First geological investigations in Australia and Antarctica by French scientists, naturalists and surgeon on voyages of discovery, between 1792 and 1840

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Proceedings of the 47th INHIGEO Symposium, Les Eyzies, France, 2022
Special issue of the *Travaux* of COFRHIGEO
T. XXXVI^BIS, 2022

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Abstract. When Binot Paulmier de Gonneville returned from a long ocean voyage in 1504, claiming to have found the fabled Great South Land, the landmass that is now Australia was still an undefined part of this imaginary southern continent. Two other French navigators set out in the late 18th century to prove the existence this legendary land in the south. They reached Australia but left few records of the nature and the shape of the country they briefly encountered. Between 1792 and 1840 seven French expeditions of discovery visited Australia, five of which as part of voyages around the world. All had embarked on these voyages with different objectives and their contributions to descriptions of the landscape and to the knowledge of Australian geology vary considerably. One of the major tasks of the first two of these expeditions led by Bruni d'Entrecasteaux (1792) and Nicolas Baudin (1801-1803) was the charting of the still incompletely known coasts of Australia. Their work resulted in the publication, in 1811, of the first complete map of the continent. Both expeditions sailed with a large complement of civilian scientists who examined and recorded aspects of the country's natural history, including its geology. The loss of relevant journals and the death of some of scientific personnel and ships' officers has severely diminished our knowledge of their findings. The following five expedition to visit Australia were commanded by Freycinet (1818) Duperrey (1824), Bougainville (1825) and Dumont d'Urville (1826 and 1839-40). On these voyages the ships' surgeons took over the role of naturalists. Most had a considerable knowledge of the natural sciences, which often included mineralogy. They made valuable contributions that provided early insights into the nature of the continent's landscapes and geology. Many thousands of specimens were collected and taken to France for study and display. The last of these expeditions sailed from Tasmania to Antarctica, where its crews were the first to discover solid land beneath the cover of ice and proved the existence of a southern continent.

Keywords: Australia – Tasmania – Antarctica – Freycinet – Duperrey – Bougainville – Dumont d'Urville

Introduction

The sighting of ice-free land in Antarctica in January 1840 by the crew of the French expedition led by Dumont d'Urville provided the world with the first firm evidence of the existence of a southern land, albeit largely hidden below a cover of ice. It was a fitting discovery as it had been another Frenchman, the navigator Binot Paulmier de Gonneville, who in *c.* 1503, may have been the first to set out in search of the imagined *Terra Australis incognita* (Sankey, 2013). He claimed to have found an idyllic land inhabited by friendly natives, to the east of the Cape of Good Hope.

The theory of the existence of a large landmass that encircled the southern part of the globe, proposed in the writings to Alexandrian astronomer, mathematician, and geographer Claudius Ptolemy (100-170 CE), would influence the perceptions of Europeans for centuries. On the sixteenth century world maps of both Mercator and Ortelius, the Great Southern Land is shown to encircle the southern extent of the globe, to enclose the Indian Ocean and, in one part, to reach north to embrace the present outline of Australia.

When in 1642, Abel Tasman set sail from Batavia for the Southern Ocean, Australia's north, west, and southwest coasts had already been partly charted by Dutch navigators. Tasman would add Van Diemen's Land (Tasmania) and the east coast of New Zealand to these discoveries. Setting a northerly course on his homeward voyage, in effect circumnavigating in a wide arc, what was then referred to as New Holland, he proved beyond doubt that it was not a part of the elusive southern continent.

Following the attempts of several French navigators to discover the southern continent, it was in 1771/72 when two French expeditions commanded respectively by Marc Joseph Marion Dufresne (1724-1772) and Yves-Joseph de Kerguelen de Trémarec (1734-1797) left Mauritius to renew the search for the southern land. The former, in the *Mascarin* and the *Marquis de Castries*, sailed in forty-degree latitudes and discovered the Prince Edward Islands, to the south of South Africa. He continued his voyage to reach Tasmania and New Zealand, but without sighting the southern continent. Kerguelen in *Fortune*, together with his second-in-command, Louis Aleno de Saint-Aloüarn, captaining the *Gros Ventre*, discovered a group of islands in sub-Antarctic waters. The commander believed that he had found the northern capes of the Great South Land. Becoming separated from his companion ship, he returned to France to announce the erroneous news of his discovery. Saint-Aloüarn followed his instructions and proceeded to the next rendezvous point on the southwestern coast of Australia. With no sign of the *Fortune*, he charted part of its western coastline on his way north to Batavia. In August 1771 he claimed the western coast of Australia for France, some eighteen months after the then lieutenant James Cook had claimed its eastern coast for Britain.

First geological observation in Australia

Before the arrival of Alüoarn, Dutch and English navigators had sailed along and had charted part of the western and southwestern coasts of Australia but had made only cursory comments on its landscape and geology; their recording of rock outcrops was mainly related to their significance to navigation. When the Cook expedition reached the east coast of Australia in 1770, its accompanying botanists, Joseph Banks and Daniel Solander, seemed to show no interest in the country's geology, and collected no specimens. It was Cook himself who gave a first, brief description in his journal of the sandstone formation of the Sydney area.

La Pérouse's expedition arrived at Botany Bay, a few days after the first British convict fleet had anchored there, in 1788. During its brief stay, the Abbé Mongez (1751-1788), considered to be the first person with expertise in mineralogy to visit Australia, discovered a white clay which he believed to be suitable for making good chinaware.

The British authorities responsible for sending the First Fleet carrying more than 1,000 convicts and crew, did not consider it necessary to include a single person with expertise in any of the sciences, other than medical officers. It therefore fell to laypersons to explore the area near their new settlement at Sydney Cove for raw materials such as clay and limestone for building and to make observations on its landscape. Arthur Phillip, the colony's first governor, in referring to the sandstone strata around the first settlement, informed the authorities in London of the outcrops of Freestone, which he compared to the Portland stone in England (Mayer, 2007).

The aims of the seven French expeditions and their personnel

The period between 1792 and 1840, during which the seven French expeditions of discovery discussed in this article visited Australia, coincided with several major regime changes in France. The first voyage, led by Bruni d'Entrecasteaux, which left France in 1791, was approved by the National Assembly and sailed with the support the monarch, Louis XVI, while the second, commanded by Nicolas Baudin, departing in 1800, was authorised by the Republic's First Consul, Napoleon Bonaparte. Louis de Freycinet, who commenced his voyage in 1817, and those that followed, sailed under the flag of the restored monarchy.

The purposes of the various voyages and the instructions given to the expeditions' commanders differed in line with changing circumstances in their home country. The missions of the first two expeditions, which arrived in 1792 and 1801, respectively, included the charting of Australia's still incompletely known coasts and, at their stopovers, to survey and study aspects of the county's natural history. The five expeditions which visited the country between 1818 and 1840 could now navigate with greater ease along its well-charted coasts. They stopped at fewer locations, and with some exceptions, for briefer periods. They found a country much changed, with larger settlements and an increased population.

The vast accumulation of new knowledge and fresh concepts in newly recognised disciplines of science in the late eighteens and early nineteenth centuries led to the appointment of personnel on voyages of discovery, who were knowledgeable in a range of scientific fields. The wide background and experience of many of these scholars allowed each to conduct surveys and make collections across several disciplinary areas. They were often assisted in their work by some of the ships' officers and even their commanders, some of whom possessed considerable knowledge of or had an interest in the natural sciences.

The first two expeditions commanded by Bruni d'Entrecasteaux and Nicolas Baudin, sailed with large complements of civilian scientist and naturalists, 9 and 23 respectively. As these savants were not subject to naval discipline, they sometimes disregarded instructions issued by their commanders and overstayed their time onshore, either voluntarily or, even, acting in a reckless manner, becoming lost. This often resulted in great inconvenience to their captains and led to heated arguments and disharmony on board. Louis de Freycinet, who had been a lieutenant on the Baudin expedition and had experienced such disputes at first hand, decided against employing civilian scientists on his own voyage in 1817-19, and instead relied on his naval surgeons to also take on the roles of naturalists. All the captains of subsequent French expeditions followed his example.

The expeditions' medical doctors had a broad knowledge of the natural sciences. They may have lacked a deeper understanding of respective scientific disciplines, but nevertheless made important observations and collected specimens during their mostly brief stays ashore.

It is a great loss to the history of the natural sciences, including to geology, and to the history of exploration that many of the scientific personnel of the two early voyages, as well as their commanders, did not survive to prepare accounts of their work and travels. Various circumstances, including wars in Europe, involving frequently changing alliances between nations and, very probably, simple negligence on the part of individuals and authorities, led to the unfortunate loss of both journals and collections. This affected particularly the records of the expeditions' geological work.

D'Entrecasteaux's expedition and the first scientific study of Australian geology

In 1791, the French National Assembly authorised an expedition to the South Seas with the aim of searching for the missing La Pérouse and his crew, who had not been heard of since his ships had anchored at Botany Bay in 1788. At the urging by members of the *Société d'Histoire naturelle*, the expedition was given the additional task of charting the continent's unknown coasts and to study its natural history. Bruni d'Entrecasteaux (Fig. 1), was appointed commander of the voyage and sailed from Brest with the frigates *Recherche* and *Espérance*. He was a native of Aix-en-Provence and the son of a member of the *Parlement de Provence*. After joining the Navy at the age of 17 he saw service in the Far East, and in 1785 was appointed as Governor of Isle de France and Isle de Bourbon.

Fig. 1. Bruni d'Entrecasteaux (1737-1793)

Expectations for the success of the voyage were high. Several individuals, foremost among them Dolomieu, had written memoires providing instructions and advice to aid the assigned mineralogist in his geological investigations. It was hoped that the expeditions findings would contribute towards advances of the theory of the Earth and perhaps result in the discovery of new mineral deposits (Richards, p. 62).

The expedition left Brest in September 1791 and after reaching Cape Town, D'Entrecasteaux decided to sail directly to Van Diemens Land (Tasmania). Following a stay there of just over a month he resumed his voyage to the Pacific Islands in what proved to be an unsuccessful search for La Pérouse. Following visits to islands to the north of Australia he returned to Cape Leeuwin, the continents southwestern point, to commence the charting of its southern coast and to provide opportunities for his naturalists to engage in their respective studies.

Among the nine scientists on board, who had been carefully selected by the *Société d'Histoire naturelle* in Paris, was the mineralogist Jean Blavier (1764-1828), the first time a member of this discipline had been chosen for such a voyage. Blavier had only recently graduated from the École des Mines (Richard, 1986, pp. 62, 66), and would have brought invaluable expert knowledge to the expedition's investigations had not illness, and, perhaps, dissatisfaction with the conduct of the voyage, led him to withdraw at Cape Town. He returned to France to a successful career, mainly as an administrator of mines.

The responsibilities for the expedition's geological investigations fell to Claude Riche (1762-1797) a medical doctor knowledgeable in both botany and geology. His enormous workload also included responsibility for the study of birds and vertebrates and measuring the temperature of the sea at different depth. Riche had studied at the university of Montpellier and, in 1787, was awarded the doctorate in medicine *"avec la plus grande distinction"* (Richard, p. 66). In 1788 we find him in Paris where he met Cuvier among other leading scientists and where he carried out research and published reports on a wide range of subjects in the physical and life sciences. He was elected a member of the *Société d'Histoire naturelle* in 179. Sketchy references in the literature refer to him engaging in geological fieldwork in the Languedoc region in southern France, probably at the time when he was studying at Montpellier. He does not appear to have published any of the results of his investigations there. The variety of rock types exposed in the Languedoc, their wide ranges in age and their different settings, would have provided him with a good introduction to geology. His seeming familiarity with current knowledge and ideas regarding the then current state of the geological sciences, and an extensive onboard library containing relevant works on the discipline, provided him with a good background to contemporary thinking.

As we now know, the effective end of the expedition in Batavia on its return voyage and the confiscation of Riche's journals and collections by the Dutch, then at war with France, ended these hopes. Riche did return to Java a year later trying to retrieve his belonging, but without success. He died from consumption in France in 1797.

The first view of the landscape that offered itself to the observers as the ships progressed in an easterly direction along the continents south coast, were of a discouraging monotony and uninspiring. Beyond high coastal dunes and often cliff-lined shores, they noted a vast expanse of low-lying terrain, of a mostly sterile nature, but with patches that had the appearance of being fertile. The great rivers the naturalists had expected to flow into the ocean did not exist and sources of fresh water were very scant. It was the lack of reserves of drinking water which forced d'Entrecasteaux to end the charting and surveying of the continents arid southern coast and set a course for Van Diemen's Land. This denied the expedition the credit for mapping the still unknown parts of the coastline and closing the last gap on the map of Australia (Fig. 2) (Duyker & Duyker, 2001, p. 107-135).

The first documented geological comments on this region are those of the commander himself who, referring to large coastal dunes, wrote in his journal (:) *"It is to be presumed that the kinds of sand mountains are formed by storms, which must be very violent on these coasts, to judge by the ways they are battered by the waves."* (Duyker & Duyker, 2001, p. 113) And (:) *"Every bit of coast we sighted on the east and west presented the same appearance: that of a steep calcareous rock*

[Eocene to Miocene] *of equal height in its whole expanse, the layers of which were completely horizontal, as well as the plateau on the summit."* (Fig. 3) (Duker & Duyker, 2001, p. 131).

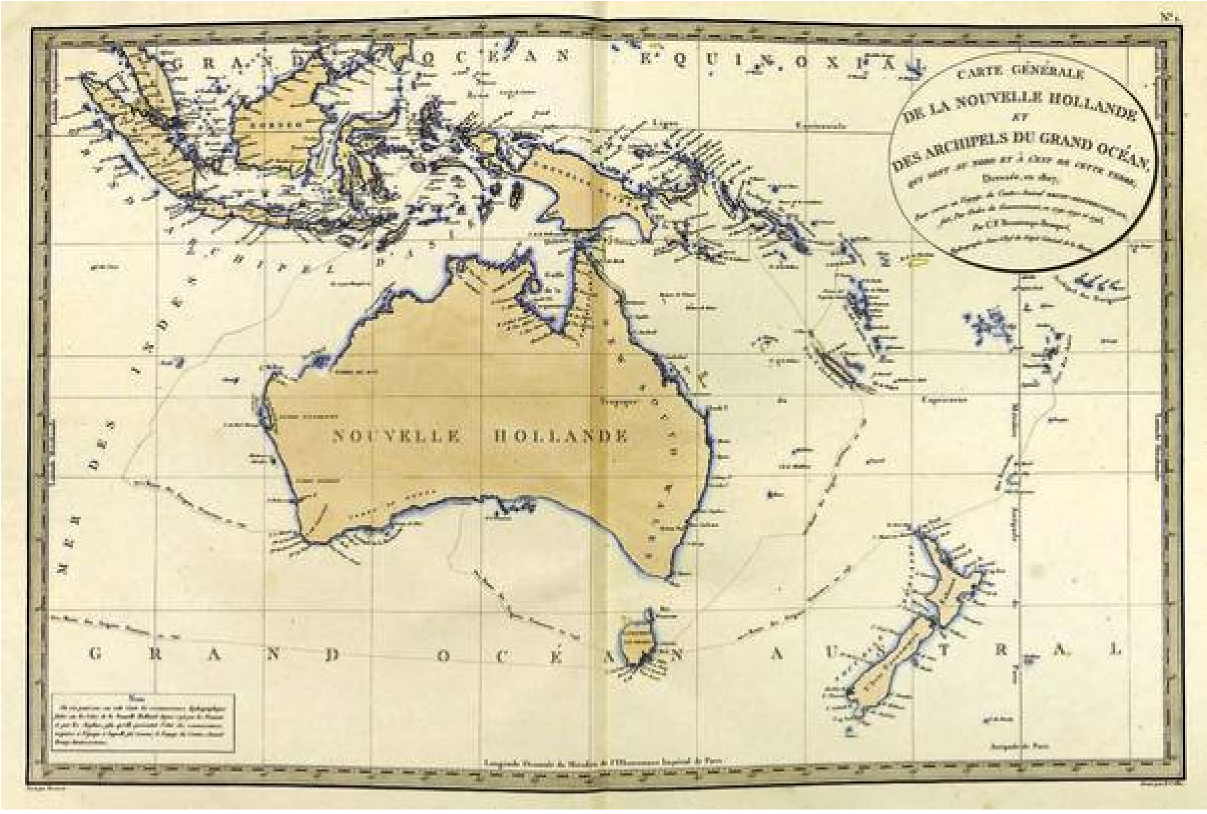

Fig. 2. Map of Nouvelle Hollande (Australia), showing the yet uncharted southern coastline of the continent and parts of Tasmania when d'Entrecasteaux's commenced his surveys in 1792

Fig. 3. Horizontal strata of Tertiary calcareous rocks exposed in cliffs along the coast of South Australia, described by d'Entrecasteaux

It seems rather ironic that the longest uninterrupted period Riche spent on land on the continent's southern coast was the time when he became lost. During a stopover at Esperance Bay, he had gone ashore with a surveying party but became separated from them. During the more than two days of his ordeal he remained calm; he even made notes of his discoveries and collected samples. It is to this episode that we owe one of his few surviving written observations on the continent's geology from an entry in his commander's journal. Standing on dunes with a view of both the beach and towards the interior, Riche was astonished to note that (:) *"Looking towards the north, the interior was very visible far inland; the country was very fertile, and columns of smoke were rising a few leagues away. The mountains at the horizon very far in the distance were not very high. It is remarkable that granite, bristling with feldspar, which forms the core of all the high primitive mountains of the globe, is here at the foundation of an immense region, very smooth and nearly at sea-level in its entire expanse."* (Fig.4) (Duyker & Duyker, 2001, p. 122).

His views were most likely based on his reading of Pallas (1771-1776), who identified the granites forming part of the core of the Ural Mountains as the oldest (Primitive) and successive sequences of overlying sedimentary rocks as younger (Secondary and Tertiary) That author's work was readily available in France and would have been part of the comprehensive onboard library. Future visiting naturalists would also have their knowledge of geology, acquired in Europe, challenged by observations in Australia.

Among the dunes he also noted large numbers of petrified tree trunks and roots in their growth position and concluded that this […] *"destroyed forest"* […] had once grown in a fertile valley located further from the sea (Duyker & Duyker, 2001, p. 119). Naturalists of later French expeditions would record the finding of many such petrifaction, particularly along Australia's western coast.

Jacque-Julien Houtou de Labillardière (1755-1834), the expedition's botanist, whose journals and collections were in time returned to him, displayed his versatility as a scientist when he discovered a coal seam at South Coast Bluff in Tasmania (Duyker, 2003, p. 145). The seam, now known to be of Triassic age and interbedded with sandstone was only a few centimetres thick (Fig. 5). Based on his apparent knowledge of European coal measure sequences, in many of which coal is associated with sandstone layers, he predicted that more substantial seems of coal would be discovered in this area. Coal was indeed mined in this region some decades later. Labillardière also speculated on the occurrence of iron ore in the area based on his noting of rust-coloured water in a stream.

Fig. 4. Outcrops of Archaean granite on the southern coast of Western Australia, like that seen by Claude Riche in 1792

Fig. 5. Triassic sandstone with coal seams, first recorded by the botanist Labillardière in 1792

The Baudin expedition 1801-1803 and the first tertiary qualified geologists to visit Australia

In October 1800 the expedition authorised by Napoleon Bonaparte and commanded by Nicolas Baudin (1754-1803) (Fig. 6) left Le Havre in the corvettes *Géographe* and *Naturaliste*, on its voyage to Australia. Its commander, born at St Martin on the Île de Ré joined the merchant navy at the age of 15. His widely varied career included service in the American revolutionary war and as captain of several botanical collecting voyages (Horner, 1987, pp. 24-35, 2006, pp. 43-55; Rivas, 2006, pp. 73-112; Jangoux, 2010, pp. 41-50). Although ten of the twenty-three scientific personnel selected for the voyage left the expedition at the Ile de France, the still large number of the scientific staff, together with a supply of modern equipment, up-to-date charts, a wide range of books and an experienced leadership, made this the most successful of the seven voyages in terms of the charting of the continent's coastline, the range of its scientific discoveries and the size and variety of its natural history collections. Baudin was to lose four more savants to disease in Australia and another two, who had long been ill, on the return voyage. The latter included the mineralogist Louis Depuch, who died on the Ile de France in 1803. Baudin himself succumbed to illness on the same island (Mayer, 2005, 2009).

The flowering of interest in the Earth, both among scientists and the public, and the significant advances made in geology in the latter half of the eighteen's century, had prompted the *Institut de France* to appoint four mineralogists to the expedition. Two of these, Denys Montfort (1766-1820), better known for his work on molluscs, and Antoine Busche (1776-?), withdrew before the ships sailed.

Louis Depuch (1774-1803) and Joseph Charles Bailly (1777-1840) were appointed as senior and junior mineralogists, respectively. The former was born in the small village of Caumont in the southwest of France and graduated from the École des Mines in 1798. His teachers had included Déodat de Dolomieu and René-Just Haüy. As Depuch generally added the title 'Mining Engineer' after his signature on documents, it can be assumed that he had worked in the mining indu-
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stry before embarking on this voyage. The loss of his journals after his untimely death limits our knowledge of the surveys he carried out and his interpretation of the country's geology. Before he became ill, he did however send regular reports of his work to his captain, which have been preserved. Bailly, born in Nancy, studied geology at the *École Polytechnique*. He does not seem to have kept a journal but produced a catalogue of the geological specimens he collected and wrote reports of his geological investigations (Péron & Freycinet, 1816, pp. 92, 142-146).

Fig. 6; Nicolas Baudin (1754-1803)

The two mineralogists received unexpected help from the multi-talented François Péron (1775-1810) who, although appointed as the expedition's zoologist, took a great interest geology. When Depuch became incapacitated, Péron took over much of his work. His descriptions and interpretations of the country's landscape and geology along its margins introduced European readers to a range of the continent's natural features (Péron, 1807; Péron & Freycinet, 1816).

At the expedition's first stopover in western Australia's Geographe Bay Fig. 7), Depuch recognised extensive outcrops of 'granite' [Precambrian granite gneiss] composed of feldspar, quartz and brilliant black mica occurring in bands. The paral lelism of these mineral bands in alignment with well-defined and regularly spaced joint planes in the rock led him to conclude that the granite was bedded (Fig. 8). He saw his discovery as confirmation of the claim by de Saussure (1779, pp. 99-100) that granites in the European Alps were stratified. Observing these outcrops prompted him to write (:) "*It is impossible not to be convinced here of the fact, which M. de Saussure was the first to recognise and which several naturalists still contest, that granites are apt to stratify"* (Baudin, 2004, p. 167). His views agreed with the those of Dolomieu, his former teacher, who in his four-fold classification considered crystalline rocks to be derived from a precipitate in the oceans and the first to form in any region (Cordier, 1796).

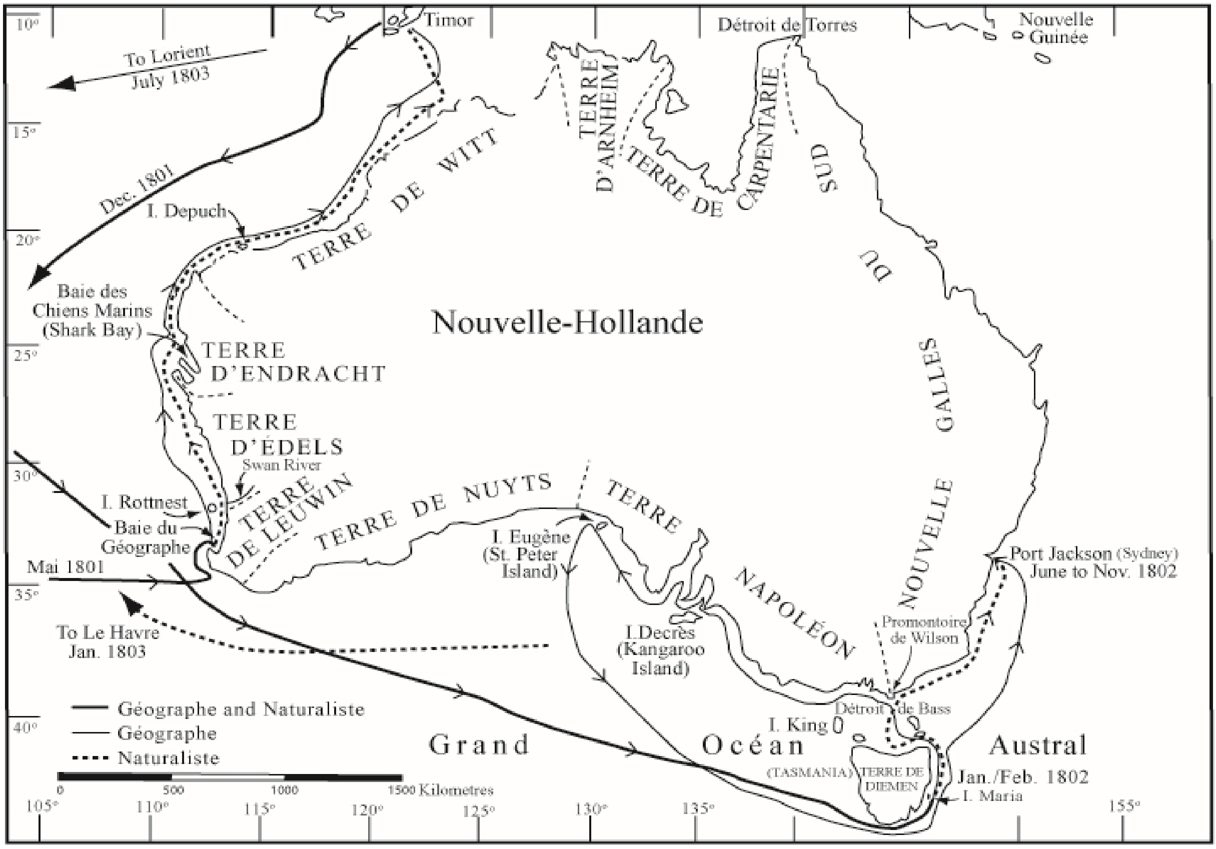

Fig. 7- Route map of the Baudin expedition 1801-1803

Fig. 8. Outcrop of Precambrian granite gneiss at Geographe Bay in Western Australia. Depuch considered these rocks to show stratification

At to the foothills of the Blue Mountains, a short distance inland from Sydney, Depuch and Bailley noted pebbles of granitic rocks in a riverbed which had been carried down from the higher ground, while the banks of the river were formed of horizontal layers of sandstone. This provided them with a good example in support of their idea that granite formed the core of mountain ranges and was the first-formed of rocks, classed as the Primitive, while the stratified sedimentary rocks were part of the Secondary and were assumed to overly the granitic core of the range. It may be thought curious that, unlike Riche some ten years earlier, Depuch seems to have accepted without question finding granites at sea level on the continent's western coast, which he himself had described as "*low-lying, or at least, not very high*" land (Péron and Freycinet, 1816, p. 60).

At the same location the two mineralogists also "*found large deposits of bituminous schist which burns with a bright flame*" (Péron & Freycinet, 1816, pp. 339-347), the first recorded finding to oil shale in Australia. Layers of the shale crop out higher in the range and it can be assumed that the 'deposits' they referred to were accumulations of pebbles in the riverbed.

Baudin's observation from out at sea of "*a chain of extremely high mountains*" (Baudin, 2004, p. 427), to the south of Sydney, and information gained from inhabitants that they extended northwards, led the visitors to the conclusion that the Blue Mountains formed only a small part of an extensive range along the eastern margin of Australia [the Great Dividing Range]. Péron went so far as state that "*these mountains of New Holland are remarkably similar to the Andes in South America in situation.*" (Péron and Freycinet, 1816, pp. 307-308).

The firsthand knowledge the two geologists had gained of the sedimentary sequences in the Sydney area and being made aware of coal outcrops on the region's coast, both to the north and south of the town, led them to suspect that the coal seams extended below the inhabited land. This prompted Bailly to write (:) "*To judge by analogy and from numerous indications presented by the composition of the terrain, one could state positively that there is a great quantity of coal beneath the very soil of Paramatta*" [then a small settlement close to Sydney] (Péron & Freycinet, 1816, p. 340). Their interpretation suggested the existence of a basin structure, now known as the Sydney Basin.

On their separate excursions to survey the geology along the coast of Western Australia, the mineralogists and Péron recognised a sequence of calcareous sedimentary rocks composed of an aeolian sequence containing petrified tree trunks and root and of marine interbeds with various species of molluscs. The shells in these strata were like those found "*living on the beaches in front of the stratified cliffs*." He assigned the strata to the Secondary and agreed that they were of a geologically young age and had in recent times emerged from the sea (Fig. 9) (Péron & Freycinet, 1816, pp. 92, 142-146). The two geologists and Péron also concluded the rock sequence found along the Swan River and on Rottnest Island in the southwest of the state were the same as those they examined in Shark Bay, more than 700 km to the north (Fig. 7). We recognise this formation today as the Tamala Limestone of Pleistocene to Early Holocene age (Mayer, 2008; Playford, 2006; Kendrick 1991).

Fig. 9. Horizontal strata of the Pleistocene Tamala Limestone

Péron also noted the presence of corals in strata now well above sea level and deduced from this discovery that an ancient ocean must once have covered the entire Earth but has since retreated to expose the land. He pondered the question of the fate of the vanishing waters but reached no satisfactory conclusion (Péron, 1804, p. 467). Péron seems to have been unaware of then recent developments in the geological sciences. It is clear from his writings that he accepted Dolomieu's classification of rock types and probably absorbed much of the latter's teaching in conversation with his friend Depuch.

Péron's finding of living specimens of the mollusc *Trigonia* on the Australian coast (Bonnemains *et al.*, 2001, p. 267) caught the attention of both Lamarck (Lamarck, 1804) and von Buch (von Buch, 1814). The former saw this as a confirmation of his theory that animals did not become extinct but merely underwent small changes over time. To the latter this provided grounds to question the view held by Werner (Werner, 1786) that sediments had been deposited uniformly in a universal ocean.

Freycinet's expedition and his surgeon/naturalists

In 1818, some 15 years after Baudin's departure from Australian shores, one of his former lieutenants, Louis de Saulces de Freycinet (1779-1841) (Fig. 10), returned in the *Uranie* in command of his own expedition. He was the first in a succession of officers who had participated in earlier voyages to Australia and who would later return leading their own expeditions. Born in Montélimar in southeastern France, he joined the French Navy at the age of 14 and took part in several engagements against the British before his appointment to the Baudin expedition. On his first voyage Freycinet had played a major part in charting the remaining unknown part of the continent's southern coast and, in 1811, had published the first complete map of the Australian coastline. The primary aim of his new mission was to conduct research into the shape of the globe [*la figure du globe*] and the elements of terrestrial magnetism. When time allowed during stopovers, he was also to carry out studies into the three kingdoms of nature and to facilitate the collection of specimens (Freycinet, 1826, pp. XIII-XIV).

Fig. 10. Louis de Freycinet (1779-1841)

Freycinet asked his two surgeon Jean René Constant Quoy (1790-1869), and Joseph Paul Gaimard (1793-1858) to also take on the roles of naturalists. Quoy was a graduate of the School of Naval Medicine in his native town of Rochefort. He took part in several exploring expeditions, followed by a distinguished career as professor of medicine and culminating in his appointment as inspector general of the naval bureau of medicine and surgery. In addition to his work in zoology and anatomy, he also had an interest in mineralogy. His fellow surgeon Joseph Paul Gaimard, born at Saint Zacharie in south-eastern France, graduated from the naval medical school in Toulon. He is best known for his Arctic voyages and his accounts of Iceland and Greenland (Gaimard,1850). Freycinet made only two stopovers in Australia – at Shark Bay on the West Australian coast and in Sydney. Fortunately for his naturalists, Freycinet's stays at these locations were lengthy ones, giving them the opportunity to make some detailed nature studies.

Quoy, ably assisted by lieutenant Duperrey, expanded the work started by Depuch and Péron who, on their visit to Shark Bay in 1801, had been the first to describe the cliff exposures limestone in this area (Fig. 9). He gave a detailed description of the stratified sequences he examined and identified the rocks as composed of quartz grains held together by a calcareous cement and containing large quantities of bivalve shells. Like Depuch before him, Quoy noted the presence of calcareous nodules with concentric layers in their interior and irregularly disturbed through the sedimentary layers (Fig. 11). While the former had believed that these concretionary bodies had formed prior to being included into the sediment, to which he referred as a breccia, Quoy concluded that they had formed in situ and stated that, "*those who believe that these globules have been transported deceive themselves; I attribute their formation to a kind of crystallisation*" (Freycinet, 1826, pp. 472-476).

Fig. 11. Concentric layers in calcareous concretions

The extensive sand dunes at the base of cliffs in Shark Bay contained abundant tubular structures, up to 15 cm long and about 3 cm in diameter. Quoy noted that they were composed of sand grains held together by a paste of calcite. And formerly held vegetable matter that had since decayed. Duperrey discovered "*an infinity of petrified trunks on a small plain surrounded by dunes.*" He informed Quoy that they were up to a meter high and had a diameter of up to 30 cm (Freycinet, 1826, pp. 472-476).

During the expedition's six weeks sojourn at Sydney in 1819, the naturalists had ample time to explore the region. It had only been five years earlier that the surveyor George Evans had made the first crossing of the Blue Mountains and descended to the western plains. Both Quoy and Gaimard made the journey from Sydney across the mountains to the interior. It is to Quoy we owe the first account of the landscape and geology of the region inland from Sydney, then known as the County of Cumberland.

He divides the land into two natural divisions: the plains and the mountains (Fig. 12). The former is an undulating terrain in the midst of which rise some small, isolated hills, extending from the seashore to the foothills of the Blue Mountains. The rocks he identified were quartz sandstones, which in coastal cliffs can be seen to form immense horizontal beds "*a wall of rocks*" and grey, horizontally layered shales [the Triassic Hawkesbury Sandstone and the overlying shales of the Wianamatta Group, respectively, forming part of the Sydney Basin sequence]. He also noted a small hill [Prospect Hill] protruding from the plain composed of an almost black igneous rock, which he referred to as 'ophite' [a dolerite laccolith of Early Jurassic age].

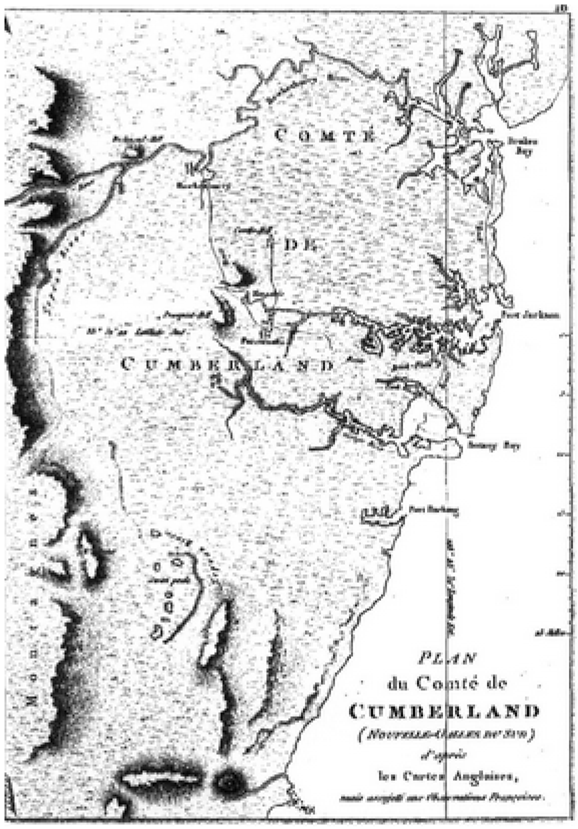

Fig. 12. Map du Comté de Cumberland

When crossing the Blue Mountains, he traced the extent of the sandstone sequence to the higher points of the divide where they were interbedded in cliffs with shales and criss-crossed by cracks [joints]. He noted that the high walls of rock rising from the valley floor were often "*hollowed out at their base, and overhanging at the top*" (Fig. 13).

Fig. 13. Blue Mountains.
The cliffs walls in valleys have a concave shape

It reminded him of the similar appearance of sea cliffs where wave erosion had given them a concave shape at their base. It led him to conclude that only the action waves could have shaped these cliffs. He was not alone in reaching this conclusion. When some 17 years later Charles Darwin visited the Blue Mountains, he became convinced that the valleys had been carved out by an ancient inland sea.

When descending the mountains on their inland side, Quoy noticed a sudden major change in the geology from sandstone to red granites, containing large crystals of pink feldspar. He and his companions had crossed the western extent of the Sydney Basin and were now travelling over the much older underlying rocks of the Lachlan Fold Belt of Ordovician/Silurian age. It was apparent to Quoy that the changes in geology had also brought about a change to the landscape. At this point, he stated that, "*we entered into a second part of the Blue Mountains*" (Fig. 14). He noted that his path had led him from a terrain of insurmountable valley walls to a country of rounded hills with gentler slopes that made walking much easier.

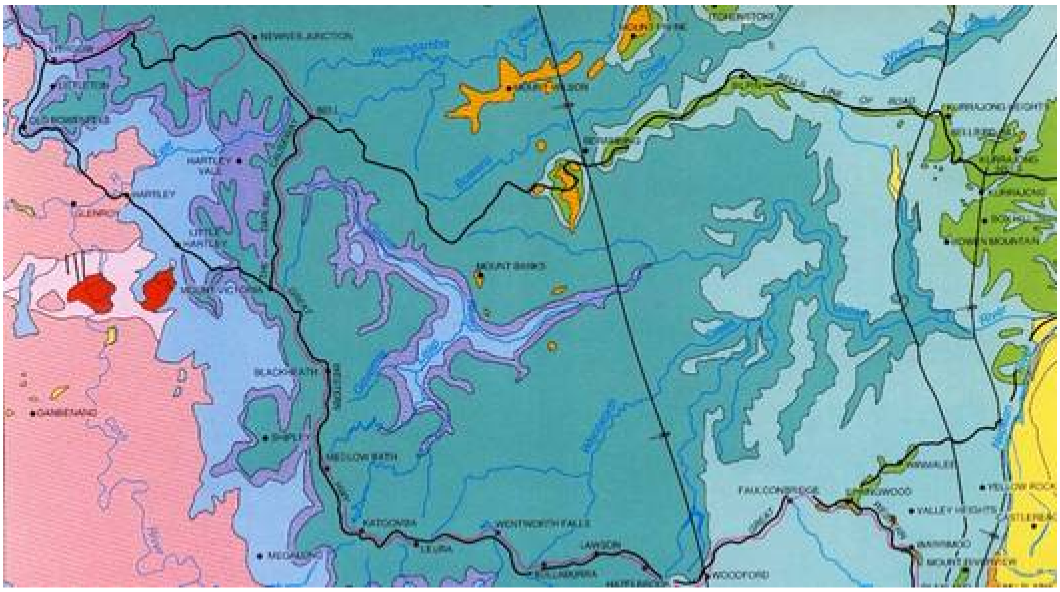

Fig. 14. Geological map of part of the Blue Mountains. The Triassic sedimentary rocks shown in shades of green form both the major and the higher parts of the range. The areas in blue indicate outcrops of Permian sedimentary rocks at the base of the Sydney Basin sequence and mark its western margin. Areas in pink and red represent granitic rocks, part of the Ordovician/Silurian Lachlan Fold Belt. From Pickett, W. and Adler, J. D. (1997). *Layers of time: The Blue Mountains and their geology*

The surgeon was also given the opportunity to travel to the southern end of the Sydney Basin where he again encountered the older rocks underlying it, in this case slates containing mica, but mainly a rock with the appearance of "*grauwacke*". He noted that the layers followed a southwest-northeast trend and were vertical, cut by numerous quartz veins of different dimensions, but did not equate the structural change in these rocks with deformation. (Freycinet, 1826, pp. 672-685).

Duperrey's expedition accompanied by the naturalist Lesson

Louis-Isidore Duperrey (1786-1865) was born in Paris and joined the French Navy in 1802. He gained valuable experience as a lieutenant on the expedition to Australia led by Freycinet and distinguished himself by carrying out work on marine hydrology. He also took an interest in the natural sciences and contributed to the collection of specimens.

In 1822 he was appointed to lead a round-the-world voyage in the corvette *La Coquille* with the main mission to explore the Pacific Ocean and its islands (Duperrey, 1839). He arrived in Sydney in 1824 for a stopover of almost three months. His surgeon René-Primevère Lesson (1794-1849) served as the expedition's naturalist. Like Quoy before him, he was a graduate of the Naval Medical School at Rochefort. Lesson's main interest lay in zoology, particularly the study of birds, but he also described the geology of the regions he visited. He was joined in this work by the expeditions second-in-command, lieutenant Dumont d'Urville, whose main interest was in botany, but who also took an interest in geology and collected geological specimens.

Together, the two made the now customary journey across the Blue Mountains, following in the footsteps of Quoy and Gaimard, but making more detailed observations of the land's natural features. Lesson, in his account of the journey (Lesson, pp. 1- 26), expresses his surprise that no detailed studies have been made of "*the natural wealth of a virgin region still almost unknown in its interior*" (Lesson, 1825, p. 1). His account of the colony's natural history includes descriptions of its geology, zoology and botany, based on his own observations and on information received from the settlers. He modestly refers to his comprehensive summary as « *une simple généralisation de quelques aperçus* » (Duperrey, 1839, p. 240).

Lesson was the first to state that the sandstones cropping out in the coastal cliffs around Sydney extended across the intervening plain to the Blue Mountains and that they were part of the same formation. He described them as stratified and composed of lightly cemented quartz grains colored by iron oxide. Like Quoy before him, he visited Prospect Hill (Fig. 12) on his way to the mountains and identified its rocks as "*composed entirely of dolerite.*"

High in the mountains, Lesson observed horizontal layers of sandstone forming vertical walls rising from deep valley floors. When descending into the valleys on the western side of the range he found "*a rich deposit of bituminous carbonized wood with matt-black conchoidal fracture and which burns with a lively flame*", and a clay containing fossilized impressions of the leaves. Lesson had reached the base of the stratigraphic sequence at the western margin of the Sydney Basin: shales and coal seams of the Permian age underlying Triassic sandstones. Here the outcrops of sedimentary rocks start to give way to granites containing "*large grains of pink felspar crystals, grey quartz and glittering mica*". He correctly marked this transition as the boundary between two mountain chains of differing geological composition (Fig. 14).

His examination of the outcrops he passed on his journey satisfied him that the granites were part of an older "*primitive terrain*" and were overlain by a younger sequence of sedimentary rocks. He appears to have accepted an aqueous origin of granite and like Quoy, concluded that the overlying rocks were marine deposits. It was only in later years that the Sydney Basin rocks were identified as fluvial in origin.

Hyacinthe de Bougainville

It was only a little over a year after Duperrey had left Sydney when Hyacinthe de Bougainville (1781-1846) arrived. He was born in Brest, the son of the famous navigator Louis-Antoine de Bougainville, who but for the obstacle presented by the Great Barrier Reef would have discovered the eastern coast of Australia before Cook. The younger Bougainville started his own career in the

French Navy as a midshipman with the Baudin expedition, some 23 years earlier. After taking part in various naval campaigns, he rose rapidly to higher ranks. In 1824 he was given command of the forty-four-gun frigate the *Thetis* to undertake a voyage around the world. Its main mission was to show the flag and to further French commercial interests. The expedition's almost three-months stopover at Sydney contributed little that was new to the knowledge of the country's natural history. Bougainville's most noted legacy to Sydney was his commissioning of a monument to the missing La Pérouse at Botany Bay, near the southern Sydney suburb that now bears his name. The tragic end of La Pérouse and of its crew at the island of Vanikoro would not become known for another two years.

Dumont d'Urville in good company with Quoy and Gaimard

Dumont d'Urville (1790-1842) (Fig. 15) was born at Condé-sur-Noireau in Lower Normandy. After studying at the Lycée Impérial in Caen he joined the French Navy at the age of seventeen and graduated from the Naval Academy in Brest. Dumont d'Urville saw service in the Mediterranean and took part in hydrographic surveys. Not long after his return to France with the Duperrey expedition he was given command of another voyage around the world, which departed Toulon in 1826. The refitted *Coquille*, now renamed *Astrolabe*, in honor of one of La Pérouse's ships, was again pressed into service. The commander was fortunate when the two veterans of the Freycinet expedition, the surgeon/naturalists Quoy and Gaimard, decided to sign up for another voyage. Dumont d'Urville himself was an accomplished botanist, who had carried out fieldwork and studied the vegetation of the Provence region. The trio were already familiar with many aspects of Australia's natural history and would add to its knowledge during their stopovers in the country (Dumont d'Urville, 1830). The few, relatively brief stopovers by the *Astrolabe* along Australia's coast, including at Sydney, did not give the naturalists the opportunity to carry out detailed geological studies. However, the search for the site where La Pérouse perished, first attempted more than 25 years before by d'Entrecasteaux, met with success, when Dumont d'Urville positively identified the location at the island of Vanikoro.

Fig. 15. Jules Dumont d'Urville (1790-1842)

The expedition's first stop in Australia at King George Sound at the southern tip of Western Australia, gave an opportunity to Quoy and Gaimard. to examine a report of the occurrence of corals at the top of one of its headlands. In 1791, the English navigator George Vancouver in company of his naturalist Archibald Menzies, had climbed what is now known as Bald Head and discovered what they believed to be fields of coral, some 200 m above sea level Vancouver, 1798). Quoy noted outcrops of course grained granite containing large crystals of pink feldspar at the base of the hill but found that Bald Head itself was composed of limestone. At its summit, he and Gaimard soon discovered that Vancouver's branched corals were petrified tree roots, similar to those they had seen at Shark Bay on their earlier visit with the Freycinet expedition (Fig. 16) (Dumont d'Urville, 1830, pp. 92, 113, 200-201).

Quoy also discovered Tertiary basaltic lava along the shores of Western Port in Victoria and obtained plant fossils from shales in the Sydney region. He was delighted when, like Péron at an earlier visit, he found a living species of *Trigonia* off the New South Wales coast. (Dumont d'Urville, pp. 137, 207-208, 210).

Fig. 16. Fossilised tree roots on Bald Head, Western Australia

Dumont d'Urville bound for Antarctica 1837-1840

In 1837, Dumont d'Urville embarked on his third round-the-world voyage in the corvettes *L'Astrolabe* and *La Zelée*. Australia would again be on his itinerary, but his more important aim was to discover land in Antarctica and to determine the location of the south magnetic pole.

His surgeon/naturalists on this voyage were Jacques Bernard Hombron (1798-1852) and Élie-Jean François Le Guillou (1806-1860). Both were graduates of the École de médecine navale at Rochefort. Hombron was also a noted botanist and had a keen interest in geology and mineralogy. During a brief reconnaissance of parts of Australia's northern coast and during their stopover at Hobart, both naturalists collected rock and mineral specimens, but the shortness of time in the field did not allow more detailed geological studies. Le Guillou on a short excursion up the Derwent River from Hobart merely speculated that "*the geologist will find great riches*" in the steep mountains that rise from its banks (Le Guillou, 1845, p. 178).

When the expedition's two corvettes arrived at Hobart, to prepare for the voyage to Antarctica, many of their crews were seriously ill. One of the ships' surgeons needed to stay in town to care for them in a make-shift hospital that had been erected onshore. Hombron, "*who did not enjoy a robust health*" (Dumont d'Urville, 1841-1853, v. 8, p. 186) was to remain behind to care for the sick, while Le Guillou sailed south with the Zelée.

In early January in 1840, Dumont d'Urville left Hobart on the perilous voyage to the frozen wastes of Antarctica in the fervent hope of discovering solid land under the cover of ice and to prove beyond doubt the existence of the long-sought southern continent, the *Great South Land* of earlier times. Before sailing he allowed the captain of the *Zelée*, Charles Hector Jacquinot (1796-1879), the choice of either joining him on the dangerous voyage or to stay behind. Jacquinot, who regarded the voyage to the icy regions as the expedition's high point and the "*most glorious if also the most dangerous part of the mission*", insisted on sailing with his commander (Dumont d'Urville, 1841-1853, v. 8, p. 98).

After a swift voyage south, the corvettes were becalmed in latitudes close to the Antarctic circle (66°.33' S). In fine weather they were surrounded by islands of ice taller than the masts of their ships. In his account Dumont d'Urville describes the magnificent display they witnessed when the sun briefly set behind the icebergs and marvelled at the greatness of the spectacle as the setting sun ushered in the brief polar night, a view to which he thought *no painting could do justice*. (Dumont d'Urville, 1841-1853, v. 8, pp. 138-139.

The eyes of everyone on deck now scanned the vast white horizon for any dark patches that might indicate the presence of land. After several possible sightings, members of the Zelée's crew were the first to positively identify the presence of ice-free land, later recognised as one of a series of eight to ten islets. As a faint brise did not allow the ships to move closer to the firm ground, open boats were despatched from each ship to explore one of the islets. That of the *Astrolabe* reached the land in 2 ½ hours and arrived shortly after that dispatched from the *Zelée*. There they raised the French flag on land "*which no human had either seen or set foot on before us*" (Fig. 17) (Dumont d'Urville, 1841-1853, v. 8, pp. 150-154). The arrivals used their hammers to collects samples of the islet's rock, a task which due to its hardness yielded no more than small flakes. Fortunately, they soon found large, loose pieces of the stone and loaded them into their boats, enough, according to one officer, "*to supply specimens to all the museums in France*". The general views among the naturalists and officer, including those of Le Guillou and Hombron, were that the Antarctic rocks were a type of coarse-grained granite or gneiss. With the benefit of present-day analysis, they have been described as paragneiss (Fig. 18) and amphibolite (Fig.19) (Godard *et al*. 2017). These specimens would represent undisputed proof to the world of the discovery of a southern land. The officers on board the two ships also succeeded in establishing the coordinates for the site of the south magnetic pole, but as it lay deep in the southern continent, they were unable to reach it.

Fig. 17. First landing in Antarctica and raising the French flag on Rocher du Débarquement

The commander named the newly discovered land *Terre Adélie*, to perpetuate the memory of his wife. The most prominent islet on which the sailors landed and collected the rock samples, he named *Rocher du Débarquement*, and to a close by cape he gave the name *Pointe Géologie* (Dumont d'Urville, 1841-1853, v.8, p. 154).

There could have been little doubt among the population of Hobart of the truth that land had been discovered in Antarctica as, according to Le Guillou, the day after the return of the ships, "*the fireplaces in many homes were decorated with pieces of granite from* Terre Adélie" (Le Guillou, 1843, p. 219).

Fig. 18. Proterozoic paragneiss collected on Rocher du Débarquement

Fig. 19. Proterozoic amphibolite collected on Rocher du Débarquement

In the introduction to his account of the voyage, Dumont d'Urville acknowledged at great length the difficulty faced by naturalists in exploring the lands they visited, given their often-limited time spent ashore and recognised that this applied particularly to geological investigations. He was aware that, "*geological observations require a much greater precision than are needed for other sciences. In zoology and botany an individual specimen can have great importance, but a rock specimen on its own has no value if you do not know the precise point from where it has been collected, the rocks on which it rests, the layer it has been taken from and those which overlie it. The making of geological observations must always proceed by the exact and precise knowledge of places and the descriptive anatomy of formations. It is only after this study that general considerations of the origin and the age of regions can be raised*" (Dumont d'Urville, 1841-1853, v. 1, pp. VII-XV).

Conclusion

The geological investigations by scientists and naturalists on early French voyages of discovery to Australia and Antarctica were mostly confined to observation along the shores of the two continents. Only the opening of a route across the Blue Mountains offered them the opportunity to travel a short distance inland. The publications of descriptions and interpretations of the geological features they examined provided both scientists and the public in Europe with a first impression of the landscape and geology of these lands. They also challenged some views about geological processes, then widely held by scholars in Europe.

The above chronicle of the geological explorations carried out by the scientists, naturalists, and ships' officers of the seven expeditions' is not exhaustive but rather provides an overview of many of their significant findings. The accounts of the various expeditions were widely read in France and, in translation, in other European countries, but remained little known in Australia. It was not until the end of the nineteenth century that the geological work of the Baudin expedition was brought to the attention of Australian scientists (Tate, 1893). One of the legacies left Australia by the commanders and officers of the first two expeditions, was the bestowal of more than 600 French names on localities along the country's shores, more than half of which are still in use today.

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