

BETTER HERITAGE INFORMATION SUMMARY OF STATE HERITAGE PLACE

COMMENTARY ON THE LISTING

Description and notes with respect to a place entered in the South Australian Heritage Register in accordance with either the *South Australian Heritage Act 1978* or the *Heritage Places Act 1993*.

The information contained in this document is provided in accordance with s14(6) and s21 of the *Heritage Places Act 1993*.

NAME: Paralana Hot Springs

PLACE NO.: 14815

KNOWN AS: Paralana Hot Springs, Arkaroola Pastoral Station [Designated place of geological significance]

ADDRESS: Adnyamathanha Country
Arkaroola Protection Area
Arkaroola 5732
CL6213/698 F254027 A101
Outside of Hundreds

CONFIRMED IN THE SOUTH AUSTRALIAN HERITAGE REGISTER:

9 October 1997

DESIGNATED AS A PLACE OF GEOLOGICAL SIGNIFICANCE:

10 April 1997

STATEMENT OF HERITAGE SIGNIFICANCE

The Paralana Hot Springs lie on a splinter of the major Paralana Fault. The springs are a rare example of radioactive, hydrothermal hot springs heated without a magma source. Research has suggested the likely sources of heat and radioactivity, however, several questions still remain around many aspects of the waters and the geological interpretation of the Paralana Hot Springs.

Being the only remaining hot springs along the Paralana Fault and in the northern Flinders Ranges, it is a rare research resource. There is exceptional opportunity to study the geology, chemistry and hydrogeology of the place and the effect on the

surrounding landscape. The place has continued to present research opportunities that make it a highly significant destination by local, national and international researchers.

Note: research undertaken since listing has identified extremophile bacteria present in the water. These organisms are of particular interest for yielding information regarding the origin of life on earth and expected life forms in similar environments on Mars. While not a part of the significance identified at the time of listing it has been recognised as a part of the significance for Arkaroola (SHP 26404), Paralana Hot Springs is predominantly located within this larger State Heritage Place.

STATEMENT OF DESIGNATION

Designated Place of Geological Significance

The Paralana Hot Springs are the only remaining hot springs present in the Northern Flinders Ranges and one of few active radon hot springs in the world. It is suggested that the radioactive waters of the hot springs are heated by the radiogenic decay of uranium-rich granitic rocks at depth, rather than volcanic activity responsible for most hydrothermal/epithermal hot springs. The springs have been an area of interest for geologists for nearly a century, seeking to better understand the source of water, the chemistry of the hot springs and the effect on, and contribution to, the immediate geology. It is believed that the springs' hydrothermal activity has precipitated and altered rocks in the vicinity, surrounding geology and within the fault zone.

Elements of Significance:

Elements of heritage significance include (but are not necessarily limited to):

- Hot springs sources, including downstream source,
- Hot springs source pool and main pool,
- Adjoining portions of Paralana creek.

Elements not considered to contribute to significance of place include (but are not necessarily limited to):

- Built structures including signage.

INDICATIVE CRITERIA (under section 16 of the *Heritage Places Act 1993*)

(b) it has rare, uncommon or endangered qualities that are of cultural significance

The Paralana Hot Springs are culturally significant to South Australia due to the high scientific research potential in the areas of amagmatic and radioactive spring evolution and the geology and chemistry of such sites. The Paralana Hot Springs are also a rare example of a hydrothermal, radioactive, radon emitting hot springs in South Australia. The springs are rare in each of these three distinctive qualities and are also the only hot springs remaining on the Paralana Fault. A deep source of water and uranium and thorium rich rocks in the Mount Painter Inlier, a part of the larger Mount Painter Region, likely provide the heated waters, and radioactivity, to the Paralana Hot Springs.

Springs, such as 'mound springs', are not uncommon in South Australia, however, the Paralana Hot Springs are the only known remaining hot springs present in the northern Flinders Ranges, generally heated to 60-63°C and with a recorded maximum temperature of 82°C. Hot springs are defined as having water temperatures above 37°C, and while heated springs occur regionally in a different geological setting, these springs do not exceed 37°C. A contributing factor, along with hot radioactive rocks, may be that many springs have sources of water at a shallower depth than Paralana Hot Springs and, therefore discharge much cooler water. Hot springs exist outside of the Northern Flinders Ranges, in areas where the Great Artesian Basin waters breach the surface, including at Dalhousie Springs, Witjira National Park and Coward Springs, Roxby Downs, but despite their comparably higher temperatures, do not reach the extreme temperatures of Paralana Hot Springs.

Additionally, there are few radioactive hot springs in Australia. Both water and gases given off from the spring are radioactive, containing radon. The closest, by distance, radioactive springs are Old Paralana Homestead Spring and Black Spring which emit only slightly above the background levels of radiation. For detailed comparison refer to Table 1.

The rare qualities of the springs provide exceptional research opportunities that are difficult to achieve elsewhere. Paralana Hot Springs have the potential to contribute to our understanding of the geology and chemistry of such features and yield research findings of international significance.

(c) it may yield information that will contribute to an understanding of the State's history, including its natural history

The Paralana Hot Springs have the capacity to yield information of exceptional geological significance about the State as they are the only remaining hot springs present in the Northern Flinders Ranges, are heated by an amagmatic heat source

and are one of a few active radon hot springs in the world. It is suggested that the sub-surface hydrothermal system connected to the hot springs have functioned over a very long period of time (possibly millions of years).

The springs would have been impacted by natural events over the eons, ranging from tectonic activity to flood events with consequences yet to be researched. Despite the natural events observed, and being a tourist destination since the 1920s, the site including its water chemistry is relatively intact.

Paralana Hot Springs are a niche 'hot pot' of distinct features as one of only a few places able to provide opportunities for research that is likely to yield geological and hydrothermal information including the hydrogeology of the area. The place may provide information about the springs water source, heat source, hydro- and geo-thermal systems, and prospects of geothermal energy. It is also used as a point of comparison internationally for non-volcanic springs. Protection and continued research are highly likely to meaningfully contribute to an understanding of this rare system and the many facets that make it significant.

Note: additional significance of the Paralana Hot Springs

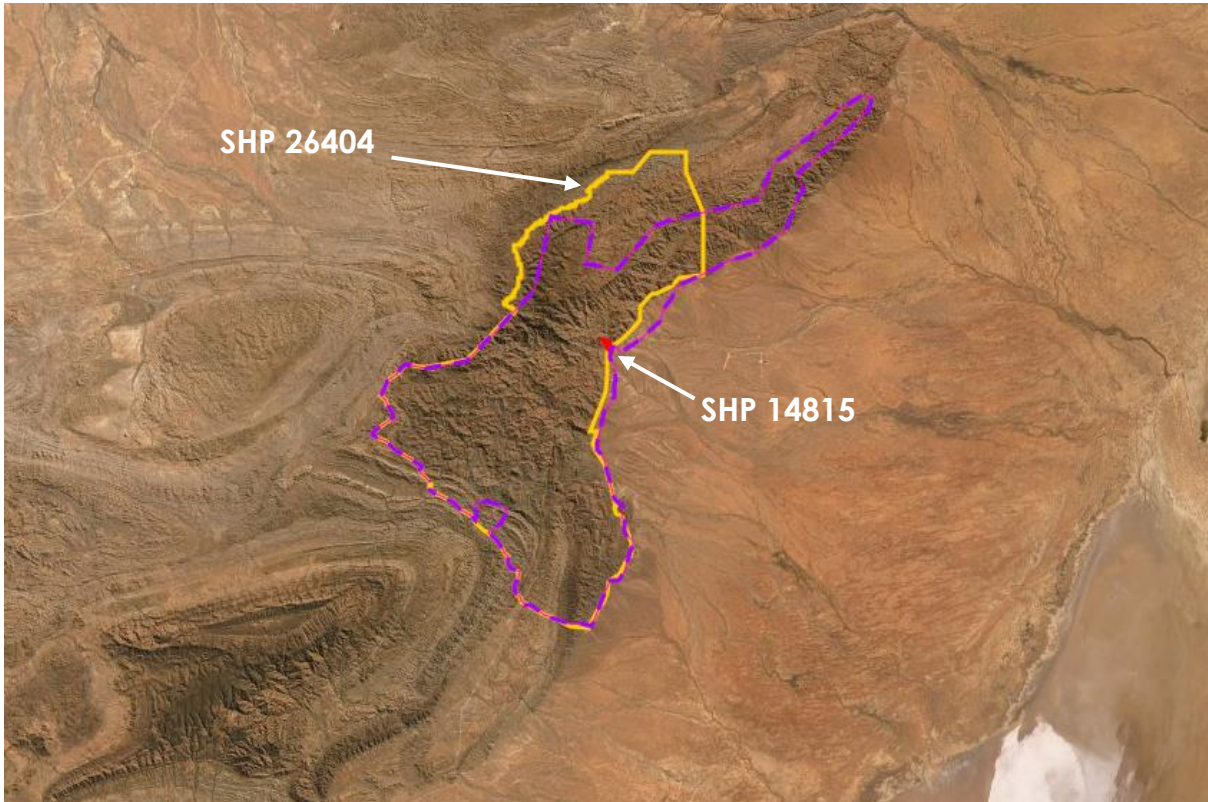
Paralana Hot Springs is predominantly located within Arkaroola (SHP 26404) (confirmed July 2012). More recent research undertaken to identify the significance of Arkaroola (SHP 26404) has investigated microbial presence and use in astrobiology/bioastronomy. The Paralana Hot Springs are a part of the Arkaroola Mars Analog Region¹ selected by the Mars Society Australia² where Arkaroola is recognised as an analogue for environments on Mars for both education and research. The extremophile bacteria present within the hot springs are of particular interest for yielding information that may relate to expected life forms in similar environments on Mars. The discoveries that could be yielded from this research have the potential to contribute to our understanding of the origin of life on Earth and Mars and is of international significance.

SITE PLAN

Paralana Hot Springs




PLACE NO.: 14815

Arkaroola SA 5732



Adnyamathanha Country, Arkaroola, Outside of Hundreds
CL6213/698 F254027 A101

LEGEND

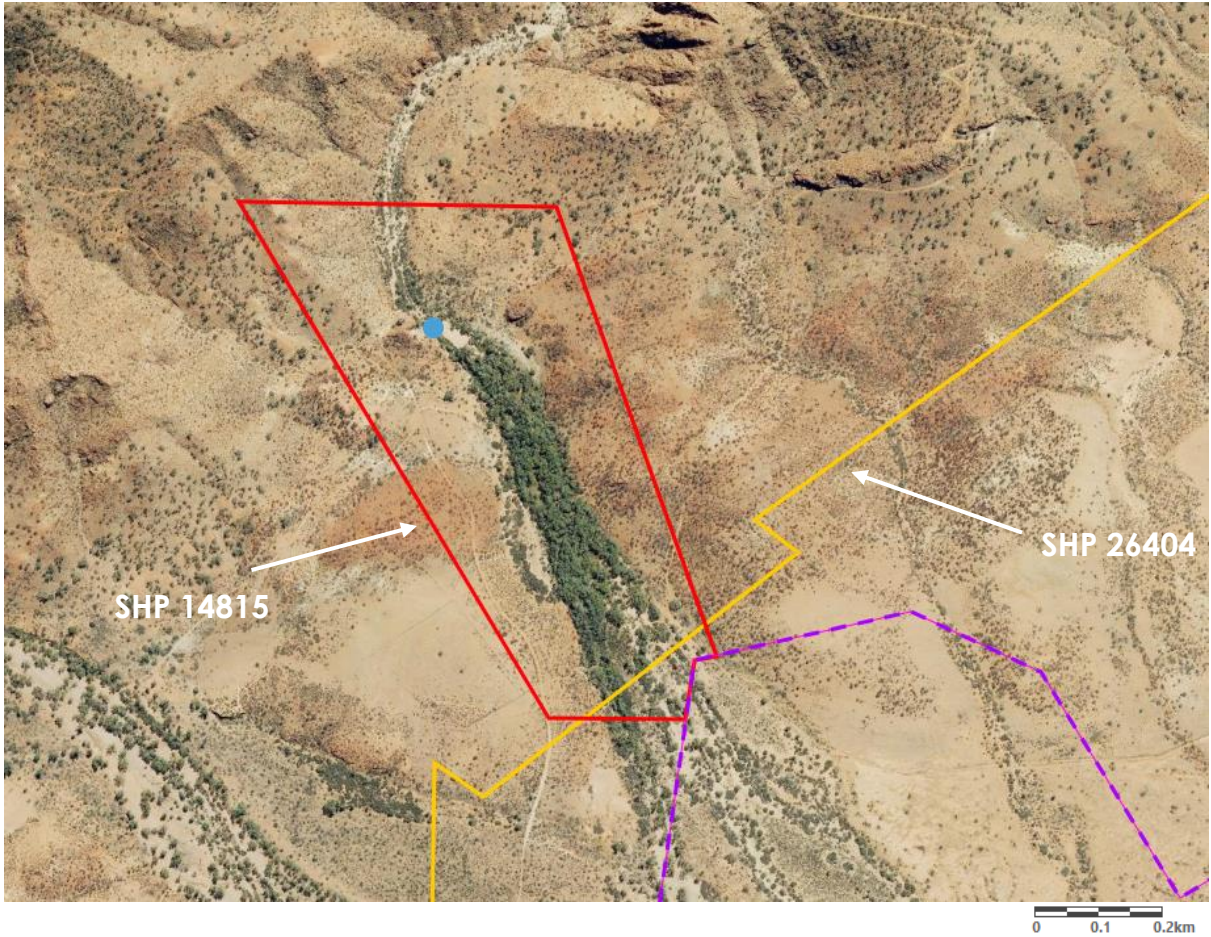
-  Existing State Heritage Place(s)
-  Parcel boundaries (Indicates extent of Listing)
-  Outline of Elements of Significance for State Heritage Place

N ↑

SITE PLAN - DETAIL

Paralana Hot Springs
Arkaroola SA 5732





PLACE NO.: 14815



Adnyamathanha Country, Arkaroola, Outside of Hundreds
CL6213/698 F254027 A101

LEGEND

N ↑

-  Existing State Heritage Place(s)
-  Parcel boundaries (Indicates extent of Listing)
-  Approximate location of the Hot Springs (boulder surface exit)
-  Outline of Elements of Significance for State Heritage Place

PHYSICAL DESCRIPTION

The Paralana Hot Springs are located partially within the Arkaroola Protection Area (SHP 26404) and wholly within the 'Arkaroola – Mt Painter Sanctuary'. The Paralana Hot Springs State Heritage Place comprises the naturally occurring radioactive hot springs and part of the associated Paralana Creek. The original surface exit of the hot springs surface waters is found at 30.1751 S and 139.4414 E³ and is released to the surface from underneath large boulders. The secondary surface exit is located approximately 50 metres downstream and is currently the primary surface exit for waters from the springs.⁴

Hot springs are defined as having water temperatures above 37°C. The Paralana Hot Springs are the only remaining hot springs to still exist along the Paralana Fault⁵ and consist of a main pool that is fed by a smaller source pool⁶ and runs into a draining creek.⁷ The springs are found on the Mount Niell Granite along the Lady Buxton Fault, which is in turn, a branch connected to the Paralana Fault Zone/System.⁸ The springs' output is currently approximately 16 litres per second. It is commonly believed that the source of water is the Mount Painter Inlier.⁹ Volcanic activity does not contribute to the heated waters.¹⁰

Instead, the source appears to be a result of meteoric water from rainfall that seeped into the ground, was heated by the subsurface radiogenic decay of deep-seated granitic rocks decay of radioactive rocks,¹¹ producing heat which in-turn produces high temperature waters that percolate down to great depths. By convection the heated waters rise again (referred to as an hydrothermal system at this stage) and are percolated many kilometres up through a fractured rock system¹², allowing water to flow up from depth at a very high temperature and gently vent at Paralana Hot Springs.¹³

The temperature of the water is generally around 60-63°C¹⁴ when it reaches the surface but has been recorded at a maximum of 82°C.¹⁵ To reach the temperatures at Paralana Hot Springs, the water source must be between 1.4 and 2.4km deep.¹⁶ Historically, the temperature is lower in the source pool.¹⁷ The temperature was also dependant on the level of surface seepage into the pools¹⁸ but at present, the stream. The Paralana Hot Springs is not a safe area for swimming or camping.

The hot springs also contain decaying radioactive materials such as radium, uranium¹⁹ and radiogenic helium²⁰ that likely contribute to hydrothermal activity.²¹ Here, groundwater dissolves high levels of uranium and other materials in the granite rock into the water²² that eventually makes its way up to the springs. The radioactivity of the springs is three to four times background radiation, though the gas emitted is considerably more radioactive²³ and potentially lethal.²⁴ Harmful metals like uranium, vanadium, molybdenum arsenic, chromium, cobalt and selenium have been recorded from the water.²⁵

Table 1: Comparison of Paralana Hot Springs characteristics to other nearby or well-known springs.

Name	Location	Fractured Rock Spring	Temp (°C)	Radioactivity	Underground water source	Depth
Paralana Hot Springs (PHS)	North Flinders Ranges	Yes ⁱ	44 ⁱ -82°C ^f	High	Mount Painter Inlier ^h	Estimated 1.4-2.4 km ^h , 'Deeper than others in the area' ⁱ
Weetootla Springs	North Flinders Ranges	Yes ⁱ	27°C ⁱ	Non-radioactive ^e	Unknown	'Deeper than others in the area' ⁱ
Nepouie Springs	North Flinders Ranges	Yes ⁱ	14.5 ^d -30.4°C ⁱ	Non-radioactive ^d	Adelaidean Rift Complex ⁱ	'Deeper than others in the area' ⁱ
Old Paralana Homestead Spring	North Flinders Ranges	Likely considering proximity to PHS	17.6 ^d -25.8°C ⁱ	Low, slightly above background ^d	Potentially same as Black Spring ^d	Shallower than PHS. Similar depth to Black Spring
Arkaroola Spring	North Flinders Ranges	Unknown	12.1 ^d -28.3°C ⁱ	No record	Mount Painter Region ^k specifically, Adelaidean Rift Complex ⁱ	Unknown
Black Spring	North Flinders Ranges	Likely considering proximity to PHS	23.1°C ⁱ	Low, slightly above background ^d	Potentially same as PHS ^h and Old Paralana Homestead Spring ^d	Shallower than PHS. Similar depth to Old Paralana Homestead Spring ⁱ
Munyallina Spring	North Flinders Ranges	Yes ⁱ	12.6°C ^d	No record	Unknown	Unknown
Dalhousie Springs	Far North	Likely ^a	37°C ^b	No record	Great Artesian Basin ^a	270-802 m ^g
Coward Springs	Roxby Downs	Unknown	29°C ^c	No record	Great Artesian Basin ^a	Unknown

Source: a) National Water Commission, 2013; b) South Australian Tourism Commission, N.D.; c) Coward Springs Campground, N.D.; d) Clarke *et al.*, 2006; e) Environment Protection Authority, 2014; f) DEW Files; g) Wolaver & Keppel, 2013; h) Brugger, 2005; i) Berthiaum, 2018; j) McNeil & Schmarr, 2011; k) Hore S.B., 2015.

Many other springs in the Northern Flinders Ranges lack the same group of distinctive features that make Paralana Hot Springs particularly significant. A comparison between several springs in the Northern Flinders Ranges and hydrogeological variables are below:

Despite the hazardous conditions, the pools contain abundant, emerald green algae, as well as darker mats of algae in the main pool.²⁶ The pool and riverbank are surrounded by shrubs and trees including native sedges and rushes and supports a healthy, largely unmodified ecosystem.²⁷ As of 2011, greater than 50 species of extremophile (organisms able to live in extreme environments) bacteria have been identified in the springs.²⁸ This includes species of Proteobacteria (also known as Pseudomonadota), Cyanobacteria, Chloroflexi, which can consist of thermophile bacteria, and Acidobacteria²⁹, which are commonly found in hot springs. It is believed that these organisms may be near equivalent to some of the first life forms on Earth in the environment in which they may have evolved. Water chemistry has been consistent for 81 years allowing bacterial life to thrive.³⁰

Brecciated granite surrounding the springs have been altered to a red, limonite-stained microcrystalline silica bearing rock³¹ also referred to as the silica-iron oxide rock jasper.³² The rock is concreted together by white silica and is believed to have been formed from precipitate within the hydrothermal hot spring water.³³ It is possible that the waters of the Paralana Hot Springs played a part in forming similar jasperoidal rocks along the Paralana fault.³⁴

Interpretive signage containing information on the geology of the place and the First Nations relationship to the hot springs is located near the springs.

Elements of Significance:

Elements of heritage significance include (but are not necessarily limited to):

- Hot springs sources, including downstream source,
- Hot springs source pool and main pool,
- Adjoining portions of Paralana Creek.

Elements not considered to contribute to significance of place include (but are not necessarily limited to):

- Built structures including signage.

HISTORY OF THE PLACE

Geological History

The Paralana Hot Springs are the only remaining hot springs along the Paralana Fault and in the Northern Flinders Ranges.³⁵ The Paralana Fault Zone/System separates the Mount Painter Inlier (Mesoproterozoic ~1590-1000³⁶ Ma (million years ago)) and Adelaide Rift Complex (850-500Ma) from the Lake Frome Embayment (Mesozoic-Cenozoic ~252-0 Ma age). It is an area with active tectonism and allows water flow from the uranium-rich Mount Painter Inlier to the younger basin sediments. Several natural springs can be found along this fault. It is believed that the Paralana Fault has been active since 1400 Ma, paused briefly ~500 Ma and was then reactivated during the Delamerian Orogeny, a major mountain building event that occurred between ~515 and ~490 Ma.³⁷

The Lady Buxton Fault, the closest branching fault of the Paralana Fault Zone/System,³⁸ separates Neoproterozoic Wywyana formation, (~850-830)³⁹, Wooltana Volcanics (~830⁴⁰-790⁴¹Ma) and some Pleistocene (Arrowie formation, ~ 2.58 Ma to 11,700 ka) sediment.⁴²

The Paralana Hot Springs have two potential underground sources of water. The first and most accepted is the Mount Painter Domain, believed to have formed during the Meso- and Neo-Proterozoic, somewhere between 1590 and 1000 Ma.⁴³ The second is the much younger Great Artesian Basin. With sediment being deposited during the Triassic-Cretaceous, ~251-66 Ma.⁴⁴

The hot springs are known as Vadaardlanha to the Adnyamathanha People, and it is recognised as a significant cultural site.

The Arkaroola region Arkaroola has 'some of the most uranium-rich granitic rocks in the world'.⁴⁵ The Arkaroola area had been a location for mining and exploration since the 1860s⁴⁶ due to the presence of uranium and other precious and valuable materials.⁴⁷

European publications first mention the Paralana Hot Springs in 1864⁴⁸ and again in 1878,⁴⁹ but not in any detail. In 1927, an article in the *Port Adelaide News* reported that the hot springs may have been a treatment for rheumatism since as early as 1907.⁵⁰

The Paralana Hot Springs were first acknowledged academically in paper published in 1912 by Geologist and Mineralogist A. C. Broughton.⁵¹ In 1924, Explorer and Geologist Sir Douglas Mawson and a small group of researchers visited the springs to further investigate its geology and chemistry.

On 1 May 1926, the Mount Painter Exploration Radium Company looked to test the springs for suitability as the centrepiece of a health resort. They cited Mawson's investigation, noting that the springs made for 'wonderfully good drinking water' and

that there had been promising results for curing rheumatism after drinking the water.⁵² Mount Painter Exploration Radium Company would then amalgamate with several other radium-based companies and form the Australian Radium Corporation.⁵³

By August-September 1926, a camp associated with the Australian Radium Corporation had been set up with sleeping areas and a public hall for visitors. There was a seat for soaking extremities in ~62°C water of the springs, and further down the stream where the water was ~45°C, a bath known as the 'crab pot' which was equipped with a hammock-like structure across the stream was created. Further downstream still was an excavated 'full bath', a 2.4 m² cut out with areas for sunbathing nearby,⁵⁴ likely retrieving water from the stream by pump.⁵⁵ Coconut matting was used to protect visitors from mud and dirt in and around these areas. One visitor suffering from sciatica and rheumatoid arthritis testified that he had been shown negative electroscope results for radioactivity.⁵⁶ It is not known what became of these makeshift structures after the eventual closing of the resort.

Mawson published his findings on the Paralana Hot Springs in 1927, the report providing the first major academic description of the springs. The publication mentioned radioactive activity, particularly in the gases released from the springs but this did not deter tourism. That same year, the Governor of South Australia, Sir Tom Bridges, bathed in the water multiple times over a few days.⁵⁷ However, the resort ceased operation in 1928 due to drought and lack of visitors.⁵⁸

In 1938, the 'Paralana Hot Springs Syndicate', led by Dr Charles Fenton⁵⁹, was formed⁶⁰ in response to an increased scientific interest in the springs. A year later, they approached the government for assistance in establishing a spa at the Paralana Hot Springs⁶¹ but were unsuccessful.⁶² In 1946, prospector William Greenwood also sought a spa project at Paralana Hot Springs but was again unsuccessful.⁶³ It is believed that this was the last formal attempt to create a health spa at the hot springs, however, the place remained a tourism destination despite its isolation.

Paralana Hot Springs have been the subject of several studies. Many focused on the geology and non-volcanic heating of the spring water. More recently the extremophile organisms have been the focus of research by NASA and others as the organisms may be a possible analogue for early life.⁶⁴ Notably the environment in the hot springs is also considered to be equivalent to that found on Mars.⁶⁵

While not recognised as a part of the place's significance at the time of confirmation on the SA Heritage Register, the presence of extremophile bacteria may provide a glimpse into the earliest evolution of life and research on this facet of the hot springs is ongoing. This aspect of the place's significance was included in the listing of Arkaroola (SHP 26404) as a State Heritage Place in 2012. Paralana Hot Springs is located predominantly within Arkaroola (SHP 26404).

In 2010, a rain event altered the morphology of the springs and inundated the pools with sediment through flooding. As a result, the primary springs exit, previously being the exit found beneath two boulders near the main pool, was moved approximately 50 metres downstream to a creek portion of the springs. This reduced the size of the pools to an estimated 3m³.⁶⁶ They had previously been reported in 1927 as large as 80m² and 1-1.5 metres deep.⁶⁷

CHRONOLOGY

Year	Event
~1590-1000 Ma	Mesoproterozoic: Earliest formation of areas of the Mount Painter Region ⁶⁸ associated with the Paralana Hot Springs. ⁶⁹
~251-66 Ma	The Great Artesian Basin is a layered marine sedimentary rock sequence deposited throughout the Triassic, Jurassic and into the Cretaceous, ⁷⁰ with glacial intervals deposited the during the Early Cretaceous. ⁷¹
1910	Uranium is noted in the Mount Painter Domain by pastoralist W.B. Greenwood. ⁷²
1912	The hot springs are briefly mentioned in a publication written by geology student A.C. Broughton. ⁷³
1926	Health spa created at the Paralana Hot Springs.
1927	Detailed description of the hot springs is published by Douglas Mawson titled 'The Paralana Hot Spring'.
1928	Health spa closes.
1939	The 'Paralana Hot Springs Syndicate' seek to create a spa at the hot springs but are unsuccessful.
1946	A final spa project sought at Paralana Hot Springs, however, again was unsuccessful.
1968	A portion of Arkaroola is gazetted as a fauna sanctuary under the <i>South Australian Fauna Conservation Act 1964-1965</i> ⁷⁴ and an Aboriginal and historic reserve under the <i>Aboriginal and Historic Relics Preservation Act</i> ⁷⁵ believed to be under the name 'Arkaroola-Mount Painter Sanctuary'. The boundary for this sanctuary was not the same as the Arkaroola Protection Area that would eventually be instated.
1972	The Sanctuary and Historic reserve status of the 'Arkaroola-Mount Painter Sanctuary' is revoked. ⁷⁶

- 1981 The hot springs are recognised as a Geological Monument by the South Australian Division of the Geological Society of South Australia.⁷⁷
- 1996 Arkaroola's sanctuary status is reinstated.⁷⁸ 'Arkaroola Wilderness Sanctuary' and 'Arkaroola – Mt. Painter Wilderness Sanctuary' are used interchangeably.⁷⁹
- 1997 April: The Paralana Hot Springs are provisionally entered into the State Heritage Register and designated as a place of geological significance.
October: The hot springs are confirmed in the State Heritage Register.
- 2010 Major flooding event alters the morphology of the hot springs pools and surface exits.
- 2011 29 July: The Arkaroola area is 'reserved from the operation of the Mining Act 1971 and the Opal Mining Act 1995 by a proclamation of the Governor'.⁸⁰
- 2012 February: Consideration given to nominating for National Heritage Listing Arkaroola.
26 April: The Arkaroola Protection Act 2012 is assented to, establishing the Arkaroola Protection Area.⁸¹
27 July: 'Arkaroola' is confirmed in the State Heritage Register,⁸² and shares a boundary with the Arkaroola Protection Area.
- 2021 The Arkaroola Protection Area is included in the submission of the Flinders Ranges for World Heritage Listing.

REFERENCES

Journal Articles

- Anitori, R. & Henneberger, R. (2004a), 'A radon-resistant microbial community'. *Microbiology Australia*, Vol. 25, no. 1, pp.30-32.
- Anitori, R., Trott, C., Saul, D., Bergquist, P., & Walter, M. (2002), 'A culture-independent survey of the bacterial community in a radon hot spring'. *Astrobiology*, Vol. 2, no. 3, pp.255-270.
- Broughton, A. (1912), 'Notes on some occurrences of silica near Mount Painter, Flinders Ranges'. *Transactions and Proceedings of the Royal Society of South Australia*, vol. 36, pp.173-177.
- Brugger, J., Long, N, McPhail, D., & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'. *Chemical Geology*, Vol. 22, no. 1-2, pp.35-64.
- Gregory, C. (2005), 'Geothermal Energy Potential at Paralana, Northern Flinders Ranges, South Australia', *Journal of the Virtual Explorer*, vol. 20, p.6.
- Thomas, M., Clarke, J., Gostin, V., Williams, G., & Walter, M. (2012), 'The Flinders Ranges and surrounds, South Australia: a window on astrobiology and planetary geology' *Episodes*, Vol. 35, no. 1, pp.226-235.

Wawryk, A. (2014), 'Conservation and Access to Land for Mining in Protected Areas'. *Journal of Environmental Law*, Vol. 26, no. 2, pp. 291-317.

Reports and Publications

- Abramovich, R. (2013), 'Nitrogen fixing potential in extreme environments', *Ph.D. Thesis*, School of Biotechnology and Biomolecular Sciences, University of New South Wales, Sydney, Australia.
- Alley N. & Hore S., (2022). 'Early Cretaceous sediments reveal a story of prolonged cold climate, glaciations, oscillating sea level and tectonic changes', *Geological Survey of South Australia*, Bulletin 57. Department for Energy and Mining, South Australia, Adelaide.
- Anitori, R., Trott, C., Saul, D., Bergquist, P. & Walter, M. (2004b), 'The Microbial Community of a Radon Hot Spring'. *Bioastronomy 2002: Life Among the Stars, IAU Symposium*, Vol. 213, pp.374-380.
- Berthiaume, J. (2018), 'Neotectonic faults of the Paralana Escarpment and their influence on uranium-bearing fluid flow', *Ph.D. Thesis*. Faculty of Science, University of Adelaide, Adelaide, South Australia, Australia.
- Blissett, A. (1971), 'Paralana Hot Spring'. In: *Regional and Economic Geology of the Mount Painter Province*. A.B. James, Government Printer, Adelaide. Bulletin 43, Part 2, Chapter 16, pp.221-222.
- Clarke, J., Thomas, M. & Norman, M. (2004), 'The Arkaroola Mars Analogue Region, South Australia' *Lunar and Planetary Science XXXV*, Conference Proceedings, Houston, TX, USA, 2p.
- Clarke, J. (2002), 'An Australian Mars Analogue Research Station (Mars-Oz): a Proposal', *Mars Society Australia Inc.*, 39p.
- Department of Environment, Water and Natural Resources (2015) 'Arkaroola Protection Area Draft Management Plan 2015'. *Government of South Australia*.
- Environment Protection Authority (2014), 'Endangered fish not affected by water quality in the Flinders Ranges, South Australia', *Government of South Australia*.
- International Atomic Energy Agency (2005), *Guidebook on environmental impact assessment for in situ leach mining projects*, Vienna, Austria.
- McBriar, E. & Mooney, M. (1981), 'Geological Monuments Part 4'. *Geological Monuments Subcommittee of the SA Division of the Geological Society of Australia Incorporated*, pp.36-38.
- McNeil, D., Schmarr, D., & White, M. (2011), 'Assessment of endemic fish (*Mogurnda clivicola*) and native vegetation at springs in the northern Flinders Ranges'. Report to the South Australian Arid Lands Natural Resources Management Board, Port Augusta. South Australian Research and Development Institute and South Australian Department for Water. *SARDI Research Report Series*, No. 518, 92p.
- National Water Commission (2013), 'Allocating Water and Maintaining Springs in the Great Artesian Basin', *Volume VII: Summary of Findings for Natural Resource Management of the Western Great Artesian Basin*, NWC, Canberra.
- Worboys, G. & Hore, S. (2013), *Arkaroola Protection Area: A field guide to selected geological features. Arkaroola Wilderness Sanctuary and Department of Environment, Water and Natural Resources*, Adelaide.
- Wülser, P-A. (2009), 'Uranium metallogeny in the North Flinders Ranges region of South Australia' *Ph.D. Thesis*, Faculty of Science, University of Adelaide, Adelaide, South Australia, Australia.

Newspaper Articles

Hargrave, E. (1864), 'Parliamentary Paper: Report and Journal of E.H. Hargraves', *South Australian Register*, 10 August, p.2. From: <<http://nla.gov.au/nla.news-article39115792>>.

BHI Summary of State Heritage Place: 14815

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Confirmed in the South Australian Heritage Register on 19 August 1993

The South Australian Heritage Council endorsed the content of this BHI - SSHP on 5 September 2024

The Mail (1926), 'Hot Springs for Health: Oasis Sanatorium in Central Australia', 1 May, p.1. From: <<http://nla.gov.au/nla.news-article58525703>>.

Lewis, H. (1928), 'Parallana Hot Springs: Health Resort Closes Down'. *The Mail*, 19 May, p.2. From: <<http://nla.gov.au/nla.news-article58553032>>.

Purvis, W. (1927), 'Paralana Hot Springs'. *Port Adelaide News*, 25 November, p.3. From: <<http://nla.gov.au/nla.news-article212969581>>.

South Australian Chronicle and Weekly Mail (1878), 'The Far North', 7 September, p.5. From: <<http://nla.gov.au/nla.news-article92264648>>.

The Mail (1946), 'Paralana Hot Springs Plan', 24 August, p.2. From: <<http://nla.gov.au/nla.news-article55873747>>.

Websites

Arkaroola Wilderness Sanctuary (N.D.), 'Arkaroola – Mt. Painter Wilderness Sanctuary – A Brief History'. From: <<https://www.arkaroola.com.au/history>>.

Australian Stratigraphic Units Database (N.D.), 'Wooltana Volcanics'. From: <<https://asud.ga.gov.au/search-stratigraphic-units/results/20586>>.

Coward Springs Campground (N.D.), 'Welcome to Coward Springs'. From: <<https://cowardsprings.com.au/>>.

Department for Environment and Water (N.D.), 'Arkaroola'. From: <<https://www.environment.sa.gov.au/our-places/arkaroola>>.

Environment Protection Authority SA (2017), 'Naturally occurring radioactive material (NORM)'. From: <https://www.epa.sa.gov.au/files/13301_info_norm.pdf>.

Queensland Government (2015), 'Sedimentary rocks (Great Artesian Basin)'. WetlandInfo Website. From: <<https://wetlandinfo.des.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/sedimentary-rocks-great-artesian-basin/geology.html#modsedi>>.

South Australian Tourism Commission (N.D.), 'Dalhousie Springs Campground, Witjira National Park'. From: <<https://southaustralia.com/products/flinders-ranges-and-outback/attraction/dalhousie-springs-witjira-national-park>>.

Books and Book Chapters

Chalmers, R. (1963) 'Minerals of the Mt. Painter Country'. In: *Australian Natural History*. The Australian Museum, Sydney, Vol. 14, no. 5, pp.153-157.

Erfurt, P. (2021), *The Geoheritage of Hot Springs*. Eds. Eder, W., Bobrowsky, P., & Martínez-Frías, J. Geoheritage, Geoparks and Geotourism Conservation and Management Series. Springer Nature, Switzerland.

Figgis, P., Fitzsimons, J. and Irving, J. (eds) (2012), *Innovation for 21st Century Conservation*. Australian Committee for IUCN, Sydney.

Greene, A., Wright, M., Aldosary, H. (2016), 'Bacterial diversity and metal reducing bacteria in Australian thermal environments'. In: *Microbes in the spotlight: recent progress in the understanding of beneficial and harmful microorganisms*. Eds. Méndex-Vilas, A., BrownWalker Press, Florida, USA.

Heldmann, J *et al.* (2006), 'Follow the Water: Applying a Mars Exploration Strategy to the Arkaroola Analog Region, South Australia'. In: *Mars Analog Research. Science and Technology Series*, Eds. Clarke, J.D.A., American Astronautical Society, San Diego, CA, Vol. 111, pp. 71–92.

O'Neil, B. (1996), ''National heroes not National Villains': South Australia and the Atomic Age'. In: *Playford's South Australia: Essays on the History of South Australia 1933-1968*. Eds. O'Neil, B., Raftery, J. & Round, K., Adelaide, APH, pp.155-176.

Wolaver, B., Keppel, M. & Love, A. (2013), 'Hydrogeology of Dalhousie Springs'. In: *Allocating Water and Maintaining Springs in the Great Artesian Basin*, Eds. Love, A. J., Shand, P.,

Crossey, L. J., Harrington, G. A., Rousseau-Gueutin, P., National Water Commission, Canberra ACT, Vol. 3, pp.81-99.

Images

State Library of South Australia: B 52421

State Library of South Australia: B 52423

State Library of South Australia: B 52424.

State Library of South Australia: B 52428

Other

DEW Files (2011) '26404 Arkaroola Assessment Report'.

Hore S., (2015), 'Mount Painter region, South Australia 1:100 000 Geological Atlas Special Series Map, DIGIMAP 00005'. Geological Survey of South Australia, Adelaide.

SITE DETAILS

Paralana Hot Springs

PLACE NO.: 14815

Arkaroola SA 5732

DESCRIPTION OF PLACE: Radon Hot Springs with continuing hydrothermal activity

DATE OF CONSTRUCTION: NA

REGISTER STATUS: Identification by Heritage Branch: 31 August 1995

Provisional Entry: 10 April 1997

Designation: 10 April 1997

Confirmation: 9 October 1997

CURRENT USE: Within 'Arkaroola – Mt Painter Sanctuary'
Partially within the Arkaroola State Heritage Place (SHP 26404) and Arkaroola Protection Area

Crown Land - Pastoral

LOCAL GOVERNMENT AREA: Pastoral Unincorporated Area

LOCATION:

Street No.: NA

Street Name: NA

Town/Suburb: Arkaroola

Post Code: 5732

LAND DESCRIPTION: **Title Reference:** CL 6204/782 D42204 A34

Hundred: Outside of Hundreds

*Paralana Hot Springs was provisionally listed under the *Heritage Act 1993* that came into effect on 15 January 1994.

Under Section 17(3)(a) of the *Heritage Act 1993*:

17—Proposal to make entry in Register

(3) The Authority may designate a place provisionally entered in the Register

as—

(a) a place of geological or palaeontological significance;

Hence, the State Heritage Place was designated in April 1997, prior to its confirmation as a State Heritage Place in October 1997.

PHOTOS

Paralana Hot Springs

PLACE NO.: 14815

Arkaroola SA 5732



Main pool of the Paralana Hot Springs (2009)

Source: DEW Files

PHOTOS

Paralana Hot Springs

PLACE NO.: 14815

Arkaroola SA 5732



Clear waters of the Paralana Hot Springs with microbial communities (2009)

Source: DEW Files

PHOTOS

Paralana Hot Springs

PLACE NO.: 14815

Arkaroola SA 5732



'The Camp accommodation at Paralana Springs.'

Source: State Library of South Australia: B 52421



'Distant view of the camp with the bathing enclosure in the foreground.'

Source: State Library of South Australia: B 52423

PHOTOS

Paralana Hot Springs

PLACE NO.: 14815

Arkaroola SA 5732



'Two patients bathing in the therapeutic water at Paralana Springs.'

Source: State Library of South Australia: B 52428

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- ¹ Heldmann, J et al. (2006), 'Follow the Water: Applying a Mars Exploration Strategy to the Arkaroola Analog Region, South Australia'. In: Mars Analog Research. Science and Technology Series, Eds. Clarke, J.D.A., American Astronautical Society, San Diego, CA, Vol. 111, pp. 71–92.
- ² Clarke, J., Thomas, M. & Norman, M. (2004), 'The Arkaroola Mars Analogue Region, South Australia' *Lunar and Planetary Science XXXV*, Conference Proceedings, Houston, TX, USA, 2p.; and Clarke, J. (2002), 'An Australian Mars Analogue Research Station (Mars-Oz): a Proposal', *Mars Society Australia Inc.*, 39p.
- ³ McNeil, D., Schmarr, D., & White, M. (2011), 'Assessment of endemic fish (*Mogurnda clivicola*) and native vegetation at springs in the northern Flinders Ranges'. Report to the South Australian Arid Lands Natural Resources Management Board, Port Augusta. South Australian Research and Development Institute and South Australian Department for Water. *SARDI Research Report Series*, No. 518, 92 pp.
- ⁴ Hore, S. (2024), Personal Communication
- ⁵ Brugger, J., Long, N, McPhail, D., & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'.
- ⁶ Anitori, R., Trott, C., Saul, D., Bergquist, P. & Walter, M. (2004b), 'The Microbial Community of a Radon Hot Spring'. *Bioastronomy 2002: Life Among the Stars, IAU Symposium*, Vol. 213, pp.374-380.
- ⁷ Abramovich, R. (2013), 'Nitrogen fixing potential in extreme environments', *Ph.D. Thesis*, School of Biotechnology and Biomolecular Sciences, University of New South Wales, Sydney, Australia.
- ⁸ Blissett, A. (1971), 'Paralana Hot Spring'. In: *Regional and Economic Geology of the Mount Painter Province*. A.B. James, Government Printer, Adelaide, Bulletin 43, Part 2, Chapter 16, pp.221-222; and International Atomic Energy Agency (2005), *Guidebook on environmental impact assessment for in situ leach mining projects*, Vienna, Austria; and Brugger, J., Long, N., McPhail, C. & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'.
- ⁹ Erfurt, P. (2021), *The Geoheritage of Hotsprings.*; and Brugger, J., Long, N., McPhail, C. & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'; Hore, S. (2024) Personal Communication.
- ¹⁰ Erfurt, P. (2021), *The Geoheritage of Hotsprings.*
- ¹¹ Abramovich, R. (2013), 'Nitrogen fixing potential in extreme environments'.
- ¹² Brugger, J., Long, N, McPhail, D., & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'. *Chemical Geology*, Vol. 22, no. 1-2, pp.35-64; and Gregory, C. (2005), 'Geothermal Energy Potential at Paralana, Northern Flinders Ranges, South Australia', *Journal of the Virtual Explorer*, vol. 20, p.6.
- ¹³ Hore, S. (2024), Personal Communication
- ¹⁴ Anitori, R., Trott, C., Saul, D., Bergquist, P., & Walter, M. (2002), 'A culture-independent survey of the bacterial community in a radon hot spring'. *Astrobiology*, Vol. 2, no. 3, pp.255-270.
- ¹⁵ DEW Files (2011) '26404 Arkaroola Assessment Report'.
- ¹⁶ Brugger, J., Long, N, McPhail, D., & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'.
- ¹⁷ Anitori, R. & Henneberger, R. (2004a), 'A radon-resistant microbial community'. *Microbiology Australia*, Vol. 25, no. 1, pp.30-32.
- ¹⁸ McBriar, E. & Mooney, M. (1981), 'Geological Monuments Part 4'. *Geological Monuments Subcommittee of the SA Division of the Geological Society of Australia Incorporated*, pp.36-38.
- ¹⁹ Anitori, R., Trott, C., Saul, D., Bergquist, P., & Walter, M. (2002), 'A culture-independent survey of the bacterial community in a radon hot spring'.
- ²⁰ Berthiaume, J. (2018), 'Neotectonic faults of the Paralana Escarpment and their influence on uranium-bearing fluid flow', *Ph.D. Thesis*. Faculty of Science, University of Adelaide, Adelaide, South Australia, Australia.

-
- ²¹ Anitori, R., Trott, C., Saul, D., Bergquist, P., & Walter, M. (2002), 'A culture-Independent survey of the bacterial community in a radon hot spring'.
- ²² Environment Protection Authority SA (2017), 'Naturally occurring radioactive material (NORM)'. From: <https://www.epa.sa.gov.au/files/13301_info_norm.pdf>.
- ²³ Blissett, A. (1971), 'Paralana Hot Spring'; and McBriar, E. & Mooney, M. (1981), 'Geological Monuments Part 4'.
- ²⁴ Hore, S. (2024), Personal Communication
- ²⁵ Erfurt, P. (2021), *The Geoheritage of Hotsprings*.
- ²⁶ Abramovich, R. (2013), 'Nitrogen fixing potential in extreme environments'.
- ²⁷ McBriar, E. & Mooney, M. (1981), 'Geological Monuments Part 4'.
- ²⁸ DEW Files (2011), '26404 Arkaroola Assessment Report'.
- ²⁹ Greene, A., Wright, M., Aldosary, H. (2016), 'Bacterial diversity and metal reducing bacteria in Australian thermal environments'. In: *Microbes in the spotlight: recent progress in the understanding of beneficial and harmful microorganisms*. Eds. Méndex-Vilas, A., BrownWalker Press, Florida, USA.
- ³⁰ Abramovich, R. (2013), 'Nitrogen fixing potential in extreme environments'.
- ³¹ McBriar, E. & Mooney, M. (1981), 'Geological Monuments Part 4'.
- ³² DEW Files (2011), '26404 Arkaroola Assessment Report'.
- ³³ DEW Files (2011), '26404 Arkaroola Assessment Report'.
- ³⁴ Brugger, J., Long, N., McPhail, C. & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'.
- ³⁵ Brugger, J., Long, N., McPhail, C. & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'.
- ³⁶ Hore, S. (2024), Personal Communication.
- ³⁷ Berthiaume, J. (2018), 'Neotectonic faults of the Paralana Escarpment and their influence on uranium-bearing fluid flow'.
- ³⁸ Brugger, J., Long, N., McPhail, C. & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'.; and Blissett, A. (1971), 'Paralana Hot Spring'.
- ³⁹ Hore, S. (2024), Personal Communication
- ⁴⁰ Australian Stratigraphic Units Database (N.D.), 'Wooltana Volcanics'. From: <<https://asud.ga.gov.au/search-stratigraphic-units/results/20586>>.
- ⁴¹ Berthiaume, J. (2018), 'Neotectonic faults of the Paralana Escarpment and their influence on uranium-bearing fluid flow'.
- ⁴² Berthiaume, J. (2018), 'Neotectonic faults of the Paralana Escarpment and their influence on uranium-bearing fluid flow'.
- ⁴³ Brugger, J., Long, N., McPhail, C. & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'; Hore, S. (2024), Personal Communication.
- ⁴⁴ Queensland Government (2015), 'Sedimentary rocks (Great Artesian Basin)'. WetlandInfo Website. From: <<https://wetlandinfo.des.qld.gov.au/wetlands/ecology/aquatic-ecosystems-natural/groundwater-dependent/sedimentary-rocks-great-artesian-basin/geology.html#modsedi>>.
- ⁴⁵ Hore, S. (2024), Personal Communication.
- ⁴⁶ Wawryk, A. (2014), 'Conservation and Access to Land for Mining in Protected Areas: The Conflict Over Mining in South Australia's Arkaroola Wilderness Sanctuary', *Journal of Environmental Law*, Vol. 26, pp. 291-317.
- ⁴⁷ Figgis, P., Fitzsimons, J. and Irving, J. (eds) (2012), *Innovation for 21st Century Conservation*. Australian Committee for IUCN, Sydney.
- ⁴⁸ Hargrave, E. (1864), 'Parliamentary Paper: Report and Journal of E.H. Hargraves', *South Australian Register*, 10 August, p.2. From: <<http://nla.gov.au/nla.news-article39115792>>.
- ⁴⁹ South Australian Chronicle and Weekly Mail (1878), 'The Far North', 7 September, p.5. From: <<http://nla.gov.au/nla.news-article92264648>>.

BHI Summary of State Heritage Place: 14815

Confirmed in the South Australian Heritage Register on 19 August 1993

The South Australian Heritage Council endorsed the content of this BHI - SSHP on 5 September 2024

-
- ⁵⁰ Purvis, W. (1927), 'Paralana Hot Springs'. *Port Adelaide News*, 25 November, p.3. From: <<http://nla.gov.au/nla.news-article212969581>>.
- ⁵¹ Broughton, A. (1912), 'Notes on some occurrences of silica near Mount Painter, Flinders Ranges'. *Transactions and Proceedings of the Royal Society of South Australia*, vol. 36, pp.173-177.
- ⁵² The Mail (1926), 'Hot Springs for Health: Oasis Sanatorium in Central Australia', 1 May, p.1. From: <<http://nla.gov.au/nla.news-article58525703>>.
- ⁵³ O'Neil, B. (1996), 'National heroes not National Villains': South Australia and the Atomic Age'. In: *Playford's South Australia: Essays on the History of South Australia 1933-1968*. Eds. O'Neil, B., Rafferty, J. & Round, K., Adelaide, APH, pp.155-176.
- ⁵⁴ Purvis, W. (1927), 'Paralana Hot Springs'.
- ⁵⁵ State Library of South Australia: B 52424.
- ⁵⁶ Purvis, W. (1927), 'Paralana Hot Springs'.
- ⁵⁷ DEW Files (2011), '26404 Arkaroola Assessment Report'.
- ⁵⁸ Lewis, H. (1928), 'Parallana Hot Springs: Health Resort Closes Down'. *The Mail*, 19 May, p.2. From: <<http://nla.gov.au/nla.news-article58553032>>.
- ⁵⁹ McBriar, E. & Mooney, M. (1981), 'Geological Monuments Part 4'.
- ⁶⁰ DEW Files (2011), '26404 Arkaroola Assessment Report'.
- ⁶¹ DEW Files (2011), '26404 Arkaroola Assessment Report'.
- ⁶² McBriar, E. & Mooney, M. (1981), 'Geological Monuments Part 4'.
- ⁶³ DEW Files (2011), '26404 Arkaroola Assessment Report'; and The Mail (1946), 'Paralana Hot Springs Plan', 24 August, p.2. From: <<http://nla.gov.au/nla.news-article55873747>>.
- ⁶⁴ Thomas, M., Clarke, J., Gostin, V., Williams, G., & Walter, M. (2012), 'The Flinders Ranges and surrounds, South Australia: a window on astrobiology and planetary geology' *Episodes*, Vol. 35, no. 1, pp.226-235.
- ⁶⁵ DEW Files (2011), '26404 Arkaroola Assessment Report'.
- ⁶⁶ Berthiaume, J. (2018), 'Neotectonic faults of the Paralana Escarpment and their influence on uranium-bearing fluid flow'.
- ⁶⁷ Berthiaume, J. (2018), 'Neotectonic faults of the Paralana Escarpment and their influence on uranium-bearing fluid flow'.
- ⁶⁸ Hore S., (2015), 'Mount Painter region, South Australia 1:100 000 Geological Atlas Special Series Map, DIGIMAP 00005'. *Geological Survey of South Australia*, Adelaide.
- ⁶⁹ Brugger, J., Long, N., McPhail, C. & Plimer, I. (2005), 'An active amagmatic hydrothermal system: The Paralana hot springs, Northern Flinders Ranges, South Australia'.
- ⁷⁰ Queensland Government (2015), 'Sedimentary rocks (Great Artesian Basin)'.
- ⁷¹ Alley N., & Hore S., (2022). 'Early Cretaceous sediments reveal a story of prolonged cold climate, glaciations, oscillating sea level and tectonic changes', *Geological Survey of South Australia*, Bulletin 57. Department for Energy and Mining, South Australia, Adelaide.
- ⁷² Wülser, P-A. (2009), 'Uranium metallogeny in the North Flinders Ranges region of South Australia' *Ph.D. Thesis*, Faculty of Science, University of Adelaide, Adelaide, South Australia, Australia; and Chalmers, R. (1963) 'Minerals of the Mt.Painter Country'. In: *Australian Natural History*. The Australian Museum, Sydney, Vol. 14, no. 5, pp.153-157.
- ⁷³ Blissett, A. (1971), 'Paralana Hot Spring'.
- ⁷⁴ Wawryk, A. (2014), 'Conservation and Access to Land for Mining in Protected Areas'.
- ⁷⁵ Worboys, G. & Hore, S. (2013), *Arkaroola Protection Area: A field guide to selected geological features. Arkaroola Wilderness Sanctuary and Department of Environment, Water and Natural Resources*, Adelaide; and Department of Environment, Water and Natural Resources (2015) 'Arkaroola Protection Area Draft Management Plan 2015'. *Government of South Australia*.
- ⁷⁶ Worboys, G. & Hore, S. (2013), *Arkaroola Protection Area: A field guide to selected geological features; and Arkaroola Wilderness Sanctuary (N.D.), 'Arkaroola – Mt. Painter Wilderness Sanctuary – A Brief History'*. From: <<https://www.arkaroola.com.au/history>>.
- ⁷⁷ McBriar, E. & Mooney, M. (1981), 'Geological Monuments Part 4'.

⁷⁸ DEW Files (2011), '26404 Arkaroola Assessment Report'.

⁷⁹ Arkaroola Wilderness Sanctuary (N.D.) 'Arkaroola – Mt. Painter Wilderness Sanctuary – A Brief History'.

⁸⁰ Department for Environment and Water (N.D.), 'Arkaroola'. From: <<https://www.environment.sa.gov.au/our-places/arkaroola>>.

⁸¹ Worboys, G. and Hore, S. (2013), Arkaroola Protection Area: A field guide to selected geological features.

⁸² Department for Environment and Water (N.D.), 'Arkaroola'.