).

I believe that this is a natural way of working for most artists, as they, consciously or subconsciously, produce knowledge as works of art, in a dynamic and emergent practice by direct material engagement, an intra-action. In my own practice, I 'see' with my eyes and my hands, and intra-act with the medium of choice and we 'dance' together until the work reaches a certain point of 'completeness'. There is sometimes an idea of what the work of art might look like when completed, however this dance of agency allows for the unexpected, *poïesis*. Direct, tacit engagement provides me with more information and knowledge about the piece, and whether or not it is ready for its next articulation, or step.

vii Philosopher, Professor of Feminist Studies and Physicist
viii https://en.wikipedia.org/wiki/Copenhagen_interpretation

Jane Bennett (2010), in *Vibrant Matter* contributes to this discussion by describing the vitality of the nonhuman:

> ...by vitality I mean the capacity of things not only to impede or block the will and designs of humans but also to act as quasi agents or forces with trajectories, propensities or tendencies of their own. My aspiration is to articulate a vibrant materiality that runs alongside and inside humans to see how analyses of political events might change if we gave the force of things more due. (Bennett 2010, locn 16 of 2417)

Bennett, however, also leans toward a separatist point of view, by differentiating between the human and nonhuman. She does however, acknowledge that we are all 'made of the same stuff', simultaneously positing 'neither a smooth harmony of parts nor a diversity unified by a common spirit' (2010, locn 57 of 2417).

Metahumanism – avoiding separateness, being accountable

Unlike posthumanist philosophies, metahumanism proclaims to not presume the separateness of anything (Vermuelen and van den Akker 2010). To extend this metahumanist manifesto described in Chapter 1 (p. 15), I combine theories by philosophers such as Karen Barad, Donna Haraway, Bruno Latour, Andrew Pickering and Carlo Rovelli as challenges to human separatism while recognising that one must be accountable for the role one plays in creating knowledge. Change, according to Barad (2007) is not entirely attributable to culture, as this denies nature any sense of agency or historicity. She contests the idea of division between nature and culture by asking *how* these boundaries are actively configured and reconfigured. Concluding that instead of relying on scale/s created by humans—effectively reinforcing a separateness between nature and culture—we should consider reality as agential and focus instead on the *practices* by which the scale/s are produced. These sentiments are also expressed by theoretical physicist, Carlo Rovelli who maintains that reality may be better understood if we:

> ... learn to move from thinking of the world as an ensemble of distinct things to thinking of it as a network of interconnected processes, we will grasp it better. (Rovelli 2016, p. 45)

This research project, with its practice-based focus, gives an account of how knowledge may be created by acknowledging its entangled, dynamic and emergent nature.

Making sense of knowledge

Guba (1990) sets forth a broad definition of a paradigm as:

> … a basic set of beliefs that guides action, whether of the everyday garden variety or action taken in connection with a disciplined inquiry. (Guba 1990, p. 17)

This is extended by Denzin (2010) and Teddlie and Tashakkori (2003):

> Paradigms consist of interlocking philosophical assumptions: epistemological, axiological,ontological and methodological. (Teddlie and Tashakkori 2003, p. 4).

Traditionally, the dominant research paradigms have focused on either quantitative (Positivism) or qualitative methodologies (Constructivism). Both methods are considered empirical, in that the study must be verifiable in some way. In *Visualising Research, A Guide to the Research Process in Art and Design,* Gray and Malins (2004) summarise and develop Guba's 1990 *Paradigm Dialogue* to include recent trends toward art and design in higher degree academic inquiry. Gray and Malins express the view that answering questions of ontology, epistemology and methodology is a collective task for current and future practitioner-researchers. In the modified version of their table (Table 1, pp. 39–39) is an additional column—*axiology*—a fourth philosophical assumption to highlight the role ethics plays in each of the paradigms (Haraway 1997; Barad 1995, 2007; Teddlie and Tashakkori 2003; Denzin 2010; Bennett 2010; van der Tuin 2014).

Contributing to the paradigm dialogue

If one steps back a little, and accepts, for the moment, that knowledge is filtered/coloured/affected/modified by the researcher's personal set of beliefs, or worldview, it is essential, that this is defined at the outset of the inquiry. This puts the research into context, and elucidates subsequent contributions to knowledge. As I type, I realise that the reader may be confused by such a statement, as they may consider their discipline's (knowledge making) paradigm as an immutable 'black-box'. This term was coined by Bruno Latour in 1988 — as a metaphor for 'knowledge'. It describes that which has been unanimously accepted by a large number of actors in a network, and established as an immutable concept. A black-boxed worldview thus implies that there is no need to state it *per se*, much less subject it to philosophical interrogation. I have noticed that when I suggest such a concept many of my scientific and artistic colleagues look bewildered. The look is often accompanied by a rather embarrassed pause, and an eyebrow raised as 'Isn't it obvious?' How do we re-open disciplinary black boxes without invoking the fearful memory of Pandora[ix]?

I am not, however, the first to do this. Specifically, I hope to build on work by other scholars, and I began with Donald Schön's (1983) quest for an inquiry into the epistemology of practice. Schön noted a distinct difference between what was classified as knowledge in academia compared to that in professional practice. In *The Reflective Practitioner* Schön (1983) begins with the assumption that competent practitioners usually know more than they can say, and that they exhibit a knowing-in-practice, most of which is tacit (Schön 1983, p. viii). He proposes a methodology of 'reflection in practice' to capture and express the knowledge/s that arise from practice. However, and acknowledging Schön's focus on professional (rather than academic) practice, I suggested in the original proposal that this is a useful methodology across all both forms. However, I tender a modification of this after studying Haraway and Barad, and propose to re-frame it as a universal research technique for the *diffractive* practitioner. The reason behind this will (hopefully) become clearer as we progress through this chapter, and the next.

Establishing a research practice paradigm — a successor science?

Estelle Barrett in *Material Inventions* (Barrett and Bolt 2014, p. 3), claims that creative arts research should be considered new paradigm for research, and uses the term 'successor science' to highlight the impact and uptake that it is having in contemporary academic circles. In response to calls for defining Creative Arts Research (Guba 1990; Gray and Malins 2004; Barrett and Bolt 2014) and with the intention of formulating my own position as researcher, the following philosophical questions were posed;

1. Ontology. *What could* research (in Art) be? What is the nature of reality in this discipline — what is knowable (real) and what is capable of being researched? For example, does the researcher believe in a reality that is discoverable and context free, or one that is a product of multiple mental constructions that are bound by context, or something completely different?
2. Epistemology. *Why might* we (artists/designers) do research? What is the nature of the relationship between the knower and the known? How are these driven by the researcher's ontological beliefs?
3. Methodology. *How might* we (artists and designers) do research? How do we make knowledge; by experiment, construction, exhibiting, observation, hermeneutics? How are these driven by one's ontological beliefs?
4. Axiology. *What values and ethics* does the researcher hold for conducting research? How do they include considerations such as accountability, social justice, aesthetics and religion?

Guba (1990) acknowledges a personal preference toward constructivism in his writing and that it is not necessarily an objective analysis. Guba also extends this to all belief systems/paradigms labelling these as 'human constructions' and thus 'subject to the errors and misrepresentations that inevitably accompany human endeavours' (Guba 1990, p. 19). While I appreciate Guba's constructivist philosophy, I feel that it stops short of being universally applicable — how does it account for the fact that science works? And in fact, taking a (figuratively speaking) quantum leap, I wonder if the lessons of quantum physics could be used to further understand the disciplines we are entangled in. Discoveries in the quantum world have opened the black box of classical physics, exposing previously immutable laws as mutable — what may be explained with precise Newtonian rules and

ix https://en.wikipedia.org/wiki/Pandora%27s_box

laws comes unstuck at the atomic level. Niels Bohr, and his Copenhagen interpretation[x] of Quantum mechanics, challenged both classical and quantum thought.

> There is an important sense in which practices of knowing cannot fully be claimed as human practices, not simply because we use non-human elements in our practices but because knowing is a matter of part of the world making itself intelligible to another part. The practices of knowing and being are not isolable; they are mutually implicated. We don't obtain knowledge by standing outside the world; we know because we are part of the world. We are part of the differential becoming. (Barad 2007, p. 185)

This worldview provokes a critical re-examination of the above core philosophical questions as they inform our understanding of concepts such as: space, time, matter, dynamics, agency, structure, subjectivity, objectivity, knowing, intentionality, discursivity, performativity, entanglement, and ethical engagement. These will be discussed later in this chapter and I will argue that considerations of such apply across both art and science. In my opinion, Bruno Latour expresses similar ideas, and re-defines society as *collectives* of the human and non-human and explains that:

> ... society is constructed, but not socially constructed. Humans, for millions of years, have extended their social relations to other actants with which, with whom, they have swapped many properties, and with which, with whom, they form collectives. (Latour 1999, p. 198)

This concept of a collective is a useful one and one that I will adopt for this exegesis to include all actants, human and nonhuman. Barad's 'spacetimemattering' has parallels with Latour's conception of the collective:

> Objects and subjects are made simultaneously, and an increased number of subjects is directly related to the number of objects stirred, brewed, into the collective. The adjective 'modern' does not describe an increased distance between society and technology or their alienation but a deepened intimacy, a more intricate mesh, between the two. (Latour 1999, p. 196)

Similarly, Alfred North Whitehead's speculative philosophy (in *Process and Reality*, 1978) also rejects the idea of reality as immutable, separate bits of matter and prefers to describe it as interrelated events in dynamic processes of 'becoming', rather than a static 'being'.Thus within this research project, I have on the one hand, artistic practice — which traditionally follows a 'linguistivist' (van der Tuin, 2014) /constructivist paradigm, and on the other, scientific practice — traditionally following a positivist paradigm (Quantum studies are not included in this generalisation). So which way to go from here? After much reading and research, I have anchored my paradigm largely on the work of Karen Barad (1995, 2007), and have used it as a tool to investigate both creative arts and scientific research practice in relation to questions of ontology, epistemology,

x https://en.wikipedia.org/wiki/Copenhagen_interpretation

methodology and axiology. I suggest this is a way forward in both art and science, with a paradigm tentatively called 'Quantum|ivism'. I am aware that there are other similar terms in circulation, with very different meanings, however for the moment it seems appropriate, both in a metaphoric and a literal sense.

The question of ontology – agential realism

> Agential realism is a framework for explaining how we understand the roles of the human and nonhuman, the material and discursive and the natural and cultural; in the production of knowledge. (Barad 1995, 2007)

Agency

Barad differs from most philosophers in that she defines *agency* as an intra-action, a 'doing' or 'being', and not as an attribute that something or someone has.

> It is the enactment of iterative changes to particular practices — iterative reconfigurings of topological manifolds of spacetimematter relations — through the dynamics of intra-activity. (Barad 2007, p. 178)

Agential realism uses the concept of performativity to explain how matter is an:

> ...active participant in the world's becoming, in its ongoing intra-activity and providing an understanding of how discursive practices matter. (Barad 2007, p. 136)

Agential realism refutes positivism and constructivism, with claims that 'separateness' is not an inherent feature of how the world is, nor a construction of human consciousness. Instead, it focuses on differences and matter as dynamic, iterative, emergent through a process of 'spacetimemattering' which makes/marks the here and now (Barad 2007, pp.136–137). It may be summarised as a relational, metahumanist, performative account of how material bodies (human-nonhuman) literally and figuratively 'come to matter'. Her aim, to move from representationalist thinking, specifically from privileging words and things to critically examining the relationality between specific re-configurings of material phenomena.

Pickering also supports a performative, rather than representational ontological idiom, and uses this to navigate through what he terms different 'worlds'. Pickering compares and contrasts the anthropological worlds of shamanism and science in this endeavour and his performative stance encourages us to think about 'practice, performance and agency—doing things' (in press, p. 4). He writes:

> The world—humans, nonhumans and whatever—just is an indefinite multiplicity of performative entities endlessly becoming in de-centered and emergent dances of agency. (Pickering in press, p. 5)

Pickering's description of this performative ontology also seeks to remove connotations of separateness and to allow knowledge to come into being, rather supposing its pre-existence, or as being true or false. He notes that this 'dance of agency' reveals and brings to light the unpredictable 'social, material and conceptual paths of knowledge creation' (in press, p. 5). This I believe, comes very close to the onto-epistemology described by agential realism. Pickering also introduces a new concept—'islands of stability'—to serve as a pivot from one 'world' to another. I liken these to Latour's concept of 'black boxes' (see Chapter 1 page 22). Pickering uses the term to anchor the successes of science, engineering and other practices (for example, reliable machines, instruments, concepts). However, he cautions that:

> Arriving at an island of stability is not a once-and-for-all achievement guaranteed by knowledge. These islands remain fragile and uncertain performative accomplishments requiring continual repair and maintenance (Swanton 2013), mini dances of agency. (Pickering in press, p. 9)

Phenomena and objectivity

Instead of primary ontological units being independent objects with autonomous boundaries and properties, agential realism adopts a Borhrian description of these as phenomena — as 'agentially inseparable intra-acting components' (Barad 2007, p. 33). This means that one cannot ever separate the 'object' from measuring agencies/apparatuses. Phenomena are thus ontologically primitive relations, and do not pre-exist as objects or things. Their boundaries and properties are determined through specific agential, human and/or nonhuman, *intra*[xi]-actions. These intra-actions are thus what give rise to meaningful concepts, or material expressions of the world.

By adopting agential reality, the epistemological inseparability of the observer and the observed is highlighted. This prompts a shift from the metaphysics of *things* to the metaphysics of *phenomena* and as a consequence one's understanding of how knowledge is made, and the nature of research as a discursive practice, is modified. Further, under the agential realism framework, devices/apparatus do not disclose a pre-existing value or concept but give a value or concept in response to a specific configuration that gives definition to the property one is looking for. They also enact a cut between the 'object' and the 'measuring instrument' and this produces specific values for the measured quantity and leaves other quantities unspecified. An classic example of this is the double slit experiment[xii]; which highlights that it is not possible to measure both particle and wave characteristics simultaneously, as the use of one apparatus that measures particle behaviour, precludes the simultaneous use of the other to measure wave behaviour. (Barad 2007, pp. 97–106)

xi intra = on the inside, within, as opposed to inter = between, among
xii https://en.wikipedia.org/wiki/Double-slit_experiment

Intra-actions include the larger material arrangement, or set of material practices that bring about an 'agential cut' (Barad 2007, p. 140) between 'subject' and 'object'. This agential cut brings about a resolution within the phenomenon from its inherent unknowable state. Different agential cuts materialise different phenomena and these are described as 'marks on bodies'. The artistic and scientific practices used in this research project (Chapter four – *poiesis*) may be described as agential cuts and the results (creative component plus exegesis) as works of of shared duality—art/science; phenomena; diffraction patterns; and/or as marks on bodies.

Intra-action

The term *intra*-action is used to clarify the causal relationship between discursive practices and material phenomena or, how discursive practices are related to the material world. It signifies the mutual creation of 'distinct' agencies which emerge (rather than precede) through intra-action. This is in contrast to *inter*-action, which assumes separate individual agencies precede the event. However, with intra-actions, the distinctiveness of agencies is relative, not absolute—they do not exist as individual elements (Barad 2007, p. 33). The idea of causality is thus challenged through this concept of intra-action, as it seeks to illuminate the world's 'aliveness' through claims of vitality, dynamism and agency. Ontology is thus inextricably entangled with epistemology, and it is not possible 'to be' without doing.

I am exploring these ideas, in what might be considered a metaphorical extrapolation, that is to say, considering the research in the macro (everyday) scale in juxtaposition with phenomena/concepts that occur on the micro (atomic) scale. Will the works produced be regarded as art, science or technology? Is it possible for these seemingly disparate qualities to be measured within the one work? Yes, as it depends on what the chosen measuring apparatus or agencies inherently 'bracket' by virtue of composition (these may consist simply of the work, a person and a check list) and/or where the artefacts (phenomena) find themselves (in a scientific paper, laboratory or in a performance or exhibition in an art gallery). The specific material (including human and nonhuman) arrangement of measuring art-ness or science-ness, often faces a similar dilemma, where one measurement prevents the quantification or qualification of its 'opposite'. That is, if one is of the opinion that works of art and science are mutually exclusive.

Thus under this paradigm, objectivity means being accountable for agential cuts, marks on bodies and phenomena. 'We' are co-constituted and entangled through the very cuts 'we' help to enact. Barad describes this as 'cutting "things" together and apart' (2007, p. 179). 'Cuts are not made from a position of exteriority or separateness, nor are they everlasting or eternal. Matter is re-defined, as a substance in an intra-active *becoming*, not a static thing but *a doing,* a form of agency' (Barad 2007, pp. 178–9). I suggest that phenomena, in the form of works of art or science, are not thought of as the

result of laboratory or studio practices created by human subjects, rather as 'diffraction patterns—differential patterns of mattering produced through complex agential intra-actions of multiple material discursive practices or apparatuses of bodily production' (Barad 2007, p. 140).

Within the paradigm of agential realism the fact that science works is accounted for, and objectivity defined but not as a scientific black box with the condition of absolute exteriority. Objectivity is possible as a condition of 'exteriority-within-phenomena'. The move is from traditional (scientific) binary thinking of object-subject, to agential separability—exteriority *within* phenomena and Barad (2007, p 174) describes it 'as the unambiguous communication of the results of reproducible experiments'. As I understand it, Barad notes that what secures the possibility of reproducibility and unambiguous communication is the Bohrian cut[xiii] enacted by the apparatus. This I believe, is a crucial point: that both the phenomenon and the embodied concepts that are used to describe them are produced by one and the *same* apparatus. It is the apparatus that enacts an agential cut within the phenomenon and it is this agential separability, or exteriority within phenomena, that provides the condition of objectivity.

The agential cut produces a local (within the phenomena) causal structure in the marking of the measuring instrument (effect) by the measured object (cause). Crucially, if the apparatus is changed[xiv], then there will be a corresponding change in the agential cut. Different agential cuts producing different phenomena. Thus the apparatus is both causally significant *and* the condition for the possibility of the objective description of material phenomena. Thus practice is pivotal in establishing ontic and semantic boundaries; between humans and nonhumans, culture and nature, science and the social.

Importantly, and why I think this worldview/paradigm has applicability across disciplines, is that it uses a performative approach to understand natural-cultural practices by acknowledging and taking into account the dynamic, emergent, intra-active nature of 'mattering', of knowledge as being. Barad describes such a world view as:

> ... a dynamic process of intra-activity and materialisation in the enactment of determinate causal structures with determinate boundaries, properties, meaning and patterns of marks on bodies. It is an ongoing flow of agency through which part of the world makes itself differentially intelligible to another part of the world and through which causal structures are stabilised and destabilised, it does not take place in space and time but happens in the making of spacetime itself. It is through specific intra-actions, that phenomena come to matter—literally and figuratively. (Barad 2007, p. 140)

A significant outcome of Barad's (2007) paradigm is the shift from *words* as primary

xiii A resolution of the inherent ambiguity between the 'object' and agencies of observation ie. inseparability (Barad 2007, p.174, 435)

xiv For an interesting anecdote about what needs to be included in an apparatus, read about the Stern-Gerlash experiment and cheap cigar smoke. http://www.physics.ohio-state.edu/~jay/828/SGPhysicstoday.pdf

semantic units to material-discursive *practices.* In agential realism, apparatuses are not just observing instruments, rather 'boundary drawing practices; specific material (re) configurations of the world which come to matter' (Barad 2007, p. 141). Apparatuses should be thought of as material-discursive practices which both produce, and are a part of, phenomena, not static or passive laboratory setups. Further, Barad describes them as 'iterative reconfigurations of spacetimematter' and a part of an 'ongoing dynamism of becoming' (2007, p. 142). The epistemological framework of agential realism, rejects both the transparency of language and of measurement , that is to say, 'language does not represent states of affairs and measurements do not represent measurement independent states of being' (Barad 2007, p. 138). Rather, the agential cut performs a causal structure among components of a phenomenon in the marking (cutting) of the 'measuring agencies' (effect) by the 'measured object' (cause). Thus the measurement can be said to express particular facts about that which is measured; and the measurement is a causal intra-action.

Space, time, matter

Spactimemattering is a term used by Barad (2007) to describe the dynamic, emergent, entangled and iterative world/universe we are a part of. 'Being' becomes a performance that 'we' all intra-act within. However, what implications does this quantum-based theory have on our concept of deep time[xv], as discussed in Chapter 1? What does it mean to our measurements of geological time, our apparatus, our scales by which we judge things? This will be discussed in Chapter 5. An example of what Barad means, metaphorically on the macro scale, of 'spacetimemattering': As I observe the specimens in front of me, we intra-act, in space and time and together they 'become' a phenomena called 'fossils'. If we change the measuring apparatus, that is, replace the human actors (without the same experience and training), they may be re-measured as 'stones', 'rocks' or 'curiosities'[xvi]. This is also an example of Pickerings (1995) 'dance of agency'—an iterative re-configuring of the world. As the measuring agencies or apparatus change, so too do the phenomena.

The question of epistemology – praxis

At this point I consider whether agential realism adequately theorises the relationship between discursive practices (knowledge making in any discipline) and the material world. Foucault (1967), attributes discursive practice to *scientific* knowledge making. However, he defines knowledge as a discursive practice consisting of a group of elements

xv Chapter 1, page 5 .

xvi Refer to Mary Anning: Locals supplemented their income by selling what were called 'curios' to visitors. These were fossils with colourful local names such as 'snake-stones' (ammonites), 'devil's fingers' (belemnites), and 'verteberries' (vertebrae), to which were sometimes attributed medicinal and mystical properties. Fossil collecting was in vogue in the late 18th and early 19th century, at first as a pastime, but gradually transforming into a science as the importance of fossils to geology and biology was understood. https://en.wikipedia.org/wiki/Mary_Anning

formed in a regular manner through functions such as observation, interrogation, decipherment, recording, and decision making (Foucault 1967). I don't agree that science has a monopoly on the production of knowledge; this is evidenced in academia by the many disciplines which offer a Doctor of Philosophy/PhD.

Re-defining non-discursive practices

In *The Archaeology of Knowledge,* Foucault lists non-discursive practices as including 'institutions, political events, economic practices and processes' (Foucault 1966, p. 162). He also argues that discourse does not underlie all cultural forms and that forms such as art and music are non-discursive. However, under the agential realism framework, Foucault's binary of discursive and non-discursive practices is challenged. Agential realism describes discursive practices as boundary re-configurations and as these are inherently material and need no material support, the concept of 'non-discursive' does not make sense (Barad 2007). Barad notes that:

> ... discourse is not a synonym for language. It does not refer to linguistic or signifying systems, grammars, speech acts, or conversations. To think of discourse as mere spoken or written words forming descriptive statements is to enact the mistake of representationalist thinking. Discourse is not what it said; it is that which constrains and enables what can be said. Discursive practices define what counts as meaningful statements. Statements are not the mere utterances of the originating consciousness of a unified subject; rather, statements and subjects emerge from a field of possibilities. This field of possibilities is not static or singular but rather is a dynamic and contingent multiplicity. (Barad 2007, p. 146)

As noted earlier, agential realism is more concerned with the way in which phenomena 'objects/concepts' emerge through scientific practices and similarly I am concerned with the way in which phenomena 'works of art or science' emerge through this intra-disciplinary practice. If one accepts that discursive practices are ones in which boundaries, properties and meaning are differentially enacted, then this project may be described as a discursive intra-disciplinary practice. It encompasses the scientific discipline of palaeobotany, and thus as a component of natural history may be considered (*à la* Foucault) as a taxonomic discourse and contribute to the project of 'a science of order'. (Foucault 2002, p. 64) However, this research also contributes to a socio-cultural discourse (the human/nonhuman collective) and to the project of critical visual discourse (Sandywell 2012).

The onto-epistemology that has been discussed at length in this chapter seeks to challenge concepts which reinforce binary thinking; and opposes the existence of 'things' as right/wrong, black/white, male/female, either/or, presence/absence to allow the revelation, unconcealing, of subtleties and/or the consideration of a third or more alternatives. Barad, unlike Pickering or Latour, refuses to take a binary human/nonhuman

distinction for granted and avoids analyses based on a presumed fixed set of inherent categories. Her aim is to remove the nature-culture divide to empower a 'genealogical analysis of how crucial distinctions [borders] are materially and discursively produced' (Barad 2007, p. 32).

The question of methodology — diffraction

Haraway (1997) was one of the first to suggest diffraction rather than reflexivity or reflection, as a more useful optical metaphor for methodology. For Haraway, the latter describes mirroring and sameness; and the former, patterns of difference:

> ... reflexivity is a bad trope for escaping the false choice between realism and relativism in thinking about strong objectivity and situated knowledges in technoscientific knowledge. What we need to make a difference in material-semiotic apparatuses, to diffract the rays of technoscience so that we get more promising interference patterns on the recording films of our lives and bodies. Diffraction is an optical metaphor for the effort to make a difference in the world. (Haraway 1997, p. 16)

Barad (2007) echoes this sentiment and writes:

> ... reflexivity, like reflection invites the illusion of an essential fixed position, while diffraction trains us to more subtle vision. (Barad 2007, p. 29)

Haraway makes the claim that Woolgar and Latour's insistence on reflexivity does not 'go beyond self vision as the cure for self invisibility. The disease and the cure are the same thing' (Haraway 1997, p. 34). Barad explains that a diffractive methodology takes into account the entanglement of ideas and materials in ways that reflexive, or reflective,

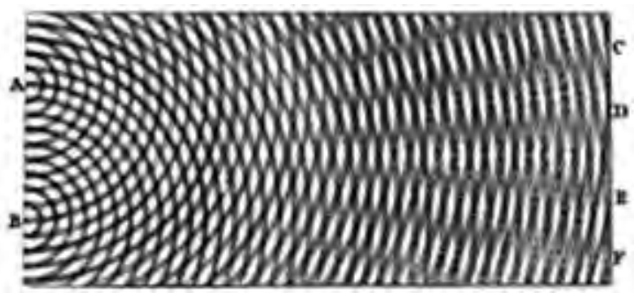

Figure 2.4: Thomas Young's sketch of two-slit diffraction, which he presented to the Royal Society in 1803

methodologies do not. In particular, this methodology pays attention to the apparatuses and agencies of knowledge production. The aim, to track how borders are produced, rather than presuming binary oppositions are already in existence. Chapter three, *technê*, discusses this diffractive methodology in greater detail and suggests how it applies to this

hybrid research practice. Figure 3 illustrates the interference patterns of particles of light passing through apertures A and B, and producing diffraction patterns at C, D, E and F.

The question of axiology – accountability

The implications of an agential realist framework increases awareness and attentiveness to the inter and intra connectedness of the world—we are a part of the world we seek to understand. This demands an ethics of knowing, of what matters in the dynamic, emergent creation of the world.

Research ethics in Australia are regulated by several guiding principles and practices. The National Health and Medical Research Council (NHMRC) provide four National statement principles of research merit: integrity; justice; beneficence; respect. These are accompanied by seven constant requirements[xvii] : social/scientific value; scientific validity; fair subject selection; favourable risk-benefit ratio; informed consent; respect of subjects; independent review. The National Statement consists of a series of guidelines made in accordance with the *National Health and Medical Research Council Act 1992*. It is intended for use by any researcher conducting research with human participants; any member of an ethical review body reviewing that research; those involved in research governance; and potential research participants.

This is a solid basis for axiology, and one that is constantly evolving to protect participants in the research process, specifically human subjects. However, I would also like to extend this approach to include the non-human. If one agrees that it has agency, is lively, then its intra-actions should also be evaluated. As human agents, there is an implied responsibility to be vigilant of what exactly may be produced and to be accountable for our part in this. Passivity, in the form of 'a modest witness', is no longer appropriate. For example, nuclear power is, on the one hand, a way to reduce carbon emissions and fossil fuel pollution, however on the other; may become a source of devastating pollution if the reactor is damaged, or if the waste leaks and contaminates water/food supplies. The question then becomes, how do we extend our axiology to include the non-human aspects of research, and thoughtful contemplation of what literally and figuratively 'matters'?

> Ethics is about mattering, about taking account of the entangled materialisations of which we are a part, including new configurations, new subjectivities, new possibilities—even the smallest cuts matter. Techno-scientific (research) practices are about making different worldly entanglements and ethics is about accounting for our part of the entangled webs we weave. (Barad 2007, p. 384)

Following on from the question of methodology, the concept of diffraction may be a means by which we may change our ethical focus, by paying attention to fine details,

xvii Nhmrc.gov.au/guidelines-publications/e72

avoiding 'black and white' binary type thinking, looking at what is different, as well as what is the same, and recognising the interference patterns of different disciplinary approaches and entanglements with the non-human, the world, the universe (Haraway 1997; Barad 2007).

Respectful engagements

With respect to this project and its inherent intra-disciplinary praxis, I concur strongly with Barad:

> ...what is needed in research, are respectful engagements with different disciplinary practices, not coarse grained portrayals that make caricatures of another discipline, from some position outside it... to remain rigorously attentive to details of specialised arguments within a given field without uncritically endorsing or prioritorizing one disciplinary approach over another. (Barad 2007, p. 93)

I am concerned about disciplinary 'black box' thinking when large groups start taking knowledge/s for granted as immutable, unchangeable, and unchallengeable laws. Seeking innovation and new knowledge may require opening/unpacking black boxes. Iris van der Tuin expresses the important point that: 'the groove of creative research is not yet as deep as the alluring groove of the two cultures of the sciences and the humanities ... creative research is privileged for developing an onto-epistemological vantage point' (van der tuin 2014, p. 271).

George Orwell's 1940 'Inside the Whale' critique of Henry Miller's 1935 book, *The Tropic of Cancer*, seems an appropriate analogy here. Orwell explains that the book lacked substance for him, as the writer was writing about something from a particular, comfortable vantage point, an expatriate's version of reality, rather than the direct, lived experience of the ethnic populace.

> For the fact is that being inside a whale is a very comfortable, cosy, homelike thought. ... there is no question that Miller himself is inside the whale. All his best and most characteristic passages are written from the angle of Jonah, a willing Jonah ... only he feels no impulse to alter or control the process that he is undergoing. He has performed the essential Jonah act of allowing himself to be swallowed, remaining passive, accepting. (Orwell 1940 , section III)

By working intra-actively within different disciplines, such as have been done in this research project, different experiences, results and audiences have been made possible. Taking on another's practice, walking a mile in their shoes, challenges 'blackboxed' disciplinary worldviews. Seeing through the eyes of another often changes one's perspective. I also observed that this combination of art/science/technology practices brings in new audiences and new authors to the research practice. Barthes, in his 1967 essay 'Death of the Author', emphasises that a text's unity lies not with its creator, but in

its destination, the audience, the readers. However, my variation on this is that the work (text, visual or otherwise) has the potential to 'birth' new authors, and without killing the original. The readers become new authors as they bring their own set of experiences to the table, and interpret or 'see' the work through these filters. A potential for newness/ creativity is thus generated with each viewing/reading. I also think it important for the human (agent) to be aware of how their work is filtered—by virtue of their race, sex, religion and so on, and how these influences may shape the text/visual and the corresponding influences this has on the world (human and nonhuman). Knox (2016) makes the assertion that 'art is dialogue based' and that:

> ... a work of art is not complete without the active engagement of the viewer. The precise meaning of a piece of art is absent without the viewer's engagement with and contribution to the dialogue that the artist initiated, and each viewer brings to the piece a different component of the conversation. This has two powerful effects; it engages and empowers the viewer, and it underscores the interdependent nature of our collective existence. (Knox 2016, p. 15)

Barad's ethics highlights the dynamic entanglement of 'knowing in being' and is critical of an anthropocentric focus:

> Even in direct challenges to Western Philosophy's traditional conceptions of epistemology, there is a tendency to continue to think of knowers as human subjects, albeit appropriately hooked into our favourite technological prostheses. In the absence of a vigorous examination of the ontological issues, the locus of knowledge is presumed to be never too far removed from the human, and so the democratizing move is to invite nonhuman entities into our sociality...to better account for the ontology of knowing. (Barad 2007, p. 378)

Axiology in academic disciplines is about accountability, of what matters and extends beyond the human, to include the agency of all things in the dynamic, iterative dance of becoming. It includes an awareness of the entanglement of all disciplines and the value of working intra-actively to avoid biases and habitual knowledge making practices.

Democracy of 'things'

Jane Bennett (2010) in *Vibrant Matter: A Political ecology of things* brackets the effects of human agents and focuses instead on matter as an 'actant' to consider how this might change the way we think about resources, commodities or instrumentality — as nonhuman agents capable of effecting change. Bennett proposes the vitality of matter to enliven it in our consciousness and as a means to consider its agency as perhaps an antidote to our 'earth destroying fantasies of conquest and consumption*'*. (Bennett 2010, locn 37 of 2417) Bennett wonders if patterns of consumption would change if we looked at rubbish (for example) as an accumulating pile of lively (as opposed to dead and inert) and potentially dangerous matter? Bennett follows Latour's definition of an actant:

> ... a source of action that can be either human or non human; that which has efficacy, can do things, has sufficient coherence to make a difference, produce effects, alter the course of events and is any entity that modified another entity in a trial something whose competence is deduced from its performance rather than posited in advance of the action. (2010, locn 23 of 2417)

If one considers the fossil subjects of this study, an example of their agency could include the traditional methods of finding, excavating, preparing, studying and so on. Consideration of the resources required to perform such reveals a large use of energy and the potential destruction of the local environment, and the potential destruction of the fossils in the process. The challenge is to balance the revelation of new knowledge with minimal impact to the environment and the specimens themselves.

Multiple research 'languages'

An agential realistic worldview also seeks to redress the uneven balance of power of language over matter. Barad echoes Nietzche's warning against allowing linguistic structure to shape or determine our understanding of the world, questioning the 'subject and predicate structure of language to act as a reflection of a prior ontological reality of substance and attribute' (Barad 2007, p. 133). Multiple research 'languages' allow new voices to 'speak' and greater communication across different groups, or as Pickering (in press) calls them, 'worlds'.

Works of art often express that which cannot be articulated in traditional textual or mathematical forms, and have the unique potential of resisting comprehensive explanation or description by quantitative or qualitative methods. Often, the more you intra-act or look the more you may see or sense—and every viewer becomes a new 'author'[xviii] of the work. They, like everything else, are created, may evolve or become extinct. The struggle for the artistic researcher is that despite the fact that art may 'speak' loudly and a picture may be worth a thousand words[xix], in academic terms—it may appear scholastically mute, neither objectively quantifiable, nor completely qualitatively describable. John Dewey (1934) in *Art as Experience* writes:

> Because objects of art are expressive, they are a language. Rather they are many languages. For each art has its own medium and that medium is especially fitted for one kind of communication. Each medium says something that cannot be uttered as well or as completely in any other tongue. The needs of daily life have given superior practical importance to one mode of communication, that of speech. This fact has unfortunately given rise to a popular impression that the meanings expressed in architecture, sculpture, painting and music can be translated into words without little if any loss. In fact, each art speaks an idiom

xviii See page xx and discussion about Barthes 'Death of the Author'

xix A thousand words seems an apt comparison, as the time taken to compose a digital image is quite comparable to the time taken to pen a textual description…Would 30 digital images thus be comparable to a 30,000 word exegesis?

> that conveys what cannot be said in another language and yet remains the same. (Dewey 1934, p. 110)

We use descriptive words and numbers to clarify and communicate what makes sense, what may be repeated or communicated with little to no loss of understanding. Works of art are often made in response to what is being sensed, though not usually presented as a definitive nor objective view of a thing, person, or event at a particular at that point in time. They are actants, lively and dynamic in the world. Works of art are exhibited for others to engage with sensually, to take or give to them, what the viewer deems appropriate. There is also, I believe, a retrospective and lively, contemplative value of art, that also contributes to the agential *work* of art in the world. The meanings, purpose, and effect have the ability and potential to change with each viewer, and each translation. The works of art are formed through dynamic, agential (human-nonhuman) intra-actions and become agential themselves in and through their creation. This process could be used to describe all works of research, and may be thought of as *spacetimematterings.*

This suggests that works of art, and their makers, have the inherent ability to sit in a space which defies a scientifically satisfying objective and complete description. This in itself is the way in which artworks and visualisations, in a research context, may be considered as contributions to knowledge/s. They re-introduce experimental curiosity through a process, of critical visual culture, of critical play[xx], into the traditional research process making space for that which is unknown to be revealed, or *unconcealed*. They also introduce new audiences to research, via traditional and non-traditional means, and help to democratise the process and results of research.

Quantum|ivism — a paradigm for research practice

As discussed earlier, an agential realism worldview does not seek to separate ontology from epistemology, as this implies that there is a separation between human and non-human, subject and object, mind and body, matter and discourse. The proposed ethico-onto-epistem-ology, Quantum|ivism is about studying practices of *knowing in being*.

> Knowing is not about seeing from above or outside, or even seeing from a prosthetically enhanced human. Knowing is a matter of intra-acting: it entails specific practices through which the world is differentially articulated and accounted for. It includes non-humans and entails differential responsiveness and accountability as part of a network of performances and is not a bounded or closed practice but an ongoing performance of the world. (Barad 2007, p. 149)

> ...what we need is something like an ethico-onto-epistemology — an appreciation of the intertwining of ethics, knowing and being, since each intra-action matters, since the possibilities for what the world may become call out in the pause that precedes each breath before a moment comes into being and the world is remade again, because the becoming of the world is a deeply ethical matter. (Barad 2007, p. 185)

xx A neologism: see Chapter 6 – conclusions and future work.

Thus in response to the questions posed at the beginning of this chapter, 'Quantum|ivism' is presented as my research paradigm for both artistic and scientific practice. It is an interpretation of the ethico-onto-epistemology of Karen Barad (via Bohr and Einstein, Butler and Haraway) and is strongly influenced by Bruno Latour's conceptions of agency, networks and black boxes. It also incorporates Andrew Pickering's 'dance of agency'. Quantum|ivism is proposed as an alternative to the polemic debates of positivism and constructivism. It follows the metamodern trend, toward more entangled, democratic and ethical processes in the production of knowledge. It is presented as a contender for Barrett and Bolt's (2014) call for creative arts practice, a 'successor science'—and for this hybrid art-science project as a useful intra-disciplinary research paradigm. It draws inspiration from the revelations of Quantum physics, which highlight the existence of seemingly incompatible dualities (think particle/wave duality of light) and also provides a diffractive (rather than reflective—mirroring of the same) methodology to examine differences within the intra-actions within a dynamic, collective of becoming.

Conclusions

A paradigm, Quantum|ivism, has been suggested for practice-based research, applicable in the arts and the sciences. It closely follows the onto-epistemology philosophy of Karen Barad and diffractive methodology of Donna Haraway, and includes insights from many other theorists such as Bruno Latour, Barbara Bolt, Estelle Barrett and Andrew Pickering. Agential realism is presented as an answer to the first two questions of ontology and epistemology; this acknowledges the agency and the liveliness of all entities in the production of knowledge. The 'dance of agency' recognises that knowledge is inextricably entangled with reality and may be thought of as 'knowing in being'. This is in contrast to the claims of Positivism (a reality exists 'out there') and Constructivism (everything is a human construction). A diffractive methodology is proposed, in place of reflexive or reflective models, to avoid mirroring sameness, and to highlight the differences that occur in agential intra-actions, the nature of measuring apparatuses and agencies. The paradigm also calls for a renewed look at the ethics of 'mattering' and taking responsibility for our part in the world's becoming. In the following chapter I will discuss diffraction as a methodology for practice-based research in art or science.

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Chapter three

technê

The task of the exegesis is not just to explain or contextualise practice, but rather is to produce movement in thought itself. It is these 'shocks to thought' that constitute the work of art, and in conjunction with the artworks, it forms the material of creative arts research. (Bolt 2007, p. 33)

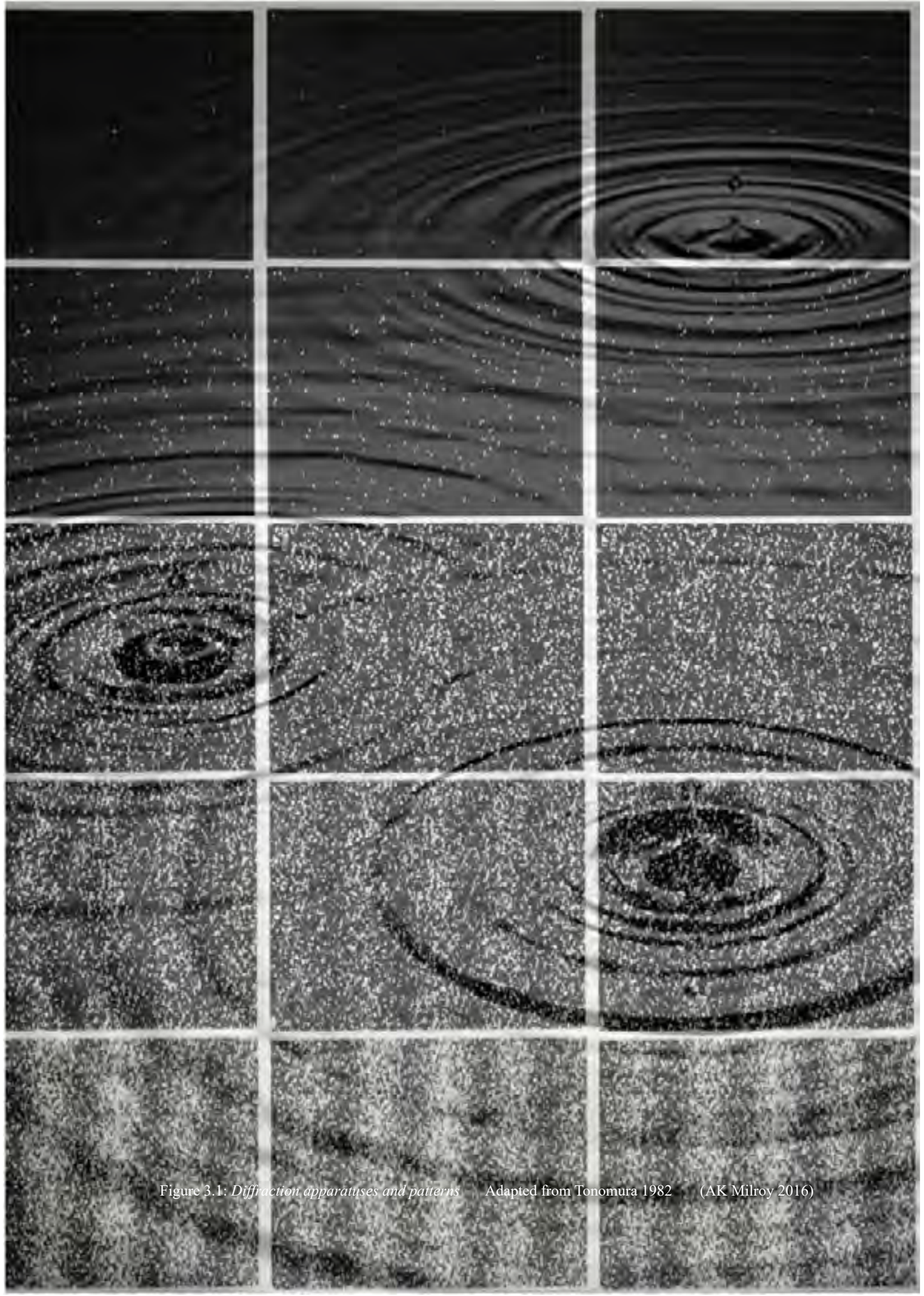

Figure 3.1: *Diffraction apparatuses and patterns* Adapted from Tonomura 1982 (AK Milroy 2016)

Technê

In Chapter one, I defined *technê*, as from the Greek τέχνη, as craftspersonship, craft or art. Here it is used to signify the methods, technologies and technical skills inherent in works of art or science. Foucault (1984, p. 255) defines *technê* as 'a practical rationality governed by a conscious aim'. However, he uses the words 'technology' or 'techniques' to encompass broader meanings of *technê*. Foucault also defines techniques as specific and localised and technologies as more general collections of specific techniques.

In my initial proposal, I tendered the following diagram as the research design/ methodology I would use. It was designed with some flexibility to allow unexpected outcomes that could potentially answer my research questions of how art/science practice could contribute one to the other to produce knowledge. The diagram's aim was to describe the hybrid artistic and scientific research practice as iterative, emergent and reflective.

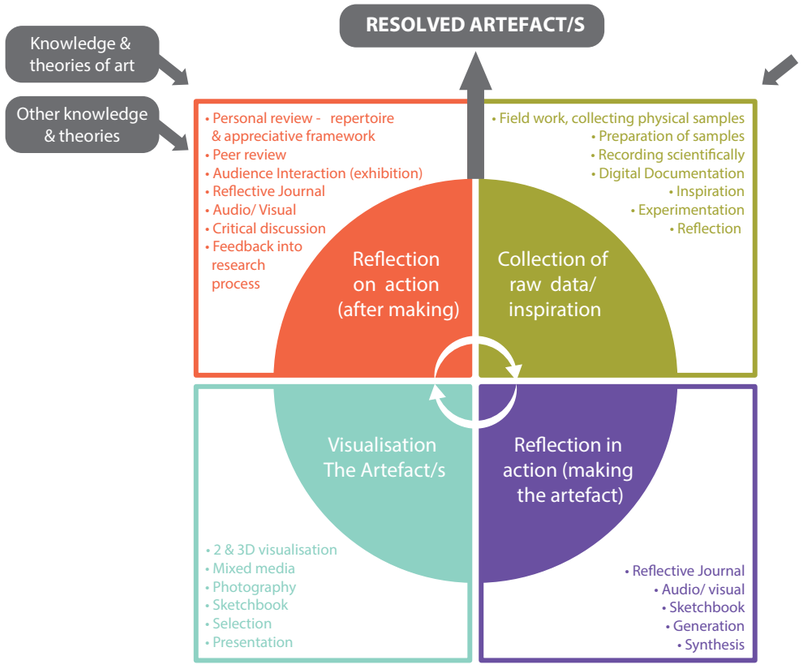

Figure 3.2: A reflective/reflexive methodological proposal (Milroy 2012)

From the outset the two dimensionality of the diagram felt less than ideal, but it was a starting point. I did anticipate that it would undergo review and would change as the project evolved. I realised that the disciplines of art and science each had their own preferred methodologies, and that to privilege either ran the risk of compromise in the other. The proposed methodology also limited the interpretation of the experience of how knowledge/s are made. The reality of working in, and on, artistic and scientific practice has been much more complex and filled with actants/agency, than I had originally anticipated. Additionally, as this hybrid type of intra-disciplinary research is still relatively novel, it provided a good opportunity to revisit research paradigms and look for methodologies that could be used effectively across both discipline areas.

One aspect of the proposed methodology however, has amplified, and that is the emergent nature of practice. The idea of methodology as emergent has had widespread application and acknowledgement (Schön 1983; Bourdieu 1992; Pickering 1995, 2012; Heidegger 1996; Scrivner 2000; Candy and Edmonds 2011; Barrett and Bolt 2007, 2013). It ties in with Quantum|ivism's dynamism, as knowledge/world/universe are phenomena emerging through practice, rather than pre-existing as entities awaiting discovery. Heidegger (1996) confirms that as processes of practice are predicated on the tacit and alternate logic of practice in time, their precise operations cannot be pre-determined, hence the methodologies have an emergent nature.

Thus, in hindsight, I realise that my original research design lent toward methodologies of reflexivity, reflection and representation. My proposal described and emphasised both a personally reflective narrative with material bodies, creating, reflecting, creating again, reflecting again; reflecting in practice and reflection on practice (Schön 1983). I was also drawn to Bourdieu's (1992), explanation for reflexivity—and agree that the researcher's relationship to the 'object' of study is crucial in practice based methodologies. Here, the researcher becomes both a knowing subject and the object of the study. Bourdieu also recognised that methodologies in artistic research are subject to repeated adjustment and do not remain fixed throughout the process of enquiry, thus indicating that practice is emergent, or dynamic. This leads to Quantum|ivism and changes the methodology to highlight concepts and processes of diffraction and performativity. It has certainly been the case in this project, and is elucidated later in this chapter, as I describe the different methods used to produce real and virtual artefacts [phenomena] in support of knowledge claims.

A diffractive methodology

The application of the ethico-onto-epistemology of Quantum|ivism denies a reflexive or reflective methodology. I also realise that *technê* cannot be separated from practice in a Foucaultian way, rather must be considered as a component of intra-actions that are inextricably entangled in praxis. Bolt (2004) describes *praxis* as the two-way action between practice and theory. She argues that art can be seen to emerge in the involvement with materials, methods, tools and ideas of practice. Bolt describes the performative aspect of the interaction and denies that the result is 'not just the representation of an already formed idea' (2004, p. 10).

Quantum|ivism prompted the re-framing of this artistic and scientific research practice as a dynamic, iterative, entangled intra-action with the world. The definition

Figure 3.3: Diffraction of waves. http://ircamera.as.arizona.edu/Astr2016/lectures/light.html

of *technê* should thus be expanded to democratically include all actants in the social/collective[i] of practice—the human and the nonhuman all have agency in the creation of a work of art or science. This sentiment is reflected by Bruno Latour, and in *Pandora's Hope* he writes:

> ... but techniques are not fetishes, they are unpredictable, not means, but mediators, means and ends at the same time and that is why they bear upon the social fabric. (Latour 1999, p. 197)

A revised definition of praxis incorporating *technê* could be: *Technê* in praxis, encompasses methods, technologies and technical skills, mediators, and apparatuses which are, at the same time, means and ends and which influence the collective that encompasses the human and nonhuman in practice.

Agential realism now comes to the fore, and with it the concept of diffraction, as a methodology. It has already been noted that Haraway introduced diffraction as a new category of semantics in 1997, and that it was taken up by Barad in *Meeting the Universe Halfway* (2007) to challenge the Western philosophy's optical metaphor of reflection. A scientific definition of diffraction explains it as a process by which a beam of light or other system of waves is spread out as a result of passing through a narrow aperture or across an edge, and is typically accompanied by interference between the wave forms produced (Oxford dictionary 2012). (Figure 3.3)The same effect may be evidenced in nature see Figure 3. One of Haraway's concerns is that reflexivity, as a critical practice,

i Remembering that Latour defines the social as collectives of human and nonhuman.

only 'displaces the same elsewhere' and in doing so creates anxiety. She recognises that this creates a 'search for the authentic' not the copy (Haraway 1997, p. 34 and 264; Barad 2007, p. 71). Science writer Margaret Wertheim's 2016 essay *Physics pangolin* highlights this neurosis. Wertheim[ii], through the work of anthropologist Mary Douglas, describes cultural linguistic systems as containing 'liminal confusions' which arise in the process of the dividing the world into categories. Such linguistic ambiguities (for example, the particle-wave duality of light) she argues, push cultures to try and remove every anomaly in their system, and this can result in obsessive categorisation. Wertheim suggests that what is encountered is not the edge of reality, rather the limits of the culture's (or discipline's) category system.

Thus the development of this project's methodology both recognises and addresses the fact I, as a researcher, am an entangled part of praxical intra-actions, and that my (diffractive) analysis takes place from within, not external to the collective of human/nonhuman. The difference is important, as it expands and democratises the theoretical focus with an accountability to what is included in the agential cut, what is left out and the phenomenon (artefact) to be analysed. In this instance, the entangled intra-actions of the researcher are from within both my own artistic practice and the scientific practices of the Queensland Museum. My initial proposal (2012) also stated:

> This research lends itself to an art–science fusion. The first stages of research in either discipline are exploration and observation. As many of the botanic specimens may be 'new' to science, or valuable as holotypes[iii], it is imperative that these are treated with due diligence and follow the guidelines set by the Queensland Museum's guidelines for best practice.
>
> The aim of the visualisations—or artefact/s are to reflect the concept of evolution and extinction in Queensland flora.

Thus I have followed the lead of theorists including Heidegger, Whitehead, Haraway, Barad, Bolt, Barrett, in moving from representation and reflection/mirroring/sameness to performativity through diffraction/interference/differences.

Bolt (2004, p. 8) in *Art Beyond Representation* also supports the proposition that artistic research is a performative, rather than a representational practice, and that within art as practice, 'a dynamic material exchange can occur between objects, bodies and images'. Further, Bolt indicates that it is through 'the dynamic productivity of material practice, that reality can get into images'. The latter comment could imply separateness— a position of exteriority, that is, a reality exists out there somewhere, independent of the human? I believe however, Bolt means (through her thesis of performativity) that reality is formed in practice, by knowing in being. Bolt does, however, claim that it is the 'potential of mutual reflection between objects, images and

ii The Beautiful Math of Coral. http://www.ted.com/talks/margaret_wertheim_crochets_the_coral_reef

iii Specimen upon which the description and name of a new species is based. https://en.wikipedia.org/wiki/Holotype

bodies', which form the basis for performative potential of images (through deformation or transformation). Given the limits of reflection, of mirroring and sameness, there is perhaps, a mismatch here, between reflection and 'performative potential'. The former implies the reporting/recording of a static entity, the latter a dynamic emergence.
More recently, Barrett and Bolt (2014, p. 3) use Haraway's concept of diffraction and Barad's ethico-onto-epistemology and propose that academic creative art research has initiated such a 'successor science'. This project differs as I search for a paradigm and methodology that may be used in both art and science research practice. Figure 3.4 shows the altered methodology. It is limited by the two dimensionality of the page: a more ideal image would be dynamic, with patterns of diffraction shown as occurring across four dimensions, including time, and intra-actions occurring simultaneously between multiple entities and thus creating an emergent collective[iv].

The aim of a diffractive methodology is to not fix the object and the subject in advance—instead the aim is to read insights in ways that help illuminate differences as they emerge, and how they get made—what gets excluded and how those exclusions matter. This is somewhat at odds with the usual 'research question' model for research. And as framed in chapter one, I prefer to think of research opportunities—to avoid prescriptive questions and answers at the outset—to allow that which is yet unknown or unknowable in advance to emerge. Serendipitous associations characterise this research project. Many of the results gained have had their genesis in experimental meanderings, meetings, collaborations and seemingly unrelated activities. I agree with Barad, that we need to take account of how both art and science research practices matter. However, to paraphrase Barad (2007), it is not enough to just recognise that they matter. With respect to my research questions, what I am attempting to do is diffractively theorise the relationship between research practice in the arts and the sciences. I avoid defining one against the other or holding either as the fixed referent for understanding the other. Part of this methodology is to identify the diffraction apparatus from which the entanglements are studied and phenomena produced. This apparatus may be human or non-human or some combination of both.

Characteristics of a diffraction apparatus

Under the auspices of Quantum|ivism, we have established that diffraction apparatuses are practices, specifically material-discursive practices. This view alters thinking about laboratory/studio setups as passive and separate sites of anthropocentric knowledge making. This reframing highlights them as open ended and recognises that they are accountable for and to the boundaries they produce—they simultaneously produce and are part of the phenomena produced. Thus the studio/laboratory is a material reconfiguration of the world and, as with phenomena, emerge as a part of

iv As per Latour's definition of same

Table 3.1: Methodological Comparisons: Reflection versus Diffraction (modified from Barad 2007, pp. 89–90)

Reflection (reflecting on representations)	**Diffraction** (accounting for how practices matter)
Mirror image: Reflection of objects held at a distance.	**Diffraction pattern**: Marking differences from within and as part of an entangled state.
Sameness, mimesis: Objectivity is about reflections, copies that are homologous to originals, authentic, free of distortion.	**Differences, relationalities**: Objectivity is about taking account of marks on bodies.
Reflexivity	**Diffractive methodology**
Representationalism: Pre-existing determinate boundary between subject and object.	**Performativity:** Subject and object do not pre-exist as such, but emerge through intra-actions.
Separate entities: Words and things.	**Entangled ontology:** Material-discursive phenomena.
Ontology | epistemology binary: Knowledge is true beliefs concerning reflections from a distance.	**Onto-epistem-ology:** Knowing in being.
Interacting of separate entities	**Intra-acting within and as part of**
Inside/ outside: Absolute separation, no difference interior/exterior.	**Differences emerge within phenomena:** Agential separability within phenomena. Real material differences but without absolute separation**.**
Words mirror things: Social | natural binary. Nature | culture binary.	**Diffraction | difference pattern** Intra-acting entangled states of nature cultures.
About representations: Finding accurate representations from afar (detached observer)	**About making a difference in the world:** Being accountable for practice and recognising that different practices materialise the world differently.
Things are objective referents: Accountability entails finding an authentic mirror representation of separate things.	**Phenomena are objective referents:** Accountability to marks on bodies. Accountability and responsibility taking account of differences that matter.
Ethics | ontology | epistemology Separate fields of study.	**Ethico-onto-epistem-ology:** Ethics, ontology, epistemology not separable.
Reading against (some fixed target/ mirror): Privileging one disciplines. Read others against it.	**Reading through (the diffraction grating):** [intra]disciplinary engagement. Boundary production between disciplines it itself a material-discursive practice; so how do these practices matter?
Subject | object fixed	**Subject, object contingent, not fixed.**
Reify, simplify, make the other into a separate object. Less attentive to and able to resolve important details, dynamics, how boundaries are made.	**Respectful engagements that attends to detailed patterns of thinking of each; fine grained details matter.**

'spacetimemattering'. The approach of this project thus has been to rethink the nature of knowledge making (in palaeo-botany) within artistic and scientific practices. I recognise that the intra-actions between the objects of investigation and the agencies of observation are indeterminate. This means one cannot subtract the phenomena from the human and vice versa and it is not possible to make a representation of the world independent of the human.

The metaphor of a diffraction grating is useful when considering the agential cuts made

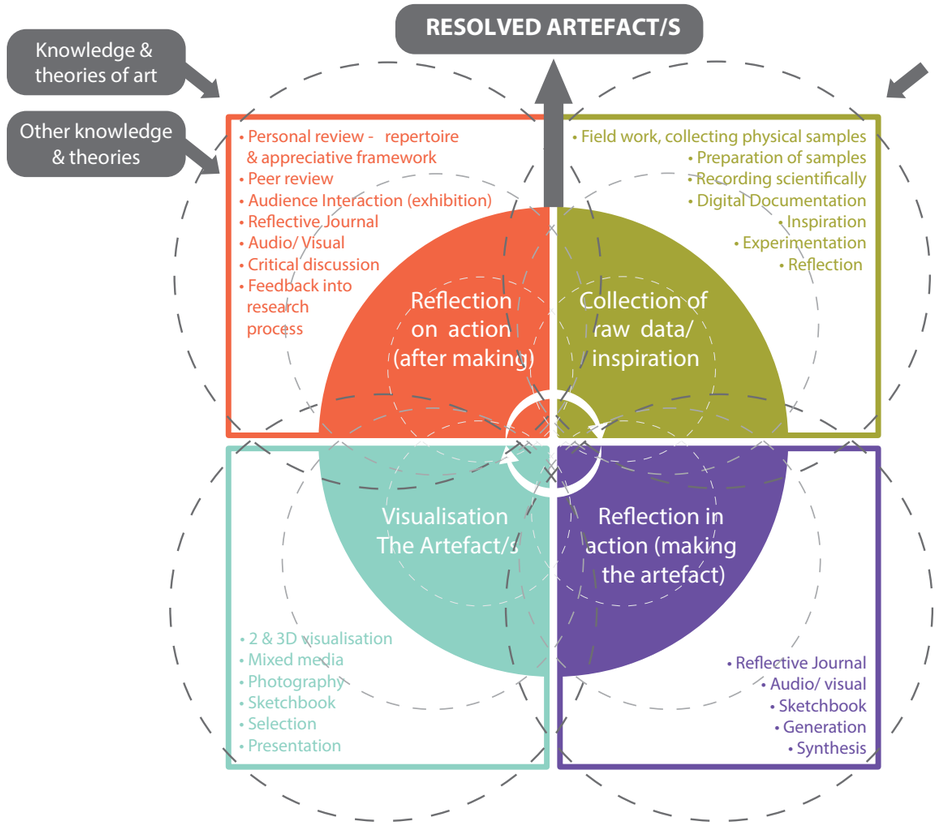

Figure 3.4: A diffractive methodology – a work in progress (AK Milroy 2016)

by practice. I refer back to Bolt's comment, on the first page of this chapter, and adjust it to suit this hybrid research practice:

> The task of the exegesis is not just to explain or contextualise practice, but rather is to produce movement in thought itself. It is these 'shocks to thought' that constitute the work of art [or science], and in conjunction with the artworks [works of science], it forms the material of creative arts [intra-disciplinary] research. (Bolt 2007, p. 33)

In some ways, there is both a literal, on the micro scale, and a figurative, on the macro scale, connotation to the use of the term 'diffraction grating' as an apparatus through which data is processed as agential or as phenomena. The Artists' book *Diffract* (Milroy and Freeman in press) is an example of this and the the authors are listed as the human diffraction gratings.

Praxis

The Scientific practice

From the first accidental discovery of fossilised leaves, this research project has been peppered with serendipitous associations and events. Inspired by these enigmatic ferns, and the associated concepts of deep time, the goal was to gain a greater understanding of the scientific practice of palaeobotany via artistic practice. Inspiration was sought through collecting raw data directly from the field; collected specimens in museum/ university/herbaria; and peer reviewed journal articles or books. A direct engagement with Queensland Museum's Geoscience Department, specifically the type collection at the Hendra campus, was initiated. The fossil specimens in this collection can also be thought of as phenomena, and are traditionally analysable by apparatuses including photography, physical sectioning, computed tomographies (CT) or microscopic scans, measurement, or preparation (removed from the surrounding matrix). In the field of palaeobotany, works of science are usually re-presented as journal articles and each specimen is deemed significant in terms of its contribution to Phylogenetics (taxonomic[v]) classification. The International Code of Nomenclature for algae, fungi, and plants (Melbourne Code)[vi] provides the guidelines for this practice. Important specimens are allocated a unique Latin name, a type number and held in internationally recognised repositories (museums or herbaria) thus allowing other researchers to continue the research by comparative phylogenies. And so the slow and steady scientific practice of observing and representing the world in minute detail begins. The aim of such scientific publications is to recognise, visualise, categorise and build a picture of what life was like, what it is like now, and thoughts of how future life could look. The palaeoclimates of the past are thought to provide clues to climates of the future. In this project, the search for inspiration was guided through the scientific practice of palaeo-botany. However, artistic practices of critical play[vii], directed and spontaneous exploration and experimentation were introduced to and entangled with the materials of palaeo-botanical study, fossil plants, and the scientific techniques traditionally used to study these.

Data collection became a two-step process. Step one was the collection of raw data from both specimens and the scientific practice. Step two involves analysing the

v https://en.wikipedia.org/wiki/Taxonomy_%28biology%29
vi http://iapt-taxon.org/nomen/main.php
vii A neologism, and a term for experimenting within research practice.

'resolved'[viii] works of art/science/technology as phenomena generated by and through practice. In essence, the same principle applies for both art and science practice: raw data is collected, and then processed through human and nonhuman apparatuses (diffraction gratings) and is analysed as resolved works/phenomena. The phenomena resulting from the entangled practices have been visualised and analysed and will be discussed in depth in Chapter four, *poïesis*.

Figure 3.5: On the dig site: south-west Queensland (AK Milroy 2010)

viii 'Resolved' as a term is used loosely here, in (agential) reality, the phenomena are not static and continue to be dynamic and lively.

Raw data

As mentioned in Chapter one, the genesis of the project was as a volunteer on a palaeontological dig. My research question investigates if and how an artist can contribute to knowledge production in another discipline such as palaeobotany and vice versa. The raw data collected was thus through direct engagement within scientific practice. The raw data was collected from three major sources:

1. In the field

Dinosaur and megafauna digs in south-west Queensland, near Eromanga and Eulo, and a palaeobotanic dig near Capella, in Central Queensland. As a volunteer, I became a member of the scientific team, and this role included activities such as finding specimens; mapping specimen location, preparation for removal from site, making plaster jackets, removal from site, storage, photography, GPS locations, journaling and preparation (removing rock matrix from the fossil with smalls pneumatic drills) and so on (Figure 3.5).

2. In the type room

Figure 3.6: In the type room (K Spring 2016)

The Queensland Museum holds type specimens in an environmentally controlled, safe collection space, in accordance with appropriate international conservation and curation guidelines. (Figure 3.6) My investigations had led me in search of information on the enigmatic fern fossils. After reading several palaeobotanical papers, I noted one that

detailed an audit of the fossil plant types in the collection. This had been performed in 1986 by Dr Andrew Rozefelds. I thus considered revisiting this survey, and focusing on the most important types—the holotypes—enabling me to deepen my visual and theoretical palaeo-botanic knowledge. The online collection database had a paucity of images of these specimens, and part of my practice included taking photographs—both in their entirety (that is, as part of a larger formation including the rock matrix) and a macro (or close up) version of the same. Each of these images included measurement apparatuses such as scale bars.

Over the course of the next couple of years I developed a supplementary database of the QMF palaeobotanical holotypes of over fifty specimens. Each came with its own idiosyncrasies and they were 'lively' within the photographic process I was trying to impose upon them. Pickering's (1995) description of a dialectic, (or rather multi-lectic) including resistance and accommodation became evident. And despite the best efforts of collection management staff—sometimes the specimens were not in the drawer where they should have been, were on loan, the label had a spelling mistake, wrong number or was absent, or the journal paper on the specimen was missing and had to be sourced (the first specimen I photographed had been first published on over 100 years ago). Most of the errors, however, could be attributed to individual researchers erratically following collection protocols.

I enjoyed 'meeting' the other researchers through reading their papers, and comparing techniques for visualisation. Many of the older specimens were hand drawn, and the early photographs were silver gelatine prints[ix]. Fine details were included by the use of microscopes, and again either hand drawn or photographed. I have been extremely lucky to work alongside two of the longest contributing palaeobotanical authors and scientists, Dr Mary Dettmann and Professor Trevor Clifford (Rozefelds *et alia*, in press). To this day, they continue to work on the fossil plants in the collection, as honorary researchers. A highlight of this project was introducing new methods of visualisation to experienced researchers and showing them new ways of seeing (this will become more apparent in the next chapter, with images made using synchrotron radiation). The database of audited details, images and papers has yet to be incorporated within the Queensland Museum Vernon[x] database system.

3. Scanning at the Australian Synchrotron

The Australian Synchrotron offers a number of beam lines which use different wavelengths of light to scan objects, samples etc for research purposes. Below are **links** to explanatory videos—what a synchrotron is, and how it works. The first is from the ABC's Catalyst show, and whilst it does not describe the IMBL beam line (the beam we operated), it does show how synchrotron radiation (high energy x-rays) are produced.

ix https://www.youtube.com/watch?v=VqWyJstBSoo
x http://vernonsystems.com/

Figure 3.7: *Degas* (ABC Catalyst 2016)

ABC Catalyst:

The National Gallery of Victoria is lined with secrets, but early attempts at solving these mysteries gave only a glimpse of what lay beneath the brushstrokes. We go behind the scenes at the NGV and the Australian Synchrotron to see how scientists are revealing concealed gems with stunning clarity. (27 September 2016).

The Imaging and Medical Beam Line (IMBL), is used for larger objects and medical processes. This project used modes 2 (first trial) and 3 (beam time) for imaging.The data generated from the scans was approximately ten terabytes in total. The specimen data was processed to volume data using the MASSIVE[xi] cluster of computers.

The artistic practice

My normal artistic practice is a direct, tacit, or haptic engagement with the world, specifically, wherever in the world I find myself at a point in time. I experiment with many different media and methods, some from my usual practice and others influenced by scientific visualisation techniques. These included:

1. Visual diaries

Part of my daily practice is to write, sketch, annotate and record experimental data into small journals. Some of these are handmade, and stitched together with Coptic binding. They provide an *aide memoire* for techniques I want to remember, or results of trials. I tend to keep separate diaries for different media, for example print making/ jewellery/ceramics and so on. These are invaluable to my daily practice and I often refer back to notes and sketches from many years past to inform and inspire the present.

2. Digital Photography

Photography has been used in the natural sciences as a recording and measuring apparatus since its invention. The photographer participates in a dance of agency with equipment: lighting—different angles of light used to highlight various characteristics, orientation; lenses—scale and colour correction. (Figure 3.8) In my artistic practice I use

xi Multimodal Australian ScienceS Imaging and Visualisation Environment

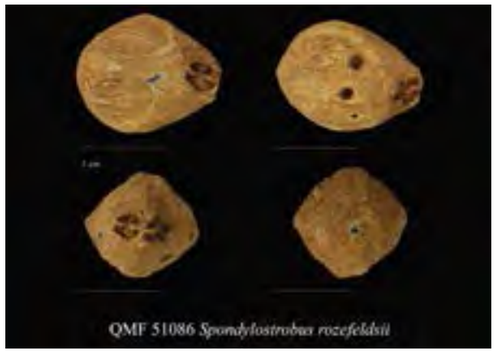

Figure 3.8: QMF 51086 *Spondylostrobus rozefeldsii* (AK Milroy 2012)

the camera in creative ways—sometimes aiming for a literal interpretation and sometimes something more abstract. Quite often I will experiment with spontaneous, counter intuitive methods to see 'what if'. In this project I experimented with traditional fossil photography (2D images with scale bars), photogrammetry and focus stacked images.

- **Photogrammetry**

The photographic knowledge and skill gained from artistic practice wasuseful when the team decided to try to create a digital, three dimensional specimen using photogrammetric techniques, a DLSR camera and inexpensive *Agisoft* software. Lateral thinking and intra-actions amongst researchers and specimen resulted in a method of taking (groups) of photographs, masking out extraneous information and processing these into a point cloud, mesh and textured rendered volume. The specimen, QMF17213 *Wilkinsonia glencoensis* (Rozefelds 1990), was used and the resulting model has been

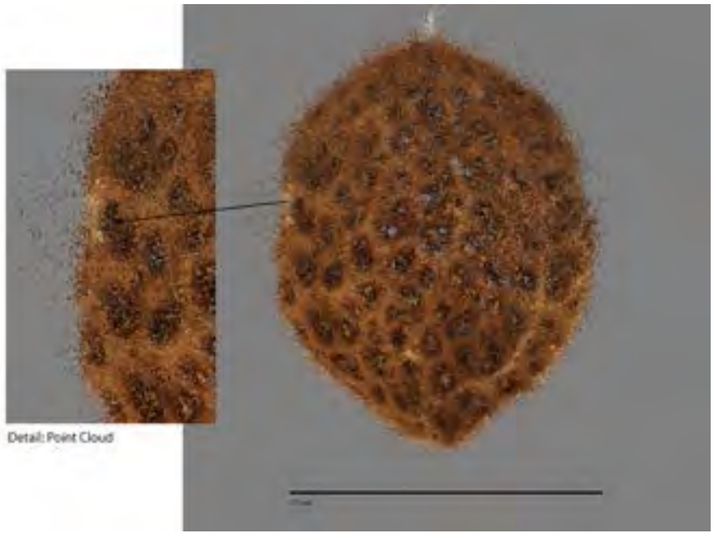

Figure 3.9: QMF 17213 *Wilkinsonia glencoensis* point cloud (AK Milroy 2012)

shared via tablets, phones, printed in 3D in plastic and gypsum. The *Journal of Natural Scientific Illustration* (Milroy *et alia* 2015) and provides a method for other researchers to use, if they require a 3D model and do not have access to laser scanning equipment. (Figure 3.9)

- **Focus stacking**

Some specimens were photographed with a macro lens and multiple images focus stacked to provide an in-focus image of small objects. The programme, *Zerene Stacker* was used to process the images. Museum colleagues, Geoff Thompson and Paul Tierney, were very generous with their knowledge of the equipment, and a light source I had in my kit was used to illuminate a specimen in amber (Figure 3.10).

Figure 3.10: Focus stacked image of flowers in amber (AK Milroy 2014)

In *Images-Music-Text* Barthes (1967, p. 14) talks about photographs, specifically those included in press, and recognises that scientific images are often regarded as transmitting a literal reality that has been technologically captured. They are presented as 'objective' images of reality however, there is much intra-action going on between the photographer, the camera, the lights and the software to produce the final image. I am reminded again of Magritte's 'treachery of images' and '*ceci n'est pas une pipe*'comes to mind. It is after all, not actually the phenomenon, rather an image of the phenomenon and as such an entity with agency in its own right. In the following discussion I would

like to substitute the word 'press' photograph for 'scientific' photograph, as I believe it applies equally. Barthes (1984, p. 15) notes that the photograph's transmission always involves an accompanying text in the form of a caption or title; he describes this as a 'co-operative'—the textual material plus image. He also observes that we tend to give the analysis of the words greater importance in our interpretation of the photograph, though he does not address why he thinks this is so. Today, in more than any other period in human history, we are bombarded with digital imagery via the internet—Big Data. This presents a special challenge, to navigate through the sheer volume of images and to judge the effects they have, and the agency they have through the medium of the internet. Visualisations permeate every aspect of our metamodern lives, and this poses an ethical issue: the effect of images on the world. Heyward and Sandywell (2012) propose a new area of critical study—that of critical visual discourse. Barthes notes that the image is not reality but is a perfect analogon and that the special status of photography is a message without a code. He describes the photograph as continuous, constant in time and without a beginning or end. Barthes describes drawings, paintings, cinema and theatre as all having obvious forms which are supplementary to the analogous element. For example, perspective, texture and sequential presentation. He concludes that artistic modes (and, I would suggest, scientific images), are intended to be 'imitative' or 'representational' and thus comprise two messages: a denoted message (the analgon itself) and a connoted message, in which society communicates what it thinks of it. For Barthes then, objectivity may also be thought of as denotation or a first order message and subjectivity as a connotation, with abstract or interpretive elements and a second order message. Despite this, he too concedes that despite defining the press photograph as denotated or objective, it has actually been worked on, chosen, composed, constructed, treated according to professional, aesthetic or ideological norms (Barthes 1984, p. 19). Barthes compares the press photograph with film, drawings, paintings, theatre, where the latter collude. He gives the example of a drawing, where the elements of composition (lines, shading, colour) are working simultaneously to denote and connote. The scientific photograph thus has an ethical paradox. Barthes describes this as striving to be neutral, or objective. Is neutrality possible? Photogenia describes (Barthes 1984, p. 19) the embellishment of the photograph through some means (lighting, exposure, printing, blurring). Finally, Barthes comes to the conclusion that we do not have access 'to the way things are' (1984, p. 24) through the press [scientific] photograph.

3. Illustration

Scientific illustrations are visualizations or depictions of a subject made by an artist, using techniques such as a drawing, sketch, painting, photograph, or other kind of image of things using a graphical representation. From the Latin word *illustra'tio, illu'stro* meaning enlighten, or irradiate. Hand drawn specimens were the preferred form

of scientific communication before the invention of photography. As an experiment, I decided to do scaled line drawings from the photographs I had taken of specimens, to ascertain if the act of drawing helped me to 'see' the specimen. (See Figures 3.11 and 3.12). This was in response to Arber (Chapter One), who reminded us of the value of making sketches, allowing one to become more familiar with the object under

Figure 3.11: QMF 17196 *Pleiogynium parvum* – digitised drawing (AK Milroy 2014)

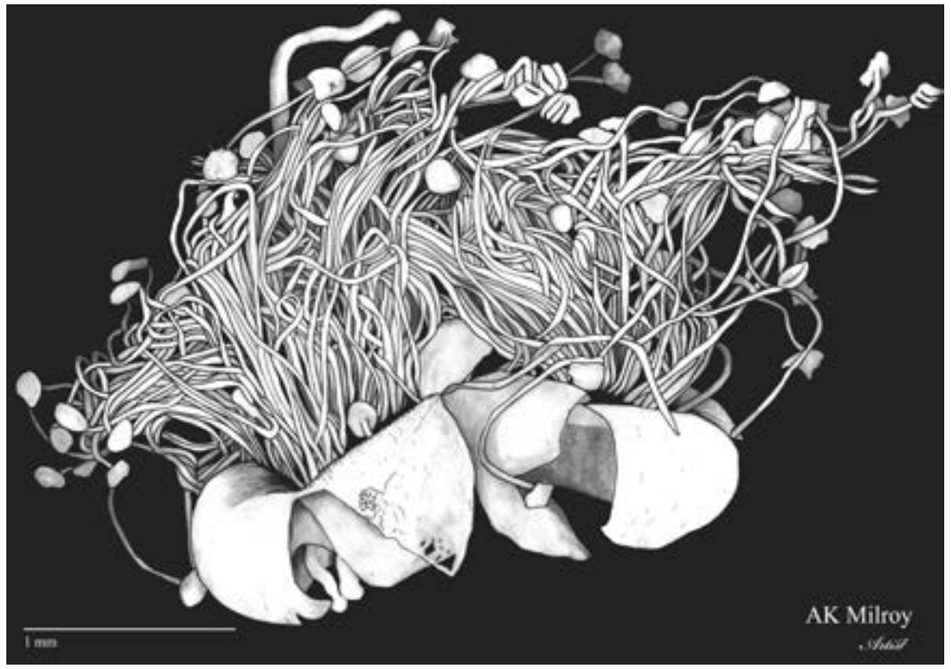

Figure 3.12: Flower in amber – digitised pencil sketch (AK Milroy 2014)

investigation.

4. Jewellery - handle-ability, fetish, memento, collecting

Through my gold and silversmithing practice I met and enacted a successful collaboration (see *Labpunk* project) with University of Queensland physicist and Lecturer, Dr Margaret Wegener (Wegener and Milroy 2014; Milroy *et alia* 2015). We took 'The Art of Physics' theme of the AIP 2014 conference and made wearable artworks from discarded artefacts from the physics lab. It was through this exhibition that I had the chance to meet scientists Anton Maksimenko and Chris Hall from the Australian Synchrotron. I was invited to test a sample or two using the Imaging and Medical Beamline (IMBL). The first trial was very successful (see 'deep time' movie, in Chapter four). It led to further scanning experiments and five days of beam time in October 2015. Some forty specimens from the Queensland Museum collection were scanned. I learned how to process the data and was able to experiment with production of visualisations using the 3D volumes generated from computed tomographies. As detailed in Chapter four, not only was new morphological information revealed but the practice also produced unique aesthetic and interesting images. The results have had multiple applications,

Figure 3.13: *Labpunk* – Wave cuff-links and particle tie-pin – Prof. Serge Haroche (AK Milroy 2014)

artistically (became part of the doctoral exhibition—*Aletheia*) and scientifically (publications, posters and presentations). These are detailed in the following chapter. Many contemporary jewellers have been inspired by Australia's endemic species. Jeweller Marian Hosking in her PhD exegesis, *Crafting and Meaning* (2008), sought to explore the themes of allusion, motif and identity through studio-based practice. Although Marian refers to her work as craft, I would argue that many, if not all, of the works are

experimental and new knowledge—these embody the concept of *poiesis*, as described in Chapter One. In my studio practice I have used similar metalsmithing techniques to Marian (saw piercing, casting and so on), however, where my work differs from others in the field is its focus on extinct fossil flora, and/or aspects relating to the process of fossilisation. Figure 3.14, is a ring fabricated from a cast organic specimen. The

Figure 3.14: Permineralised – Black boxes collection: Stories in Small Spaces (AK Milroy 2015)

specimen was 'lost' in the casting process, and replaced with sterling silver. The work 'permineralised'[xii] was exhibited as 'Black Boxes installation' in the Studio West End, Stories in Small Spaces[xiii] exhibition.

5. Three dimensional printing

In the early stages of the project I realised that a new method of visualisation of three

Figure 3.15: 3D Printing trials (AK Milroy 2013)

xii Fossilised through the precipitation of dissolved minerals in the interstices of hard tissue.
xiii http://greenvalegallery.com/2015-exhibition-calendar/

dimensional objects could be by 3D printing. Personal machines had become accessible and so I purchased a kit from the Netherlands and built my own. It took a week to construct, however, the calibration of the machine proved to be difficult, and although I did manage to print my very own plastic Stanford Bunny, I finally decided to use more reliable sources, such as the Fab Lab in Adelaide, and the Edge in Brisbane. In 2015 I trialled a print with a gypsum powder printer at the University of Southern Queensland.

The results are detailed in the next chapter and are unique 3D printed and coloured sculptures, generated from my photogrammetric model of an extinct rainforest fruit. Personal 3D printers continue to improve since the initial trials and I used a small printer as a performance piece in the *Aletheia* exhibition, detailed in Chapter four.

6. Laser Cutting / Etching

From the digital images of the fossil holotypes (Figure 3.8), a scientific practice of illustration was followed to make line drawings (Figure 3.11). These were subsequently converted to vector files in Adobe Illustrator and etched into A3 clear perspex sheets using a laser cutter at the State Library's *Edge* facility. Twenty-five plates in total were made, including a cover. These were used to produce relief and intaglio prints and the Artists' book, *Anamnesis*, described in the next chapter.

7. Print Making

Figure 3.16: *Knowing* – pierced and etched copper plate – intaglio and embossed bookplate (AK Milroy 2013)

Print making was used to produce one of the first works in response to the thesis topic, as a bookplate was created for the Studio West End 'Bookplates Unbound' project. 'Knowing' is an embossed image and intaglio text (Figure 3.16.) Printmaking techniques were used again for the 2016 'Manifest' project, a celebration of 50 years of the Australian Print Council, with 'unconcealedness' 3D print and chine collè[xiv] onto paper (Figure 3.1). Both projects were acquired as limited editions for the State Library of Queensland's artists' book collection

8. Artists' Books

Several Artists' books were produced during this project and included artefacts and collaborations from art and science. These explorations culminated in an artistic residency at Columbia College, Chicago, and the publication *Diffract* was produced as a collaboration between Brad Freeman (Editor of Journal of Artists' Books – JAB) and myself. The Artists' books produced are listed below:

- *Living in the Anthropocene:* Photographs, hand bound, brass GPPS plate.
- *Biography of a Physicist:* Overhead transparency film, fibre optic, LED light source, perspex, timber.
- *Diffract:* Offset printed on the Heidelberg GTO (ein farben) in June 2016 at the Center for Book, Paper & Print, as part of an arts residency sponsored by Columbia College Chicago and Central Queensland University. The paper is Mowhawk Superfine 80lb text ultrawhite smooth. Diffract is included with JAB41 (Spring 2017).
- *Trumped up Empathy:* A collaborative event involving Brad Freeman, AK Milroy, Tim Mosely and the Heildelberg GTO at the Center for Book, Paper & Print Columbia College Chicago, June 2016. JAB Books.
- *Anamnesis:* A twenty-five page perspex book, etched with line drawings of palaeobotanical holotypes from the Queensland Museum Collection, using the State Library's Edge laser cutter, printed and constructed in book form.

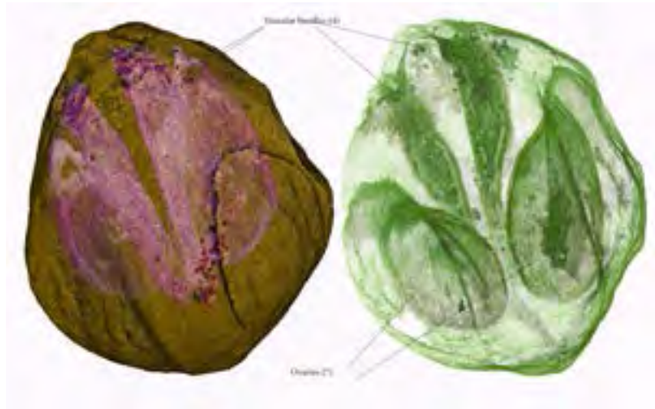

Figure 3.17: *Spondylostrobus rozefeldsii* – creative non-fiction (Maksimenko, Milroy and Rozefelds 2015)

xiv Printmaking term in which the image is transferred to a surface that is bonded to a heavier support in the printing process. https://en.wikipedia.org/wiki/Chine-coll%C3%A9

9. Computed tomographies using synchrotron radiation.

The works produced from intra-actions with the Australian synchrotron are revealed in the next chapter. The final visualisations however, were produced on my private computer system, which was built specifically to cope with the large file sizes. Most of the volumes were around fourteen gigabytes, which require a minimum of sixty-four gigabytes of RAM and twelve gigabytes of GPU power. Synchrotron scientists, particularly Anton Maksimenko and Chris Hall, mentored us through the technical practice from scan to visualisation. Although I am not aware of other artists working in the same hybrid art-science practice, I have noticed artist Erica Seccombe uses microcomputed X-ray technology to create animated projection installations of living plants from volumetric data rendered in *Drishti* (Limaye 2012). However, as I understand it, the micro computed tomography CT facility uses medical grade x-rays, this system is not as powerful, nor as fast as, the Synchrotron x-ray radiation: however it is better for smaller items (less than 1mm) and which is a current limitation of the IMBL.

Coding the data — measuring apparatus

Works of art-science or science-art? How the works are coded depends on how they are to be 'read', what diffraction gratings – measuring apparatus are to be used? In creative art research I suggest it is the works of art, that code the data for use in exhibitions. The exhibitions are a diffraction grating through which we come to 'read' the work in a particular way. If we chose instead to put the image into a scientific journal, the journal becomes the diffraction grating, and the work is 'read' through the languages of science, botany, biology, and palaeontology for example. I believe it is possible for an image to be both a work of art and a work of science. This is evidenced in the research outputs provided in this exegesis, where some are traditional, and take the form of journal articles, presentations, posters, while others are non-traditional such as exhibition items and performance pieces. The apprehension of an artefact is conditioned by such contexts. Each context is a cultural 'genre' with its own conventions, traditions and expectations. Arguably, the scientist is more likely to conform to those expectations. Conversely, the artist is expected not to conform (yet still remain within the constraints of artistic institutions). Chapter four includes hyperlinks to a range of research outputs produced during the doctoral candidacy.

Analysing the data — praxical knowledge/s

Heidegger (1996) states that praxical knowledge implies that ideas and theory are the result of practice rather than the opposite. Barret and Bolt (2007) concur and call for a way to recognise this emergent process as adding value and knowledge, by making the processes of knowledge making, as practice, more transparent and ultimately shareable. This is also reflected by many current artistic research practitioners. Bolt (2004), contemplating the tool-human relationship, proposes an understanding of the complex relationship between humans, objects, tools, ideas and materials in artistic production. Reading through Heidegger, she notes that in the production of a work, that the artist or craftsperson is not the sole creator or master of the work of art and that it lies in 'its social constitution' (2004, p. 9, p. 93). Further, she explains that the artist's relationship with their tools is not about mastery—instead, the artist is co-responsible for revealing the artwork. Artistic practice thus involves intra-actions with other contributing human and nonhuman elements that make up the particular artwork. Again, referencing Heidegger, Bolt notes that this co-creation can reveal something and start it 'on its way into arrival' (Heidegger 1977, p. 9 in Bolt 2004, p. 75). Through this dynamic and productive relation, art emerges as a revealing. The outcome of the experiment may reveal itself in terms of art, science, technology, education and so on, depending on the context or, in other words, the agential cuts or the apparatuses utilised—social/cultural/institutional/technological. This bringing forth, may be described by the term *aletheia*, an unconcealedness. According to this conception, each event involves an unpredictable unique and complex encounter (Bolt 2004). In this particular research experience, it is not only art that emerges or is revealed. New works of science, technology and education may also be revealed. How these are interpreted and labelled, the marks made by agential cut/s, are dependent on the measuring apparatus/s used. This unique aspect of the results of this research project lie in their ability to sit within different disciplines and to reveal themselves in different ways to specific audiences. In such a situation, I realise how important the ethics of mattering is—how the works are presented, what knowledge/s they proclaim or reveal, and the effects of these knowledges on other practices and practitioners and the human/ nonhuman.

Dewey (1934) also made an important point in that practice needs to be expanded to include both repertoire and appreciative systems — critical practice, if you like. These are the processes by which we judge the quality and effectiveness of our artefacts of praxis. I define repertoire as the catalogue of works of art or science a practitioner knows or is prepared to perform, including the acts of making and exhibiting. Appreciative systems include things such as acceptance for publication (peer review); presentations at conferences: inclusion in exhibitions: shows: critical reviews (verbal or written); sales to private and public collections; and registration in University databases.

This is a developing area within artistic research practice. How does one adequately analyse the data, the works of art and science, that have been produced? Currently the ERA requires research statements to accompany each Non-Traditional Research Output (NTRO) submitted. Whilst such research statements are not new to arts based research, they are uncommon in scientific circles, and thus I have included a brief summary to explain what is required.

ERA research statements – NTROs

NTRO outputs nominated for ERA require peer review, and, as part of the submission of an institution, this takes the form of a statement identifying the research component of the output. Despite this, I do not believe that they bring to attention the different visual literacies that are present, the subtleties and unique contributions that each being brings to the intra-action. Thus I feel it is important to not only seek for universal truths, rather to consider how each of the individual truths may contribute under different measuring apparatuses. Often such contributions are revealed with retrospect, or when in conversation with someone or something. Similarly, the significance of the art/science work may not be realised within the time period it was made; it may takes days, weeks, months, years, millennia, before the full significance of the work is realised. During the course of this research I have observed scientists trained in one method of observation (2D, sketches and sections, to scale, photographs and so on), looking perplexed when presented with a different form, such as 3D computed tomographies. 'I do not know what I'm looking at' may be translated to 'I'm not familiar with looking in this way'. Learning how to 'see' in another discipline requires training and time. For example, radiographers are adept at 'reading' ultrasounds which may appear as meaningless grey static to someone from another field.

Conclusions

The original proposal described and emphasised both a personally reflective narrative with material bodies, creating, reflecting, creating again, reflecting again: reflecting in practice and reflection on practice. However, as the project evolved, I realised that the disciplines of art and science each had their own preferred methodologies, and that to privilege one ran the risk of compromise in the other. The original reflective methodology also limited the interpretation of the experience of how knowledge/s are made. The reality of working in and on artistic and scientific practice has been much more complex and filled with actants /agency, than originally anticipated. Additionally, as this hybrid type of intra-disciplinary research is still relatively novel it has provided an opportunity to revisit research paradigms and examine a diffractive methodology, an intra-disciplinary research tool. The changes in this project's methodology from reflective to diffractive both recognises and addresses the fact the researcher is an entangled and responsible part of praxical intra-actions, and that diffractive analysis takes place from within, not external to the collective of human/nonhuman. This difference is important, as it expands and democratises the theoretical focus with an accountability to what is included in the agential cut, what is left out and the phenomenon (artefact) to be analysed.The phenomena resulting from this diffractive methodology are presented for analysis in the next Chapter, *poïesis*. These works of art and science are presented as two dimensional images, which makes them unique and different from the three dimensional digital volumes.

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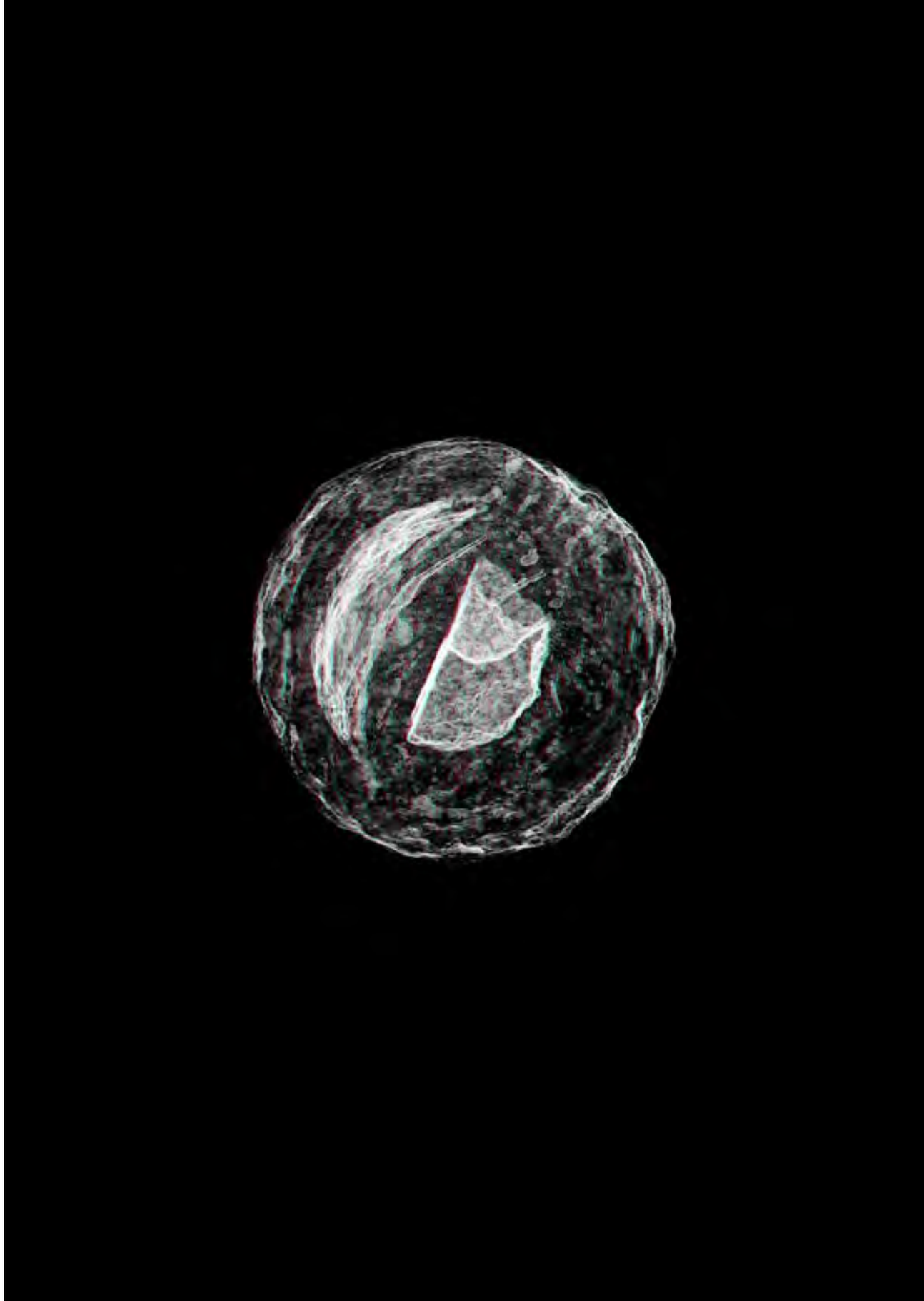
Chapter four

poïesis

The arts provide us with a way of working out an understanding of something too [new or too] complex to describe. The [entangling] of facts and intuition, perception and interpretation, documentation and comprehension may make the arts 'unscientific', but this entanglement is also absolutely essential for knowing new things. The purposes of Leonardo's mark–making was not to visualise something he knew but to know something he'd [visualised]. Art and science at their roots share [practice–based] approaches to investigation and study; the arts have more latitude to dive into the deep end and come up speculating, while the sciences, being more cautious, measure the pool drop by drop. (Knox 2015, p. 10)



(Opposite) Figure 4.1: *Unconcealedness* from Studio West End *Manifest* print exhibition (AK Milroy 2016)

Chapter four: *poïesis* – new knowledge

Introduction

In Chapter one I gave brief definitions of the terms *epistêmê, technê* and *poïesis*. In Chapter two I developed the notion of *epistêmê*, as knowledge, and proposed the Quantum|ivism research paradigm, which follows an agential realistic ethico–onto–epistemology of 'knowing in being'. This describes knowledge as a dynamic, iterative, emergent intra-action, a dance of agency, between the collective of human and nonhuman. Table 6.1 (pages 166–167) provides a summary of this paradigm's proposed philosophical orientation. Chapter three investigated *technê* within this paradigm and the pivotal role practice plays in knowledge creation. I suggested that in order to create works of art, or other new works of research, a certain level of technical ability is required in the medium of choice (art, science, language etc.) and made a distinction between art and craft by proposing that Art has *poïesis* or the ability to reveal 'knowing in being' by virtue of novelty, uniqueness or newness. Craft was described as associated with high aesthetic and utilitarian qualities, and accompanied by a high level of technical skill gained over an extended period of time, from a sustained practice using specific media or materials. This definition could be extended to include objects which have the potential to be produced as multiples and made by a number of different craftspeople. Specifically, a recipe, a brief, or a formula is followed to give a predicted or predictable result. Bolt (2004, p. 119) reading through Heidegger defines craft[person]ship as 'when the equipmental character of the activity comes to the fore' and that sign work, or the manipulation of existing signs, is 'akin to the work of the crafts[person]'. I too recognise that craft and art share contiguous borders, and that it is conceptually easy to move between these in creative activity. However, I propose *poïesis* as a differential—a transformation—that moves a work from craft to art when it happens, and conversely, in its absence from art back to craft.

Poïesis comes from the Greek ποιέω, 'to make,' and is the root of the modern word poetry. According to the Stanford Dictionary of Philosophy, it was first used as a verb, an action that transforms and continues the world. Heidegger (1977, p. 10) referred to *poïesis* as a 'bringing forth, a threshold occasion; a moment when something moves away from its standing as one thing to become another'. Barbara Bolt in *Art Beyond Representation* considers art is a 'poïetic revealing' (2004, p. 9). Thus it is an act of creativeness, initiated by curiosity, which brings into being something which has not been seen before. I also include works of science in this defintion of *poïesis* as they too have the ability to move from 'craft' (routine laboratory procedures and results) to 'science', something new or novel in the world (for example, the discovery and classification of a 'new' genus or species).

Continuing the theme of Quantum|ivism, I developed a diffractive method of critical analysis of the research results defining works/phenomena as *poïetic* revealings of capital A, Art, or capital S, Science, as new knowledge. The accompanying research statements qualify that the works have the condition of *poïesis*, of being new contributions to knowledge. The results of the research are reviewed as TOs and/or NTROs created by the agential cuts as described in Chapter three. The following questions (from Chapter one, page 22) were addressed: Is the work novel, creative? Was its final form uncertain at the outset? Was the practice systematic and planned and are the results transferrable and reproducible? With regards to the latter, to avoid confusion about art and craft, reproducibility relates to technique rather than output. For example, Impressionism was a new, *poïesis,* way of painting, however it continued to use traditional techniques of paint, brushes and canvas. In this project, the techniques utilised were new to both the art and science practices, and the visualisations unique. It is possible to use the same techniques to produce new visualisations of other objects.

Thesis Creative Component – *Aletheia* exhibition

Background

As with many innovations the following works were sparked by serendipitous meetings made possible via a separate collaboration with physicist MJ Wegener (University of Queensland) as we presented our 'Labpunk' project for the 2014 Australian Institute of Physics Congress (Wegener and Milroy 2014; Milroy *et alia* 2015). In addition to my interest in collaborating to produce wearable works of art—inspired by the conference theme 'the Art of Physics'—I also hoped to discuss modern scanning technologies with other researchers. Whilst researching reference articles for the Museum's type collection I noticed a new method of CT scanning, one which used synchrotron radiation. I wondered if this technique could work on the plant fossils I had been studying. On the first day of the exhibition at the conference, a synchrotron scientist visited the 'Labpunk' exhibition and when asked about the potential of my samples, he replied 'I'm not sure but we could do a trial or two to see'. Several emails and months later, I was fortunate enough to be advised of a day when the Imaging and Medical Beamline (IMBL) had a few hours of spare capacity in between scheduled experiments.

First Trials

April 11, 2015 the date of the first trials. As there was not a lot of lead time available I had to self-fund an overnight trip to Melbourne. When discussing which samples to take, my Queensland Museum Supervisor was not confident that the silicified Capella rainforest fruits would provide any new information, as some of these had been scanned using medical CT equipment at a local hospital (Rozefelds *et alia* 2014) however he agreed to trial this non-destructive form of investigation. I was particularly intrigued by a small round fruit from the Capella site, which resisted classification as it did not

reveal enough morphological information to allow phylogenetic classification. I also requested samples of Australian amber with inclusions, and took two, one with a small flower and one with an insect. The inclusions were both around one millimeter in size. Three silicified fossil fruits from the Capella site were also included. The smallest of these was approximately one cubic centimetre, and the largest approximately eight cubic centimetres. These were identified as 1. Small round fruit (unknown); 2. QMF 58645 *Spondylostrobus rozefeldsii* (Dettmann and Clifford, 2002); and 3. QMF 17213 *Wilkinsonia glencoensis* (Rozefelds 1990). The samples were scanned on Mode 2 of the Imaging and Medical Beamline. The inclusions in the amber proved to be too small to get any useful information. However the first live scans of the silicified Capella sample, *Spondylostrobus rozefeldsii* (Dettmann and Clifford, 2002), approximately one cubic centimetre in size, revealed detailed internal structures. Anton and I were both taken by surprise by these images—how could such delicate and soft organic features such as ovaries and vascular bundles have left their traces in the now permineralised (stone) sample? Figure 4.2 is an image from the original paper, showing the traditional means of photographic visualisation. The video 'deep time' is a contemporary visualisation of the same specimen and has been presented at several scientific conferences (see following research statement). A paper incorporating this new knowledge is in process. The scans confirmed that the fossil's genus and species allocations were appropriate, but more importantly are assisting to rule out many of the proposed family allocations, leaving a likely classification within Anarcadiaceae (Rozefelds, pers comm, 2016).

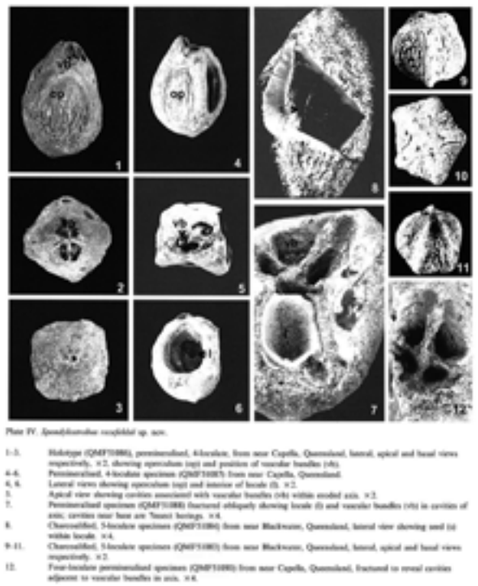


Figure 4.2: Plate IV – *Spondylostrobus rozefeldsii* (Dettmann and Clifford, 2002)

Research Statement – 'deep time' video

Research background

Visualisations of extinct species often rely on perceived relationships with extant ones by comparison with identified morphological features. In palaeontology, and specifically palaeobotany, classification is extremely difficult as it is rare to find specimens which represent the species in its totality. More often than not they are incomplete; fragments, bits of leaves or fruits, impressions are all that remain. Reconstructing a visual of what the plant could have looked like or which species it may be related to, produces what I like to term, a work of 'creative non–fiction'. The rarity of specimens also means researchers avoid destructive techniques, such as thin sectioning. Permineralised specimens are effectively organic remains turned to stone. Dettmann and Clifford (2002) identified the specimen as *Spondylostrobus rozefeldsii*, and came to this conclusion through the study of other contemporaneous types and by thorough examination of the external features—and assumptions of internal features based on these.

Research contribution

The introduction of a new method of CT scanning, using synchrotron radiation and Mode 2 of the IMBL at the Australian Synchrotron revealed, for the first time, in a non-destructive manner, delicate internal features such as ovaries and vascular traces/bundles.

950104 The Creative Arts (including graphics and craft)

930203 Teaching and Instruction Technologies

970104 Expanding knowledge in the Earth Sciences

040308 Palaeontology (including Paylnology)

19104 Visual culture

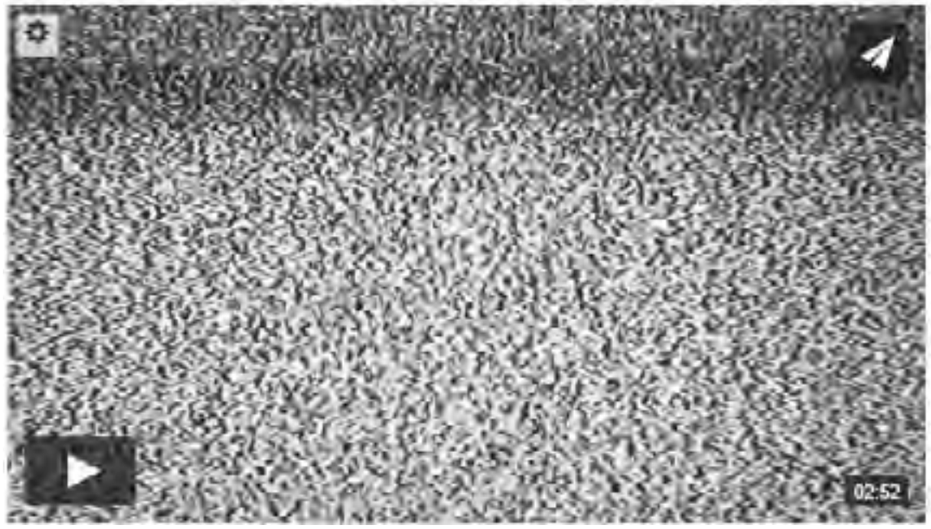
190502 Fine Arts (including sculpture and painting)

Research Significance

The video has allowed the scientific research to reach new audiences, and as such allows a safe virtual access to valuable type specimens from the Queensland Museum Collection. It has also been presented and discussed at the following conferences:

- AOFSSR 2015 (Australian Synchrotron) (Presenters: AK Milroy, AC Rozefelds, A Maksimenko)
- Creative Labs (Queensland Museum) 2015 (Presenter: AK Milroy)
- School of Education and the Arts, Central Queensland University (SEDUA) Annual Symposium 2015 (Presenter: AK Milroy)
- Queensland Museum Townsville (Presenter: AC Rozefelds)
- Smithsonian fellowship (Presenter: AC Rozefelds)
- *Aletheia* art exhibition 2016. Green Vale Gallery. (Presenters: AK Milroy, AC Rozefelds, A Holmes).
- PDU2 (Palaeontology Down Under 2) 2016 (Presenter: AK Milroy)
- APPC–AIP 2016 Conference and Congress (Presenter: AK Milroy)

Figure 4.3: *deep time* please click on image or play CD (Green Vale Studio & Gallery 2015)



Beam Time

Based on the success of the initial scans, a proposal was submitted to investigate extinct and extant botanical specimens. Five days of beam time was awarded and some forty specimens were scanned in November 2015, on Mode 3 of the IMBL at the Australian Synchrotron. The approximate value of this beam time was estimated to be around $50,000 or $10,000 per day. The team: Andrew Rozefelds, Queensland Museum, Anita K Milroy (Central Queensland University), Gary Pattemore (University of Queensland), Anton Maksimenko (Australian Synchrotron).

Each specimen was scanned and approximately 2000 scans were generated. The initial scans were recorded using a CMOS camera, which captured the images on the detector. These files were then examined for various artefacts ('zingers' and so on) and re-saved according to artefact reduction settings as deemed appropriate by the User. After some basic training in *CSIRO XLI CT* software, I began the process of artefact removal and file conversion to 32 bit TIFF files. From this point, the files were resaved as 8 bit TIFF and this format allowed their import into the software programme *Drishti*. All operations were performed on the *MASSIVE* computer cluster at Monash University. It took approximately forty hours to process the data: remove artefacts, convert from 32bit to 8bit TIFF files and then into a *Drishti* volume. The process had to be occasionally repeated due to noise or distracting artefacts. The raw data, once processed, was moved to a longer term data storage area on *MASSIVE*, however the ten terabytes of processed data was difficult to access from this slower access point, and a file transfer protocol (Filezilla) was initiated which facilitated copying the volumes to a local hard drive. This process is continuing and I have transferred the data for forty samples to date.

Most of the specimens, once set up on the scanning platform, took approximately ten to fifteen minutes to scan. Larger specimens had to be 'stitched' together after a series of scans were taken to capture the specimen in its entirety. This of course, meant larger file sizes, which are difficult to manipulate on a standard personal computer. The process was not always easy and despite the fact that the software programme *Drishti* was available via the *MASSIVE* cluster, it proved to be unreliable and difficult to progress from the volume generated to images, movies etc. After several attempts I realised that I had to upgrade my studio PC system if I was to have any chance of developing unique visualisations of the fossil and living fruits/samples. After discussions with Synchrotron staff, I decided to invest in a custom PC 'build' to allow the further development of visuals. The Graphical Processing Unit (GPU) and Random Access Memory (RAM) were the most important features and the final build has sixty-four gigabytes of RAM and twelve gigabytes of GPU power. Another important addition to the production of high resolution visuals was a 4K screen.

It is important to note that at each stage of the process, there is an intra-action between the human and nonhuman, each with its unique agency directly affecting visual outcomes. Manipulating the volumes, the scanned data, using the tools available within the software programme are unique to the researcher, and the visualisations, once developed, were often difficult to replicate. The process is extremely subjective as I was able to choose what to keep, what to delete, what colours to use, whether to shade or not shade and so on. The process was very exciting, as I did not know what to expect at all and some unusual and unpredictable phase contrasts revealed images of 'hidden' internal structures. The following video is a work in progress of one of the specimens, capturing the echoes of the internal structures. It is included in a published paper (Rozefelds *et alia*, in press) for the *Review of Palaeobotany and Palynology* and was presented at the 2016 Palaeontology Down Under (PDU2) Conference in Adelaide.

The video is deliberately slow, and with a simple music accompaniment. It captures an instant in time, an amazing agential cut—a dance of revealing, unconcealedness between human and nonhuman, some thirty million years in the making. Clicking on the image will take you to the Vimeo site, and the password is 'AKMilroy'.

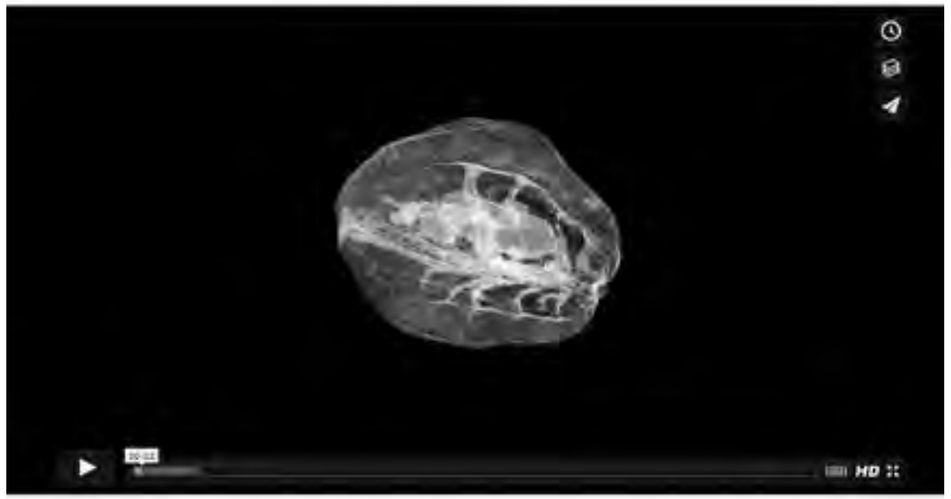


Figure 4.4: Fontainocarpa foraminata (Rozefelds, 1990) (AK Milroy 2016)
please click on image or play CD, 'Moonlight Sonata' by Kai Engel
http://freemusicarchive.org/music/Kai_Engel/Irsens_Tale/Kai_Engel_-_Irsens_Tale_-_04_Moonlight_Reprise

Other selected works from the exhibition

Following are selected items from the *Aletheia* exhibition, and are accompanied by an ERA research statement to attest to the contribution to new knowledge. The first are a series *Unconcealedness* 1–17 depicting for the first time ever, the internal morphologies of long extinct fossil fruits and some modern day comparison. It is the first time these specimens have been scanned and visualised using synchrotron radiation. These were rendered in passive anaglyph 3D, so viewers with red/cyan glasses could get some idea of 'seeing' in three dimensions, the internal structure of a long extinct specimen. Each specimen was lively and multi-lectic and some specimens revealed more than others. The 3D aspect added an element of 'low tech' interaction, to works that were produced in a 'high tech' environment. The size was deliberately personal, to encourage an intra-action between each work and the viewer. This gave the viewer an experience of revelation similar to what I had encountered when processing the data. The visualisations echoed illustration techniques of the past, with genus and species name in copperplate engraving at the top, and a list of human diffraction gratings through which support and technical assistance was provided. The final work, however, was created on my studio computer, and thus the visualisation's colours and composition were a product of my imagination, intra-acting with the specimen data and the hardware and software. Another ten specimens were visualised, however these were not chosen for inclusion in the *Aletheia* exhibition. All are scientifically significant and provide a portrait of long extinct species, in never before seen detail. They are also significant artistically, as the techniques used to acquire, process, visualise and exhibit the data are novel. To my knowledge, there has never been an art exhibition of palaeobotanical type specimens from the Queensland Museum collection prior to this event. Figure 5.

Wilkinsonia glencoensis is a coloured three dimensional gypsum powder print, produced from a model constructed through the process of photogrammetry. This is the first time a fossil fruit specimen has been visualised in this manner, in both original and massive size, and in this medium. Traditionally a plaster cast is made of the fossil, and then painted to look like the original fossil.

WG Performance, involves a 3D printer using the photogrammetry model to prints in layers over a period of four hours. During the *Aletheia* exhibition, viewers were asked which fossil was printing, and many returned several times to check the print and identify the fossil. Despite the prevalence today of personal 3D printers, I noticed that not many people had actually had the opportunity to see such a printer in operation.

Aletheia – Spondylostrobus revealed, was a collaborative effort between myself, Anton Maksimenko and Serena Coghlan. An interesting 'how to' on a facebook post prompted an experiment with perspex, an iPad and a four part video of *Spondylostrobus rozefeldsii* revealing and concealing in a continuous loop. The four sided clear perspex pyramid reflecting four images gave the impression of a 'hologram' and viewers could stand on any of the four sides to watch the performance.

Anamnesis was inspired by botanical illustrations and printmaking—and its form, an Artists' book, invites the viewer to travel back through deep time. The line drawings etched onto clear perspex are the ghosts of long past environments. Twenty five images make up the pages in the book, and each of these was relief printed onto Magnani Anigonni 425 250 gsm paper.

The Crowned Jewels was inspired by the notion of holotypes as these are often described as the 'jewels in the crown' of museum collections. The crown has been forged from titanium, and selectively anodised with resists, using line drawings of the holotypes as inspiration and pattern. A sterling silver band is riveted to the piece, with the genus and species names of the holotypes etched into it.

Carbon copies are 3D printed models of three of the fossil fruit, Pleiogynium parvum, Pleiogynium wannanii and Wilkinsonia glencoensis. The 3D volumes were created by CT scans and photogrammetry. Collaborator Saeed Dadvar from Deakin University has created a unique cellulose based powder for printing, which is fired in a kiln with argon gas at 1100 degrees celcius. The final product is pyrolised, black and extremely tough and durable. I used my 3D models in this material to produce experimental and wearable works of art for the APPC–AIP 2016 Plenary speaker gifts.

Figure 4.5: Dr Ashley Holmes opening Aletheia exhibition – Saturday 2nd May 2016 @ Green Vale Gallery (On-line photography 2016)

Research Statement – *ALETHEIA* Exhibition

Research background

The following works have been selected as exemplars from the Aletheia Exhibition held at Green Vale Gallery, Brisbane in May 2016. Over one hundred and twenty guests attended the Vernissage preview event and included academics, industry professionals, artists, scientists and members of the general public. The exhibition remained open to the public for a period of seven days.

Unconcealedness 1–17
Wilkinsonia glencoensis
3D Performance piece
Aletheia—Spondylostrobus revealed
Anamnesis
The Crowned Jewels
Carbon Copies

Research contribution

950104 The Creative Arts (incl. Graphics and Craft)
930203 Teaching and Instruction Technologies
970104 Expanding knowledge in the Earth Sciences
040308 Palaeontology (including Paylnology)
19104 Visual culture
190502 Fine Arts (including sculpture and painting)

Research Significance

This is the first time that palaeobotanical types from the Queensland Museum have been presented in an interactive art exhibition. The specimens themselves are rare, valuable and fragile and only accessible to bona fide researchers. The art exhibition presented the specimens in a new and creative manner, demonstrating both artistic and scientific innovation. Artistic practice–based innovation was demonstrated by the use of synchrotron radiation and associated hardware and software to produce a variety of visualisations. Scientific innovation was demonstrated by revelations of never before seen internal morphologies. The use of high level science in the production of exhibition and digital performance pieces was appreciated and subsequently chosen to open, exhibit and provide Plenary speaker gifts at the APPC–AIP 2016 conference and congress in Brisbane. It is anticipated that the *Aletheia* exhibition will also be showcased at the Australian Synchrotron in 2017.

Figure 4.6: Aletheia invitation front (above), reverse (below) (AK Milroy 2016)

Unconcealedness 1–17

© AK Milroy 2016 Digital works on paper 210mm x 297mm

Unconcealedness I – Pleiogynium wannanii exterior
Unconcealedness II – Pleiogynium wannanii interior i
UnconcealednessIII – Pleiogynium wannanii interior ii
Unconcealedness IV – Pleiogynium wannanii interior base
*Unconcealedness V – Pleiogynium timorense exterior**
*Unconcealedness VI – Pleiogynium timorense interior i**
*Unconcealedness VII – Pleiogynium timorense interior ii**
Unconcealedness VIII – Wilkinsonia glencoensis interior i
Unconcealedness IX – Wilkinsonia glencoensis interior ii
Unconcealedness X – Pleiogynium parvum interior i
Unconcealedness XI – Pleiogynium parvum interior ii
Unconcealedness XII – Pleiogynium parvum exterior
Unconcealedness XIII – Small round fruit interior
Unconcealedness XIV – Small round fruit exterior
Unconcealedness XV – Fontainocarpa foraminata interior
Unconcealedness XVI – Fontainocarpa foraminata exterior
Unconcealedness XVII – Fontainocarpa foraminata

Inspiration:

Type fossils from the Queensland Museum collection and extant* specimens from the Queensland Herbarium.

Materials:

Reconstructed CT volumes from Mode 3 of IMBL at the Australian synchrotron and 3D volume data. Drishti and Adobe Photoshop software. Personal computer, Canon printer, Epson matte photo paper. 3D red/cyan glasses. Red perspex frame, clear perspex cover.

Method:

Fossilised and living fruits were scanned at the Australian Synchrotron on mode three of the IMBL beam line. Data processing to Drishti volumes via the MASSIVE cluster of computers. At each stage of this process the visualising artist was able to make creative decisions and interpret how the specimen might best be visualised—from positioning the specimen on the scanning table, to the number of scans, the energy of the beam and so on. Similarly, interpreting the raw data and deciding what to leave in, or take out—were these odd marks scanning artefacts or vital information?—had repercussions for the final image. Processing as 3D volumes in Drishti also enabled the artist to interpret the phase contrast, to reveal the internal structures, to enhance, to colour, to shadow and even to decide to layer with red and cyan to make the images three dimensional with the use of red-cyan 3D glasses. The final images are the artist's unique and novel interpretations of evolution and extinction and revealing; of new knowledge in both art and science as works of creative non-fiction.

Technical and Support:

A Maksimenko, AC Rozefelds, AM Holmes, DL Brien, C Hall, K Spring.

Pleiogynium wannanii

AC Rozefelds, ME Dettmann, TH Clifford, 2014

AK Milroy

Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Pleiogynium wannanii

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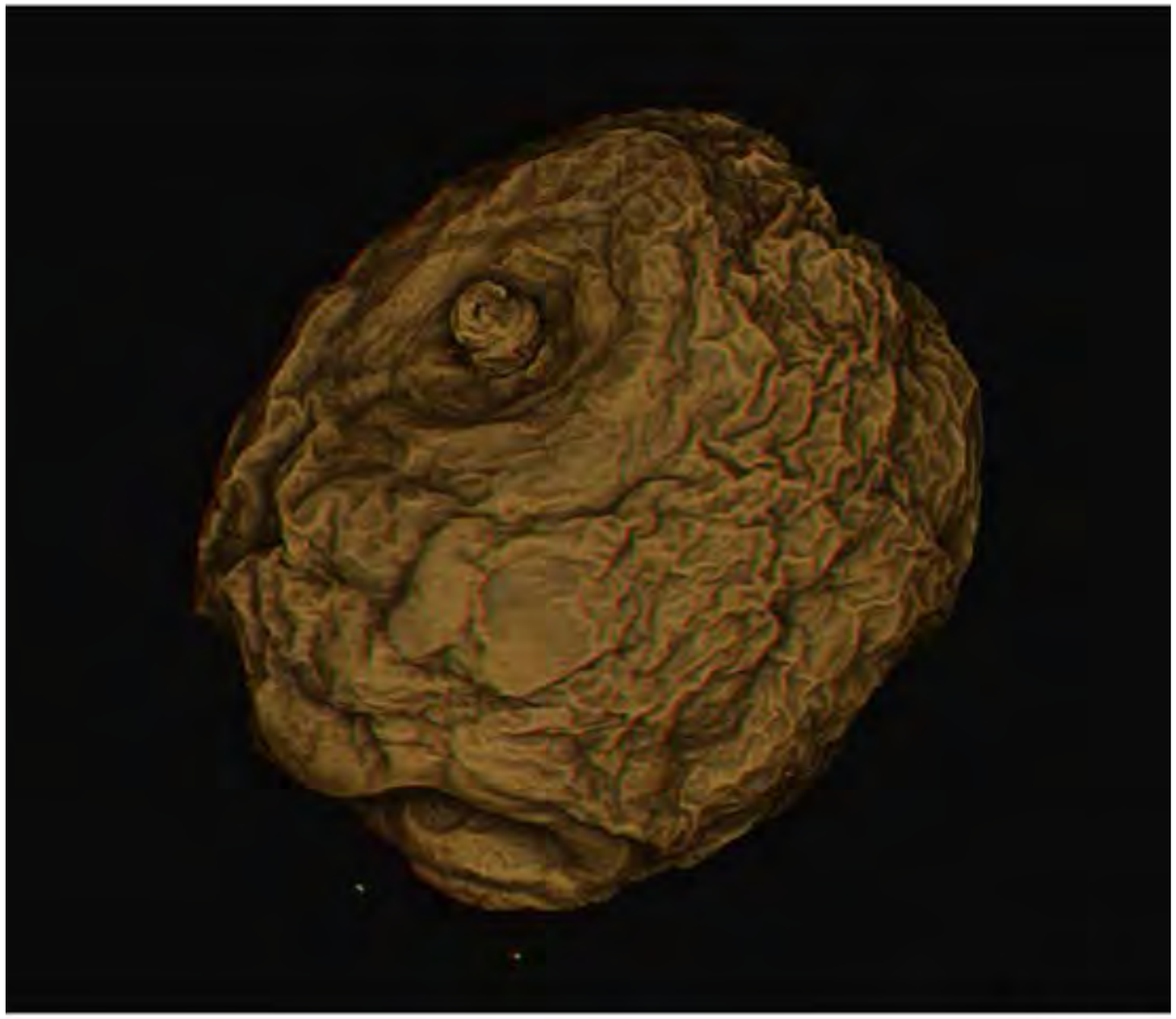
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Pleiogynium timorense

(DC de Candolle) PW Leehouts 1952



AK Milroy

Artist

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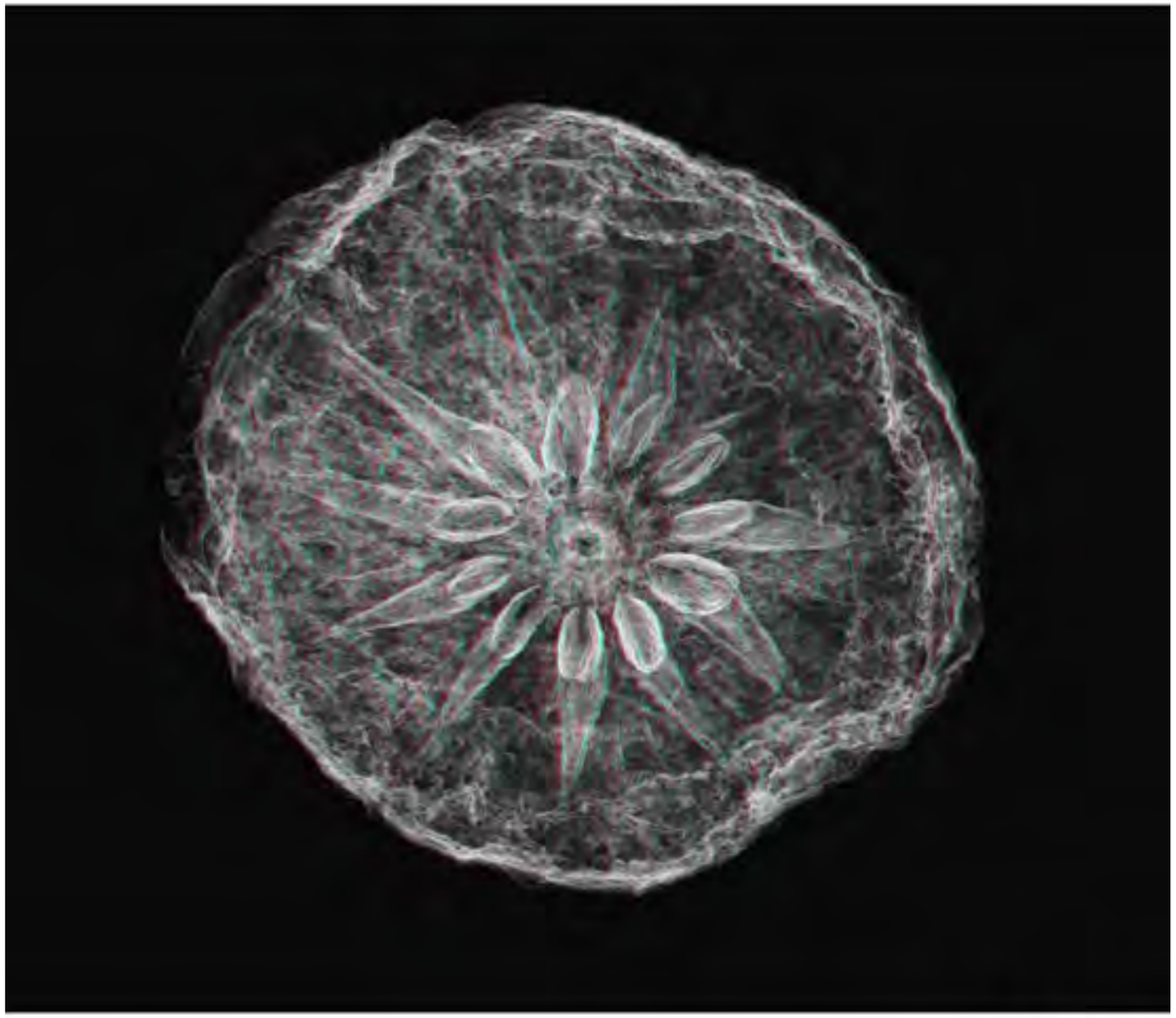
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Pleiogynium timorense

(DC de Candolle) PW Lechouts 1952



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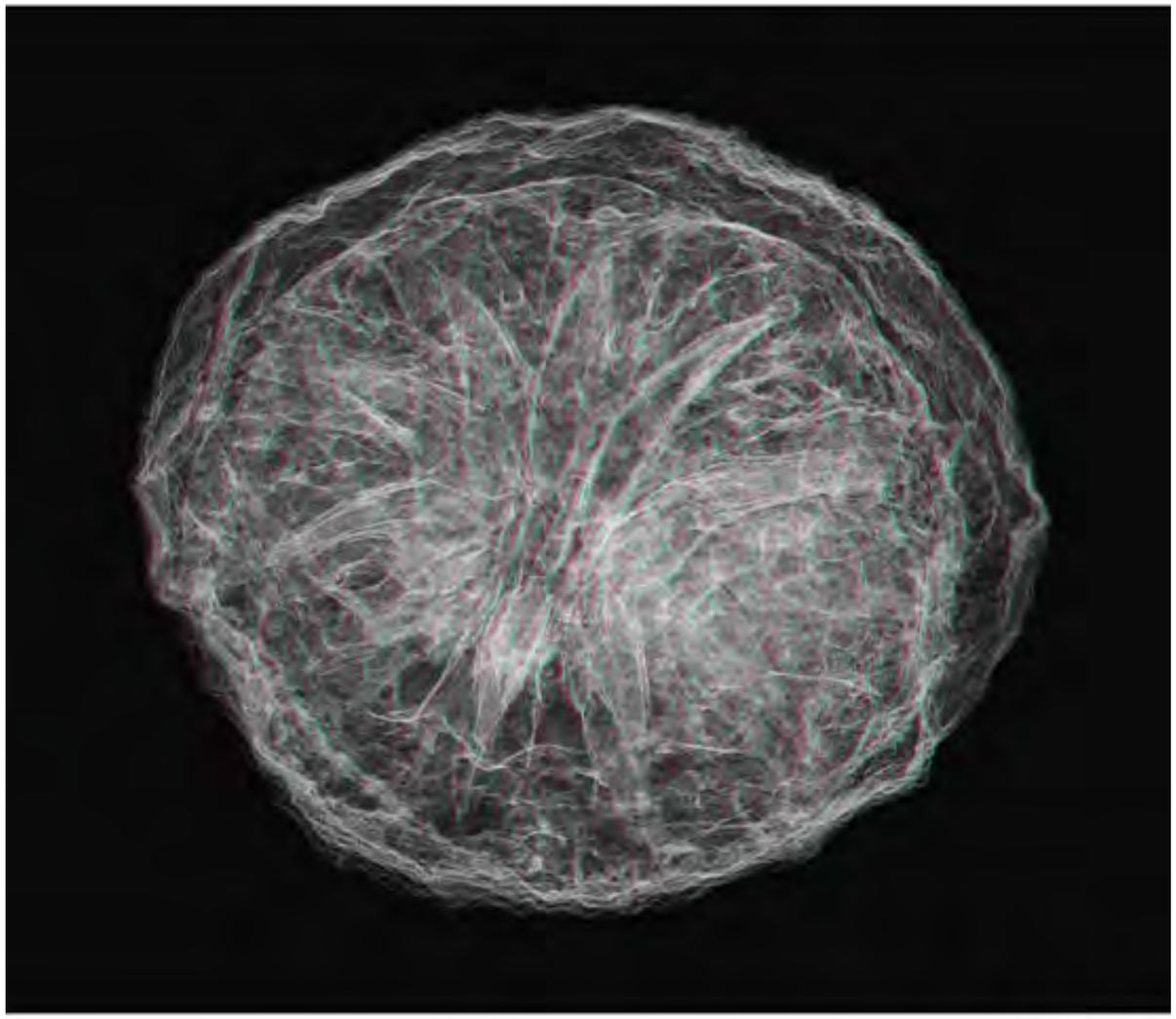


AK Milroy

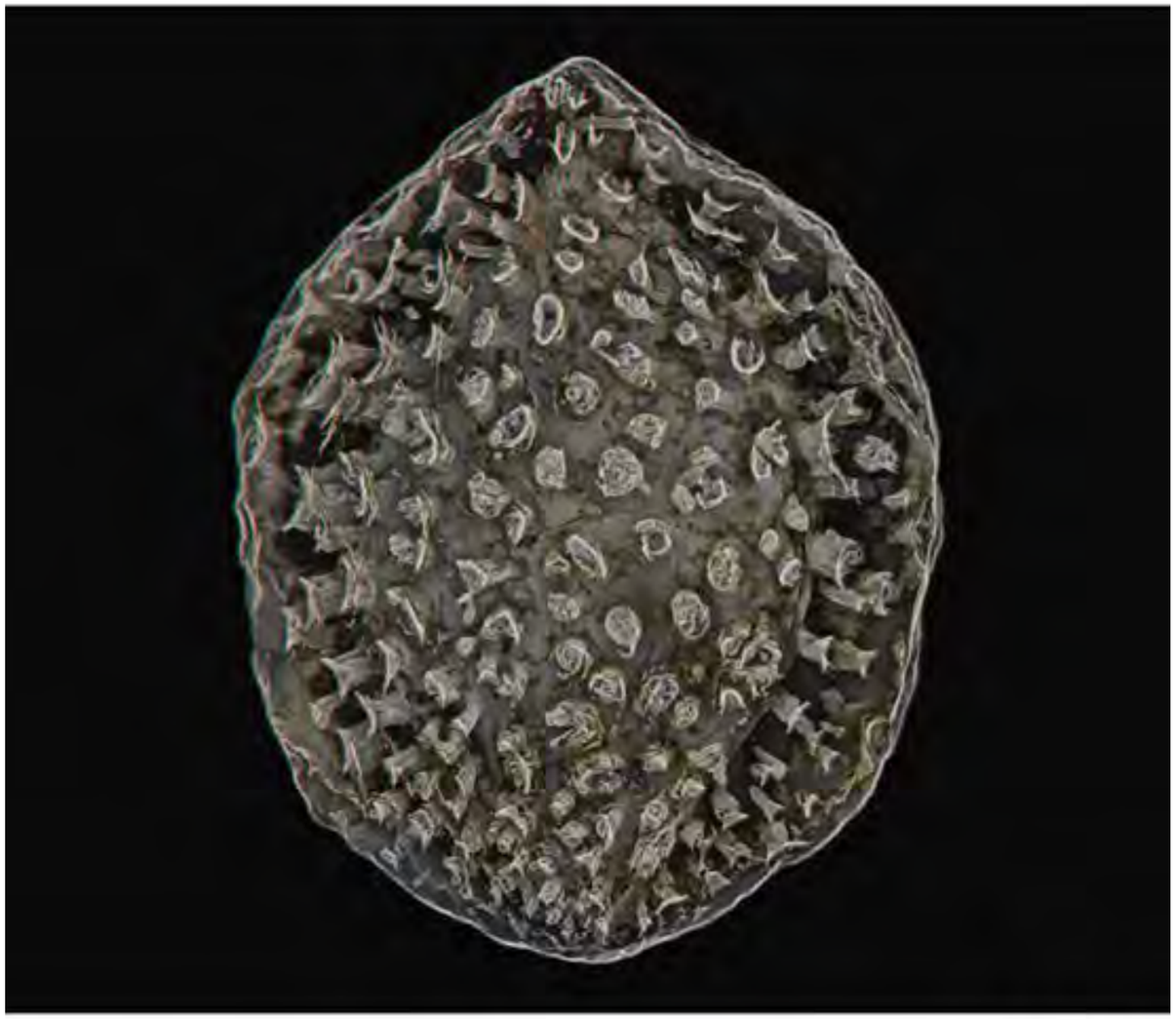
Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Wilkinsonia glencoensis

AC Rozefelds 1990



AK Milroy

Artist

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AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Wilkinsonia glencoensis

AC Rozefelds 1990

AK Milroy

Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Pleiogynium parvum

AC Rozefelds, ME Dettmann, TH Clifford, 2014

AK Milroy

Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Pleiogynium parvum

AC Rozefelds, ME Dettmann, TH Clifford, 2014

AK Milroy

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AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Pleiogynium parvum

AC Rozefelds, ME Dettmann, TH Clifford, 2014

AK Milroy

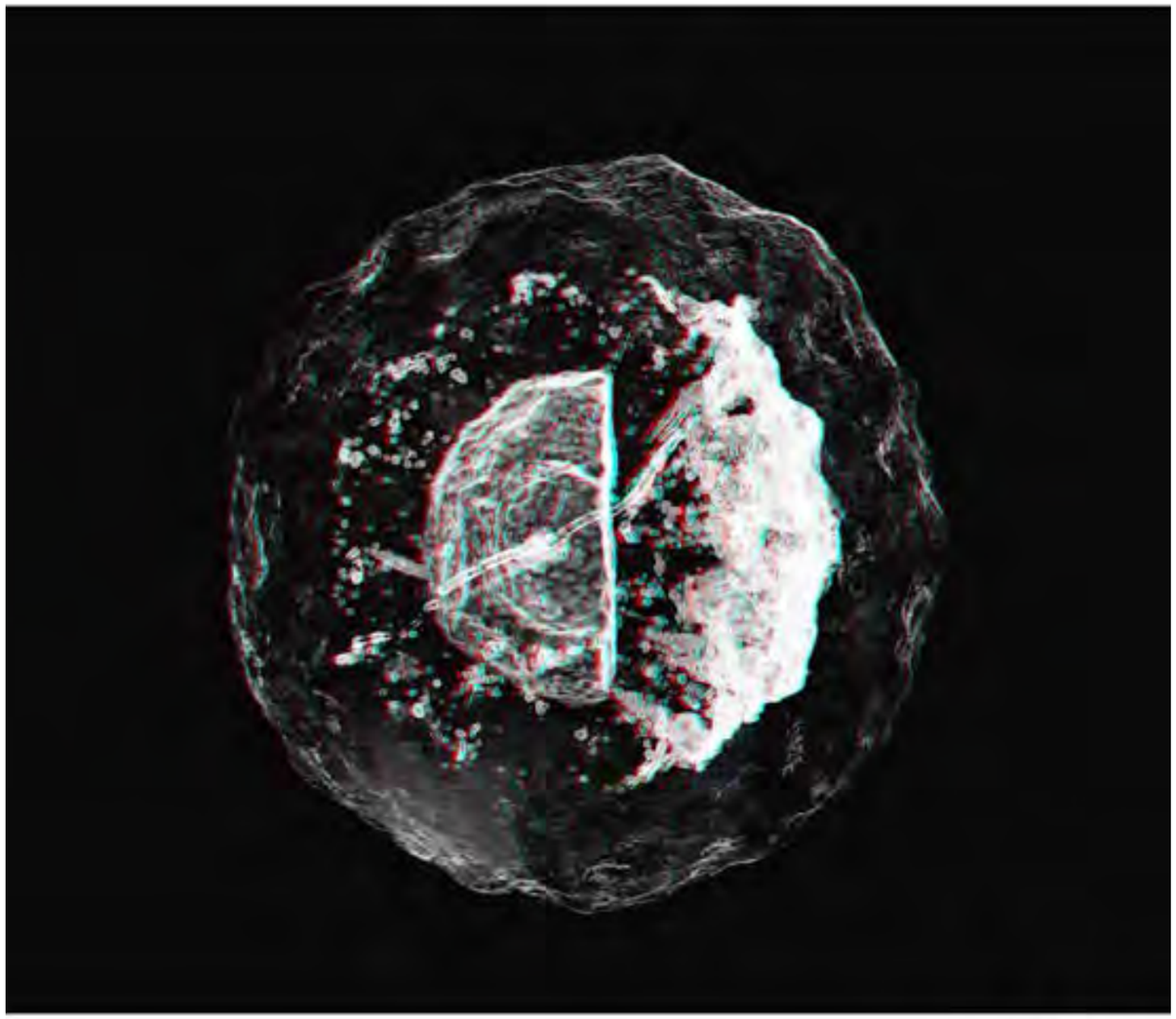
Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Small round fruit

Capella region, central Queensland



AK Milroy

Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Small round fruit

Capella region, central Queensland

AK Milroy

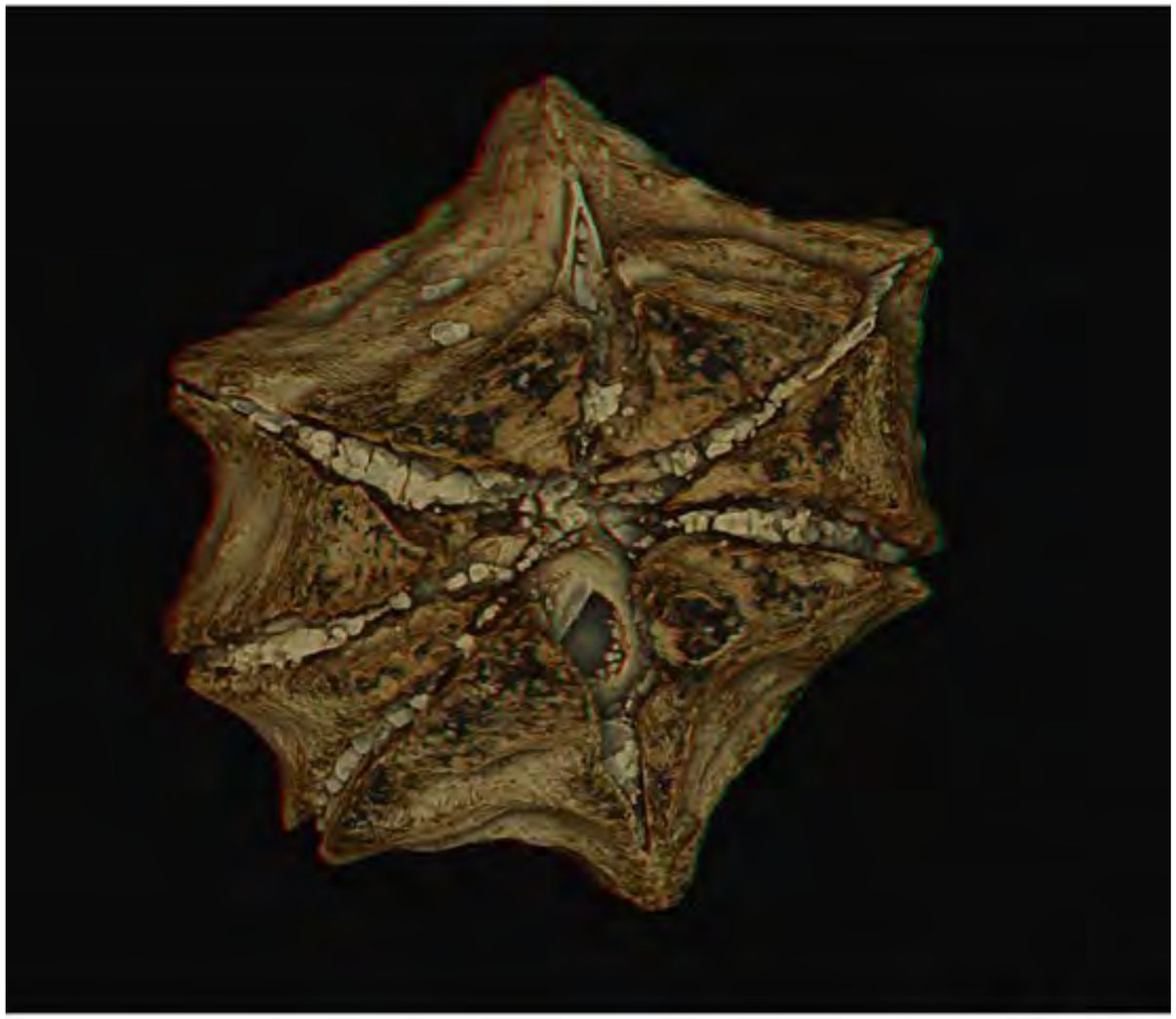
Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Fontainocarpa foraminata

AC Rozefelds 1990



AK Milroy

Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Fontainocarpa foraminata

AC Rozefelds 1990

AK Milroy

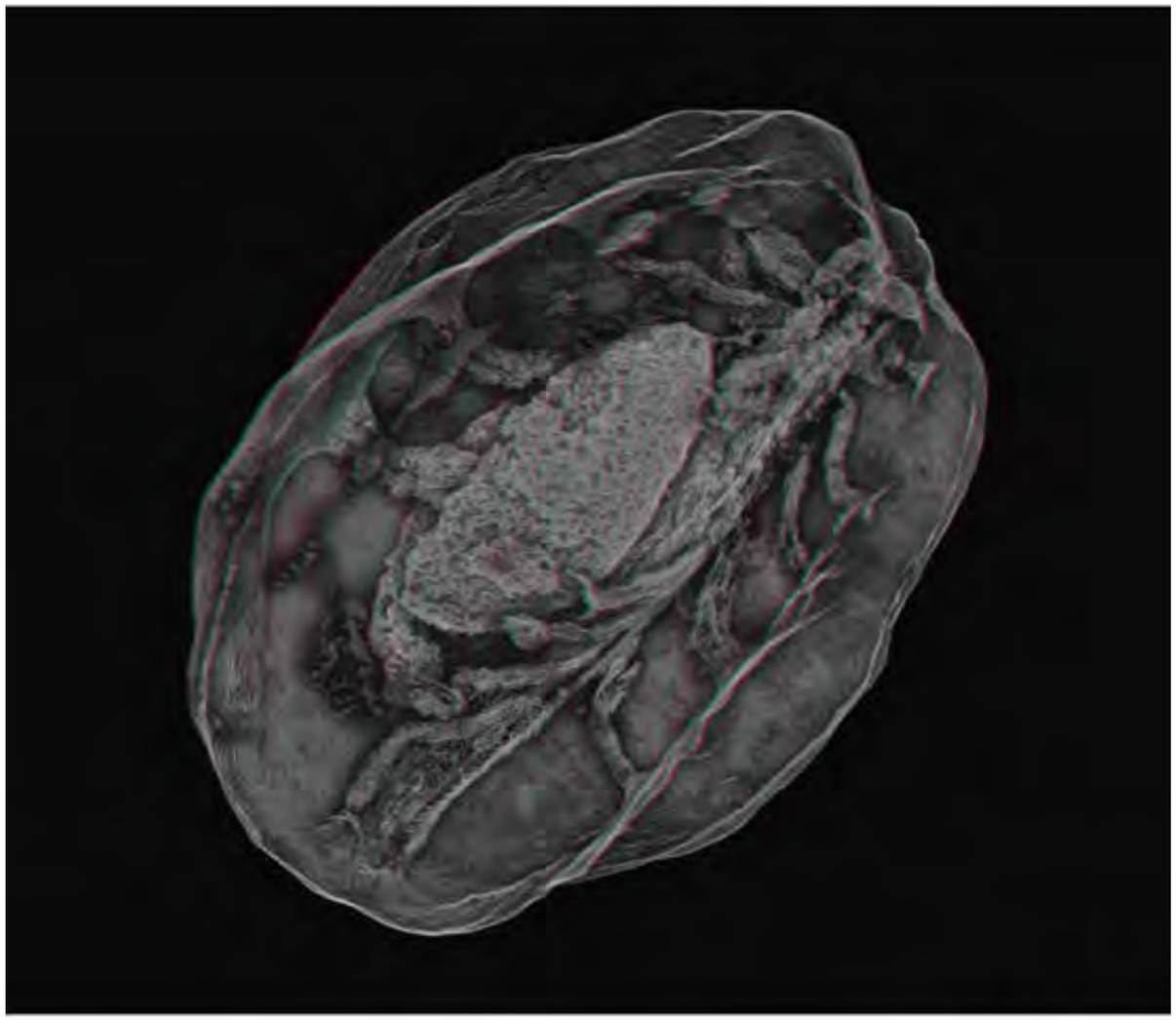
Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Fontainocarpa foraminata

AC Rozefelds 1990



AK Milroy

Artist

A Maksimenko
AC Rozefelds
AM Holmes
DL Brien
C Hall
K Spring

Technical and support

Wilkinsonia glencoensis – time scaled

© AK Milroy 2016 Gypsum powder, inkjet print. Dimensions: large: 36cm x 28cm x 10cm, small 5cm x 3.5cm x 1.5cm.

Inspiration

Type specimen QMF 17213 Wilkinsonia glencoensis (Rozefelds, 1990). A Cenozoic silicifed fossil fruit from the Capella region in Central Queensland. Related to Athertonia diversifolia (Atherton Oak). The aim was to create a virtual 3D model, and a 3D printed 'sculpture' of the fossil using new techniques (Milroy *et alia* 2015). Traditionally, museum collection models are made by plaster and hand painted.

Materials

3D inkjet gypsum powder print, build material VisiJet PXL[i]. Perspex. Tablet.

Method

The 3D model was constructed using a DSLR camera and Agisoft Photoscan for the photogrammety. See Milroy et al (2015) article in JNSI. Printing by Ellipsis Media[ii] at the University of Southern Queensland on a ProJet CJP660 Pro printer[iii]. The virtual model was displayed using Meshlab software on a tablet.

Technical and support

AC Rozefelds, R Kenneally, S Coghlan, AM Holmes, S Hocknull, K Spring, D Lewis.

i http://www.3dsystems.com/sites/www.3dsystems.com/files/22-83101-s12-01-asds_ghsenglish-australiavisijet_pxl_colors.pdf
ii http://www.ellipsismedia.com.au/
iii http://www.3dsystems.com/3d-printers/professional/projet-660pro

Figure 4.24: Dr Andrew Rozefelds with 3D gympsum powder print models of *Wilkinsonia* (AK Milroy 2015)

WG performance

© AK Milroy 2016 Blue PLA 1.75mm filament dimensions

Inspiration:

Type specimen QMF 17213 Wilkinsonia glencoensis (Rozefelds, 1990). A Cenozoic silicifed fossil fruit from the Capella region in Central Queensland. Related to Athertonia diversifolia (Atherton Oak). The aim, to visualise in real time, a three dimensional fossil specimen.

Materials:

3D printer, blue PLA filament 1.75mm diameter.

Method:

The original photogrammetry 3D model was decimated and saved as *.PLY file. Printing was calibrated using *Cura* software. Printing took approximately four hours.

Technical and support:

S Coghlan.

Figure 4.25: WG Performance (AK Milroy 2016)

Aletheia – *Spondylostrobus* revealed

©AK Milroy 2016 Acetate, perspex, ipad, premier pro movie. Dimensions

Inspiration:

Type specimen QMF 58645 *Spondylostrobus rozefeldsii* (Dettmann and Clifford 2002) from the Queensland Museum Collection and serendipitous associations and 'eterdodynic conversations' resulted in this multi-media work which uses a modern ear optical illusion to produce a faux 'hologram' of this long extinct rainforest fruit. Travel back and forth thirty million years with Spondylostrobus.

Materials:

Acetate, perspex, ipad, looping video of fossil fruit.

Method:

Re-formatting the original animation of *Spondylostrobus rozefeldsii* to reflect onto the four sides of the pyramid, and matching the proportions of the iPad screen.

Technical and support:

A Maksimenko, S Coghlan, J Wilkinson.

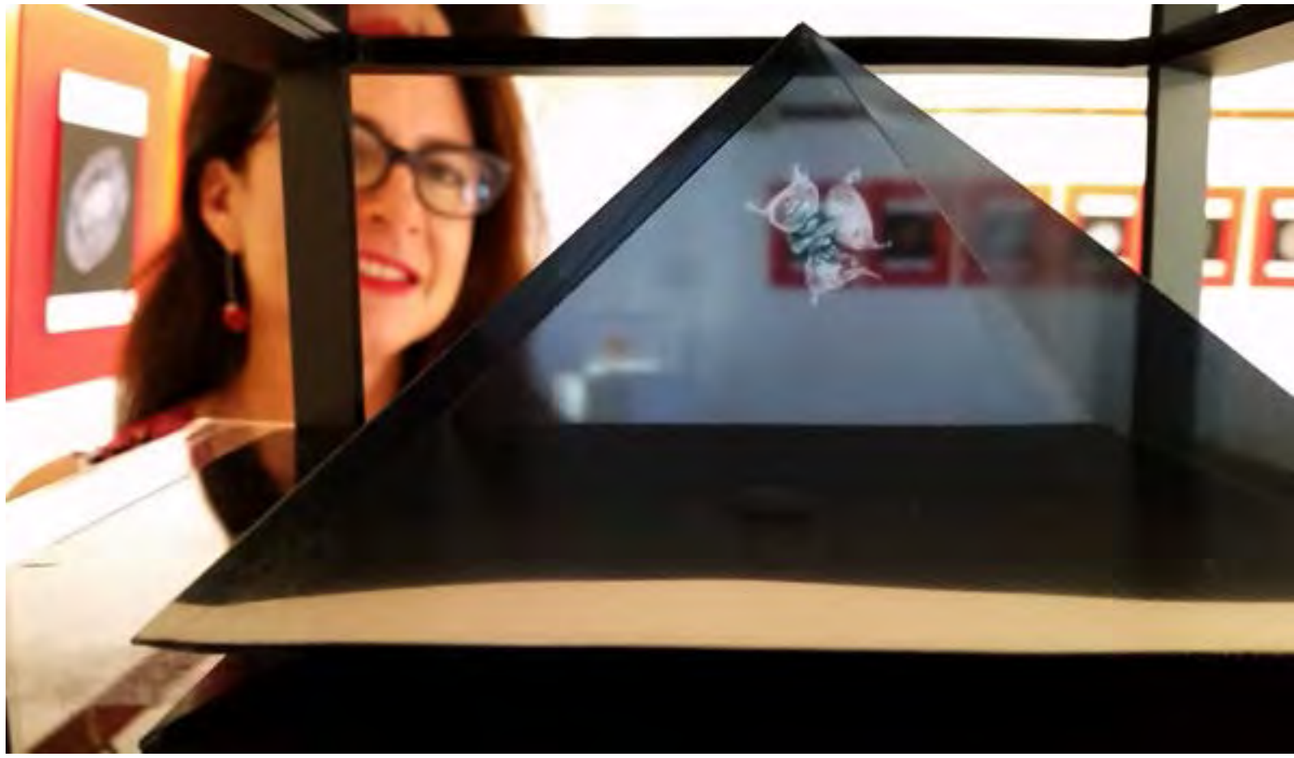


Figure 4.26: Aletheia — *Spondylostrobus* revealed (Milroy, Maksimenko & Coghlan 2016)

Anamnesis

©AK Milroy 2016 Perspex, Magnanni Anagoni 250gsm paper. Dimensions

Inspiration

Palaeo–botanic holotypes from the Queensland Museum Collection:

QMF 17411 *Sarcopetalum jackieae* (Rozefelds 1991)

QMF 32157 *Dawesia cupulata* (Clifford 1995)

QMF 32478 *Gingko wintonensis* (McLoughlin, Drinnan and Rozefelds 1995)

QMF 33259 *Pleuromeia reniformis* (Cantrill and Webb 1998)

QMF 32543 *Phyllopteroides macclymontae* (McLoughlin, Drinnan and Rozefelds 1995)

QMF 33261 *Helicorhiza duckworthensis* (Cantrill & Webb 1997)

QMF 18088 *Elaeocarpus peterii* (Rozefelds and Christophel 1996)

QMF 1582 *Asterotheca hillae* (Walkom 1924)

QMF 17196 *Pleiogynium parvum* (Rozefelds, Dettmann and Clifford, 2014)

QMF 12324 *Cidarophyton rewanese* (Cantrill & Webb 1998)

QMF 18315 *Millerocaulis donponii* (Tidwell & Clifford 1995)

QMF 17170 *Palissya ovalis* (Parris, Drinnan & Cantrill 1995)

QMF 967 *Nilssonia mucronatum* (de Vis) Walkom 1924, 1926

QMF 16768 *Elaeocarpus cunningii (*Rozefelds 1990)

QMF 6993 *Gliechenites wivenhoensis* (Herbst 1974)

QMF 9509 *Austrosequoia wintonensis* (Peters & Christophel 1978)

QMF 16735 *Fontainocarpa foraminata* (Rozefelds, 1990)

QMF 15440 *Elaeocarpus spackmaniorum* (Rozefelds 1990)

QMF 13401 *Cyclostrobus clavatus* (Cantrill and Webb 1998)

QMF 16122 *Cissocarpus jackesiae* (Rozefelds 1990)

QMF 16183 *Grammatocaulis donponii* (Tidwell and Rozefelds 1990)

QMF 17808 *Yulebacaulis normanii* (Tidwell and Rozefelds 1991)

QMF 7075 *Donponoxylon jacksonii* (Tidwell, Brooks and Wright 2013)

QMF 17213 *Wilkinsonia glencoensis* (Rozefelds, 1990)

Materials and method

The holotype specimens were photographed, and from these scale drawings were made. These were converted to digital files, and then vector images and etched onto perspex plates. Twenty-four of the plates were relief rolled with Charbonnel black ink, and the cover sheet printed intaglio. Each plate took approximately one week from photography to line drawings to etching to printing. After each plate was printed the perspex was cleaned and formed into a concertina Artists' book form.

Figure 4.27: *Anamnesis*, Artists' book: perspex, hand drawings laser etched and printed (AK Milroy 2016)

The Crowned Jewels

© AK Milroy Titanium, sterling silver Dimensions 56cm diam x 15cm

Inspiration

Inspired by the palaeobotanical holotypes in the Queensland Museum Collection. Traditional techniques of visualisation by line drawings subsequently used as design elements and resists.

Materials

Titanium, sterling silver, anodising circuit, resists.

Method

Titanium and sterling silver construction. Experimental development of forming titanium and selective colouration by anodising with resists. The sterling silver band was hand forged and genus and species names were etched in nitric acid.

Technical and Support

S & E Rothbrust

Figure 4.28: *The Crowned Jewels*, Hand formed titanium, selective anodising, etched sterling silver band (AK Milroy 2015)

Carbon Copies

© AK Milroy 2016 Sterling silver, 18kt gold, 3d Carbon prints, nickel silver
4cm x 3cm x 1cm (*Wilkinsonia*) 2.5cm x 2.5cm x 1cm (*Pleiogynium*)

Inspiration

Gifts for Plenary speakers at APPC–AIP 2016 conference and congress, carbon composite 'regenerated' palaeobotanical fossil types**:**
QMF 17213 *Wilkinsonia glencoensis* (Rozefelds 1990)
QMF 17196 *Pleiogynium parvum* (Rozefelds, Dettmann and Clifford 2014)
QMF 57033 *Pleiogynium wannanii* (Rozefelds, Dettmann and Clifford 2014)

Materials

Sterling silver, 18kt gold, carbon composite powder, nickel silver.

Method

The 3D models used in the jewellery items are carbon composite 'regenerated' palaeobotanical fossil types fabricated by 3D printing. Models by AK Milroy. Carbon materials and 3D printing by Saeed Dadvar, Rangam Rajkhowa, Xungai Wang of Frontier Materials, Deakin University, Melbourne.

Technical and Support

M Wegener, AC Rozefelds, A Holmes, D Lee Brien, S Dadvar, R Rajkhowa, Wang X.

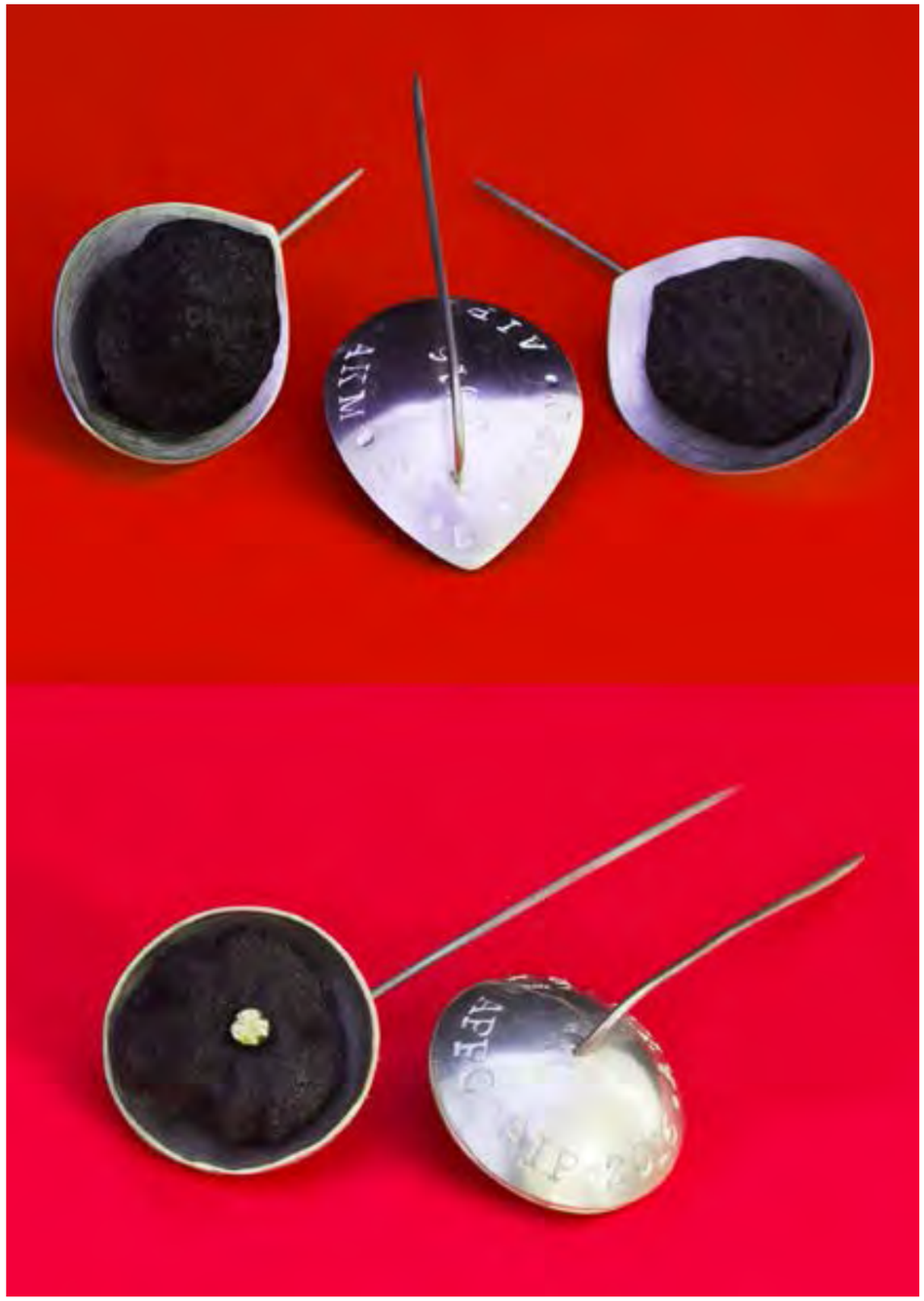


Figure 4.29: 'Carbon Copies' *Wilkinsonia* and *Pleiogynium* in 3D cellulose/carbon print, sterling silver, 18kt gold. (Milroy & Dadvar 2016)

Conclusions

The artefacts of creative non-fiction presented in this chapter are positioned as works of both Art and Science. The two practices have entangled and intra-acted to produce a body of work that has multiple applications, as aesthetic objects, communication devices, education and visualisations for inclusion in scientific publications. These intra-actions have allowed rare palaeo–botanical specimens to be visualised digitally using synchrotron radiation and specialist hardware and software. The work of art contributes to the scientific practice by democratising the collection, presenting the specimens in new and innovative ways, and introducing new audiences to the study of palaeobotany. The work of science has contributed to the art practice by introducing new technologies, participants and specimens for inspiration. The visualisations presented in this chapter highlight extinct and extant fossil plants and allow new comparisons of both classified and yet to be classified specimens. The following chapter will deal briefly with the concept of time through theories of evolution and extinction.

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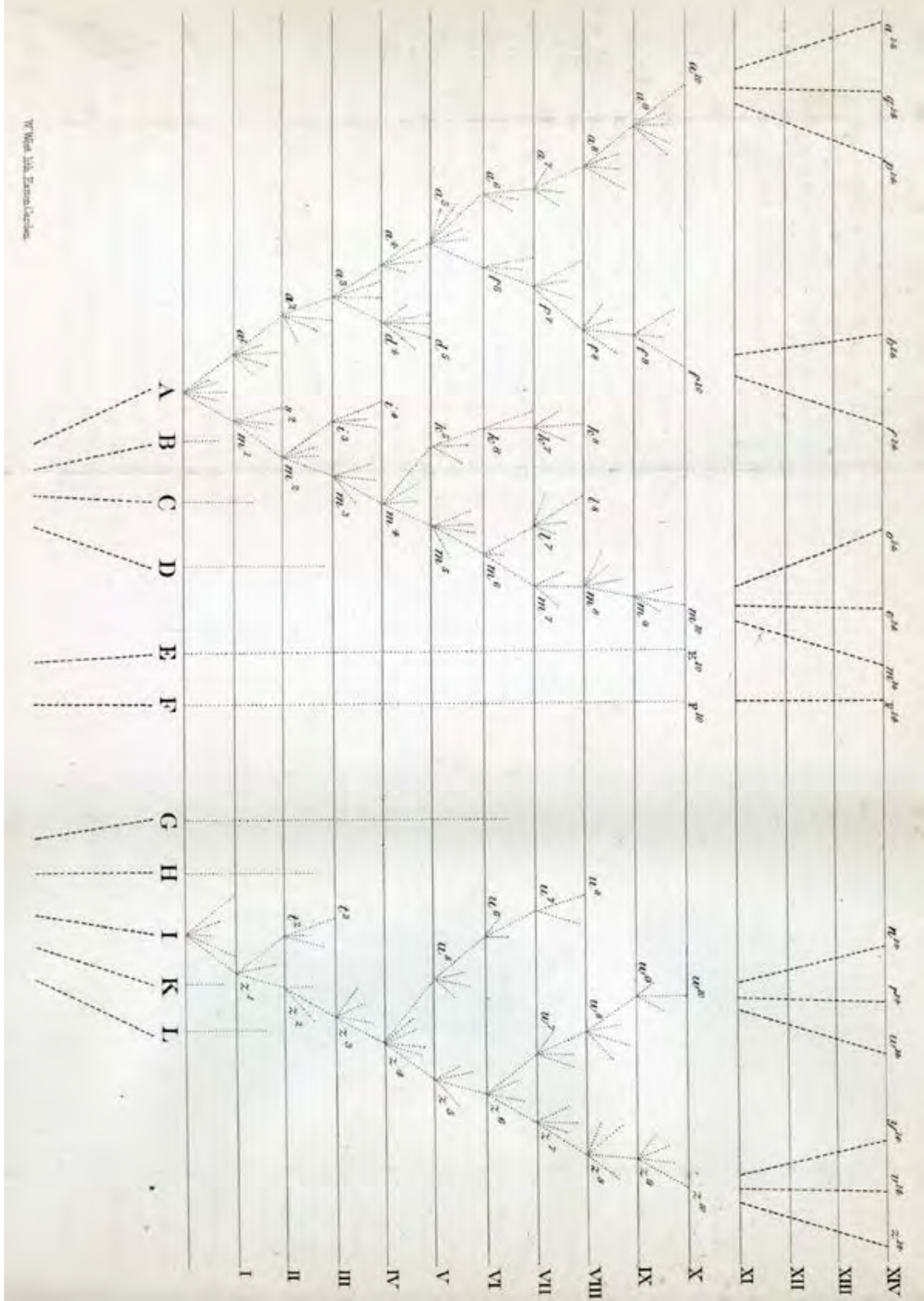
Chapter five

evolution and extinction

Time is real, its characteristics are unique, its effects cannot be explained in other terms. It distinguishes itself from space, from objects, from its multiplicitous representations in mathematical, formulaic or geometrical terms, or in the images and representations provided in the visual arts, through effects that are not spatial, objective, measureable or quantifiable, although it has no language of its own, no models on which to base itself except those provided by the impulse to spatialization. (Grosz 2004, p. 249)

Fundamentally, time does not exist. Time exists for us. Up and down exists for us but there's no up and down in the universe. The idea that time is not integral to the structure of reality is not something everybody agrees with, but many people are working on it. It might be true, and this would mean that the universe is something very different from what we think. (Rovelli 2016, p. 45)



(Opposite) Figure 5.1: Facsimile of Darwin's tree of life: from *The origin of species* 1859 (Darwin 1968, pp. 160–161)

Chapter five: evolution and extinction

The introductory quotations set the scene for a complex topic—time. In this chapter I have briefly summarised the concepts of evolution and extinction, whilst concurrently acknowledging contemporary thought and theory in relation to the notion of time. I realise that time is a research subject in its own right and hope to revisit it in future projects. However, I will re-visit the notion of 'deep time' within the framework of evolution and extinction, to compare it to the conceptualisation of time within the Quantum|ivism paradigm. In doing so, I examine the 'timely' characteristics of works of art and science, as memes, and the metaphorical parallels these have with their biological counterpart, genes.

Historian, geologist and academic MJS Rudwick (2005) and palaeontologist, evolutionary biologist and historian Stephen Jay Gould (1987) have both written similar accounts about the 'construction of time' in their description of geohistory. Both acknowledge the revolutions, or paradigm shifts (to use Kuhn's 1962 definition of the term) that have spurred a 'quantum leap' in human knowledge and consciousness and which have de-centered the human from its place in the universe. Gould (1987) notes that there was one revolution which was not been given its due and that is the discovery of 'time'. He asserts that this began with the birth of geology and manifested significantly from the seventeenth century onwards. Both Gould and Rudwick recognise that geology brought into focus, for the first time, the magnitude of the geological time scale and the new notion of a prehuman history. This is exemplified by the work of French naturalist, and oft referred to as 'father of palaeontology', Georges Cuvier (1769–1832). He and his successors hoped to 'burst the limits of time' by making the prehuman history knowable to human beings in the present, just as physicists had already 'burst the limits of space' by making the movements of the whole solar system knowable (Rudwick 2005). The scientific focus turned from the whole universe to the earth, as geologists began to unravel its immensely long and complex history.

Rudwick and Gould, in their own narratives, both pay attention to the practices and the practitioners, examining in detail how they arrived at their conclusions, 'the ways in which specific concrete claims to reliable knowledge were formulated, argued over, and consolidated or rejected in the course of reconstructing geohistory during the age of revolution' (Rudwick 2005, locn 263). And both writers individually confirm the knowledge inherent in images or visualisations. Gould writes, with reference to Rudwick (1976):

> ... if texts are unified by a central logic of argument, then their pictorial illustrations are integral to the ensemble, not pretty little trifles included for aesthetic or commercial value. Primates are visual animals and illustration has a language and set of conventions all its own ... but scholars have been slow to add another dimension to their traditional focus upon words alone (Gould 1987, p. 18)

Gould also makes the observation that in nineteenth century Britain it was the 'gentlemanly elite' who gained power and subsequently imposed which sciences were fit for 'advancement' and that this in turn generated a body of English speaking intellectuals, and the start of the 'two cultures' of scientists and non-scientists. CP Snow's Rede lecture of 1959 documents this split in intellectual life, elements of which continue to this day (Snow and Collini, 1998).

I would like to reframe these accounts of deep time using as a 'measurement apparatus' the collective of geohistory. In doing so, I observe that these individual accounts could be regarded as diffractive analyses of the genesis and development of 'deep time'. A characteristic of a diffractive methodology includes observing all aspects of practice, and I notice axiological considerations, for example the 'intellectual elite' of the time—who were described as mostly white, male, and educated and who decided what would be taken seriously and what would not. However, Gould (1987) emphasises that it is what is taken for granted that deserves the most ethical scrutiny. He also summarises how religious and scientific practices and knowledge claims have interacted in ways to cause significant variation according to place, time and social location. Gould concludes that the science of geology revolutionised the widely held view that the earth was not stable nor bound by unchanging 'laws of nature' but is a product of nature's own history[i]. He labels these 'maps of knowledge' as human constructions, embedded in the 'contingencies and specificities' of history. Further, Gould explains that geology owes its success to a 'transformation of practice' (1987, p. 154) by using fossils as the key to ordering by age. For example, early geologists such as James Hutton and Charles Lyell could grasp the concept of deep time though could not establish a scale, or record the agential cuts (Barad 2007), within this seeming 'infinitude' until the fossil record established criteria of uniqueness for each moment of geohistory. The transformation in practice, was from thinking of time as a mineral 'cycle' of geometric logic, to seeing time as an 'arrow'. It was this revolutionary thought that initiated the concept of geological time—by following the contingent history of organisms. Gould discusses taxonomic classification, in which characteristics are treated as *homologous*—the retention of features shared by common ancestry along time's arrow of genealogy; or *analogous*—active evolution of similar forms in separate lineages as evidence of time's cycles. Taxonomists separate homology from analogy and base classifications on homologies alone, 'for taxonomies record pathways of descent' (Gould 1987, p. 198). This historicization of the earth, translated through the science of geology, was soon extended to other parts of the natural worlds, specifically in Darwin's conception of the historical quality of living organisms (Gould 1987; Rudwick 2005).

i We are a part of that nature which we seek to understand (Bohr)

Figure 5.2: Page from Darwin's notebook – a visual of evolution (Darwin 1837)

Evolution

Charles Darwin (1809–1882) is famously associated with the term evolution, although others were working on theories of transmutation[ii] of species at the same time (Burrow 1968). Interestingly, the word 'evolve' does not make an appearance in *The Origin of Species* until the very last paragraph:

> Thus from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved. (Darwin 1968, p. 459–460)

Replication, natural selection and evolution are the key themes to Darwin's theory. However it does not account sufficiently for other momentous events, such as the Cambrian explosion or the great Ordovician biodiversification—scientists to this day have no way of knowing exactly what caused this explosion of life and are forced to consider that 'it's possible that what we're looking at here is a random event' (Caron 2016, p. 45). Darwin, however, explained such events as due to the 'imperfection in the geological record' and writes:

> ... if numerous species, belong to the same genera or families have really started into life all at once, the fact would be fatal to the theory of descent with slow modification through natural selection...but we continually over-rate the perfection of the geological record, and falsely infer, because certain genera or families have both been found beneath a certain stage, that they did not exist before that stage'. (Darwin 1968, p. 309)

Darwin uses the same explanation for sudden major extinctions. Although given the newness of Geology and Palaeontology as sciences in his time, it is understandable that he assumed that the body of knowledge would continue to grow and fill the taxonomic gaps. Darwin's appreciation of Lyell's work on the *Principles of Geology* (1830–1833) and the corresponding revolution in natural science to include incomprehensively vast periods of time, were the basis for his confidence that 'evolution by natural selection is a slow and steady process' (Darwin 1968, p. 293). Indeed many discoveries predicted by Darwin have provided 'missing links' to his theory[iii] of evolution. Biologist, JBS Haldane, when questioned about the validity of evolution as a theory, facetiously replied: 'evolution will fail if we find fossil rabbits in the Precambrian'[iv]. Le Page (2016) explains that what he means by this is that evolution predicts the progressive change over time from the millions of fossils unearthed around the world, that is to say, 'multicellular organisms should come after unicellular ones, jawed fish should come after jawless fish'

ii The action of changing or the state of being changed into another form.
iii Darwin's predicted moth. https://en.wikipedia.org/wiki/Angraecum_sesquipedale
iv https://en.wikipedia.org/wiki/Precambrian_rabbit

etc (Le Page 2016b, p. 78). To challenge evolution, scientists need to find one or two exceptions to the theory, ergo fossil rabbits in pre-Cambrian sediments, and none have been found thus far.

David Attenborough in his 2013 documentary series, *Kingdom of Plants* comments that angiosperms[v] (flowering plants) upset Darwin's idea of evolution by suddenly appearing in the fossil record and producing a vast number of species in a very short space of time, approximately140 million years ago and during the age of dinosaurs. This is termed the early Cretaceous period by palaeontologists. Attenborough informs the viewer that Darwin called it 'an abominable mystery' as it was at odds with the slow and gradual characteristics of evolution. Scientists have been working on an explanation of exactly what happened to stimulate this sudden explosion of plants, and at this point in time attribute it to two major events: the first, a doubling of genetic material allowing quicker adaptations to changing environments; and secondly, the development of symbiotic relationships between plants and animals (Attenborough 2013). Initially, scientists recorded an absence of angiosperms in the fossil record during the Cretaceous period. Ancient Mesozoic vegetation is described by worldwide observations of habitat dominance by ferns, conifers, ginkgos and cycads, in addition to Bennettitales and other extinct seed plants (Hill 1994, Friis *et alia*, 2011). Certainly, in 2010, on the first palaeontological dig in which I participated, the plant groups in the clay matrix were identified as predominantly ferns and conifers. Friis *et alia* (2015), however, report that recent techniques involving scanning electron microscopes (SEM) and synchrotron-radiation X-ray tomographic microscopy (SRXTM)[vi] have revealed tiny flowers from sieved material and has confirmed the rapid diversification of angiosperms in this period. These early angiosperms have been described as 'small in stature, with rapid life cycles'. They could 'exploit disturbed habitats in open and understorey conditions and exhibited seed dormancy' (Friis *et alia* 2015, p. 551). Nichols and Johnson (2008) suggest that fossil plants might help to answer questions relating to the extinction period of sixty-six million years ago, between the Cretaceous and the Paleogene eras, previously called the K-T boundary, now known as the K-Pg boundary[vii].

The specimens featured in Chapter four, however, are from Capella in Central Queensland. They have been identified as existing in the Cenozoic[viii] period, and the floral profile of the site confirms angiosperm dominance. The area today is characterised by flat volcanic plains and Brigalow forest with remnant rainforest vegetation, however the fossil site itself is now mostly agricultural land. Many of the extinct specimens

v a plant of a large group that comprises those that have flowers and produce seeds enclosed within a carpel, including herbaceous plants, shrubs, grasses and most trees. Gymnosperms, in comparison, are plants within a group that have seeds unprotected by an ovary or fruit, including conifers, cycads and gingko.

vi This type of beam line is not yet available at the Australian synchrotron. The computed tomographies produced for this research were produced using the IMBL beam line, http://www.synchrotron.org.au/index.php/aussyncbeamlines.

vii Formerly known as the K-T, Cretaceous-Tertiary, boundary.

viii Approximately thirty million years ago.

have affinities with extant genera existing in small pockets of rainforest in north-eastern Queensland but include plants that appear to be extinct. For example, the extinct genus *Spondylostrobus* does not have close relatives in Australia. Friis *et alia* (2011) also note that the angiosperm rise to dominance is due to their 'extraordinary developmental and evolutionary plasticity' (p. 1). This conception of evolution has also been applied to cultural phenomena. Richard Dawkins (1976) in *The Selfish Gene* was the first to identify that cultural phenomena followed similar evolution as biological phenomena. He was the first to use the word 'meme/s' and defined these as 'fundamental units of cultural evolution, in parallel with the already well established idea of the gene as the fundamental unit of biological evolution' (Brook 2008, p. 18)

Cultural Evolution

Donald Brook (2008) in *The awful truth about what art is*, puts forward that 'art' is the appropriate name for a 'transhistorical and transcultural category of memetic invention' (p. 8). He contrasts this with 'kinds' as the entities that change in evolutionary ways. Brook defines creativity as 'memetic innovation' (p. 10) and 'art as revelation' (p. 7), and thus parallels the concept of *poïesis* as discussed in the last chapter. It is important to note that the word used by Brook is meme-tic not *mime*-tic. The former suggests parallels with biological concepts of evolution, the latter repetition without change. Brook describes craft as mimetic, and art as memetic. Brook modifies Dawkin's conception of memes:

> ... neither the word 'art' nor classifying term 'the work of art', is the name of a cultural kind with a history.'Art' is the name of a category of memetic innovation and is the unchanging propellant fuelling the engine of cultural revolution. (Brook 2008, p. 15)

He states that an item of a cultural kind can have parents and thus is 'metaphorically progenitive'. I understand what Brook is saying about the idea of a category, and would thereby, use his reasoning to identify 'Science' as a category of memetic innovation. The categories of Art and Science have evolved into their current form in the last few hundred years, as separate disciplines/categories. Thus I pause at Brook's use of the word 'unchanging' as applied to the category of Art; this seems at odds with its definition as 'memetic innovation'. I believe the definition implies that both the category and the cultural kinds within, have agency, liveliness, dynamism, creativity and are emergent. Hence the category itself would also change/evolve over time —not just the 'kinds' or subsets within. The category 'Art' as it exists today is unlikely to have had the same characteristics as 'Art' in prehistoric times; it would have had another name and most likely have been encompassed by other categories such as religion. Knox (2016) affirms this and makes the point that science and art were one and the same at this time, and similarly, culture and nature were not bifurcated.

Donald Kuspit (2004) in *The End of Art*, argues that art is over because it has lost

its ‘aesthetic import’. He claims that ‘art’ has been replaced by what Alan Kaprow calls ‘postart’, a new category that elevates different characteristics in the definition of what art is. Such a change of name and associated characteristics may be considered as an example of the ‘memetic-ness’ of the category. I would argue that both ‘Art’ and ‘Science’ are not immutable, but mutable categories that do change with agential intra-actions and have the potentiality for evolution and extinction. Brook’s modified definition of Dawkin’s concept of memes is as follows:

> ... purposefully directed actions with broadly predictable outcomes, intentionally undertaken in recognised cultural contexts. Every exercise of a meme is an action purposefully directed toward the generation of an item of a cultural kind that can reasonably be expected to win public recognition. (Brook 2008, p. 32)

In light of the previous chapters’ discussions of practice, dynamism, emergence and intra-action, this definition does not appear to take into account the possibility of the *spontaneous* generation, evolution or loss of a cultural kind. Neither does it mention the agency of the nonhuman. This theory, under the Quantum|ivism paradigm, needs to be re-considered in more democratic terms, to include the liveliness of all actors within the collective.The theory, or the ‘truth’ about art as a category also assumes that it will always remain unchanging within the collective, as ‘art’. I argue that art (and science) as categories are performative, and thus like other cultural/biological systems, will evolve or become extinct.

Extinction

Georges Cuvier (1769–1832) is credited as establishing the concept of extinction with his comparative anatomical studies of quadrupeds (Rudwick 1997). Cuvier writes:

> The principal question being to know the extent of the catastrophe that preceded the formation of our continents. It is above all a matter of determining whether the species that existed then have been entirely destroyed or solely modified in form or simply transported from one climate to another (Rudwick 1997, locn 600 of 4371)

It is important to note that in Cuvier’s time, Geology as a science had yet to be established and was a ‘speculative’ theory of the earth. However, it was Cuvier’s authoritative anatomical analysis of the ‘Ohio animal’ or ‘American *Incognitum*’ (Rudwick 1967, locn 1069) that established extinction. The animal was shown as belonging to a different family as living elephants, and a distinct genus in its own right. Cuvier established the genus of ‘Mastodon’ to account for it and in 1806 he published a paper detailing his theories of extinction, from detailed observations of fossils, and included the mastodon as an exemplar. He also indicated that the event that had caused the extinction was a ‘transient marine incursion of some speed’ (which explained the marine life accompanying the fossils in the stratigraphy). Cuvier’s catastrophic theory did

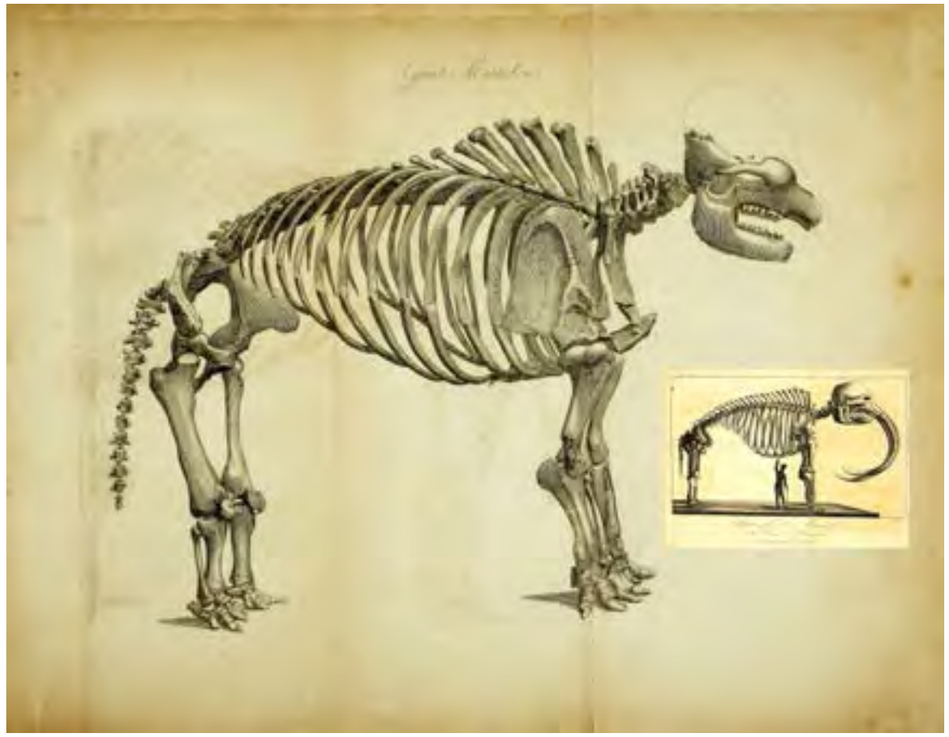


Figure 5.3: Cuvier’s 1806 mastodon – facsimile of original etchings
insert: Eduard de Montule’s 1821 drawing of ‘mammoth’ skeleton – Peele’s Philadelphia Museum

not sit well with contemporary geological theory which adhered to a slow and gradual progression of life. It does, however, fit the current meteoroid impact theory that heralded the demise of the dinosaurs (Alvarez *et alia* 1980). Cuvier actively opposed the slow, gradual transformist interpretation of species as proposed by Darwin and Lyell and more generally saw his research as ‘busting the limits of time’ (Rudwick 2005).

Paul Semonin’s (2000) *American Monster* is an interesting anecdote about the discovery of the mastodon. He discusses how cultural myths affect what we think we ‘see’ by documenting the phases of the mastodon’s taxonomic classification. Initially the beast was not thought of as a herbivore (like living elephants), rather as some strange mighty American *incognitum*, a fierce carnivorous beast, and was exhibited with the tusks facing downwards to promote this theory (see insert in Figure 5.3). Semonin describes this initial classification as symbolic of a new country’s nationalist desires entangled with biblical creationist stories of the time. Dinosaurs had not yet been discovered and the concept of a pre-human history and extinction officially began with Cuvier’s systematic analysis of the animal’s anatomy in the memoir ‘Sur le grande mastodonte’ in 1806.

Cosmologist and physicist Lisa Randall (2015), amongst many others, highlight the difficulty in using the fossil record to understand extinctions and global catastrophic events as it is incomplete and usually only the hard bits of animals or plants are preserved,

not the soft tissue. This is particularly so with the fossil plant record, which is frequently sparse or fragmented and it is rare to find a whole specimen, that is, a plant with roots, leaves, reproductive structures and so on. As a result of initiatives led by this project's research practice, the silicified fossil fruits of the Central Queensland Capella region have been scanned with synchrotron radiation and for the first time have revealed, in exquisite detail, delicate internal morphologies. This is very significant to classification and understanding of past palaeo-climates and is also useful for others in the field as a non-destructive technique to see inside specimens. Artistic visualisation is also very useful for generating public interest and communicating scientific values.

Order and chaos — creative time

In a search to understand the mass extinction that occurred sixty-six million years ago, Physicist Walter Alvarez investigated a geological anomaly, the *Scalia Rosa* in Italy, a thin layer of clay. At this time, geology was still dominated by a gradualist viewpoint. Alvarez's interest was in the dating of geological events and in order to determine how long it took to deposit the thin layer of clay, he turned to dating by measuring its iridium content. What he found is known as the 'iridium spike' and this led to a meteoroid impact theory, subsequently validated by the discovery of the Chicxulub impact crater in the Yucutan. Such a large impact explains the sudden and catastrophic demise of life on earth at the end of the Cretaceous period. In this layer, which is found around the world, there is a high concentration of iridium as compared to surrounding layers. This, plus the crater, and evidence such as spherules, tektites, and shocked quartz, indicate a large impact. Randall (2015) in *Dinosaurs and Dark Matter,* comments that geologist Charles Lyell may have interpreted a thinness of K-Pg layer as misleading and concluded that despite appearances it had taken many years to create, and that Darwin is likely to have thought the formation was simply an illusion created by an inadequate fossil record. However, speculative work undertaken by Randall (2015) has led to the theory of a double disk of dark matter in the plane of the Milky Way, which they claim was responsible for triggering the meteoroid's final trajectory to earth, and caused the catastrophic extinction of many species, including the dinosaurs, on earth. Further, Randall surmises that although no one can be certain, it is likely that comets from the hypothesised Oort cloud[ix] are responsible for such big impacts and that the periodicity that is observed by such impacts could be explained by the influence of dark matter[x]. This theory has implications for the narrative of deep time, as it highlights the entanglement of the earth within the universe and expands the geological focus to incorporate cosmological events. In contrast, Grosz (2004) describes time as linear, with one event proceeding the next, and as an ontological element:

ix A theoretical cloud of predominantly icy planetesimals believed to surround the Sun.

x Transparent type of matter accounting for 26% of the universe (Randall 2015, p.21) https://en.wikipedia.org/wiki/Dark_matter.

> Time inhabits all living beings, is an internal, indeed constitutive, feature of life itself, yet it is also what places living beings in relations of simultaneity and succession with each other insofar as they are all participants in a single temporality, in a single relentless movement forward. (Grosz 2004, p. 5)

Generally speaking, this applies very well at the earthly macro level as evidenced by Newton's laws. However, physicist Carlo Rovelli challenges this view and describes the complexities of our conception of time through discussion of gravity, quantum mechanics and thermodynamics. He suggests that it is heat that makes us aware of the 'flow' of time. Heat always tends to cold but not vice versa, and it is this that makes the future different from the past. It is, he explains, Boltzman's[xi] idea of *sheer chance* that explains this, and that it is to do with probabilities. The probability of something going from hot to cold is much greater than going from cold to hot. These probabilities depend on our specific way of inter-acting with things. Rovelli explains:

> Probability does not refer to the evolution of matter in itself. It relates to the evolution of those specific quantities we interact with. Once again, the profoundly relational nature of the concepts we use to organise the world emerges from these interactions. (Rovelli 2014, p. 55)

So what exactly is the flow of time? Rovelli remarks that philosophers and physicists agree that the idea of a present that is common to the whole universe is an illusion and that a generalised universal 'flow' of time does not make sense. Somehow, he says, the answer has to do with heat, and time sits at the centre of the tangle of problems raised by the intersections of gravity, quantum mechanics and thermodynamics. Rovelli is hopeful that Stephen Hawking's recent discovery that black holes are hot may provide some clue as to the true nature of time, as studying these may produce the 'Rosetta stone' of physics and translate the three theoretical intersections mentioned above.

> Time does not exist except to us. A more speculative idea is that our feeling of passing time depends on us, not on the universe, and is due to our imperfect knowledge of the world. In a sense, time is our ignorance. (Rovelli 2016, p. 45)

The concept of probability is also discussed by physicist Nicolas Gisin (2016). He uses the neologism of 'creative time' to describe the temporality we experience. Gisin states that the universe is not so precisely determined as our infinitely precise numerical description would have us believe. He suggests that there is a degree of intrinsic randomness that triggers its fate. For Gisin, the concept of free will does not mean humans can invent the future, nor create new possibilities, but merely influences which pre-existing potentialities become actualities. He follows the thought of the Copenhagen interpretation of Quantum theory—that is, the act of making a measurement 'collapses' the wave function describing a quantum system into one of a number of pre-ordained possibilities. Gisin describes Quantum theory as a random non-deterministic theory which creates a determined world. Time, to him, is more than a parameter of evolution, rather is

xi https://en.wikipedia.org/wiki/Ludwig_Boltzmann

instead a ‘true creation’ that cannot be captured, a ‘flowing time’. He concludes that for science to make sense free will and a flowing time must both exist.

Quantum|ivism

Grosz (2004), reading through Darwin, regards time as a separate entity, an evenly spaced progression of moments, an immutable universal background and/or an ontological primitive. However, under the paradigm of Quantum|ivism time, space and matter are considered relative, entangled and are marked by dynamic intra-actions. It is this idea of an emergent dynamism that co-creates space, time and matter. Agential cuts, and phenomena make marks on these diffraction patterns and create a ‘sedimenting historiality’ (Barad 2007, p. 180). Darwin’s tree of life in Figure 1, when turned on its side, could represent a diffraction grating, with species A and B acting as apertures, intra-acting within the collective in space and time, producing agential cuts or marks, which are revealed via measuring apparatus as species alive at a relative space-time on earth. The resulting phenomena on the far right—evolved species—could be described as interference patterns and the act of measuring these, via classification, reveals their similarities and differences as evolutionary links to A and I.

Under Quantum|ivism’s agential realism, the past and the future are enfolded participants in matter’s dynamic, and emergent becoming. [The concept of the Last Universal Common Ancestor, LUCA, as a direct ancestor of every living thing (DNA sequencing has confirmed that all living creatures share a common origin) (Le Page 2016, p. 77) and thus evidence that past is in the present and the future]. However, like electrons and the quantum leaps they take, we have a probalistic, and not determinate answer to the question of where and when phenomena will emerge and leave their mark, until of course, they are measured.

Conclusions

The visualisations of botanical specimens, of portraits of evolution and extinction, as provided in Chapter four may thus be regarded as phenomena that provide a sedimenting historiality within the space-time-matter narratives of evolution and extinction. Time in this sense may be thought of as ‘creative time’ and is co-constituted with space and matter. This is significant to the project as it confirms the application of the agential realism of Quantum|ivism and highlights the dynamic, entangled and emergent nature of knowledge production across all disciplines. The final chapter summarises the findings of the research and responses to the research questions. It also puts forward suggestions for future work, in both the arts and sciences.

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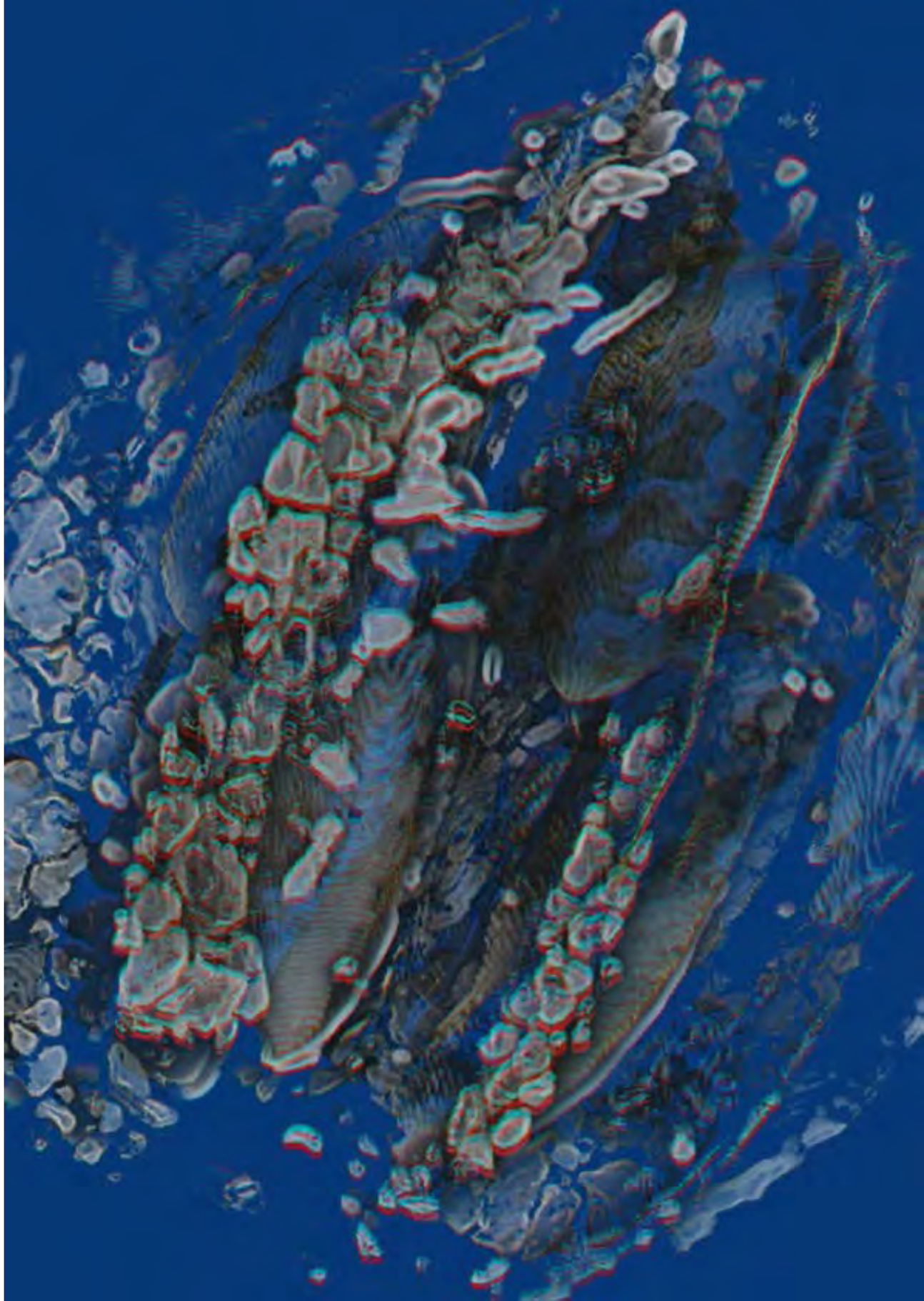
Chapter six

conclusions and future research

Physics is a lot like the arts. But not just because of its sheer beauty, even if it is beautiful. It's not just because it's hard and you want to do it better, even if that's also true. Physics is like the arts because art has the ability to open our eyes to a different perspective on the world. When you listen to Shakespeare, when you read Dostoevsky, then your vision of humanity is changed. Physics does the same thing — it opens our eyes to something new, more wide and true. (Rovelli 2016, p. 44)

(Opposite) Figure 6.1: QMF 16735 *Fontainocarpa foraminata* (AK Milroy 2016)



Chapter six: conclusions and future research

Summary

The research questions:

> In what ways, if any, can the outcomes of a practice-based visual arts researcher significantly contribute to the development and communication of knowledge/s in traditionally scientific disciplines?

and conversely;

> In what ways, if any, can scientific research practices significantly contribute to the development and communication of knowledge/s in an artistic practice?

The method used to answer these questions is practice-based research. Using the theoretical framework *epistêmê, technê and poïesis*, it was anticipated that, by participating in and analysing the knowledge development, procedures and communication practices of two arguably disparate disciplines, there might be suggested ways for the fine visual arts to contribute to the earth and physical sciences, and vice versa. There are a large number of outcomes from the sustained period of practice that constitutes the doctoral candidature from 2012 to 2016. These include Non-Traditional Research Outputs (NTROs) as literal and figurative art works produced during the research, and also traditional research outputs (TOs) in the form of published papers, conference presentations, and formal research statements concerning the artworks presented as NTROs. These contributions have added to the conversation on practice-based visual arts research within specific fields of science and vice versa. These outputs are listed on pages 164–169 as evidence of sustained research practice. However the detail of them is not intended for formal examination. The examinable work is the record of the *Aletheia* exhibition presented in Chapter four of this exegesis.

This project was framed as a 'blue skies' or basic research approach in Chapter one and through practices of recording, diffracting (Haraway 1997; Barad 2007), making, and analysing the research outcomes—as works of art and science, insights into practice-based artistic research, scientific research, and research paradigms were revealed. These are in addition to artefactual outputs detailed in Chapter four *poïesis* as traditional and non-traditional research outcomes for artistic and scientifc practice.Whilst a practice-based methodological approach was an appropriate choice for this hybrid project it was not clear at the outset exactly how an arts practice could contribute significantly to scientific knowledge, nor how a palaeontological science practice could contribute to artistic knowledge. Jill Bennett, reading through Donald Brook and Ross Gibson, defines art as experimental—'with anything and everything: raw matter, time, relationships, things and tendencies'(2012, p. 1). This is contrasted with the experimental nature of

science which is often characterised by its rigorous and controlled conditions. *Studies in Material Thinking* volume 08, 'Experimental Art', discusses the nature of 'experimental' in the arts and sciences and investigates the [diffractive] outcomes of combining artistic and scientific practice. One of the authors, physicist Paula Dawson (2012) discusses the science and art of holograms through works which literally and metaphorically use the concept of diffraction. For example, when discussing works such as *'There's no place like home'* Dawson notes that:

> Interference results in the production of something entirely different from the sum of the parts. In viewing and contemplating holographic works conceptual interference can occur between virtual images, real images, after images, mental images, real objects and bodily sensations. (Dawson 2012, p. 17)

Knox (2016) describes art and science as two essential components of knowledge production. He describes art as symbolic, comprehensive and critical and compares this with science's direct, verifiable bond with 'reality', and that knowledge production necessarily requires input from both:

> Art and science are both [practice] based systems of investigation and study; 'knowing for each of them comes from 'doing', from extreme observation, from working with the materials and exploring the limits of an area of focus. (Knox 2016, p. 442)

The raw data for the *Aletheia* exhibition was sourced predominantly from palaeontological practice, and subsequently entangled with [experimental] artistic practice to produce innovative techniques and outputs. Brook (2012) describes the term 'experimental art' as a tautology — 'in the sense of 'experiment' in which the result of one's activity is not anticipated, art cannot but be experimental' (Brook 2012, p. 3). The engaged and intra-active scientific practice included working on palaeontological digs and performing a holotype audit of palaeobotanical specimens in the Queensland Museum's collection. Over fifty holotypes were studied and photographed in detail. The scientific papers relating to these specimens informed the artistic practice as diagrams, illustrations, photographs and figures spanning almost two centuries were examined in detail. To use Brook's (2008) expression, the *memetic innovation* embedded in these images documented a narrative of evolution for these scientific visualisations. These ranged from labour intensive works requiring 'old' technologies, such as sketches in pen or ink on paper to a combination of machine enhanced visuals using the 'new' technology of scanning electron microscopy. My challenge was to produce new knowledge by investigation and experimentation, with a view to interpreting the data and communicating it with the creativeness of the eternally questioning artistic [scientific] mentality. This involved the adaptation of new visualising technologies for both scientific and artistic purposes. An emergent, entangled experimental approach was taken. Initially

this involved digital photography, using techniques such as focus stacking multiple images and creating three dimensional forms with photogrammetry produced phenomena — visualisations — which have been used in arts practice as exhibition items, and as materials for wearable art/jewellery, and also in science practice as images for journal articles and items for communication and display. The involvement of the artist in this scientific practice may be considered as ways in which State collection specimens are able to be democractically accessed by specialists and non-specialists alike (Milroy and Rozefelds, 2015).

The collaborative nature of this art practice lent itself to novel combinations of people, things, places and time: *spacetimematterings* (Barad 2007). The *Labpunk* (Wegener and Milroy 2014) art-physics collaboration was successful in its own right, but also provided a valuable opportunity to meet researchers from other disciplines. This networking led to the opportunity to investigate more technologically advanced ways of imaging and visualising Queensland's fossil biota. As detailed in Chapters Three and Four, a collaboration with synchrotron scientists resulted in the collection of new raw data which became the basis for the artifactual thesis component, the *Aletheia* exhibition and body of work. Synchrotron radiation was used to scan fossil fruit and revealed internal structures of silicified specimens from Capella in Central Queensland in unexpectedly high detail. It was the first time these specimens, unique to Queensland, had been visualised in this way. Previous studies using standard medical grade CT scans had revealed some internal structure in the genus *Pleiogynium* (Rozefelds et al, 2014,) but this had been unsuccessful on other specimens. Nationally and internationally, the use of synchroton radiation and neutron scanning for palaeo-botanical specimens is gaining recognition and use, but knowing which specimens will or will not reveal new information is still very experimental. Dawson et al (2014) provide a comparison of x-ray and neutron imaging techniques at the Helmholtz Centre for Materials and Energy, Berlin, using a fifty million year old Eocence fossil plant from Antarctica. The specimen was encased in a carbonate nodule from *La Mesata formation*, Seymour Island, Antarctica and was composed of impressions and compressions of an Araucarian conifer branch. Researchers found that in this instance, neutron scanning produced more detailed results as the specimens contained remnant hydrogenous materials and neutrons are strongly attenuated by hydrogen. X-rays, on the other hand, are insensitive to hydrogen and sensitive to heavy metals. (Figure 6.2)

In other studies, Smith et al (2009) used the TOMCAT beamline in Switzerland as a non-invasive, non-destructive and high resolution method of scanning fossils from the Paleozoic, Jurassic, Cretaceous, Paleogen and Eocene Eras, in order to predict cryptic morphologies. In this instance synchrotron radiation was used for X-ray tomographic microscopy (SRXTM). This beamline, different in structure and function to the IMBL,

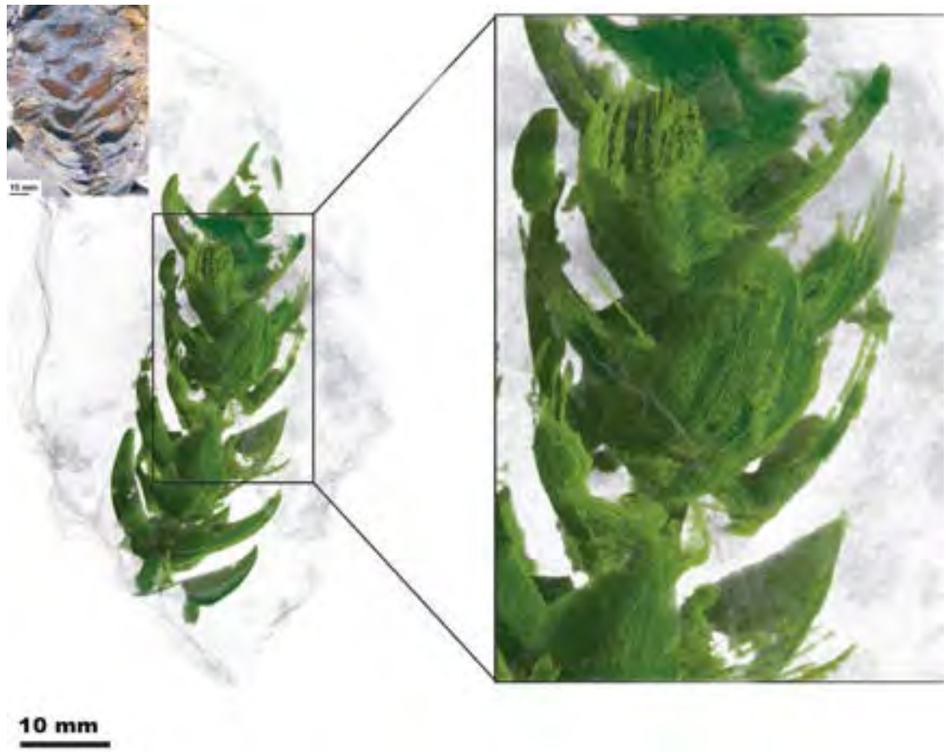


Figure 6.2: Reconstructed computed tomography — Araucarian conifer: top left, fossil in matrix (adapted from Dawson et al, 2014)

was well suited to show cell level detail of extinct and extant samples. The IMBL is currently planning the inclusion of a micro CT facility which is likely to be of great benefit to specimens of less than one cubic centimeter.

The *Aletheia* body of work also continues to contribute to the scientific practice with many future papers to be written to describe this new information to the palaeo-botanic community. The first scientific paper from this work is currently in press, using the *Fontainocarpa foraminata* (Rozefelds 1990) specimen visualisations and animation. Others, focusing on the first specimen, *Spondylostrobus rozefeldsii* (Dettmann and Clifford 2002) and a summary of the results of the forty specimens scanned in October 2015 are in process. The success of the synchrotron visualisations in 2015 led to a successful application and grant to scan the specimens with neutrons at the Lucas Heights DINGO Nuclear facility in October 2016. The peer review comments accompanying the application highlight the increased interest in intra-disciplinary studies and the novel results these may produce. The scanning has been completed and a grant will be applied for to assist with the processing and communication of this data. The email summary of reviewer's comments from the successful DINGO grant application includes the

following [my underlines]:

> **Reviewer 1**. The proposed project is very interesting and has a high chance of success. The specimens in question are important for evolutionary history of the Australian floral biota, and sound promising for successful data collection...the intersection of art and science is a very interesting angle for this kind of research. I think there is a lot of potential for CT scan technology to be incorporated into broad public outreach endeavours. These scans will be an important step towards this.
>
> **Reviewer 2**. This is a great palaeobotanical project which is sure to see significant outcomes on the phylogenetic relationships of Jurassic to Cenozoic gymnosperms and angiosperms in Queensland. As presented in the proposal deducing floral affinities from fossils can be quite tricky at best, and sometimes inferred relationships can be quite perplexing on many levels. Using DINGO it is hoped that some of these taxonomic riddles can be solved as previous imaging has seem mixed results.
>
> **Reviewer 3**. This proposal is interesting in addressing several problems at once. On the one hand, data will be used to explore the nature of the fossil plants selected and their evolutionary relationships. On the other, it also seeks to compare different methods of scanning plant fossils, which to my knowledge has received very little attention previously. Overall this proposal appears well thought out, with some potentially very interesting results possibly coming out of these analyses of benefit to several different groups of researchers.
>
> **Reviewer 4**. Imaging techniques are very important in the study of fossil material, particularly techniques that do not damage valuable specimens, and this study will allow direct comparison between the benefits of two such imaging techniques by application to fossil plant material. The project will add scientific value to unidentified museum specimens and potentially will provide important new information on Australian floral history from three fossils flora of different ages. It is excellent to see that opportunities for public engagement are being considered in this project as well and I look forward to seeing the digital models of these specimens on-line. This project is very worthy of being granted neutron beam instrument time.
>
> **Reviewer 5**. I have not seen such a significant research project on palaeobotany in Australia in recent years. This project uses significant permineralised specimens that are rare in Australia, yet they preserve the most detailed of internal structures of all fossils. Detailed internal structures that can be determined using non-destructive methods, such as CT, are at the forefront of current research in Europe and will allow the applicants to study crucial internal fruit/seed anatomies. Results will enhance understanding of forest biodiversity and ecology through time in Queensland and determine fruit/seed evolutionary adaptations and ultimately the critical phylogeny of plant groups, which are unresolved in Australian fossil and extant plants. This is a well thought out project and experiment, with details on preliminary work, including publication of preliminary results. Further results will result in publication in high level discipline-specific journals. I strongly recommend this project be given requested time on both the DINGO and other requested equipment at ANSTO.

Note that the physics discipline peer reviewers concurred with the opinion about the paucity of knowledge of the Australian fossil biota that was expressed in Chapter One. They praised the significance of successful synchrotron results, and encouraged the innovative approach to studying botanical specimens with non-destructive scanning technologies. The reviewers also recognised that art practice has value as a vehicle for outreach and public engagement. There was interest for the provision of online digital visualisations. From the ongoing demand for the exhibition of the *Aletheia* work and from the above peer review it may be concluded that the project contributes to many cultural areas, disciplines and modes of communication between specialists and non-specialists.

As phenomena, the works of research are significant for either discipline. The measuring apparatus one chooses determines whether it is a work of art or of science. It, the apparatus, include peers and criteria of art-ness or science-ness. I tender that the works presented have an art-science duality, or even an art-science-technology multiplicity.

The literature reviewed in Chapter two, *technê*, illustrates that worldwide, this type of scanning is at the leading edge of research and the rarity of the specimens adds valuable knowledge to the global evolution and extinction of angiosperms. It is also the first time that palaeobotanic specimens from the Queensland Museum have been presented as works in an artistically creative format, or been used as the basis for an art exhibition. The art practice creates images as phenomena which have yet to be comprehensively defined and con-textualised. New phenomena require new words to describe and classify them, visualisations provide a point of revelation from which further conversations are possible.

Diffraction Gratings

Returning to the Quantum|ivism paradigm: metaphorically, as with experiments with the photon, with its inherent wave-particle duality, the diffractive intra-disciplinary methodology enables intra-actions between actors in the collective of human and nonhuman. Each contributor may be both an individual entity and an effect. Poietically, there is a correspondence in the physics of the technology producing the data from which the visualisations have been developed. The data are records of the diffraction patterns recorded from photons passing through the atomic structure of the fossil.

The artworks, the artist, the scientist and the viewers, also do ‘work’ as diffraction gratings. Here, the visuals entangle with human researchers and form agential cuts, such as classification of a new genus or species. The agential cuts also include a revised approach to research praxis in science and art, and contributions to visual culture. They may be interpretive displays or performances. The adoption of an agential realist framework acknowledges the relationship between the material and the discursive. As highlighted by Barad (2007), phenomena, or the works of Art or Science, are not just

maps of the visual, they also map geopolitical, economic and historical factors as well. The viewer is a crucial part of the entanglement and their intra-actions alter the work, thus adding to the ongoing dynamic dance of agency. Some aspects of the phenomena may be taken as scientific truths, such as the internal morphological features of the scanned fossil fruits, or as socio-cultural statements about the Anthropocene, or as works of Art formed by the use of new media and presented in innovative formats. Key to the attainment of the research results, were the intra-disciplinary and intra-collective practices. Collaborations were achieved with a diversity of audiences, colleagues, technology, hardware and software.

The synchrotron computed tomography (CT) scans from the IMBL enabled three dimensional volume data to be generated, and these formed the visualisations in two and three dimensions detailed in Chapter four. Creative outputs from these scans included: images on paper, 3D prints in new materials, jewellery, videos and animations. A version of the *Aletheia* exhibition was also showcased at the APPC–AIP 2016 conference and congress in Brisbane. An artistic, interpretive performance of the research results was presented as a large digital format projection at the welcoming function. It was accompanied by pianist Jenni Flemming, improvising concurrently on grand piano and electronic keyboard. This performative collaboration is a further example of how the science can be translated in artistic dimensions.

Praxical Intra-actions – Collective Collaborations

A summary of the large number of outcomes generated from the sustained period of practice that constitutes the doctoral candidature from 2012 to 2016 is provided below. These include Non-Traditional Research Outputs (NTROs) as literal and figurative art works produced during the research, and also traditional research outputs (TOs) in the form of published papers and conference presentations. These contributions have added to the conversation on practice-based visual arts research within specific fields of science and vice versa. However, it is noted the detail of them is not intended for formal examination. The examinable work is the record of the *Aletheia* exhibition presented in Chapter four along with this exegesis.

Other methods used to collect and generate data and research outputs included active participation in exhibitions, conferences and collaborations with other artists and scientists. The aim was seek collaborations with peers, from both art and science, and to intra-act by way of respectful, ethical engagement, neither privileging one discipline over the other nor using one as a fixed referent for the other. This includes considerations of the liveliness of the nonhuman, as evidenced by explorations in environmental issues (see '100% recycled' and 'Labpunk' notes on sustainability) and the (multi)-lectic including resistance and accommodation in the art of metalsmithing as described by Milroy, Wegener and Holmes (2015), and Wegener and Milroy (2014).

Exhibitions (NTROs)

The following exhibitions have featured work inspired by this research project:

2012

- The extant landscape, Eromanga Basin (Brisbane)
- Bookplates unbound (Curated by Studio West End: Brisbane)
- 100 % recycled (Jewellery and Metalsmiths' Group of Queensland: Brisbane City Library)

2013

- Confluence/influence (Jewellery & Metalsmiths' Group of Queensland: Brisbane City Library)
- Talking through jewellery with Laura Bradshaw Heap (Queensland College of the Arts: Griffith University, Brisbane)
- Addition/subtraction (Studio West End, Brisbane)

2014

- Labpunk (AIP 2014: Australian National University, Canberra)
- Draw Me a Discovery—Cafe Scientifique (University of Queensland, Brisbane)

2015

- Lux Lumens (Jeweller & Metalsmiths Group of Queensland, Sydney)
- abbe (Artists' books Brisbane Event - Griffith University)
- Stories in Small Spaces (Curated by Studio West End: Impress Art Gallery Brisbane | Gympie Regional Gallery)
- Advanced Certificate of Excellence (ACE) Exhibition (The Goldsmiths' School, Brisbane)

2016

- Manifest Printmaking Exhibition (Curated by Studio West End: Impress Art Gallery Brisbane | Firestation Gallery Melbourne)
- 'Aletheia' - Green Vale Gallery (Brisbane)
- CQU Creates - Central Queensland University, Rockhampton
- Creative non-fictions I & II acquired for CQUniversity Collection.
- 'Aletheia' - APPC–AIP 2016 Congress (Brisbane, December 4-8)

Post doctorate 2017

- Salon - World Science Festival
- *'Aletheia'* - Australian Synchrotron
- 'deep time' - the Planting, Woodford folk festival

Conferences and Residencies during candidature (NTRO & TO)

2011

- Artist In Residence. Eromanga Dinosaur Dig.

2014

- POPCAANZ. Popular Culture Association Australia and New Zealand.
- Presentation: *What's my holotype?* AK Milroy
- Presentation: *Reconciling the two cultures.* MJ Wegener & AK Milroy.
- Presentation: *Democratising the collection*. AC Rozefelds and AK Milroy.
- Australian Institute of Physics Conference. *The Art of Physics.* ANU, Canberra. Labpunk exhibition and co-creator of Plenary speaker gifts.

2015

- AOFSRR 2015 Asia Oceania Forum for Synchrotron Radiation Research. *Visualising evolution and extinction through silicified fossil fruits from Queensland* (Milroy, Maksimenko, Rozefelds, Holmes).
- Creative Labs. Queensland Museum. Keynote : 'Deep time' presentation and workshop faciliatator.
- SEDUA:School of Education and the Arts annual conference. Central Queensland University, Brisbane. 'Deep time' Presentation.
- abbe: Artists Book Brisbane Event. Griffith University, Brisbane. Biography of a physicist .

2016

- Columbia College Chicago, *Artist in Residence*. June/July 2016. Collaboration with Brad Freeman, editor of JAB (Journal of Artists' Books). Production of *Diffract*. Due March 2017.
- Palaeo Down Under 2 PDU2. Adelaide.
  - Presentation: *Visualising Evolution and Extinction using Synchrotron Radiation.*
  - Workshop chair and facilitator: *Computed Tomography at the Australian Synchrotron: a palaeontological user's perspective.* Co-chair Dr Anton Maksimenko, Australian Synchrotron.
- Joint 13th Asia Pacific Physics Conference – and 22nd Australian Institute of Physics Congress. APPC–AIP 2016. *Artist in Residence.*
  - Welcome function digital performance: Sunday 4th December, 2016.
  - *Aletheia* exhibition: 4th to 8th December, 2016.

Publications during candidature (TOs)

I. Milroy, AK and Freeman, B 2017, 'Diffract', *Journal of Artists' Books*, JAB 41, Spring, in press.

II. Rozefelds, AC, Milroy AK, Dettmann ME, Clifford, HT and Maksimenko, A in press, 'Synchrotron computer tomographic (CT) scans complement traditional techniques in understanding the internal anatomy of permineralised *Fontainocarpa* (Crotonoideae, Euphorbiaceae) fruits from the Oligo-Miocene of eastern Australia', *Review of Palaebotany and Palynology.*

III. Milroy, A, Wegener M, and Holmes, A 2015, '*Labpunk* – Curiosity, Intra-action and Creativeness in a Physics-art Collaboration', *Transformations*, issue 26.

IV. Milroy, AK and Rozefelds, AC 2015, 'Democratizing the collection: Paradigm shifts in and through museum culture', *Australasian Journal of Popular Culture*, 4: 2+3, pp. 115–130.

V. Milroy AK 2015, 'Talking through jewellery with Laura Bradshaw-Heap and AK Milroy, 'Was and is to be', *Paillon*, Jewellery and Metalsmiths Group of Australia (Queensland Chapter).

VI. Milroy, AK and Wegener, M 2015,'Network Nodes – jewellery at the edges, gaps, borders of Art and Science :Introducing the Labpunk collaboration', *Paillon*, Jewellery and Metalsmiths Group of Australia (Queensland Chapter).

VII. Milroy, AK, Rozefelds, AC, Coghlan, S, Holmes, MA and Hocknull, S, 2015,

Figure 6.3: Page detail from *In search of ancient Queensland* (Image: Milroy, Maksimenko and Rozefelds 2016)

Digitising the collection: Evaluating photogrammetry as a means of producing a digital, three dimensional model', *Journal of Natural Science Illustration*, vol 47, no. 3, pp. 3–10.

VIII. Milroy, AK and Wegener, MJ 2014, *Labpunk* – The Art in Physics, Poster, Australian Physics Congress.

IX. Wegener, MJ and Milroy, AK 2014, 'The Art in Physics - Creating *Labpunk*, *Australian Physics*, Mar-Apr, vol. 51, no. 2, pp. 53–56.

X. Image in books: *'Spondylostrobus rozefeldsii', In search of ancient Queensland* (Cook & Rozefelds 2015), p. 228. (Figure 6.3)

Grants (TOs)

- SEDUA Seed Grant Application: Value $3,900. *AK Milroys' Aletheia Exhibition at the APPC-AIP 2016 conference and congress 2016.* Collaborator: Saeed Dadvar, Deakin University.
- ANSTO, Lucas Heights DINGO facility, proposal ID 5346: Value $21,000. *Evolution of the Australian flora: visualisations of the internal anatomy of permineralised fossil fruits and cones.* October 2016. Collaborators: Anton Maksimenko, Andrew Rozefelds, Joseph Bevitt, Floriana Salvemini, Ashley Holmes.
- ANSTO, Australian Synchrotron IMBL facility, proposal ID 9722: Approximate value $50,000 (approximate for five days of beam time). *Evolution of the Australian flora: visualisations of the internal anatomy of permineralised fossil fruits and cones using the Imaging and Medical Beamline (IMBL) at the Australian Synchrotron, Melbourne.* 21 October – 25 October, 2015. Collaborators: Anton Maksimenko, Andrew Rozefelds, Ashley Holmes, Gary Pattemore.

Interpretation

Retrospect, research significance and validity

To a commercially oriented fine artist, works of art are validated by a monetary transaction and acquisition by a public or private collection. For an artist involved in academic research, the validation system is different: research statements replace the artist's statement, peer review includes selection into curated exhibitions, and the sales focus leans toward procurement by public collections, museums, art galleries and so on. However, I think both commercial and research outcomes are valid forms of research significance. If a work is popular, and sells, it may become part of the visual culture of the day, and is a comment on such. However, the non-sale of a work does not necessarily diminish its research significance. There are many examples over time of artist-researchers whose work is not recognised until long after they are deceased. Sometimes

a work needs the passage of time to allow a phenomenon of retrospection to reveal that which was captured in technique, subject or practice, by the artist/researcher at the time. For a scientist, the analysis of works of science are often more straightforward and each scientific discipline has an established peer review process, complete with its specialist language, and this acts as validation and gatekeeper of new knowledge claims. Traditional research outputs (TOs) generally fall into the hierarchial categories of refereed articles in academic journals, papers in conference procedings, posters and so on.

A diffractive methodology encourages a constant evaluation of the data/artefacts and analysis to reveal new knowledge/s. 'Being in conversation' with the work often teases out meaning and hidden knowledge[i]. This is part of the work that art does, it provides visual phenomena, prima facie without linguistics, clearly articulated descriptions or causations. It provides lively intra-actions, and 'conversations' birthing new authors, new agential cuts. The work is to allow the evolution of phenomena: to be regarded, re-interpreted in a dynamic dance of agency. Iris van der Tuin (2011), reading Henri Bergson and Karen Barad diffractively, says we should refrain from putting words at center stage, as this constrains, simplifies or deceives critical analysis by virtue of what Bergson terms a 'spatializing act', formed by preexisting concepts, linguisticism and utilitarianism. Barrett (2007) describes the innovative potential of arts practice as research:

> The innovative and critical potential of practice-based research lies in its capacity to generate personally situated knowledge and new ways of modelling and externalising such knowledge, while at the same time revealing philosophical, social and cultural contexts for the critical intervention and application of knowledge outcomes. (Barrett 2007, p. 2)

From the results presented in this thesis, comprising the creative component *Aletheia* exhibition and this exegesis, there is confirmation that the artistic practice has contributed significantly to the development and communication of knowledge/s particularly in the scientific discipline of palaeobotany and vice versa. The new knowledges were achieved by the introduction of a new research paradigm, Quantum|ivism (see Table 6.1) diffractively re-investigating artistic and scientific black-boxed research methodology. One of the assumed limitations of a non-specialist scientist, that is to say, not having specific training as a palaeobotanist, was in actuality a source of innovation as it brought new ways of thinking, of 'looking' and visualising, outside of, and in addition to traditional forms. Applying a keen sense of observation, interest and curiosity, and training to 'look' in a different manner, the artist can often see things which may be missed by an eye trained by a different, but equally rigorous (scientific) practice. An aptitude for embracing and utilising new technologies has also been a vital part of this artistic practice, adding extra dimension to traditional forms of visualisation. The

i See article in Academi.edu 'Talking through Jewellery': https://www.academia.edu/19879395/Talking_through_jewellery_with_Laura_Bradshaw-Heap_and_AK_Milroy

Table 6.1: For future discussion – Quantum/ivism, a 'work-in-progress' paradigm

PARADIGM	**Ontology** The nature of the 'knowable' The nature of reality.	**Epistemology** The relationship between the knower (inquirer) and the known (or knowable)	**Methodology** *Techne in praxis* How should the inquirer find knowledge.	**Axiology** Beliefs about the role of values or ethics in conducting research.
	Spacetimemattering (Barad 2007)		**Practice-based**	**Democratic**
QUANTUM|IVISM **Artistic** (Gray & Malins 2004) **Successor science** (Barrett & Bolt 2014)	**Ethico-onto-epistemology (Barad 2007)** Practices of knowing and being are not isolable; they are mutually implicated, we know because we are part of the world in its differential becoming.		**Diffractive methodology (Barad 2007, Haraway 1997)** **The Mangle of Practice** – a [multi] lectic including resistance and accommodation (adapted from Pickering 1995 & in press) Practitioner [diffracts] in and on practice. Methodologies are modified in response to diffractions [interference patterns] and synergistic events. Team/collaborative approach. Collective, rather than a society of humans and non-humans. (Latour 1999) Need to critically examine technique /practice – as the *poïesis* of artisan is the same as modern (broad scale) technologies. Differences due to the nature of the measuring apparatus. Exposition (Schwab & Borgdorff 2014) Reflective synergistic (Schön 1983)	**Democratic** Social justice **Ethics, Aesthetics, Religion** **Democracy** for stakeholders Critical constructionists feminists, critical pedagogy, performance studies, oral historian **Interpretive interactionists** Particular possibilities for intra-acting exist at every moment and these changing possibilities entail an ethical obligation to intra-act responsibly in the world's becoming, to contest and rework what matters and what is excluded from mattering (Barad 2007). We are responsible for the cuts that we help enact because we are an agential part of the material becoming of the universe (Barad 2007). **Vibrant Matter: Jane Bennett (2010)** Liveliness of matter. Looking at the nonhuman as a source of action – has efficacy can do things, can make a difference, produce effects, and alter the course of events. Collective human and nonhuman (Latour 1999) Agency (Latour & Woolar 1979; Latour 1999) Creative evolution *elan vital*. Bergson (1907 Fr/ 1911 trans)
	Agential realist (Barad 2007) Naturalist Realities exist in the form of both immutable natural laws and mechanisms (mathematics) AND multiple mental constructions, socially and experientially based, local and specific, dependent for their form and content on the persons who hold them. Multiverse (Hawking & Mdlodinow 2010) A metaphysics of *phenomena* (Barad 2007) Speculative realism (Whitehead 1938) Practitioner–researcher Leonardo da Vinci Intra-disciplinary	**Bearing witness** (Webb 2012) Sensuous Objective subjectivist (Scientific practitioner?) Or Subjective objectivist (Art practitioner?) The inquirer, a practitioner, moves from one orientation to another, depending on what is being inquired. M-Theory (Hawking & Mdlodinow 2010) Space, time and matter are mutually constituted though the dynamics of the world's iterative intra-activity (Barad 2007). There is an important sense in which practices of knowing cannot fully be claimed as human practices, not simply because we use non-human elements in our practices but because knowing is a matter of part of the world making itself intelligible to another part (Barad 2007, p. 185)		
	Emergent Dynamic Phenomena = primary onto-epistemological units	Agential intra-action Discursive knowledge making practices	Diffractive Practice-based Measuring apparatus	Liveliness Entangled Collective Democratic

introduction of this artistic practice has also contributed to the scientific disciplines by virtue of new audiences, new methods of visualisation, new methods of communication as evidenced by a diverse array of phenomena, as exhibitions, works of art/science, collaborative conference presentations, and intra-disciplinary collaborations. This chapter has demonstrated that NTROs, and the *Aletheia* exhibition in particular, are new ways of communicating scientific knowledge to specialist and non-specialist audiences alike. By taking the science out of the type room and research journals and into more broad academic practice has allowed new visual outcomes, which also provide new scientific (morphological) knowledge. The visuals, as stills, video or in three dimensions have a dual function, including communication in traditional scientific routes, such as journal articles and books.

The scientific practice has contributed to the artistic practice by means of inspiration — new subject matter, new techniques using existing equipment, such as photogrammetry and new technologies such as computed tomographies utilising synchrotron radiation. The artistic practice has been enriched and expanded by virtue of these new sources of inspiration, technology and new audiences. The combination of practices has catalysed other collaborations, such as scanning using neutrons at the Lucas Heights DINGO facility in Sydney.

Challenges

The inherent hybridity of this project was both invigorating and challenging. The challenges included choosing a research paradigm and methodology which would work across both disciplines. Quantum|ivism has been proposed in this exegesis, but is arguably worthy of a research project of its own to investigate in greater depth the potential application and feasibility of such an intra-disciplinary approach.

The success of the project also relied heavily on the relationships between individuals in different disciplines. There had to be a high level of mutual respect and consideration for the project to progress. It would be difficult to replicate the success without researchers taking turns to facilitate the forward movement of the project.

Peer review and thesis examination is harder to access in the hybrid research practice, as specialists do not always feel comfortable when the study goes into territory with which they are not familiar. Similarly, if they are very familiar with the discipline they may have very set ideas of what/how/when it should be done/ written. There is also a residual bifurcating element of the 'two cultures' (Snow 1959) to contend with to dispel the myths that science is the only serious and real method for knowledge production. Knowledge making, as demonstrated by this project, is best served by multiple practices, of which the visualising practice of art is as crucial as the scientific practice.

This doctoral candidature produced a wealth of different outcomes in multiple media as summarised in this chapter. The list of outcomes is presented as evidence of the

practice-based aspect of the research, and also of the intra-actions that have informed the exegesis. However, it is the *Aletheia* exhibition works as documented in Chapter four and this exegesis, as a component of the overall thesis which are presented as evidence for examination. The risk of what Sandry and Willson (2014) call the 'invisibility of technological systems' is also a concern as the technology used to produce the images is significant and required a high degree of intra-action between researcher, specimen and technologies. This might not be immediately apparent and care needs to be taken, via the ethico-onto-epistemology of Quantum|ivism to reveal the agency, the power and consequence of these systems. The work undertaken to produce the images of Chapter four, is equal in skill and observation as Turpin's '*Organ vegetale*' presented in Chapter one, pages 18–19. However this may not be immediately apparent to the viewer due to the digital nature of the images, versus the traditional and easily recognisable artistic skill of hand rendered images. Bolt (2004) makes note of this issue:

> In a technocratic epoch, it is so easy to confuse the work-being of the work with its equipmental-being. In our efforts to design the world, the equipmental aspect of the work is revealed and the work-being of the work stays under cover. (Bolt 2004, p. 116)

The digital files created which subsequently were used to produce the artefactual component of this thesis require significant storage space and computer processing capabilities. Having these available for access is currently very challenging, however discussions initiated with the High Powered Computer Centre at CQUniversity are one means by which this may be solved. Currently the data is stored on the Australian Synchrotron's MASSIVE long term storage. However, this is designed as a temporary facility and will need to be moved to a longer term solution as soon as is possible.

Research in a specialist field, such as palaeobotany, is usually undertaken by researchers with the same type of training, education and field experience. However, in this instance, it was crucial to inventive practice to introduce new skills by the addition of a team member who 'sees' differently and who is able to bring a whole new skill set to the discussions. A high level of technical ability or aptitude was required to be able to process the data and then use it visually. The initial computing requirements for processing the CT data make it difficult as an accessible technique. Application for beamtime is required. Follow up processing is also difficult as the researcher needs significant computer processing power.

Interpretation of images may be difficult as researchers need to be able to 'read' or 'see' what is inherent in the scans, and this is a field of study in itself. Analysis of two dimensional photographs is very different to manipulation and examination of three dimension digital volumes. Colleagues at the Synchrotron made the comment that, unlike this project, much of the data obtained by researchers at the Synchrotron does not always

get processed, utilised fully, published or moved from long term storage.

Future work

Possible ARC Linkage Grant

This intra-disciplinary practice has used the skills from one practice to complement and enhance the other and vice versa. The contributions to knowledge have been justified and a more democratic reporting and access of research results has been demonstrated. The access and sharing has not remained within specific academic disciplines but has been exhibited, engaging non-specialists, initiating thoughts, catalysing, inspiring, doing things in a different way. The proposal for future work involves continuation of processing of data, including the ten terabytes from the synchrotron scans, and an additional five terabytes the from DINGO scans. It will include visualising the research results in a variety of 2D and 3D formats, for publication in papers, exhibitions and for outreach programmes. Currently the team is workshopping a concept for an ARC Linkage grant to continue the work. The research would involve CQUniversity, the Queensland Museum, ANSTO's Lucas Heights facility and the Australian Synchrotron. A great many of the specimens are as yet unclassified; however, with the new information on internal morphologies, these are now able to be studied phylogenetically. I also plan to use the visuals produced as exemplars in the complex relationship dialogue between visual competence and visual literacy.

Big data

Knox (2016) defines 'Big Data' as 'datasets with sizes beyond the ability of commonly used software tools to capture, curate, manage and process within a tolerable elapsed time' (pp. 442–3). This project has certainly added to the phenomenon of ever increasing 'Big Data'. The processing of the large number and size of files was only possible with the computing power of the MASSIVE cluster of computers. Despite the ability to access the cluster of computers remotely, it was difficult to process the 3D volumes via the portal. The subsequent generation of creative visualisations was made possible by the researcher's upgraded personal computer, one that had been specifically built to cope with large volumetric data rendering. Data storage is an important issue; what to store, where and how to democratise access to this information is currently being investigated. The implications:

> Compiling, scaling and processing this new and vast data universe require the best of science and technology, while exploring issues of meaning in Big Data calls for the symbolic, complex, critical interpretations of the arts. We need all forms of human knowledge production applied in concert, at full speed and in every direction; science will do the essential counting while art will extract the meaning. Big Data is art's new territory. (Knox 2016, p. 3)

'Big Data' is a serious consideration for our planet, and while I believe science is also able to translate, and art is able to count, I concur with Knox that the future of research requires the multiple, flexible tools inherent in an intra-disciplinary approach to research.

This research project has had a Renaissance style journey; initiated by curiosity to experiment within the disciplines of science and art, and has led to practice-based methodologies, inventiveness and innovation through an emergent paradigm of Quantum|ivism. The works of art and science presented within this thesis embody *epistêmê, technê and poïesis*, and in doing so, provide novel scholarly visualisations of evolution and extinction in Queensland flora.

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