INTERPRETATION AS A VITAL INGREDIENT OF GEOTOURISM IN COASTAL ENVIRONMENTS: THE GEOLOGY OF SEA LEVEL CHANGE, ROTTNEST ISLAND, WESTERN AUSTRALIA

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At a time of increasing global awareness of the exploitation of the Earth’s resources and the environmental impacts of human activity, this article stresses the importance of geological education. It highlights that in a tourism hot spot containing globally significant geological features and processes, it is essential to create educational interpretative themes that provide engaging scientific information to generate appreciation and awareness of climate change. Appropriate literature is reviewed, which includes a brief account of the geology of Rottnest Island. The review emphasizes the interpretive importance of carbonate geological features displaying evidence of sea level change events, exposures of Late Pleistocene aeolianite, and Holocene dune formations. Sea level change is regarded as an especially relevant geological theme for interpretative product development on the island. Such a theme provides the foundation for the interpretation of scientific data that can link the visitor to the significance of environmental change. The article concludes that educative geological themes, as presented via tourism, can provide a dialogue between the public, scientists, and the media about global climate change.

Key words: Geotourism; Coastal tourism; Interpretation; Sea level change

Introduction

Geotourism is a tourism activity that centers on the appreciation of, and conservation of, geological resources through accurate interpretation of the Earth’s processes and landforms (Dowling, 2011). The focus of this form of nature-based tourism therefore is on highlighting geosites, landscapes, and landforms unique to a natural area (e.g., Newsome & Dowling, 2010). Dowling (2011) asserts that geotourism is the third dimension in natural area tourism, when combined with its two other components the biotic elements (flora and fauna), as it illustrates the geological foundation on which these elements exist in nature. Offering tourists and locals access to geological features and processes

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in natural or urban environments, geotourism has the potential to achieve sustainable geoconservation by generating awareness and interest, while at the same time creating economic benefits for communities through tourism opportunities (Dowling, 2011; Newsome & Dowling, 2010).

Given that Rottnest Island contains world-class geological features such as stromatolites, salt lakes, evidence of sea level change, exposures of aeolian Tamala Limestone, and Late Pleistocene/Holocene dunes (Playford, 1988), an opportunity exists to interpret these for Rottnest Island. In doing so, the nature-based tourism profile that Rottnest Island currently offers can be expanded with a view to raising the geosciences and ecological literacy of the public and policymakers. Furthermore, Palmer and Newsome (2010) highlight the need to invest in developing geologic interpretive material and opportunities and for Rottnest Island management to capitalize on the increasing international interest in geotourism.

It has been previously acknowledged that there is a lack of geological interpretive information along tourist routes on the island (Palmer & Newsome, 2010) and Rottnest Island Authority (RIA), which manages tourism on the island, would benefit from further research on the tourism value of the island’s geologic features. Currently, any geotourism is limited to the complex and outdated geological education material being used by the museum and there is a lack of appropriate interpretive signage (Palmer & Newsome, 2010). The only geology guidebook for Rottnest Island is the work of Playford (1988), which is essentially a researcher’s field guide and is likely to be too complex and detailed for the tourist. The guide, however, offers substantial and detailed description of the geology of Rottnest Island. Moreover, Rottnest Island Management would benefit from expanding and modifying Playford’s (1988) work to produce an updated guidebook that provides simplified, accurate interpretation of specific geosites. The geological content for the proposed guidebook can be modified for other applications such as interpretive panels, maps, and displays within the museum. All of these applications have the ability to generate revenue while enhancing the island’s local and international tourism status. Rutherford, Kobryn, and Newsome (2014) have recently evaluated scientific (environmental and geology) and management-related data (risk, access) through multiple-criteria evaluation to identify areas most suitable for geotourism.

The relevance of Rottnest Island in the global context lies in the island’s evidence for sea level fluctuations in response to global climate change. Climate change has been explored in the coastal tourism context by Zeppel (2012), Zeppel and Beaumont (2011), and by Scott, Hall, and Gössling (2012). Moreover, Zeppel and Beaumont (2011), from an analysis of Australian Sustainable Tourism Cooperative Research Centre Reports, note that a key recommended action is to “increase credibility and awareness that climate change is occurring” (p. 8). Zeppel (2012) reiterates this in the context of the Great Barrier Marine Park, where customer education has also been a focus. The development of climate change-related interpretive content is thus a timely strategy for the Rottnest Island Authority. Accordingly, this article, through a review of the relevant interpretation and geological literature, will assess the significance of interpretation, especially in regard to climate change, for geotourism on Rottnest Island. In doing so, it will identify the island’s specific geological resources and highlight key interpretive themes that raise awareness about climate change in coastal environments.

Rottnest Island as an Existing Tourism Destination

Rottnest Island (Fig. 1) is located approximately 18 km west of Fremantle, Western Australia, and contains important geological, biophysical, cultural, and wildlife resources for researchers, the local visiting public, and international tourists (Brooke, Creasey, & Sexton, 2010; Palmer & Newsome, 2010; Playford, 1988). The island attracts over 560,000 visitors annually, is a tourism hotspot in Western Australia, and is recognized internationally as an iconic tourism destination (RIA, 2011). Rottnest Island has been operating as a tourism destination since the 1900s and was recognized as an A-class nature reserve for tourism in 1997 under the Western Australian Land Management Act 1997 (Playford, 1988; RIA, 2009). Forty-eight percent of the annual tourists are repeat visitors (RIA, 2011). Of these visitors, 70% are from Western Australia, 15% from interstate, and 16% from overseas, highlighting its attractiveness as a local holiday destination (RIA, 2009, 2011). The majority of the
this work has recently been completed by Rutherford et al. (2014), who mapped areas of geotourism interest in the context of environmental factors and risks such as erosion, access to transport, and profile of the visitor (able to walk long distances through to limited mobility).

Geology of Rottnest Island and the Legacy of Sea Level Change

Rottnest Island is part of one of the world’s most extensive Quaternary aeolian (windblown) limestone dune systems (Brooke et al., 2010; Playford, 1997) and is part of a chain of calcareous coastal dunes occurring along the south-western coastline of Western Australia (Hearty, 2003; Hearty, Hollin, Neumann, O’Leary, & McCulloche, 2007; Playford, 1988). The island is composed of bays and beaches separated by rocky limestone cliffs that back onto undulating active parabolic dunes (Gozzard, 2011; Playford, 1997). The coastline is fringed by shallow marine platforms that cut into Pleistocene aeolianite, comprising the cross-bedded Tamala Limestone (Fig. 2A). The island has an extensive system of saline lakes containing stromatolites, algal mats, and marine molluscan assemblages (e.g., Herschell Limestone). Specifically, the Herschell Limestone stratigraphy, elevated platforms, notches, and visors in the Tamala Limestone along the inland lakes provide evidence of Quaternary sea level
Figure 2. A selection of photographs from various locations on Rottnest Island showing the range of geology and coastal geomorphology available for geotourism opportunities.
change (Fig. 2B, 2C). Although there is still some debate regarding the exact details of Quaternary sea level change along the south-west coastline of Western Australia, including Rottnest Island, it is agreed that sea level fluctuation has been significant (Brooke et al., 2010; Hearty et al., 2007; Hearty & O’Leary, 2008; Wyrwoll, Zhu, Kendrick, Collins, & Eisenhauer, 1995). Global research and geological records show that ~120,000 years ago, during the last interglacial period, sea level was at its peak at around 6–9 m higher than at present (Braganza & Church, 2011; Church & White, 2006; Hearty et al., 2007; Intergovernmental Panel on Climate Change [IPPC], 2007; Spooner, Deckker, Barrows, & Fitfield, 2011; The Royal Society, 2010).

At around 130,000 years ago the south-western coastline of Australia was 10 km further inland than it is today and extensive sand deposits derived from fluctuating interglacial sea levels form the Tamala Limestone/Spearwood Sands of Swan Coastal Plain on the present day mainland. During the last glacial maximum 20,000 years ago, sea level retreated approximately 120–140 m below present levels and the coastline was about 12 km west of Rottnest Island (Braganza & Church, 2011; Playford, 1988, 1997). The global sea level changes correlate with the deposition of sediments (e.g., Rottnest Limestone, Tamala Limestone, and Herschell Limestone) on Rottnest Island, as illustrated by the modified graph of Chappell and Shackleton (1986) as seen in Playford (1988) (Fig. 3).

Furthermore, Quaternary sea level fluctuations are also evident in the island’s fossil reefs, which are exposed 2–3 m above present sea level, as seen in the elevated platforms and double notches in the limestone cliffs around the island (Kendrick, Wyrwoll, & Szabo, 1991). Furthermore, geological features that extend below present sea level (e.g., the sub-marine dunes of Tamala Limestone, fossil roots that extend into the limestone, and the doline hole structures of the salt lakes) mark the changes in successive sea levels over the Pleistocene and Holocene (Playford, 1988, 1997). The timing of Rottnest Island Quaternary sea level features correspond to those of other islands (e.g., Bahamas, Bermuda, and the Yucatán Peninsula, Mexico) located in regions at similar latitudinal locations in the world (Carew & Mylroie, 1997; Szabo, 1978; Vacher & Quinn, 2004; Vacher & Rowe, 1997).

The shell deposits in the lakes and the deposits found in Lake Herschell and the Lake Vincent quarry (Fig. 2D) also provide timing evidence

![Figure 3. Sea level curve in relation to limestone deposition on Rottnest Island. Source: (Playford, 1988).](image_url)
### Description of the Geology and Geological Features Supporting Evidence of Historical Sea Level Changes

<table>
<thead>
<tr>
<th>Geology &amp; geomorphology</th>
<th>Description</th>
<th>Source</th>
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<tbody>
<tr>
<td>Coastal shoreline</td>
<td>Weathering and erosion forms the distinct shoreline storm benches, platforms, visor, and notches. Rocky calcarenite headlands, bays and shallow platforms (extending ~200 m from the shore) cut into the Late Pleistocene and early Holocene dunes (coastal Tamala Limestone) which occur as shoreline notches and lie just below the overhanging visors. The bays with less wave action display horizontal platforms and storm benches close to the water, where the highest platforms are found at headlands facing the predominant southwest swell. Coastal Tamala Limestone consist of a hard calcrete top layer underlain with softer limestone containing cemented calcite root systems (rhizoliths) which forms a brittle and fragile coastline.</td>
<td>Semeniuk and Searle (1987), Playford (1988, 1997), Masselink and Hughes (2003), Short (2005)</td>
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<tr>
<td>Salt lakes &amp; brackish swamps</td>
<td>Salt lakes thought to be collapsed cave system or doline that formed during the Pleistocene epoch, contain shell deposits (Herschell Limestone), algal sediment layers and living cyanobacteria (stromatolites). Lake salinity range from 15,000 mg/L to 68,000 mg/L, due to thick sediment and algae layer forming a sealant preventing ground water to flow in.</td>
<td>Playford (1988), Backhouse (1993), Playford (1997)</td>
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<tr>
<td>Sand dunes</td>
<td>Part of the Quindalup and Spearwood Dune complex of the Late Pleistocene and Holocene eras (~125–10 K years ago). Exposed dunes are subaerial accumulations of weathered Tamala Limestone, composed of calcium carbonate minerals, quartz sand, and molluscan fragments.</td>
<td>Playford (1997), Hearty (2003), Hearty and O’Leary (2008)</td>
</tr>
<tr>
<td>Stratigraphy (geological sedimentation)</td>
<td>Predominant geological feature of Western Australian islands and coastline from Shark Bay to the south coast. Remnants of Pleistocene and Holocene dunes (Spearwood and Quindalup) composed of aeolian quartz sand and shell fragments (molluscan fauna) which forms by cross-bedded accumulation followed by subsequent cementation processes. Lithification strengths will vary depending on the extent of natural erosion and the presence of fossilized root structures (rhizoliths) and solution pipes.</td>
<td>Playford (1988, 1997), Brooke (2001), Haig (2002), Tapsell, Newsome, and Bastian (2003), Short (2005), Lane (2011)</td>
</tr>
<tr>
<td>Herschell Limestone</td>
<td>Composed of weakly lithified Holocene marine shell deposits of some 220 plus molluscan fauna species and lime sand that formed in tidal zones when sea level was ~2.4 m higher than today. Stratigraphy is divided into two formations: upper Baghdad member at 0.6 m thickness and the Vincent Member below at ~0.55 m. Some of the molluscan species are not found in the waters of Rottnest today.</td>
<td>Playford (1988), Gozzard (2011)</td>
</tr>
<tr>
<td>Rottnest Limestone</td>
<td>Interlayer of coral limestone and shelly calcarenites found between layers of Tamala Limestone, formed around the interglacial period (~120,000 years BP, when sea level was ~6–9 m higher than today. Contains fossilized Staghorn, Brain, and Tubular corals, and cemented mollusc/gastropods, prominent coral species Acropora sp.</td>
<td>Szabo (1978), Playford (1988, 1997), Greenstein and Pandolfi (2008)</td>
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<tr>
<td>Sea level change (late Pleistocene &amp; Quaternary)</td>
<td>Exposed fossil coral are predominant interpellations of past sea level changes in a carbonate setting, and fossils of the last interglacial period have been documented around the world, including the Bahamas and Australia. Exposed fossil corals are found ~3 m above the high tide line at Fairbridge Bluff on Rottnest Island, suggesting sea level would have been ~2.5 m higher than today, as the coral would have been submerged in meters of water to have grown to such the extent. Elevated platforms and double notches are consistent with sea levels being ~2.4 m higher than today.</td>
<td>Kendrickick et al. (1991), Carew and Mylroie (1997), Playford (1997), Vacher and Rowe (1997), Vacher and Quinn (2004)</td>
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(Continued)
section is therefore to review pertinent literature that forms the background and basis for developing interpretive content and recommendations for geotourism on Rottnest Island.

Rottnest Island thus contains an extensive array of classic carbonate features, and according to the geoheritage “significance” grading system outlined in Brocx (2008), its geological attributes range from global to local significance. For example, the fossilized corals found ~3 m above the present high-tide line (Fig. 2E) and the elevated shoreline feature around the inland lakes (Fig. 2B) provide evidence of sea level change events of global relevance (Playford, 1988). The extensive limestone cliffs rich in marine assemblages and fossil root channels, and the active parabolic dune terrain, are locally important because they explain the geological processes occurring in that region (Brocx, 2008; Brocx & Semeniuk, 2007).

Given that Rottnest Island contains world-class geological features, with particular illustrations of Quaternary sea level change events, its geotourism profile can be realized by developing geological educational content through the design of appropriate interpretative products. The aim of the next section is therefore to review pertinent literature that forms the background and basis for developing interpretive content and recommendations for geotourism on Rottnest Island.

The Importance of Interpretation in Geotourism

Interpreting complicated scientific information and providing environmental education for tourists is an important part of quality natural area tourism operations (Ham, 1992; Moscardo, 2000; Pastorelli, 2003). Hughes and Ballantyne (2010) emphasize the importance of communicating ideas and concepts to inspire, entertain, and interest visitors through interpretation. Geological interpretation requires explaining what can be seen as somewhat “dry” and complicated geological features, unlike other aspects of nature-based tourism that are more appealing to learn about, such as flora and fauna (Hlad & MacFayden, 2003). Accordingly, interpretation is important for the visitor because it is a way to increase visitor knowledge, appreciation, and satisfaction as well as the provision of safety information during tourism activities that take place in the natural environment (e.g., Moscardo, 2000). Communication during the
interpretive process involves cognitive processes that inform and orient people by creating interest, a sense of place, and attachment (e.g., Hughes & Ballantyne, 2010; Newsome, Moore, & Dowling, 2013; Orams, 1995).

Tilden’s 1957 and 1977 definition and principles are the foundation by which to understand interpretation. Tilden (1957) described interpretation as an art and communication designed to accommodate visitor expectations, needs, and attitudes. Core principles were originally presented by Tilden (1957) and these have subsequently refined and expanded upon by others (e.g., Crabtree, 2000; Ham, 1992). These principles emphasize the importance of interpretation having a theme and associated messages, active involvement by the tourist, employment of maximum use of the senses, the fostering of self-discovered insights, and that the tourist finds the whole learning experience of relevance and useful. The precontact, actual, and postcontact stages of the interpretive experience have been succinctly discussed by Orams (1995) and Fennell (1999).

The precontact phase is of particular importance as it is at this stage that the visitor lacks information and interpretation can be tailored to furnish answers to questions that may have been generated before the actual on-site interpretation takes place (see Fennell, 1999).

Interpretative techniques can be applied in various forms such as presentations, displays, information panels, interactive activities, guided tours, websites, and publications (e.g., Ham, 1992). The Department of Conservation (DOC, 2005) notes that creating interpretive media requires research, knowledge, management, and a vision to combine science and art in order to provide visitors with clear communication and the best interpretation techniques. When assessing suitable interpretative design, Hughes and Ballantyne (2010) emphasize the importance of developing an interpretation plan. Such a plan includes identifying the target audience, establishing an objective and theme that highlights the unique characteristic that is the subject of interpretation, and determining the best interpretive medium/design. Furthermore, any natural-area tourism interpretive endeavor should assess the prevailing environmental conditions and determine if there are management concerns and constraints involved at the chosen site (Hughes & Ballantyne, 2010).

The DOC (2005) and Hughes and Ballantyne (2010) state that interpretative communication should be enjoyable, colorful, fun, and interactive so it is easy for the visitor to remain engaged. There are several interpretive techniques that will automatically attract the visitor’s attention, these include the use of color, using comparisons and metaphors, humor, and surprise to help the visitor connect and engage with the subject.

Museums and visitor centers are public areas that can facilitate multiple interpretive media. They are generally the focal point and front line for the delivery of information on an area. They usually contain sections that can accommodate a large variety of visitor interests and have more than one theme (DOC, 2005; Newsome et al., 2013). The Pinnacles Desert Visitor Centre in Namburg National Park, north of Perth, Western Australia, provides detailed information specific to the history, cultural significance, and theories of formation of the limestone Pinnacles (see Newsome, Dowling, and Leung, 2012). The major advantage of an interpretative center is that it is a central locality that can house a range of interpretative applications, and it is where visitors know that information can be obtained. Visitor centers usually have staff to answer questions or help obtain information for the visitor. Interpretive centers also have drawbacks: for example the initial cost of building a visitor center or museum can be high, and upgrades to displays and maintenance of the facility can be limited if the center does not have adequate funding (Newsome et al., 2013). Furthermore, the staff who provide support and educational services for a visitor center need to be trained to accommodate the visitors’ needs and be knowledgeable about the location and its natural resources.

Guided interpretation is the face-to-face delivery of information and ranges from guided cave tours to eco-boardwalk tours, vehicle tours, and in-house presentations and talks. It is regarded as an effective and powerful interpretation technique (e.g., Black & Weiler, 2005; DOC, 2005; Pastorelli, 2003; Wearing & Neil, 1999). Key advantages are that tour guides can encourage active engagement with visitors and the information and knowledge a tour guide possesses can easily be updated (Newsome et al., 2013). Often such interpretation is carried out by visitor-center staff, eco-tour operators, or, as in the case of most of the Rottnest Island, guided tours.
by volunteers. Tour guides can use a wide range of interpretation styles, and can help enhance the visitor experience by supplying in-situ information on geology and landscapes as well as catering to their specific needs and interests. Guided tours can also include nature walks, bird watching, marine mammal observation, and snorkeling, and the tour can take place on a boat, by vehicle, or on foot, the last of these being the most common mode. Such tours are able to cater for all audiences and interactive communication between the guides and visitor is achieved by asking visitors questions and getting them actively involved in the interpretive experience. Guided tours can provide the tourists with the opportunity to visit remote and difficult to access areas and in such situations tour guides can be proactive in regard to visitor management or safety issues (e.g., DOC, 2005). The disadvantages of tour guiding as an interpretive strategy are that effective interpreters need to be trained and committed to communicating necessary content to the audience. This is essential for effective interpretation and visitor satisfaction. Time and resources are thus required for the education and training of guides in effective interpretation skills (Newsome et al., 2013).

Maps are a good way to highlight geological points of interest within an area. They can be tailored to follow a specific route and can be a tool to direct approved access and thus aid in visitor management (e.g., Kranendonk & Johnston, 2009; Norman & Whitfield, 2006). Geotour maps are a cost effective and portable form of interpretive information that can be distributed through many avenues. Publications such as guidebooks and brochures can provide visitors with initial orientation of a natural area and can be used as a reference for further learning. They usually contain information on geology, landscapes, plants, and wildlife and they often include maps, photos, diagrams, and illustrations (Dowling, 2011; Newsome & Dowling, 2010).

Geology guidebooks are used to explain historical and regional geology such as landforms, minerals, rocks, and processes and are frequently termed “geo-tour guides” (Dowling, 2011). Publications are an effective portable means of distributing information to the tourist and are a cost-effective interpretative technique (Newsome et al., 2013). Guidebooks can be tailored to various levels of understanding and designed for specific purposes (e.g., Copp, 2001; Lane, 2011; Turner, Kelman, Ulmi, & Turner, 2010).

Although guidebooks can provide visitors with precontact, contact, and postcontact information, and can be kept as a souvenir, they have various limitations. For example, guidebooks and similar publications do not allow for visitor interaction or help to answer any specific questions that might be raised about an area. For some tourists, such as the multiday hiker, the size and weight of a guidebook will override the decision to obtain one, regardless of the valuable information the guide may contain. Compact versions, which can complement any existing interpretive panels along the route, are a useful compromise. The Western Australian Department of Environment and Conservation has published a collection of pocket-sized guides on various topics including marine and terrestrial ecology, wildflowers, and geology. The small, compact size makes them ideal to carry while at the same time providing comprehensive information that enhances visitor knowledge. However, publishing and updating such guides often requires time and additional funding.

Interpretive panels are used in natural area tourism as they are a cost-effective means of communicating information to a large number of visitors in both indoor and outdoor settings (Hughes & Ballantyne, 2010). They are usually permanent free standing, self-explanatory boards that often contain colorful illustrations, diagrams, pictures, and words to highlight ideas, concepts, and themes (DOC, 2005; Hughes & Ballantyne, 2010; Moscardo et al., 2007). Hughes and Ballantyne (2010) provide a useful account of the design of interpretative panels for geotourism, stating that that the main criteria for interpretive information involves the creation of a theme that encourages the visitor to seek further information on the content being interpreted. Moscardo, Ballantyne, and Hughes (2007) and Hughes and Ballantyne (2010) recommend that the content should tell a story using metaphors, humor, and educational analogs to convey information and connect the visitor to the geotourism site. Layering of interpretative content can be done by creating blocks of information with headings and subheadings associated with illustrations and this approach provides the visitor with the opportunity to choose the level of detail they want to read while on site.
There are both advantages and disadvantages with the application of interpretative panels (DOC, 2005; Hughes & Ballantyne, 2010; Newsome et al., 2013) The major advantage of interpretative panels is that they can be implemented in remote areas where visitor centers are not practical, and they are more cost effective than tour guides. Panels can be used to highlight significant wildlife, plants, landscapes, and geology and bring attention to access and safety requirements. Disadvantages include the need for maintenance due to weathering, the lack of ability to answer visitors’ questions, responsibility of learning falling to the visitor, and it is possible that the panel may have an impact on scenic values. Newsome et al. (2013) also highlight that interpretive signs are often subject to vandalism and replacement can be expensive and time consuming.

Technological developments such as websites, virtual designs, and smart phones, have revolutionized the format of interpretation over the last decade or so (e.g., Outhier, 2011). Applications (apps) are now important tools that provide the tourist with information and many websites contain maps, itineraries, and schedules of activities (Newsome et al., 2013). Connecting people with web-based information through mobile devices is becoming a major interpretive medium with visitors desiring information to be available on their mobile computer devices (smart phones, laptops, and touch pads).

This demand is evident by the increased use of websites and mobile phone applications being incorporated into tourism operations. For example, the Department of Parks and Wildlife in Western Australia is catering for such increased demand and has supplied informative content for walks published on the Every Trail website (Every Trail, 2014). Every Trail Guides provide a downloadable phone app for hiking and walking trails around the world. Partnering with the Department of Parks and Wildlife, 14 apps are currently offered for trails around Western Australia (Every Trail, 2014) including apps for Penguin Island and the Shoalwater Islands Marine Park, Namburg National Park, and the Leeuwin Naturalist National Park (Department of Environment & Conservation [DEC], 2011). The apps provide visitors with a clearly mapped route with updated information on points of interest that are numbered and marked along the route. Users can click on the point of interest on their device and information on that site then becomes visible on screen. This provides direct information and convenience for tourists. Virtual tour apps are also being employed in museum and visitor center interactive strategies.

Another means of linking information to people through mobile devices is to use QR codes (Lyne, 2011). The QR (quick response) code is a bar code image that can be read by mobile phones and transfer or link you to another site, such as a webpage. It is a purpose-built bar code that has a URL code (website link) built into it and by scanning or taking a picture of the code on your mobile; the code directs the user to the URL site. QR codes are a simple way to transfer information because they can provide links to URL sites, geocordinates, and information text. For geotourism this means providing geological content for the apps, interactive websites, virtual tours, and links to URL sites using QR-code technology. Inserting a QR code on an interpretive panel, map, or guidebook will allow for the visitor to access further information on the area or topic. QR codes can easily be created and updated without changing interpretive signage.

The Importance of Interpretation in Geotourism Development on Rottnest Island

The island’s extraordinary carbonate geologic features (stromatolities, evidence of sea level change, exposures of Late Pleistocene aeolianite, and Holocene dunes) present examples of geological phenomena, particularly relating to global climate change (Playford, 1988). Both past and current tourism have not capitalized on the geological value on the island in an engagement/educational sense. This is in contrast to many other areas of Western Australia where interpretive panels and landscape viewing points have been installed to engage the visiting public with deep landscape history via the provision of information about geological features (e.g., Figs. 4 and 5). Furthermore, in the global context, tourism during the last 10 years has seen a rapid growth in visitor interest in geology and sites that explain the nature of geological phenomena. This is exemplified in the rapid rise of the European and global Geopark movement (particularly
Figure 4. Interpretive sign explaining rock strata at Kalbarri National Park, Western Australia.

Figure 5. Interpretive sign at the lake Thetis living stromatolite site, south Western Australia.
in China), where governments and local communities have recognized the tourism value of their geoheritage (Dowling, 2011; Dowling & Newsome 2006; Newsome & Dowling, 2010; Newsome et al., 2012). Today there are many places around the world (e.g., Fig. 6) where viewing platforms, walking trails, and educational facilities have been developed with the intention of protecting, showcasing, and engaging the public with geology (Dowling & Newsome, 2010; Newsome & Dowling, 2010).

Rottnest Island is a long-established natural-area tourism destination and RIA currently provides visitors with a selection of interpretative educational products that focus on cultural, historical, ecological, and wildlife attributes. For example, a set of guidebooks highlighting the marine wildlife, birds, terrestrial flora and fauna, and cultural and Aboriginal heritage are available for purchase and the museum contains a selection of historical artifacts, information, and (rather dated) visual displays illustrating some components of the geology on the island. In order to accommodate the demand for information being available through mobile devices, the RIA education and interpretation division has created a downloadable GPS map-based phone app that is linked through the EveryTrail mobile website. This convenient interactive device provides visitors or potential visitors with information and locations of popular recreational activities and historical material around the island. Visitors can also create their own trail map of the island and upload personal photos and comments that allow sharing through social media platforms.

RIA also provides visitors and school groups with educational products and activities that highlight the cultural history and environmental significance of the island. Environmental education is facilitated through the Rottnest Island Education Team, which offers the visiting public a range of activities that provide opportunities to learn about the unique environment of the island, including information on the marine and terrestrial flora and fauna, bird life, cultural and Aboriginal heritage,

![Figure 6. Viewing platform with interpretive panels at the Deokmyeong Dinosaur Footprint Site, South Korean coastline.](image-url)
as well as outlining the island’s environmental management and conservation initiatives. There is an array of educational programs for primary and secondary schools that encourage active learning through experiencing the environment through hands-on activities and environmental education programs geared toward teachers and researchers (RIA, 2012).

RIA has recently commenced the construction of the proposed “RIA Coastal Walk Trail” project. The coastal walk trail is a comprehensive trail network that aims to offer visitors greater exposure to the cultural, historical, and natural features of the island to offer, while minimizing access via informal trails and thus mitigating environmental degradation (RIA, 2012; Syrinx, 2010). The first stage of the coastal walk trail has been completed, and visitors can explore the west end of the island via the interpretative signage trail at Cape Vlamingh (Fig. 1). However, interpretative material highlighting the extraordinary geology and geomorphology of Rottnest Island is presently limited.

Hose (2006) and Dowling (2011) maintain that geointerpretation should effectively promote sustainable tourism and provide opportunities for tourists to connect to the natural area they are visiting. Geointerpretation should answer questions and create self-learning through illustrations, words, and pictures, and promote visitor appreciation of the area being visited (Newsome & Dowling, 2010; Newsome et al., 2013). Furthermore, Henriques, dos Reis, Brilha, and Mota (2011) explain that in the context of geoconservation, educating the public about geological processes:

Provides citizens with the tools to face environmental problems arising from the depletion of geological resources, . . . and the skills and knowledge they gain will improve forward-thinking choices, such as supporting legal protection for natural heritage areas and the establishment of geotourism and geoheritage sites. (p. 117)

B. Joyce and Brohl (2008) stress the importance of geological education in the context of global change and overexploitation of resources, where they state,

People around the world are becoming more conscious of nature and recognize the importance of the protection of its natural heritage and resources . . . and that the public does not know how to respond to this global change because education on how geoscience (geological processes) and society are linked to resource exploitation is missing. (p. 209, 212)

They further go on to say that “finding engaging ways to bring back to people an understanding of the important processes that control our planet can be achieved through the educational content derived from geotourism and geopark interpretative products” (B. Joyce & Brohl, 2008, p. 212). For example, an interpretative sign that simply connects everyday products to geological resources, such as how limestone is an ingredient for toothpaste and that the minerals of limestone make the shells of marine organism, can go a long way in enhancing our understanding of the human connection with geology (B. Joyce & Brohl, 2008).

Accordingly, interpreting what might be considered somewhat “dry” aspects of geology is essential for the success of geotourism, and this depends on providing techniques that best suit explaining geology to create appreciation and lasting impressions (Newsome & Dowling, 2010; Newsome et al., 2013). Identifying the geological features on Rottnest Island and creating informative and scientific interpretative products can provide educational content that generates an understanding and awareness of Earth-system processes. At present the geological educational opportunities on Rottnest Island are underutilized and limited to a few interpretative panels.

Table 2 therefore draws attention to some interpretative themes that can be introduced as the educational content for geotourism on Rottnest Island. The geological content in Table 2 is organized into the three main themes (i.e., sea level change, environmental change and historical conditions, and carbonate geology of the island). To this end, the lake area contains an abundance of geological features, has the potential for suitable tourism access, and has minimal environmental management considerations, making this area an excellent focus for the development of geoschool educational content. Furthermore, a combination of the RIA Coastal Walk Trail spatial data combined with a geosite database developed by Rutherford et al. (2014) can be used for the creation of a geointerpretative trail around the lakes, with the major educational focus...
on environmental change, specifically in relation to Quaternary sea level changes and the previous connection of Rottnest Island to the mainland. Such information can be delivered through a combination of interpretative panels in the field, maps, guidebooks, visual displays, and Smartphone applications and interactive touch screen virtual tours facilitated through Geographical Information System (GIS) mobile devices.

An example of geological interpretation for tourists is to draw attention to the role that global ice volume plays in sea level fall and rise. The evidence from Rottnest Island shows that it was once part of an extensive area and covered in vegetation such as *Eucalyptus gomphocephala* woodland. One line of evidence for the occurrence of large trees lies in the presence of exposed rhizoliths and large fossilized root channels (Fig. 2F) of trees that were once widespread on the island. The trees were growing at a time of low sea levels when the global ice volume was at its maximum extent around 18,000 years ago. Interpretive content could explain the relationship

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<th>Themes/Subthemes</th>
<th>Global Significance</th>
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<td>Rottnest Island’s connection to the mainland (bathymetry, fossil Emu footprints, Aboriginal artefacts)</td>
<td>Evidence to support how to plan for future changes in the earth’s climate. Aboriginal occupation post separation from the mainland (~5.6 ka).</td>
<td>Bindon et al. (1978), Playford (1988), Richardson et al. (2005), Brooke et al. (2010)</td>
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<td>Elevated shore line platforms, notches, and visor along the inland lakes</td>
<td>Historical global eustatic sea level change information, planning for climate impact (development and geotourism)</td>
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<td>Environmental change and historical conditions</td>
<td>Connection to mainland; global Holocene sea level correlations; collapsed cave systems; salt production and road building materials</td>
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between global ice volume and mean sea level, going on to explain that when the ice caps melted as a result of an increase in temperature marking the end of the last ice age the sea level rose. This information coupled with interpretation delivered at various sites on Rottnest Island that provide evidence of former high sea levels serves to point out an important mechanism controlling the position of shorelines in the past and possibly in the future. Geological interpretation can then be “brought alive” by adding information such as how humanity is afflicting the world’s climate through global warming. Visual aids, such as satellite images over the Arctic showing the diminished range of summer ice since 1979, and the implications for future rises in sea level, can then serve to highlight the meaning gained from the Rottnest geotourism story (e.g., Flannery, 2006).

Conclusion

Natural area tourism destinations that contain world-class geology have the opportunity to engage the wider public in the connection between society and the geological features. For example, carbonate islands, reefs, and atolls at various locations around the world demonstrate significant geological evidence of the earth’s ever-changing climate (Vacher & Quinn, 2004). Carbonate islands similar to and including Rottnest Island, the Bahamas, and Bermuda are at risk of being impacted by human-induced climate change as seen through rising sea levels and extreme coastal weather events. A recent study conducted in Australia (Turton et al., 2010) found that tourism destinations are not investing in climate change adaptive strategies due to the conflicting perception of climate change impacts. There is increasing literature on how climate change will affect tourism, especially in coastal areas. For examples see Department of Climate Change (2009), Simpson, Gössling, Scott, Hall, and Gladin (2008), Zeppel and Beaumont (2011), Scott et al. (2012), and Zeppel (2012). Rottnest Island, via geotourism, can contribute to the debate via the deployment of suitable interpretive content. The importance here, however, is in bridging the gap between geology and public education. Gozzard (2012) notes that by using geological themes that are significant to the public and creating a “dialogue between the public and earth’s history” through interpretive media and educational packages attempts can be made to fill this important gap in knowledge dissemination to the public.

Rottnest Island is a premier local, national, and international tourism destination with a richness of carbonate geology and associated environmental attributes (e.g., warm ocean temperatures, warm temperate climate, tropical marine biota) and demonstrates globally significant examples of geology that relate to climate change (e.g., sea level fluctuation undercut notch marks, elevated marine fossils, stratigraphic exposures, and molluscan assemblages) (RIA, 2011; Table 1). The development of geotourism products and opportunities such as interpretive panels along board walks, geotour guide books and interactive GPS map-based mobile devices (phone apps and tablets) would serve to improve geotourism on the island and enhance the tourist’s awareness and appreciation of the environment (Palmer & Newsome, 2010). Furthermore, in a geologically rich environment it is possible to incorporate geological scientific data into accessible and engaging information in order to generate public awareness with the aim of captivating and educating the visitor about geology and environmental conditions that relate to global climate change. It is very likely that many off-shore island and coastal settings around the world have not yet capitalized on their geoheritage as tourism resources. The case of Rottnest Island serves as a strong reminder that the overall natural area tourism profiles of many islands and coastal environments are yet to be realized.

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