Government of **Western Australia**
Department of **State Development**

Palaeontology Survey of the Broome Sandstone - Browse LNG Precinct Report

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Lastly but not least, Dr Steve Salisbury of the University of Queensland is thanked for assistance in locating relevant palaeontological sites and sharing his knowledge of them in the vicinity of James Price Point.

Preface

It should be noted that while primary authorship of this report rests with Richard McCrea, Curator of the Peace Region Palaeontology Research Centre, British Columbia, Canada and Dr Martin Lockley, Professor of Geology at the University of Colorado at Denver, USA, support for the development of a number of sections rests with other members of the survey team. In particular **Section 3.1 Geological overview and palaeo-environment** was drafted by Dr Peter Haines, Senior Geologist with the Geological Survey of Western Australia with a small addition regarding the area at James Price Point prepared by Martin Lockley. In addition **Section 1.3** and **Appendix 2 Summary of Existing Knowledge** were developed by Dr Neale Draper of Australian Cultural Heritage Management. Lastly **Section 1.1 Background**, was provided by the Department of State Development.

Glossary of terms

Ankylosaurs: see Thyreophorans

Footprint: A synonym for a single 'track' (see trackway and tracksite). Likely has a morphology that reflects the track maker's foot anatomy if well preserved.

Ichnology: the study of tracks and traces. Thus, a tracker is an ichnologist.

Ichnotaxonomy: the scientific process of naming of trace fossils. Essentially adopts the same procedures as used in naming other fossils, and living plants and animals as laid down in the International Code of Zoological Nomenclature (ICZN). Thus a "track species" is an ichnospecies (e.g., *Megalosauropus broomensis*) and a "track genus" is an ichnogenus.

Megatracksite: a regionally extensive track-bearing unit of strata, that can be reliably correlated for tens of hundreds of kilometres. Also popularly known as a "dinosaur freeway". Well studied megatracksites are mostly identified as ancient coastal plain deposits.

Ornithopods: (from Ornithopoda, meaning bird foot) A group of vegetarian dinosaurs belonging to the bird hipped group (Ornithischia). Mostly bipedal, and mostly three-toed, with blunt digits.

Sauropods: (from Sauropoda meaning reptile foot). Long-necked, long-tailed dinosaurs also know as a 'brontosaurs' belonging to the lizard hipped dinosaurs (Saurischia). Quadrupedal vegetarians and almost all large with elephantine feet.

Stegosaurs: see Thyreophorans

Theropods: (from Theropoda meaning beast foot). Carnivorous dinosaurs belonging to the lizard hipped group (Saurischia). Almost always bipedal, and mostly functionally three-toed.

Thyreophorans: (from Thyreophora meaning shield bearers) a group of vegetarian dinosaurs that includes the armoured dinosaurs (Ankylosaurs, (referring to fused armour) and the Stegosaurs (meaning plated dinosaurs). Both groups were mostly or exclusively vegetarian quadrupeds. Their tracks, especially the front footprints, are difficult to tell apart.

Trackway: a series of tracks (or footprints made by a single animal progressing in a discernable direction.

Track site: a single location with recognized tracks and trackways. May be as few as a single track, or may be as many as thousands of tracks and trackways. Usually distinguished from other track sites by having a separate geographical location. Many important sites have their own geographical or other names.

Trampling: in the context of fossil footprint studies 'trampling' usually refers to track-bearing surfaces where the density of tracks is so high as to make individual tracks

and trackways difficult to discern. Most such trampled layers are attributed to large dinosaurs like sauropods.

True track: an impression made on a primary (original) track surface.

Type material. Specimens used as the basis for formally naming new species, ichnospecies etc (see ichnotaxonomy) are known as 'type specimens' or holotypes, and the sites from which they originate are 'type localities.' *Megalosauropus broomensis* is the only type specimen example from the Broome area. Specimens of the same type from the type locality are referred to as topotypes.

Undertrack: footprint impressions caused by the transmission of pressure to substrate layers underneath the primary track surface

1 Introduction

1.1 Background

The State of Western Australia (WA), through the Minister for State Development (the Proponent), proposes to develop an onshore, common-user Liquefied Natural Gas (LNG) Precinct to process natural gas from Browse Basin gas fields off the West Kimberley coast. The Department of State Development (DSD) has been charged with advancing this proposal under direction of the Proponent. Woodside Energy Limited (Woodside) was appointed as a potential Foundation Proponent for the Precinct under the Preliminary Development Agreement signed in October 2009. This Agreement established Woodside as a partner with the State Government in bringing the project to completion.

The Browse Liquefied Natural Gas Precinct (BLNG Precinct or Precinct) would consist of LNG processing facilities and associated infrastructure, and would be located in the vicinity of James Price Point, approximately 60 kilometres (km) north of Broome, on the west Kimberley coast of Western Australia (**Figure 1**). The BLNG Precinct would provide a location for processing gas and associated products from the Browse Basin with an LNG production capacity of up to 50 million tonnes per annum (Mtpa). If it were to occur, full development of the Precinct would most likely be phased in as demand for additional processing capacity arises. The Precinct would accommodate a minimum of two proponents at one location and enable sharing of common-user facilities such as the port, roads, infrastructure corridors and workers' accommodation. A Precinct Plan has been developed to meet the requirements of the Commonwealth Government.

A detailed and comprehensive assessment has considered the environmental, social, economic, heritage and strategic implications of the Precinct should it reach its full capacity. The assessment process has involved desktop studies, field surveys, modelling, data analysis, impact assessment and stakeholder consultation, the results of which are documented in the BLNG Precinct Strategic Assessment Report (SAR) released for public comment in December 2010.

The purpose of the Strategic Assessment Report is to meet the requirements of the State and Commonwealth governments in accordance with the Terms of Reference. The Strategic Assessment includes a high level impact assessment (including social factors), a description of the strategic proposal, identifying 'future proposals' (to be approved under the *Environmental Protection Act 1986* (the EP Act)) and the Precinct Plan (to be endorsed under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act)), and includes the Proponent's proposed draft conditions that may be applied to future proposals. The document includes a summary of existing information, identifying main impact areas and sets out the proposed management arrangements, mitigation and safeguards to ensure impacts are managed.

The Strategic Assessment Report is presented in seven parts:

Part 1: Executive Summary;

Figure 1 The location of the Precinct south of James Price Point

Part 2: Strategic Assessment Process including Site Selection, Facilities Description and Consultation Process;

Part 3: Environmental Assessment – Marine Impacts;

Part 4: Environmental Assessment – Terrestrial Impacts;

Part 5: Social and Heritage Assessment;

Part 6: Commonwealth Matters including Precinct Plan, Management Arrangements and Matters of National Environmental and Social Significance; and

Part 7: Supplementary Information on Wastewater Discharges, Hydrocarbon Spills, Benthic Primary Producer Habitats and Coastal Processes.

In addition the Proponent's Response to Submissions made on the documents listed above has been prepared. This comprises a Summary Report which describes the public submissions process and a consolidated list of questions raised during the public submission process along with the Proponent's response to each individual question which is provided as an Appendix to the summary report.

Finally, this report has been prepared at the request of the Environment Protection Authority (EPA) **(Appendix 1)** following consideration of submissions from the public. This additional work also acknowledges that subsequent to consideration of palaeontology in the SAR the area of the Broome sandstone in the intertidal zone (including at the Precinct location) has been included in the National Heritage List for its palaeontological values and so is now a matter of National Environmental Significance.

1.2 Objectives of the Study

Based on EPA (2011- **Appendix 1**) requirements, as far as practicable the proposed survey needs to identify all potential fossil features within the Lower Cretaceous Broome Sandstone within the proposed BLNG Precinct footprint at James Price Point. In addition, the field survey should examine other locations on the Dampier Peninsula which are known or likely to have significant dinosaur trace fossils within the region.

The key objectives of the survey are:

1. To document and geo-reference fossilised dinosaur footprints and other fossil features within the Browse LNG Precinct outline and the wider James Price Point Area, and other areas of the Dampier Peninsula; and,

2. Using data gathered under objective 1 and published and unpublished literature; place the paleontological features that may be impacted by the development into a local, regional, national and international context.

1.3 Summary of Existing Knowledge

Few details have been published of the fossil traces of flora and fauna in the Broome Sandstone formation. **Appendix 2** provides a more detailed summary of the palaeontological research which has been conducted and published to date.

Several locations have been recorded previously as sites for dinosaur tracks in exposures of the Broome Sandstone formation along the west coast of the Dampier Peninsula. These general locations and the sources of information for their identification are listed in Table 1.

Table 1 Recorded Locations for Dinosaur Tracks in the Broome Sandstone Formation, Dampier Peninsula (see **Appendix 2** for source details and internet links to these references).

Location	Description of Dinosaur Tracks	Source
Crab Creek (end of Crab Creek Road, north coast of Roebuck Bay, also known as Red Cliffs)	Dinosaur footprints	Long 2002: 182
Crab Creek (end of Crab Creek Road, north coast of Roebuck Bay, also known as Red Cliffs)	Stegosaur (?) prints (vandalised through theft in 1996)	Long 1998, 2002; Latham vs. the Queen 2010
Gantheaume Point (below lighthouse)	Emu-like tracks, *Megalosauropus broomensis*	Glauert 1953; McWhae et al 1958; Colbert & Merrilees 1967
Gantheaume Point (500m North)	Sauropod prints	St. Mary's College, Broome website
Gantheaume Point (2km South)	Sauropod prints	St. Mary's College, Broome website
James Price Point - most at the point itself, one a short distance to the north	Sauropod tracks, ornithopod tracks, (theropod tracks?)	Confidential Submission to EPA 2010
Quondong Point	Sauropod prints	St. Mary's College, Broome website
Quondong Point	Dinosaur prints (at least three different types)	EPA 1991
Riddell Beach (North West end)	*Megalosauropus broomensis* tracks	Colbert & Merrilees 1967
Quarry Beach, Reddell Beach [sic Riddell Beach]	Dinosaur footprints	Lambert & Elix 2004
Roebuck Bay (North shore, at base of Pindan cliffs)	Occasional dinosaur footprints	D.E.C. 2003
Roebuck Bay (North shore, at Black Ledge)	Sauropod tracks	Sparks, nd

South of James Price Point near the Browse LNG Precinct Southern pipeline corridor)	Sauropod tracks, ornithopod tracks, (theropod tracks?)	Confidential Submission to EPA 2010
Town Beach, Broome	Sauropod prints	St. Mary's College, Broome website
Multiple sites spread along 80-100km of west coast of Dampier Peninsula	Large & moderate-sized theropods (some definitely *Megalosauropus*); small tridactyl prints, possibly theropod; moderate and large size sauropod tracks, indeterminate "rectangular outline" prints; stegosaur (?) tracks; possible swimming/paddling traces.	Thulborn 1997
Sites range as far to the north of Broome as outcrops of the Broome sandstone are known; Gantheaume Point	Large number of trackways, more than six types of tracks, including some of the world's largest sauropod tracks. *Megalosauropus* (Gantheaume Point), Sauropods, ornithopod tracks cf. *Muttaburrasaurus* (beach exposures of the Broome sandstone around the Broome region), Stegosauridae (beach exposure Broome Sandstone, north of Broome (vandalised in 1996).	Long 1998
Discontinuous exposures of Broome Sandstone for approx. 200 kilometres, west coast of Dampier Peninsula, from the bird observatory at Roebuck Bay north to Cape Leveque	At least 15 different types of footprints	Australian Heritage Commission 2011; Salisbury 2011b
Intertidal areas between highest and lowest astronomical tide, from Roebuck Bay along the west coast of the Dampier Peninsula	dinosaur tracks	Commonwealth Gazette (2011)

These locations and the recorded surface exposures of the Broome sandstone along the west coast of the Dampier Peninsula between Roebuck Bay and Coulomb Point are shown in **Figures 2** and **3**.

Figure 2 Dinosaur track locations and the recorded surface exposures of the Broome sandstone between Quondong Point and Coulomb Point

Figure 3 Dinosaur track locations and the recorded surface exposures of the Broome sandstone between Roebuck Bay and Cape Latreille

2 Methodology

2.1 Survey Locations

James Price Point is located approximately 60 km north of Broome. The survey area encompasses all the intertidal areas of Broome Sandstone within the BLNG Precinct and adjacent areas near James Price Point (see **Figure 1**). In addition, areas outside the BLNG Precinct boundaries will be surveyed in order to provide a regional context. This will include survey at Roebuck Bay (Red Cliffs), Riddell Beach and Gantheaume Point near Broome and other sites that may be identified by local informants.

The survey strategy was determined following comment received from the EPA and SEWPaC and analysis of high resolution aerial photography and near shore bathymetry by the field survey team comprising expert palaeontologists and geologists.

2.2 Field Methodology

- Using spring low tides in late September/early October survey the paleontological features of the Broome Sandstone.

- Significant palaeontological sites and features will be spatially recorded by Differential GPS (using qualified surveyors) to a high degree of accuracy where possible, or otherwise by standard GPS as far as possible. Sites and features will be recorded by high resolution digital photography, and 3D imaging techniques. Two techniques will be used to create 3D images: photogrammetry and anaglyphs. In addition, supplemental tracing and mapping of selected sites will be employed. Tracings are made on clear acetate film for use in comparison with 2D and 3D images. Traditional

compass, tape and grid mapping of selected sites/features will also be used to produce scale maps of significant areas. Field measurements of larger trackway features will also be made, especially those not easily recorded by smaller scale imaging techniques.

- Features will be identified (interpreted) as definitively as possible by the expert palaeontologists.

- The geological stratigraphic context of the identified palaeontological sites and features will be recorded, including any associated palaeo-environmental evidence.

- Arrangements have been made for a University of Queensland palaeontologist, Steve Salisbury and local Traditional Owners to guide the teams to areas where significant fossils have been reported which are believed to be at James Price Point. This will save a significant amount of time. Access to information on this knowledge prior to commencing the survey is also continuing to be sought.

- Two teams will be established to ensure better and more rapid coverage of the selected areas. In most instances these teams will work in close proximity to allow expert consultation on interpretation of features. For further efficiency of coverage teams may sometimes go to different locations.

- A local tourism operator with knowledge of the locations of features around Broome has also been engaged as a guide to save time in establishing regional context.

- It should be noted that a flexible and adaptive approach is required in this instance as there remain some uncertainties with regard to access to some sites. Accordingly the survey plan may be modified in order to maximize the input of the highly specialized skills available to the team. This may include conducting more detailed work in some areas than is anticipated in the survey plan such as more comprehensive cataloguing of sites in Roebuck bay which will help establish the Regional context.

Consideration may be given to further field data collection between 12-15 October when there are reasonable tides should it be deemed necessary or practicable.

2.3 Team Members and Roles:

- International expert Palaeontologists (2) – Chief investigators, catalogue key paleontological features, places these features in local, regional, national and international context. Primary authors for reports.
- Field survey geologist with local/regional experience (1) – provide expert input into the field survey and report.
- Field survey geomorphologist with local/regional experience (1) – provide expert input into the field survey and report.
- Field Surveyors (2): Using DGPS, catalogue and geo-reference significant paleontological features as appropriate.
- Traditional Owner Representatives (as necessary) – to ensure the survey does not impact on any cultural heritage values.
- Team Coordinator (1) – DSD officer to manage and support the teams.

2.4 Fieldwork Contingencies and Final Survey Schedule

Fieldwork in cooperation with Yawuru and Jabirr Jabirr (via the KLC) Traditional Owners proceeded as planned. The Goolarabooloo group with palaeontologist Steve Salisbury refused to cooperate with the survey if the full survey team attended, and insisted that only the two visiting experts (no geologist or surveyors) should attend the survey with them at James Price Point. Consequently, the expert palaeontologists and the team coordinator attended the James Price Point and BLNG Precinct shore-crossings survey on the designated days, while the geologist, geomorphologist and surveyor surveyed areas close to Broome to provide regional context information. The final survey schedule (as conducted) is shown in **Table 2**.

In relation to the actual field data collected it should be noted that due to the relative abundance of tracksites found and the requirements for locating, photographing and cataloguing of as many track site locations as was practicable there was limited use of more time consuming data collection tools. In particular relatively few tracings were made and traditional compass, tape and grid mapping of trackways was restricted to one example of a sauropod trackway. In addition while photogrammetry data was collected, it is not a part of this report but is included with all other datasets collected.

Table 2 Palaeontological Field survey Schedule (actual).

Day	**SUN 25 Sept**	**MON 26 Sept**	**TUES 27Sept**	**WED 28 Sept**	**THURS 29 Sept**	**FRI 30 Sept**	**SAT 1 Oct**	**SUN 2 Oct**	**MON 3 Oct**	**TUES 4 Oct**
Morning time/tide	0303 3.62m	0347 2.55	0428 1.56	0506 0.76	0542 0.26	0617 0.12	0650 0.34	0723 0.90	0756 1.73	0831 2.72
Evening time/tide	1529 2.78m	1609 1.94	1646 1.26	1722 0.81	1756 0.63	1829 0.75	1900 1.14	1932 1.78	2003 2.62	2038 3.57
Morning	Richard McCrea arrives	Rich McCrea follow up survey cable Beach. Peter Baldwin, Peter Haines, Neale Draper arrive.	0930-1130hrs Jabirr Jabirr (JJ) Traditional Owner Consultation – Environment and Cultural Heritage Team (ECHT) meeting at KLC.	0500hrs hovercraft Roebuck Bay (Red Cliffs/ Crab Creek Rd site). 4WD to Riddell Beach. DEC Yawuru Rangers 5:00 am to 9:00 am 0900hrs media	Barred Creek and Willie Creek with JJ reps; Cable Beach.	Team 1 James Price Point with Salisbury, GBL & JJ – northern pipeline crossing. Team 2 Gantheaume Pt & Beach.	Team 1 James Price Point with Salisbury, GBL & JJ – Port Precinct. Team 2 Coconut Well; Port Beach.	Team 1 James Price Point with Salisbury, GBL & JJ – Port Precinct, JPP. Team 2 report writing.	Red Cliffs and Riddell Beach – field inspection with international experts to verify 2nd team recording	Brief ECHT at KLC on results.
Afternoon	Reconnaissance survey Cable Beach	Town Beach survey.	Department of Environment and Conservation (DEC) Yawuru Rangers 2:00 pm to 5:30 pm – Gantheaume Point	Afternoon Cable Beach, Gantheaume Pt. (DEC Rangers leave for fire training).	Lockley arrives 1220hrs, picked up by Team 1; Quondong Point with Salisbury, Goolaraboolo (GBL) & JJ. Team 2 Riddell Beach.	Team 1 James Price Point with Salisbury, GBL & JJ – southern pipeline crossing. Team 2 Red Cliffs/ Crab Creek Rd.	Team 1 Gantheaume Point. Team 2 report writing	Team 1 James Price Point with Salisbury, GBL & JJ Team 2 report writing.	Report Writing & Briefing preparation	Brief Yawuru Corporation. Depart evening flight for Perth

Note: Further surveys were planned between 12 and 15 October to coincide with low tides of between 1.14m and 1.69m. This resulted in additional field survey at Town Beach and Cape Leveque undertaken by Richard McCrea and Peter Haines on 12 and 13 October. Access to the Precinct area was also sought at this time but protester blockades prevented this. This access was denied despite negotiation which indicated support for access would be provided under similar conditions to that provided during the previous survey. The survey team subsequently returned to Perth early.

2.5 Indigenous knowledge

The EPA requested that the survey should "include, where possible, incorporation of local indigenous knowledge of dinosaur footprints." This objective was achieved near the Precinct area through the participation on surveys of Dr Steve Salisbury who had knowledge of sites known to Goolarabooloo Traditional Owners.

2.6 Independent Peer Review

The EPA have requested that there be an independent peer review of the survey design with the peer reviewer's comments addressed and incorporated into the design as appropriate prior to the start of the survey. The peer reviewer's comments will be made available directly to the EPA and SEWPaC.

The same peer reviewer will also review two survey reports. One of these will include geo-referencing of features for the EPA and SEWPaC and the other, for public release, will exclude precise location information. It is the job of the peer reviewer to ensure they are identical except for the exclusion of location information. Reviewer's comments on these reports are to be addressed and incorporated as appropriate into the final report.

The peer reviewer is to provide a close out statement to verify whether the final reports have appropriately dealt with the reviewers previous comments. Peer reviewer comments and close out statements will be made publicly available, excluding any precise location information.

Two peer reviews were undertaken. One reviewed both the survey design and the final reports. The other was only able to review the final reports. Copies of their reviews are provided in **Appendix 5**.

3. Results

3.1 Geological overview and palaeo-environment

The southwest coast of the Dampier Peninsula displays four main geological units. The oldest is the Early Cretaceous Broome Sandstone which is overlain unconformably by Quaternary-aged consolidated coastal deposits (calcarenite) and variably consolidated red sandy ("Pindan") soils. The youngest geological unit comprises modern coastal sediments on active beaches, tidal and supratidal flats, and back beach dunes.

Broome Sandstone

Definition: The type section of the Broome Sandstone is the cliff section exposed at Gantheaume Point where it consists of flat-lying red, yellow and white fine to medium grained micaceous sandstone and minor mudstone. The Broome Sandstone disconformably overlies the Late Jurassic marine Jarlemai Siltstone (not exposed in the study area), and is overlain by the shallow to marginal marine Melligo Sandstone in northern parts of the Dampier Peninsula.

Thickness: The Broome Sandstone reaches 280 m in water bores in the Broome area (Gibson, 1983). Only about 12 m is exposed at the type section (at low tide); most coastal outcrops are even thinner.

Distribution: Subsurface studies (petroleum wells, water bores, seismic) indicate that the Broome Sandstone extends from the Cape Leveque area in the north to the southern end of Eighty Mile Beach in the south, and up to approximately 100 km inland from the coast (Gorter et al. 1979). It also extends offshore. Outcrops, however, are restricted to local thin costal exposures, mainly around the Dampier Peninsula and a few local hill or creek bed exposures inland. The distribution map of Gorter et al. (1979) appears to include marine facies believed to be a lateral age-equivalent of the Broome Sandstone but currently mapped separately as Jowlaenga Formation (Tyler et al. 1993); Jowlaenga Formation mainly crops out the northeastern side of Dampier Peninsula.

Age: Early Cretaceous (Valanginian to Barremian) based on limited biostratigraphic data (Nicoll et al. 2008).

Depositional environment: Playford et al. (1975) considered the Broome Sandstone to be a freshwater or possibly paralic deposit. In contrast, Yeates et al. (1974) and Towner and Gibson (1980, 1983) interpreted the Broome Sandstone to be a shallow marine deposit. Towner and Gibson further qualified the environment as “near shore” because of the juxtaposition of non-marine indicators (terrestrial plants and dinosaur tracks) with what were considered marine indicators including the sedimentary structures and invertebrate bioturbation. Marine bivalves have been reported, but these are mainly restricted to the outcrops exposed at or near Cape Leveque; these were originally placed in the “Leveque Sandstone” (Brunnschweiler, 1957) but later included in the Broome Sandstone. Thulborn et al. (1994) considered that dinosaur tracks are found in two different depositional settings within the Broome Sandstone, specifically a lagoonal/tidal paleoenvironment and a terrestrial swamp/forest paleoenvironment.

This study

This study has been restricted to examination of outcropping Broome Sandstone within 7.5 km of Broome (Cable Beach, Gantheaume Point, Riddell Beach, Riddell Point, the port area, Town Beach, Red Cliffs/Crab Creek). No outcrops of Broome Sandstone were observed between Cable Beach and the Quondong point area. The majority of observations indicate an interbedding of flood plain and eolian depositional environments. Significantly, no evidence for marine deposition was seen in the Broome area.

A brief examination of an inferred marine age-equivalent of the Broome Sandstone (Jowlaenga Formation) near One Arm Point showed significant differences in depositional environment compared to the Broome area and confirmed previous reports of marine deposition for this formation.

Evidence for eolian deposition: (**Figures 4 to 7**). High angle cross beds up to 1 m in thickness are common in the upper intertidal zone and along cliff tops between Gantheaume Point and the port area. Foreset dips reach up to 40 degrees with no evidence of post depositional steepening or other deformation. Low amplitude ripples are occasionally present on the steep foresets at oblique angles to the foreset dip. Such features are diagnostic of eolian deposition. Beds of angular sandstone intraclasts associated with this facies are interpreted as deflation lags.

Evidence for flood plain deposition: (**Figures 8 and 9**) Sandstone beds displaying current ripples, climbing current ripples and relatively small to medium scale trough and tabular crossbeds are abundant in the Broome Sandstone. Desiccation cracks are common, occurring as well-developed polygonal structures on a scale of tens of centimetres with ‘V-down’ morphology and infill of sediment from above. These can

be distinguished from smaller and less regular syneresis cracks. Relatively small scale channel deposits are present and often contain a basal lag of sandstone intraclasts and plant fossil remains. Possible paleosol horizons were observed. The observations are consistent with flood plain or delta plain deposition with ephemeral shallow water bodies.

Lack of marine influence: No marine macrofossils were observed; even if conditions were not right for the preservation of actual shell material, moulds of shells would be expected, at least occasionally and this would include lagoonal facies, if such were present. Invertebrate bioturbation, while locally present, is not abundant (hence the excellent preservation of fine sedimentary structures) and no types of bioturbation observed are unique to the marine environment. If marine, abundant invertebrate bioturbation would likely destroy most of the finer bedding features; this is the case for the Jowlaenga Formation (assumed lateral equivalent of the Broome Sandstone) as observed near One Arm Point. The only fossils found in the Broome Sandstone near Broome were terrestrial plants including leaves, sticks and wood (moulds and rarely silicified). Desiccation cracks, which are common in the Broome Sandstone, do not normally occur in marine environments including the intertidal zones as the sediment is never exposed long enough to allow full drying and cracking. These features do form in supratidal zones and in many non-marine environments such as flood plains.

Figure 4 Large-scale high angle (35°) cross beds with oblique low amplitude ripples on the steep foresets, Riddell Beach. These features are typical of eolian (wind) deposition.

Figure 5 Close-up of the outcrop above showing low amplitude ripples in cross section on steep cross bed foresets.

Figure 6 High angle foresets (~40°) typical of eolian deposition, Riddell Beach.

Figure 7 A possible deflation lag concentrating sandstone intraclasts within inferred eolian facies, Riddell Beach.

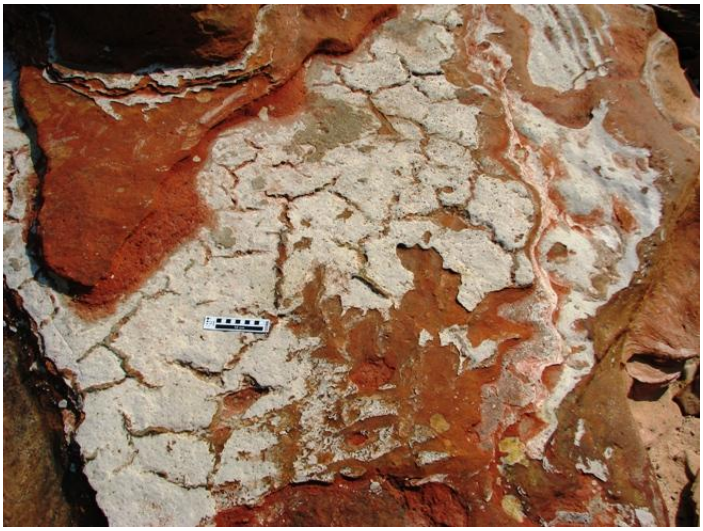

Figure 8 Polygonal desiccation cracks indicative of periodic drying and shrinkage of clays, Riddell Beach. In this case the cracks in a white silty sandstone layer are being filled with coarser red sandstone from the bed above. Syneresis cracks (shrinkage and cracking unrelated to desiccation) are also common in the Broome Sandstone but are smaller and do not form regular polygons.

Figure 9 Terrestrial plant debris including fossil leaves in a channel deposit at Gantheaume Point.

Quaternary consolidated coastal deposits (calcarenite) (Figures 10 to 13)

These deposits include old dune, beach and other coastal deposits composed of mixtures of siliciclastic sand and calcium carbonate grains (including broken shell fragments) cemented with calcium carbonate. The dune deposits are finer grained (fine to medium sand) and display large crossbeds and swales and occasionally low amplitude ripples as observed in active dunes nearby. Invertebrate tracks and burrows may be preserved. Cemented beach deposits are coarser than dune deposits and contain abundant broken shell debris and small pebbles. Such deposits dip seaward at low angles. Weathering of calcarenite in the upper intertidal and supratidal zone can create sharp jagged karstic topography. In the lower intertidal zone the calcarenite commonly forms flat platforms with abundant pot holes.

Figure 10 Consolidated coastal dune deposits near Coconut Well north of Broome. Older deposits of calcarenite are visible in the background.

Figure 11 Calcarenite deposits in the intertidal zone at Coconut Wells. The circular hollows may represent solution pipes, although similar features are sometimes interpreted to mark the positions of former tree trunks.

Figure 12 Calcarenite in the lower intertidal zone showing abundant pot holes, Cape Boileau (mouth of Barred Creek).

Figure 13 Coarse to gravelly calcarenite representing consolidated calcareous beach deposits (foreground) near the boat launching ramp at the port in Broome. The material, which is largely comprised of broken shell debris and small gravel, dips gently seawards as does the modern beach. Outcrops of Broome Sandstone (background and right middle distance) poke through the younger calcarenite deposits.

Quaternary red sandy ("Pindan") soil (Figure 14)

Red sandy soils form prominent low cliffs up to 10 m high along the west coast of Dampier Peninsula and around Roebuck Bay. The informal term "Pindan" is commonly applied to these deposits. This material is at least partly of windblown origin, but includes flood plain and other alluvial sediments. The degree of lithification decreases up through the profile with unconsolidated red sands of the modern land surface at the top.

Figure 14 "Pindan" soils overlying Broome Sandstone at Riddell Beach. Broome Sandstone crops out in the foreground. The lower part of the "Pindan" soil is quite well consolidated in this area and locally may be difficult to distinguish from the Broome Sandstone. It contains ferruginous conglomerate (clasts derived from Broome Sandstone) and layers of limonite (ironstone).

Comments regarding features at James Price Point

Our observations in the James Price Point area, including the Northern point of the Port Precinct, suggest that certain track-bearing localities are unusual. Stated in the most general terms there is considerable evidence that some of the track-bearing surfaces represent inclined or undulating original topography (**Figure 15)**. While it was not possible to analyse the sedimentary facies in detail, enough was observed in the higher parts of the intertidal zone, where outcrops are not too heavily encrusted,

to indicate that a study of the palaeotopography of the sedimentary environment would be fruitful and important to place the track-bearing units in proper geological context. Furthermore, we know of no sand dominated systems that appear to have such suites of tracks associated with pronounced palaeotopography of the type observed. Support for this conclusion, i.e., that the sedimentary facies is unusual and on need of further study, comes from some of the observations made at Broome Sandstone outcrops in the south of the region around Riddell Beach (see above). Here eolian deposits have been reported and confirmed unequivocally, at least locally, within a section that also contains fluvial deposits. These observations not only add to the existing interpretations of Thulborn *et al* (1994), which identify "Swamp/Forest" and “Lagoonal" deposits, but they also point to hitherto undocumented aspects of the paleoenvironment that potentially have considerable palaeobiological implications.

Well-known track-bearing deposits associated with Mesozoic eolian facies almost exclusively contain an entirely different suite of tracks (of small mammals, protomammals, arachnids etc.), and it is intriguing to consider the possibility that such tracks might potentially be found in this facies in the Broome area. Even without such discoveries the juxtaposition of sauropod tracks and other diverse, large dinosaur footprints in sand dominated fluvial systems close in space and time to eolian deposits raises hitherto unanswered questions about dinosaur habitats and palaeoecology in the region.

Figure 15 Palaeontologist, Steve Salisbury, points to one of several light coloured horizontal footprint features associated with an inclined surface that indicates a sloping and irregular original topography.

3.2 Dinosaur palaeontology

Summary of Results

Note on terminology: In order to evaluate the local, regional and international significance of tracks in the 'Broome area,' and at individually surveyed localities within this proposed development area it is necessary to have unequivocal designations for individual survey points, track sites, general geographic locations, regions etc., (see **Table 3**).

Table 3 Terminology use for tracks, track sites, general locations etc., arranged in order of increasing geographical extent.

Individual tracks within track sites (see photos, selected diagrams and selected GPS locations) **Track sites** (with letter prefix and number suffix designations see list in Results and appendices) **General locations** within Broome area (given geographical names: see **Table 4**) **Local context** refers to known track-bearing outcrops in the Broome area (see Discussion) **Regional context** refers to record in Western Australia/Australia: see Discussion) **International context** (see Discussion)

As shown in **Table 4** the entire 'Broome area' was divided into 15 general locations. Within each of these, individual track sites, with site designations and GPS locations, were defined. Thus the following terminology is used (with reference to the appropriate text section in brackets):

Table 4 Broome sandstone area summary of Dinosaur tracksites surveyed

(Note: Sites in bold are those listed as potential impact areas)

Locality name	Number of Tracksite localities	Broome Sandstone Yes/no	THEROPOD TRACKS (TP)	SAUROPOD TRACKS (S)	ORNITHOPOD TRACKS (O)	THYREOPHORA TRACKS (TH)
North Pipeline	0	Yes				
James Price Point	7	Yes	TP	S	O	TH
Port Area	9	Yes	TP	S	O	TH
South Pipeline	4	Yes	TP	S		
Quondong Point	3	Yes	TP	S		TH
Barred Creek	0	No				
Willie Creek	0	No				
Coconut	0	No				

Well						
Cable Beach	8	Yes	TP	S		TH
Gantheaume Beach	3	Yes	TP	S		
Gantheaume Point	4	Yes	TP	S	O	
Riddell Beach	4	Yes	TP	S		
Port Beach	4	Yes	TP	S		
Town Beach	7	Yes	TP	S		
Red Cliffs	5	Yes	TP	S		
Tracksite total	58					
% Broome Sst sites with tracks	11/12 = 92%		11/12 = 92%	11/12 = 92%	3/12 =25%	4/12 =33%

As noted above (**Table 4**) the survey covered 15 general locations between the North Pipeline area and the southern end of the Broome peninsula (**Figure 16 and Figure 17**). These areas differ in topography and coastal geomorphology, and can be broadly divided into rocky headlands, and sandy beaches. The former tend to have more track-bearing exposures (track sites) at all levels within the intertidal and even low supra-tidal zones, whereas the latter have fewer, and in some cases no, identifiable track-bearing exposures (track sites).

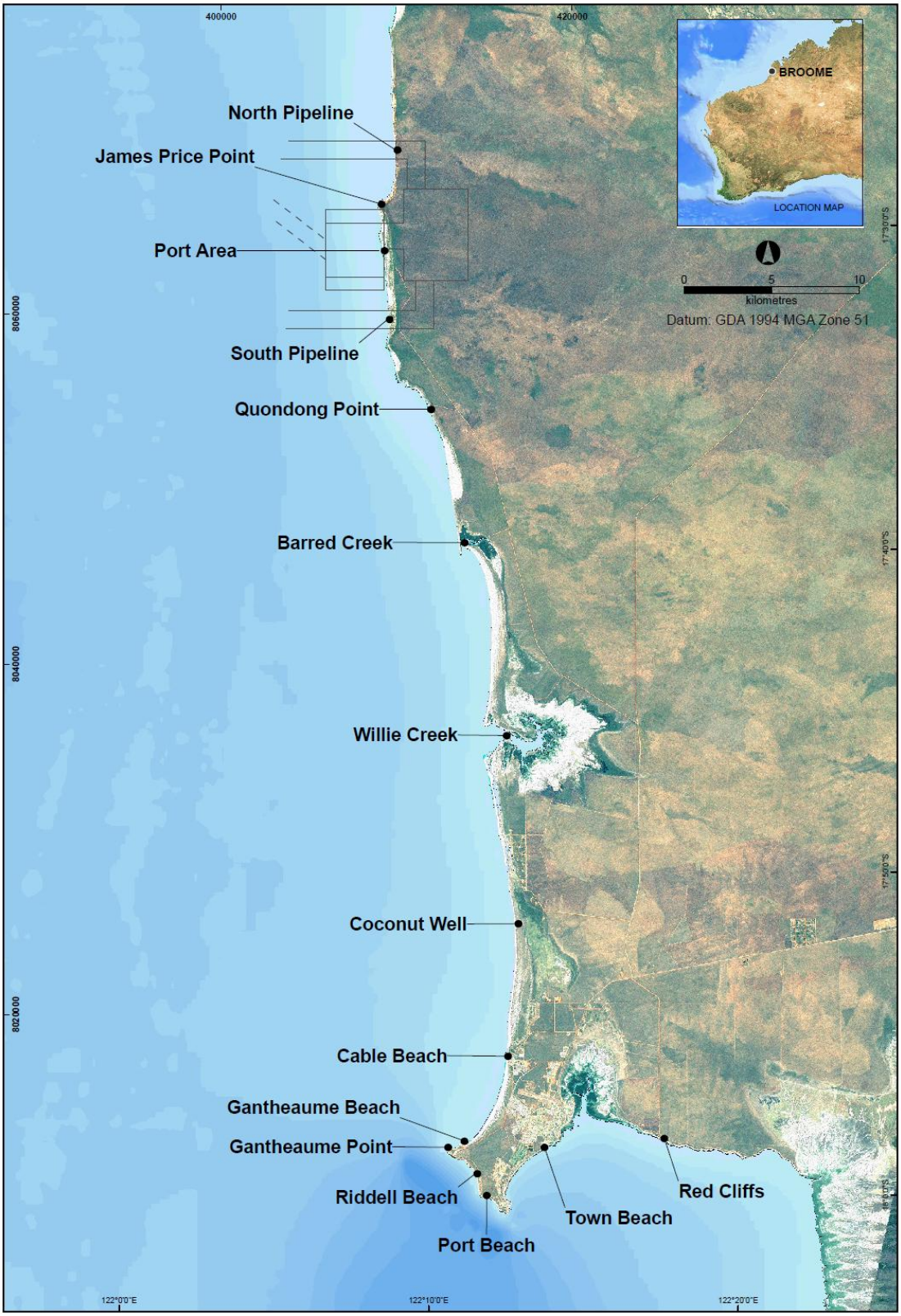

Figure 16 Locality of areas surveyed

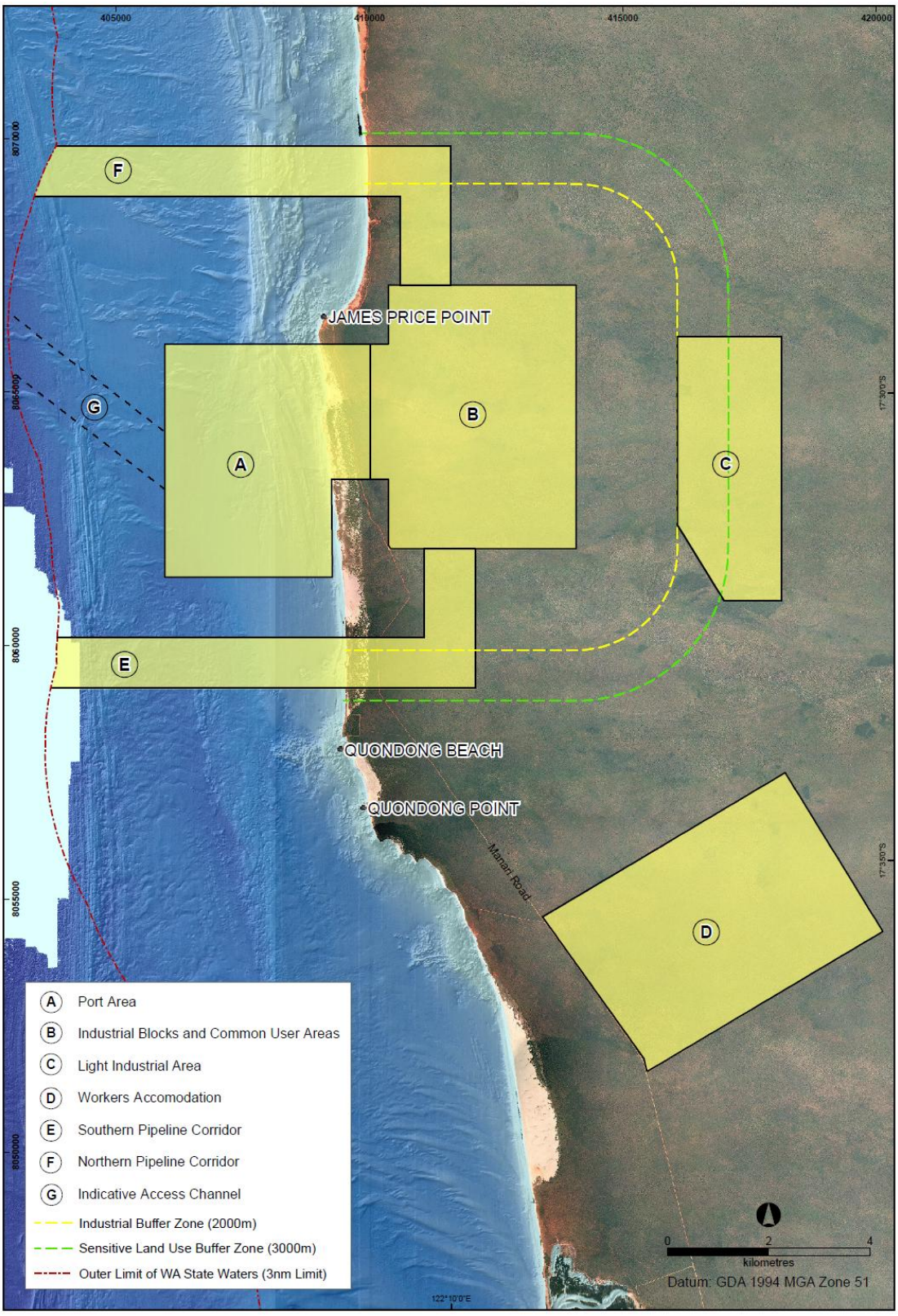

Figure 17 Map of potential direct impact areas correspond with shore crossing areas of “A”, “E” and “F”.

Broome Sandstone outcrops were located at 12 of these general geographic locations (**Table 4**). Given that there is no evidence of any Mesozoic outcrops at the

three locations that lack Broome Sandstone outcrops (see Geology section) they need not be considered further as a potential source of dinosaur tracks. However, at 10 of the 12 remaining Broome Sandstone locations dinosaur track sites were identified. As indicated in **Table 4**, the two locations without unequivocally identified dinosaur tracks correspond to the North and South pipeline corridors. [There is one possible trample site within the South Pipeline Corridor and a few more just to the south of this area where there is a potential for direct impact but these are not unequivocally identified tracks]. Of the 10 remaining locations that yield tracks, only the Port Precinct area is currently designated as a zone of direct impact. However, the area between the Port Precinct and the northern Pipeline Corridor, i.e., a significant part of James Price Point, as well as Quondong Point, represent locations where multiple track sites are known.

In order to compare what has been found in the direct impact area of the Port Precinct, the nearby areas of James Price and Quondong Points, and the more distant areas to the south we have distilled the data summarized in **Table 4** to show what was identified from the five northern locations (between the northern pipeline corridor and Quondong Point) and the ten southern locations south of Quondong point (**Table 5**).

Table 5 Distribution of track sites and track types between the northern direct and indirect impact areas and the southern areas.

Locality group	Number of Track site localities	Broome Sandstone Yes/no	THEROPOD TRACKS (TP)	SAUROPOD TRACKS (S)	ORNITHOPOD TRACKS (O)	THYREOPHORA TRACKS (TH)
5 sites N from Quondong Pt	23	Yes	TP	S	O	TH
10 sites S of Quondong Pt	35	Yes	TP	S	O	TH

A significant result of the summary presented in **Table 5** is that 23 of the sites identified during the survey occur in the northern area. It is also significant that all major track types are represented in this area.

In order to assess the diversity of tracks found at any one of the 12 locations identified during the survey, it is helpful to have an overview of the track types found in the area as a whole. Related to this contextual approach it is also helpful to be able to compare stratigraphic sections between different sites, because as is the general rule, track occurrences are very often tied to the local stratigraphy. These considerations are important for several reasons. First, an overview helps give us a larger sample, so that we can better understand the diversity of track types and the range of modes of preservation. This in turn may allow a degree of predictability as to what might be found at any given site. Second, where tracks at a given site are incomplete, eroded or otherwise show sub-optimal preservation our ability to identify them is improved by familiarity with the ichnology of the region as a whole: e.g., it may be possible to identify tracks showing inferior preservation that otherwise might be missed. Third, at any given site, especially ones where more survey time would be desirable it is possible to anticipate and locate track occurrences based on stratigraphic continuity with other adjacent sites.

Based on these considerations and the tables presented above it is possible to draw the following conclusions about the occurrence of tracks in the area as a whole as well as in the northern division and the direct impact area.

Track Preservation: Dinosaur tracks and trackways observed in the field during the course of this survey were found to be preserved as natural moulds though some natural casts were observed as well. In spite of previous reports of Broome Sandstone tracks being mainly preserved as "undertracks" we found that the vast majority of tracks were preserved on the original track surface, though at some sites these original surfaces were often the worse for wear from natural erosion. It is possible that some previous reports of "undertracks" were in fact the top surfaces of sediments infilling original natural moulds (i.e. where natural casts had not yet been dislodged from the natural moulds). The true nature of such tracks is made apparent when they are found in vertical cross-section **(Figure 18).**

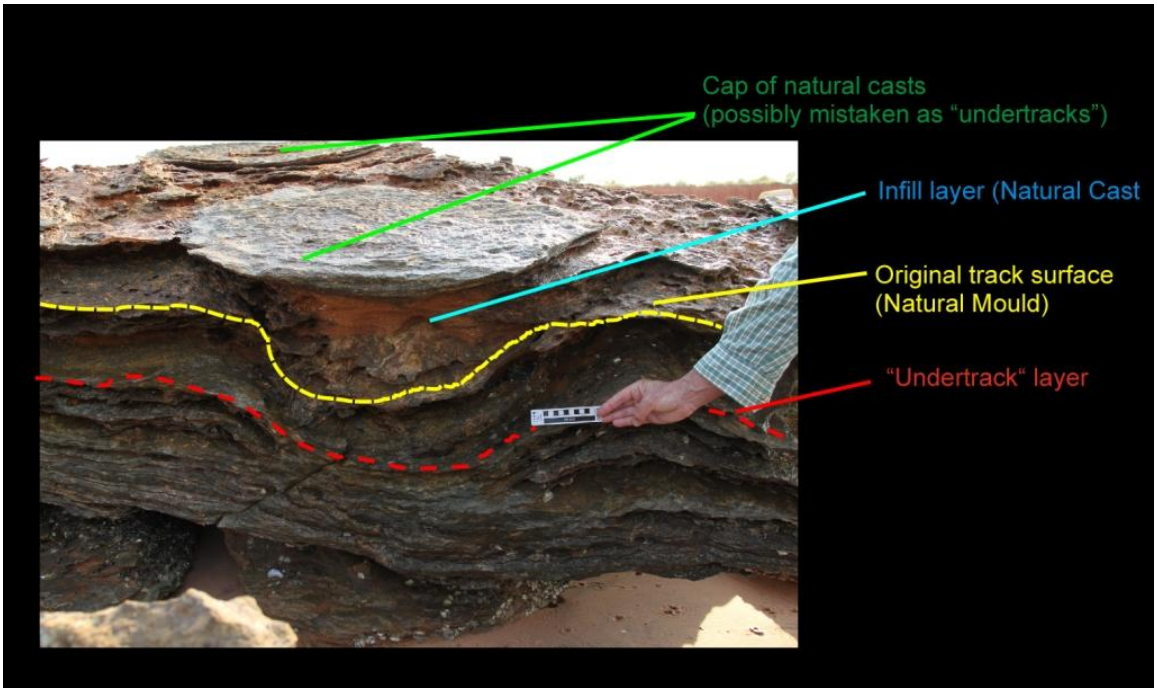

Figure 18 Vertical cross-section of sauropod track at Red Cliffs

In the area as a whole we have well-preserved and less-well-preserved examples of four major groups of dinosaurs: the theropods, sauropods, ankylosaurs and ornithopods. The former two groups (theropods and sauropods) represent the saurischian clade, which is abundantly represented (at ~83% of localities) and the latter two (ankylosaurs and ornithopods) represent the ornithischian clade represented at ~25 and ~33% respectively of localities surveyed. This result is in itself significant for there are not many Cretaceous track site areas where these four groups are represented by tracks, or by body fossils. This observed association of sauropod, ornithopod and ankylosaur tracks is unique on a global scale making the Broome Sandstone ichnofauna globally significant.

For the whole area, we may summarize the survey data for each group as follows:

Theropod tracks with recognizable to good preservation are found at most sites examined during the survey of track sites at locations in the Broome area. They range in size (foot length) from ~20 to ~50 cm (**Figures 19 to 24**[1]), with the scientifically named and locally famous *Megalosauropus broomensis* (Colbert and Merrilees, 1967) falling in the middle of this size range. All tracks represent functionally tridactyl (three-toed) bipeds. Some tracks form recognizable and measurable trackway segments. Our preliminary studies suggest that there are at least two and possibly three additional morphotypes. See Discussion for further information.

[1] Note regarding the following images: In many instances two types of the same track image is provided. The left image is a standard two dimensional format. The right image is three dimensional anaglyph viewable with simple 3d glasses (red left eye, blue right eye) found in many children's 3d books.

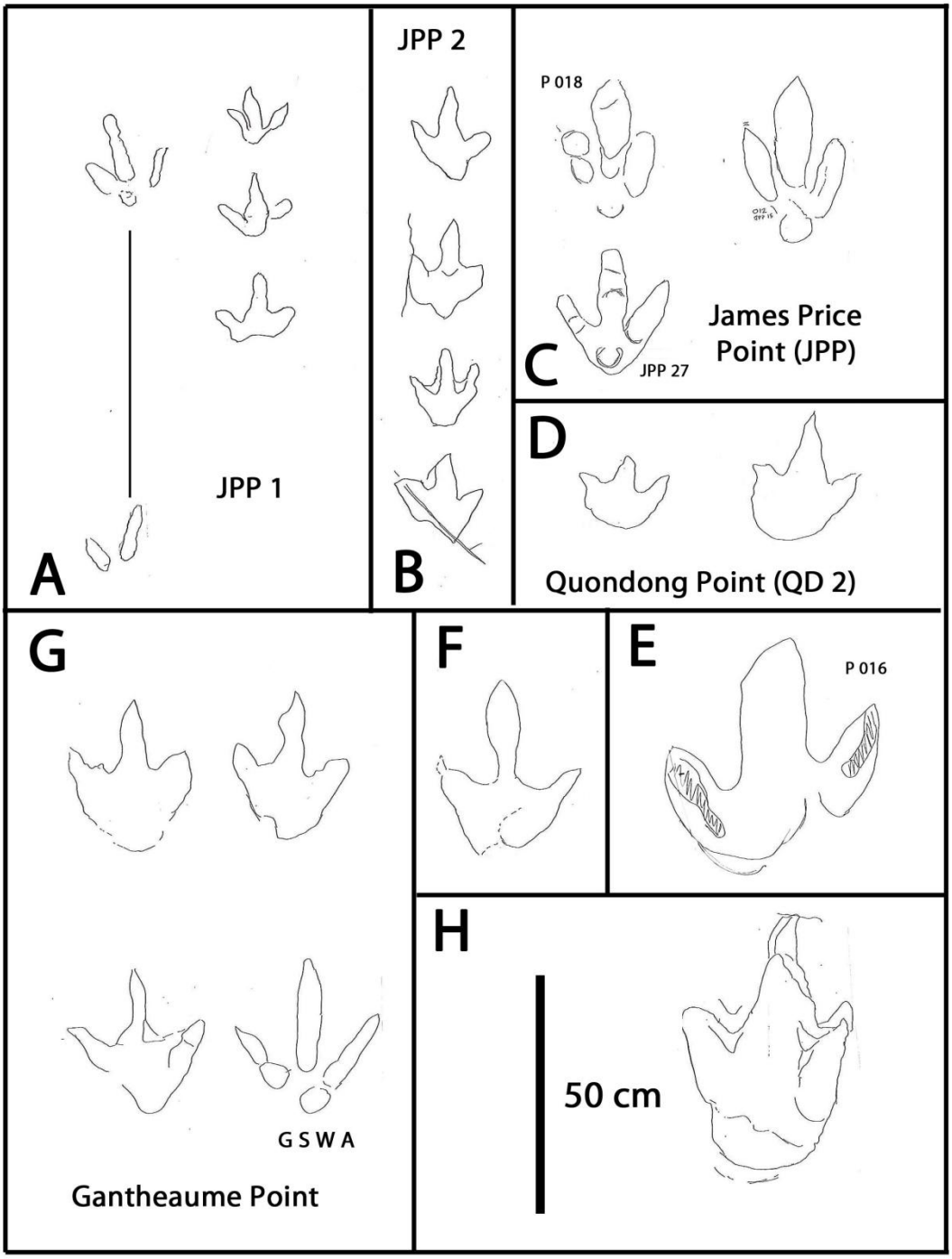

Figure 19. Theropod tracks from the Broome area. A- E. Tracks from the James Price Point and Quondong Point areas, all drawn from original tracings at the same scale. Note that the smaller tracks (frames A and B) are smaller (footprint length ~20 cm) than any previously reported from the area. Likewise, the largest specimen E, as well as H from the Riddell Beach area, are larger (footprint length ~50 cm) than any previously reported. Tracks F-H are all from the southern area and include medium sized (footprint length ~30-35cm) tracks from the *Megalosauropus broomensis* type locality. GSWA refers to a replica of *M. broomensis* held on the Geological survey of Western Australia collections. Compare with **Figure 21**.

Figure 20. *Megalosauropus broomensis* type specimen from Gantheaume Point.

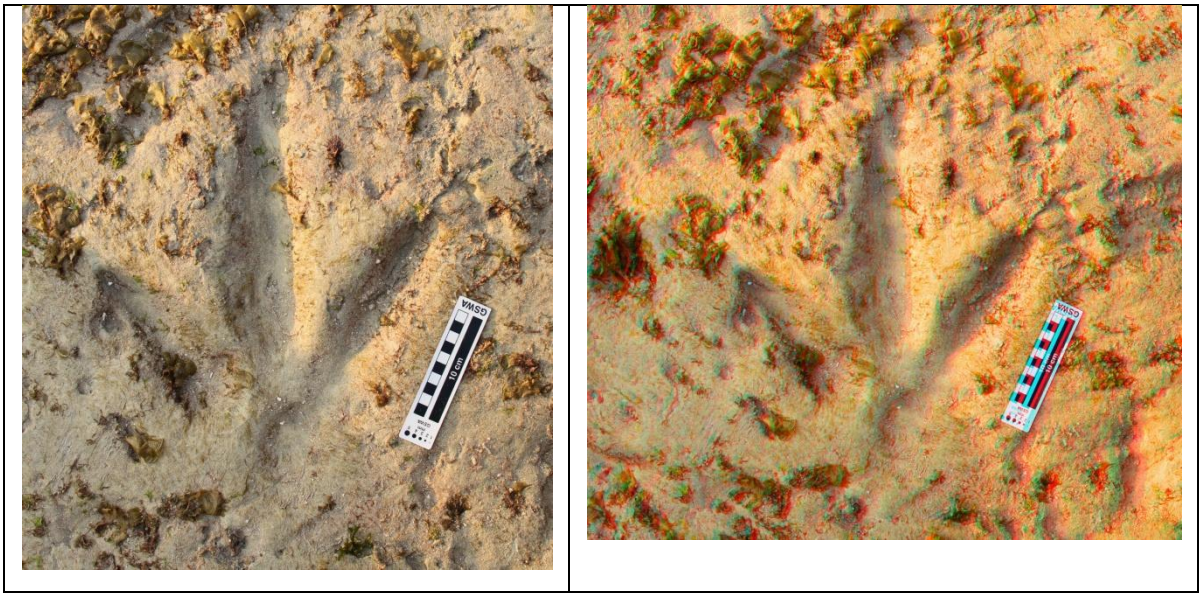

Figure 21 Medium theropod track *Megalosauropus broomensis* from Gantheaume Point (left 2d, right 3d)

Figure 22 Medium theropod track *Megalosauropus broomensis* from Gantheaume Point (left 2d, right 3d**)**

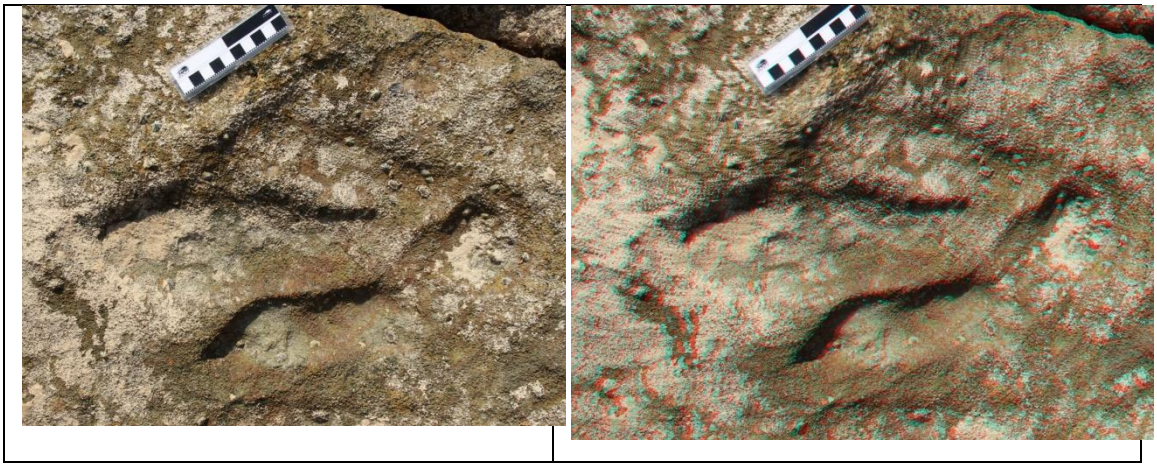

Figure 23 Medium theropod track, ichnosp. indet. (left 2d, right 3d)

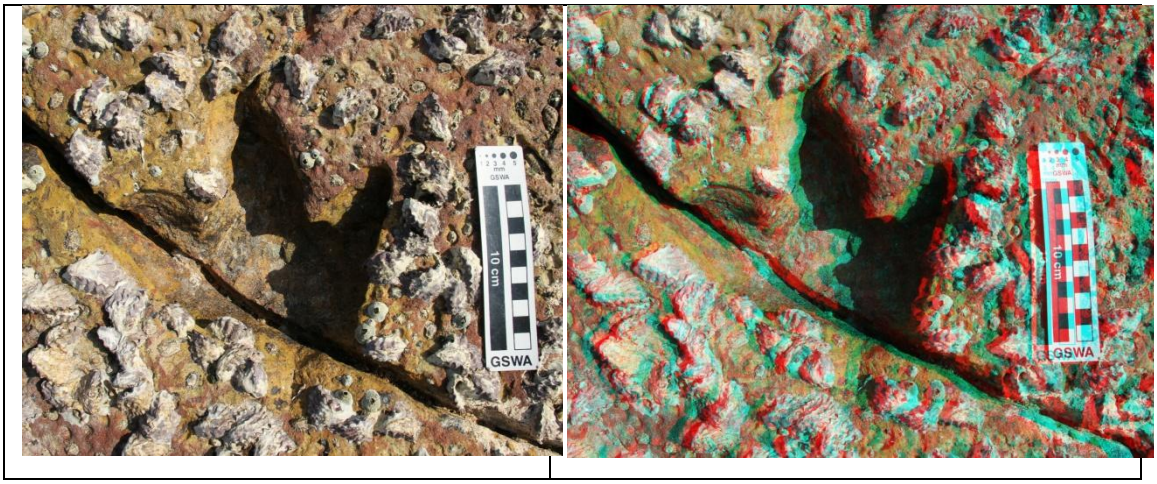

Figure 24 Small theropod track, cf. *Irenichnites* (left 2d, right 3d)

Sauropod tracks are extremely abundant at most sites examined during the survey of track sites at locations in the Broome area. As with the theropod tracks preservation ranges from recognizable to good. Some tracks form recognizable and measurable trackway segments, which allow differentiation of manus and pes (front and hind) footprints (**Figures 25 to 27**), and determination of straddle patterns (trackway width). Some pes tracks show impressions of the larger claws representing digits I and II. Some areas are heavily trampled, attesting to the abundance and/or repeat activity of the track-makers. See Discussion for further information.

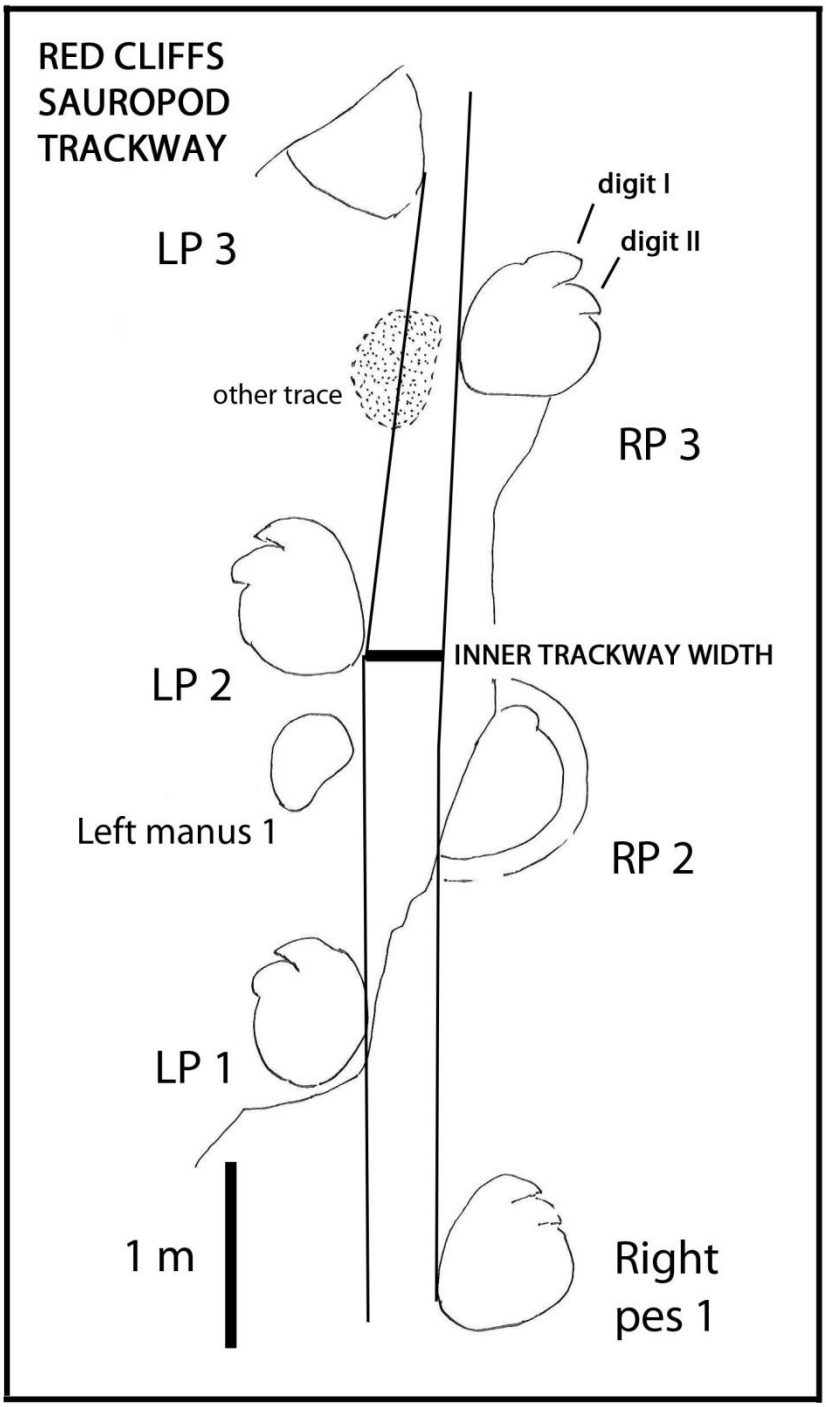

Figure 25 A sauropod trackway from Red Cliffs area. This scale map is the first to illustrate a single, unequivocal sauropod trackway from the Broome area. The trackway is wide gauge with clear traces of pes digits I and II. Only one clear manus trace was observed.

Figure 26a Sauropod trackway from Red Cliffs area - 2d image.

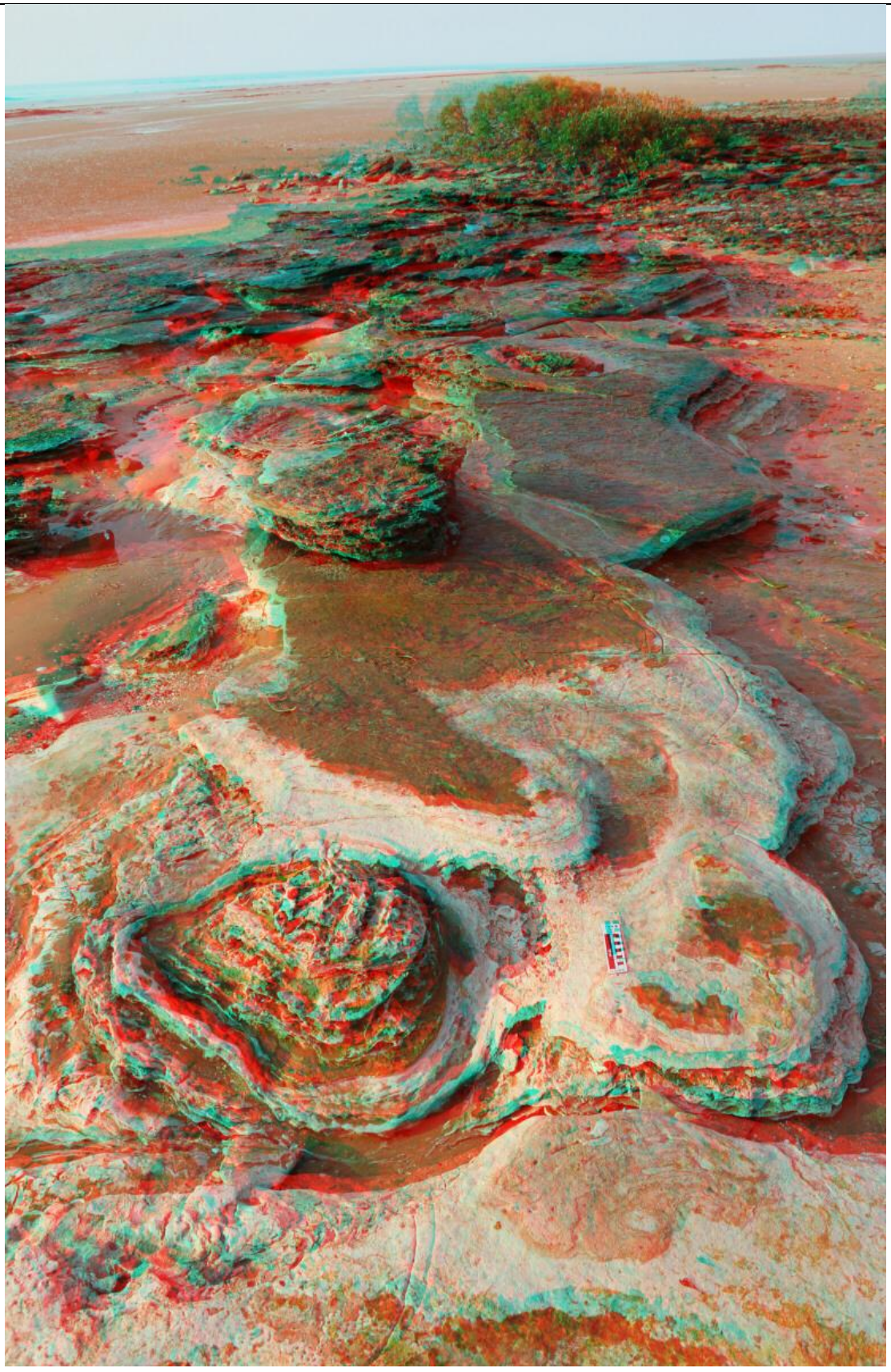

Figure 26b Sauropod trackway from Red Cliffs area - 3d image.

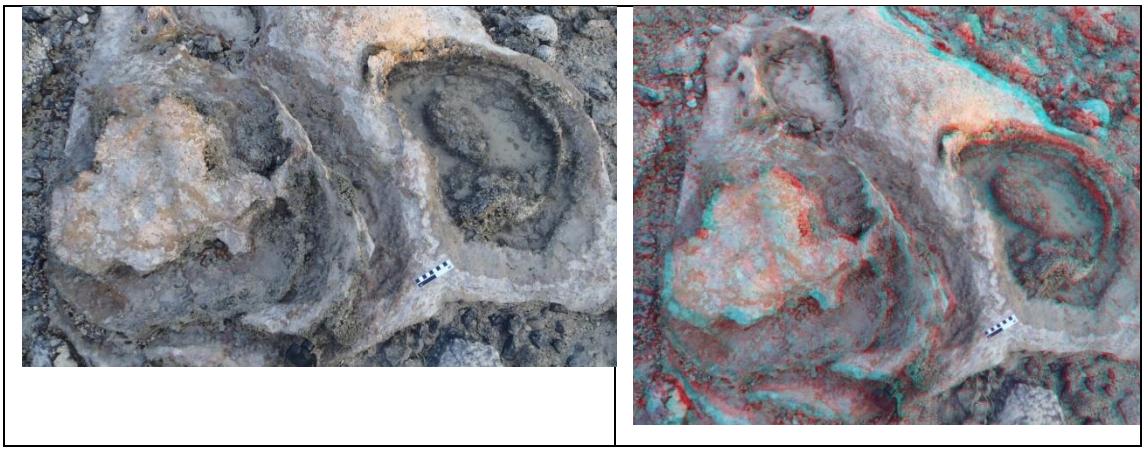

Figure 27 Sauropod manus and pes from Broome area (left 2d, right 3d)

Thyreophoran tracks occur sporadically at several sites examined during the survey of track-sites at locations in the Broome area. The tracks indicate a quadrupedal track-maker with a four toed pes (hind foot) and a five toed manus (front foot): **Figure 28 - A and B**. This combination suggests an ankylosaurian trackmaker, and in turn raises questions about the reports that some of the tracks may have been made by a stegosaur (see discussion). The best preserved hind footprint is illustrated in **Figure 29.**

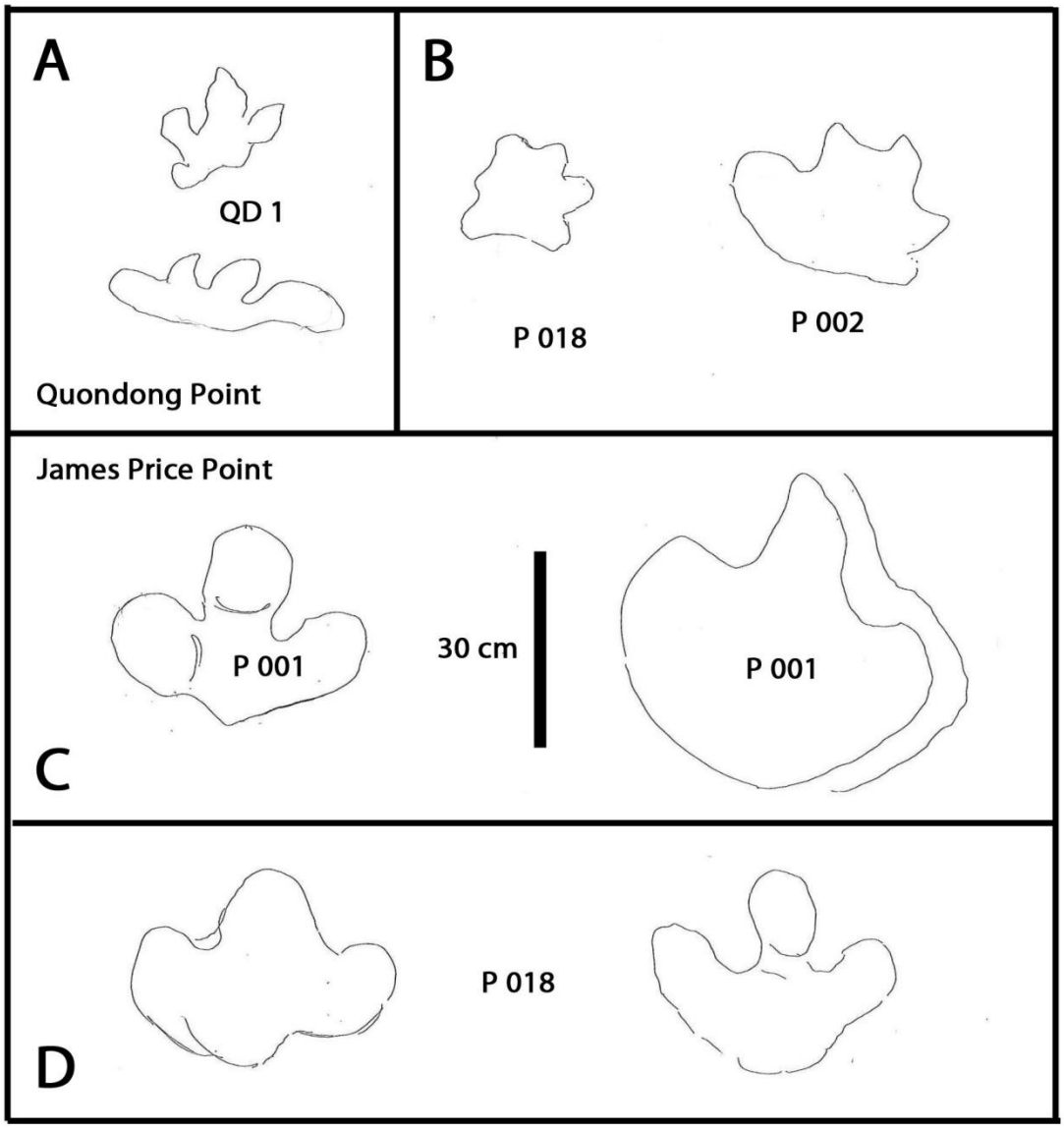

Figure 28. Ornithischian tracks from the Broome area. A-B five toed tracks probably the front footprints of thyreophorans. C and D ornithopod hind footprints. All drawn from original tracings to the same scale.

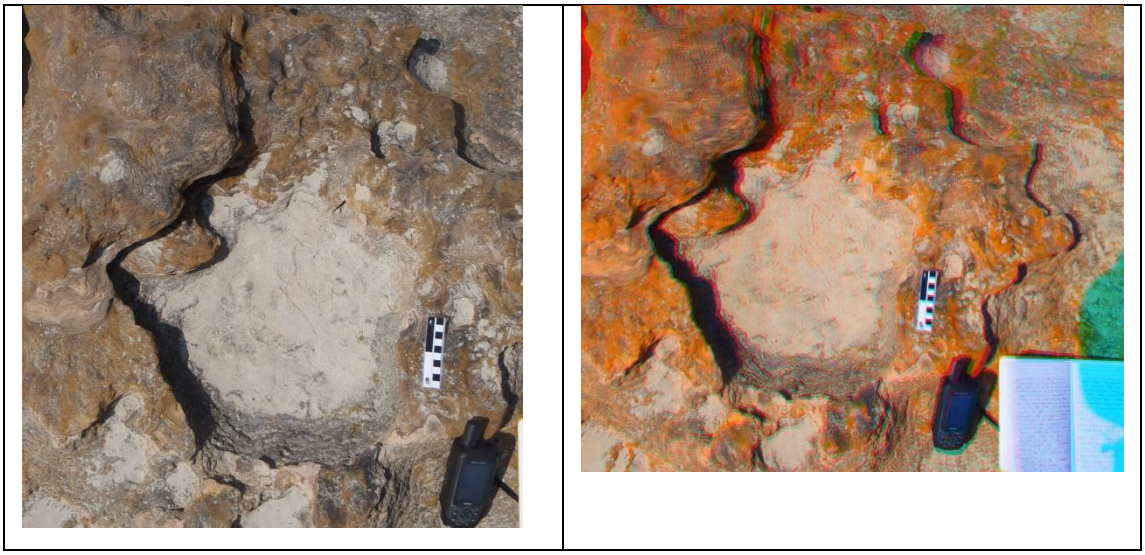

Figure 29 Ankylosaur left pes track cf. *Tetrapodosaurus borealis* (left 2d, right 3d)

Ornithopod tracks occur sporadically at several sites examined during the survey of track sites at locations in the Broome area. Based on size ranges it is inferred that two different track-maker types may be represented. The tracks indicate a blunt toed biped (**Figure 28 - C and D** and **Figure 30**)

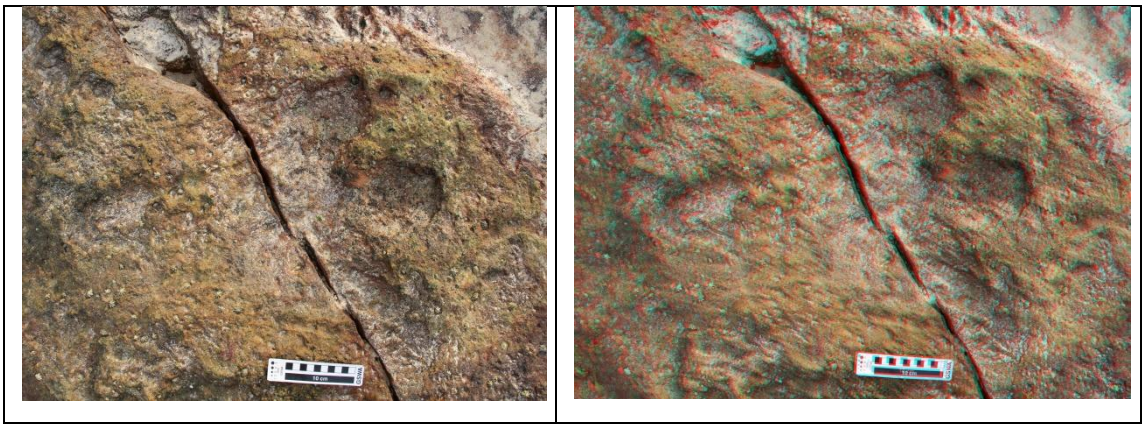

Figure 30 Ornithopod pes (left 2d, right 3d)

All four of the major groups of tracks outlined above (**Figures 19 to 30**) are represented in the Port area (P) where there is the potential for direct impact, as well as in the James Price Point (JPP) and Quondong Point (QP). While some of the sauropod, ornithopod and thyreophoran and ornithopod tracks from these three areas may be equally well- or better-represented in other areas, some of the theropod tracks from the JPP area were among the best exposed and represented the most complete trackway sequences observed during the survey. In addition the relationship between the track-bearing layers and the palaeo-topography in the northern part of the Port area, as discussed in Section 3.1 are of particular interest and worthy of further detailed study.

Individual findings at survey locations

The objective of this survey was to confirm suspected potential for fossil tracks and track sites within the boundaries of the proposed LNG Hub as well as to make comparisons with track sites outside of these boundaries. It is not necessary, and it is not possible for such a survey to locate and document every track or every track site within the survey area. The investigators while confident that their findings reflect something close to the true potential of track occurrences within the survey area acknowledge that they likely did not see every track that was exposed during the time this survey took place and that much remains to be discovered during the course of future research. It is our opinion based on the data we have collected that future finds will likely be made within the general areas we indicate as having such potential.

We further acknowledge that our findings were based on the conditions of the Broome Sandstone exposures that were present during the time of this survey. We have observed track sites that for example were visible during an initial visit to Cable Beach. During a follow-up visit a few days later it was found that a couple of track sites had been covered by sediment deposited during recent tidal cycles. If relatively small-scale tidal cycles can cover and uncover track sites within such a short time frame (Confidential Submission, 2010: 15) then larger storm and cyclone events may be capable of covering or uncovering track sites to a much greater extent. There could be no chance in the time-frame of this survey to observe tracks or track sites (if they exist at all) that may be buried by sand as the result of past storms or cyclones.

Cable Beach

(September 25 - 26 & 28 - 29, 2011)

This locality has large surfaces of in situ shelving sandstone which are exposed only at times of the lowest tides. Examination of these surfaces did not reveal any dinosaur tracks during the period of this study. However, there is a concentration of small irregular outcrops of Broome Sandstone higher up on the beach including some dislodged boulders and slabs of the same which possessed several individual tracks (CAB001-009). All tracks were preserved as natural moulds and there were no discernable trackways. The potential for further finds at this locality is likely limited unless a cyclone event or similar storm exposes new bedding planes.

CAB001: Eroded footprints with displacement rims. Medium-sized with no easily discernable morphology.

CAB002: At least one small print with infill on a large slab.

CAB003: Deep pes with possible manus partially infilled. Ankylosaur.

CAB004: Single tetradactyl print, well-preserved and clear morphology.
Ankylosaur pes.

CAB005: Partial theropod print of medium-size with digital pads evident.

CAB006: Relatively large, wide-gauged trackway of an invertebrate. The walking trace of a crab across a rippled and lithified recent sand dune.

CAB007: Small tetradactyl pes (small ankylosaur).

CAB008: Small tridactyl print. Small theropod.

CAB009: Partial track of a small theropod.

Town Beach
(September 26 & October 12, 2011)

The Town Beach locality has an extensively exposed intertidal area with small outcrops of in situ Broome Sandstone sediments which are covered with mud, broken coral, rocks and macrofauna. All tracks discovered were natural moulds, often with considerable infill (natural casts) still adhering. The majority of tracks found were those of sauropods (single prints, a single manus/pes set and at least one partial trackway), but one theropod track was found as well. The mud and macrofauna covering the in situ track-bearing sediments could very well be covering smaller track features.

TOWN001: Tridactyl print partially covered with infill.

TOWN002: Two trackway sequences of large circular tracks (5 tracks in one, 4 in the other). Probable sauropod.

TOWN003: Infilled partial print with displacement rim.

TOWN004: Large circular depression with a smaller depression in front of it.

TOWN005: A large, circular depression. Sauropod track.

TOWN006: Large elongate depression with a smaller horse-shoe shaped depression in front of it. Sauropod pes and manus (left).

TOWN007: Sauropod print.

Gantheaume Point/Beach
(September 27 - 28, 2011)

Gantheaume Point has quite a large outcrop exposure of Broome Sandstone which forms high cliff walls at the point itself as well as large in situ surface exposures seaward. There are massive blocks of dislocated Broome Sandstone in the area around the cliffs, but their occurrence decreases as one moves away from the cliff region.

The Gantheaume Point localities contain among the best record of large and medium theropods found to date in the Broome Sandstone and include the locality of the holotype of *Megalosauripus broomensis* (Colbert and Merrilees, 1967). Many of the theropod tracks noted in this survey were covered with encrusting macrofauna common in intertidal areas, though a few were not.

There is one occurrence of large ornithopod tracks with one trackway of three prints which is found near the top of the cliff. Several sauropod tracks and a few sauropod trackways were discovered to the north of the point toward Cable Beach. All prints found were natural moulds, however many tracks, especially the sauropods, still possessed considerable infill (natural cast material).

Gantheaume Point is one of the rare sites where plant fossils were found. The plant fossils were relatively abundant where found and seemed to have a modest diversity. Some gingko-like leaves were found and there were a few varieties of fern-like foliage. At this time we aware of few publications of the palaeoflora from the Broome Sandstone (White, 1959 and McLoughlin, 1996).

GAN001: Large tridactyl tracks (ornithopod). Three prints in one trackway and one print alone.

GAN002: Plant fronds. Possibly fern.

GAN003: Pseudo-track.

GAN004: Two deep tridactyl tracks ~30cm in length. Theropod.

GAN005: Large and medium theropod tracks.

GAN006: Theropod tracks (probable site described by Colbert & Merrilees, 1967).

GAN007: Two sauropod trackways.

GAN008: Two infilled sauropod tracks in sequence.

GAN009: Sauropod track with some digit impressions evident, but middle of print infilled.

Redcliffs/Crab Creek Road

(September 28 & October 3, 2011)

The Redcliffs/Crab Creek Road site is a long stretch of beach with considerable outcrop, mainly in the form of low-relief in situ bedding planes in the intertidal region. The surfaces of the bedding planes have fewer encrusting macrofauna in comparison to others.
The in situ tracks are preserved as natural moulds. The large majority of tracks found were those made by sauropods and many of the tracks found were in lengthy trackway sequences. One medium-sized theropod track was found.

REDC001: Long sauropod trackway (~14 manus/pes sets – little distinction between manus/pes). 2.7m pace, 2.9m stride, pes 80cm length.

REDC002: Intersection of two sauropod trackways with infill (originals underneath). At least 9 manus/pes sets in one trackway.

REDC003: Sauropod print in cross-section.

REDC004: Single theropod print.

REDC005: Sauropod trackway.

Riddell Beach/Port Beach
(September 28 & October 3, 2011)

The Riddell Beach site is a long, sandy beach with in situ Broome Sandstone as well as large blocks of dislocated Broome Sandstone scattered over the beach or in small to large piles. The majority of tracks and trackways found were those attributable to sauropods although tracks and trackways of theropods were present as well. Most of the tracks are natural moulds, but some isolated natural cast blocks were found here as well.

RID001: Sauropod trackway.

RID002: Sauropod track area. A lot of tracks within a 4-5m2 area.

RID003: Partial tridactyl print (theropod?).

RID004: Single small theropod print.

RID005: Sauropod tracks with some in cross-section.

RID006: Sauropod trample site.

RID007: Large theropod trackway.

RID008: Isolated block with a natural cast of a large theropod track.

Quondong Point
(September 29, 2011)

Low relief outcrop of the Broome Sandstone occurs seaward of the beach sand. There are stretches of exposed bedding plane surfaces close to the beach, but further seaward these surfaces become littered with loose rocks. There are at least three in situ surfaces that have been trampled by sauropods. Tracks of theropods, ornithopods and thyreophorans have been identified at a two of these trampled surfaces.

QUON001/QDIII: Sauropod trample surface with some trackways evident.

QUON002/QDII: Sauropod and theropod tracks on a surface covered with fossil plants (fronds).

QUON003/QDI: Sauropod trample site with a big tridactyl track (*Amblydactylus*?) and some thyreophoran manual prints.

James Price Point

The James Price Point area for the purpose of this report includes areas within direct impact zones (Port Precinct and the pipeline corridors) and areas outside of these impact zones.

North Pipeline Corridor
(September 30, 2011)

The only outcrop in this area was exposed in vertical section on the west-facing cliffs. The facies preserved in this area did not appear suitable for preservation of tracks and may be composed of sediments deposited in deeper water environments as evidenced by the high amplitude, gently rounded ripple crests and the laterally persistent and uniform bedding planes composed of clean and well-sorted sediment (medium-coarse sst).

South Pipeline Corridor

(September 30, 2011)

Only SPIPE001 is within the South Pipeline Corridor, SPIPE002-004 are south of the southern boundary of this corridor.

SPIPE001: Possible trample area.

SPIPE002/MBI: Possible tridactyl pes (& manus?) (ornithischian).

SPIPE003/MBII: Possible tridactyl track.

SPIPE004/MBIII: Possible sauropod tracks in section.

Port Precinct (Including James Price Point)

(October 1-2, 2011)

North to south the Port Precinct area extends for 2.66km. The site was visited on two separate mornings with the most favourable low tides in the company of Steve Salisbury. We found track sites were present within a zone within 750m of the northern boundary of the Port Precinct area. We were not shown and did not find any dinosaur track sites in the southern 2km of the Port Precinct area. Out of sixteen track sites we documented (not including two others that were rejected in the field as 'pseudo-tracks') nine sites were documented within the boundary of the planned Port Precinct area while the other seven track sites are located north of this boundary. This general area exhibits a relatively high diversity of vertebrate ichnotaxa (theropod, sauropod, ornithopod and thyreophoran) as well as some of the more impressive and scientifically significant larger-scale track surfaces.

PORT001/JPPXVIII: Large track surface with medium-sized ornithopod tracks (series of four pes prints), several other ornithopod prints, and sauropod and theropod too.

PORT002/JPPXX: Tetradactyl pes. Probable ankylosaur pes print.

PORT003: Sauropod trample surface, strike continuation of PORT001

PORT004/JPPXXXI: Sauropod trample site, same as PORT001 & PORT003.

PORT005: Sauropod trackway.

PORT006: Pseudo-print & ornithopod pes.

PORT007: Sauropod tracks.

PORT008/JPPXXXV: Pseudo-tracks

PORT009: Pseudo-tracks

PORT010/JPPXXIV: Trample site.

PORT011: Ornithopod trackway with 3-4 prints and two other prints in area.

PORT012/JPPXV: Theropod track with metatarsal pad and terminal swelling in middle digit.

PORT013/JPPII: Large, oyster-encrusted surface with numerous small theropod trackways.

PORT014/JPPI: Oyster-encrusted surface with small theropod tracks and trackways. Likely a continuation of the same surface as PORT013/JPPII.

PORT015/JPPVII: Sauropod trample site.

PORT016/JPPXII: Large theropod print.

PORT017/JPPXXVII: Medium-sized theropod print

PORT018/JPPIV: Sauropod, ornithopod and theropod tracks and perhaps a thyreophoran manus.

Zones of Direct Impact (North and South Pipeline Corridors and Port Precinct Area)

Based on the site data collected during the course of this survey we are able to make some judgements regarding the degree of palaeontological sensitivity within the areas of proposed direct impact.

We view the area within the present defined boundaries of the Northern Pipeline Corridor to have very low palaeontological sensitivity as no sites were found and though Broome Sandstone outcrop was present in vertical section of the cliffs these sediments did not appear to represent environments that were suitable for potential track-makers.

We also view the area defined by the present boundaries of the South Pipeline Corridor overall to have low palaeontological sensitivity. There was one possible dinosaur trample site near the southern edge of this area and any planned development should take this into account to mitigate any potential for adverse impact.

The northern 750m section of the Port Precinct impact area has been shown to contain a significant number of track sites and the ichnofauna is diverse (theropods, sauropods, ornithopods and thyreophorans). This study did not find any tracks in the southern section of the Port Precinct impact area, but observations based on an aerial map **(Figure 31)** indicates that there is a continuation of potential track-bearing outcrop another 150m to the south. We agree that it is advisable to consider the northern 900m within the Port Precinct impact area to be considered to have high potential for fossil track resources. Any plans for industrial development in the Port Precinct area should include achievable mitigation strategies to avoid any negative impact to the fossil resources within the northern 900m area.

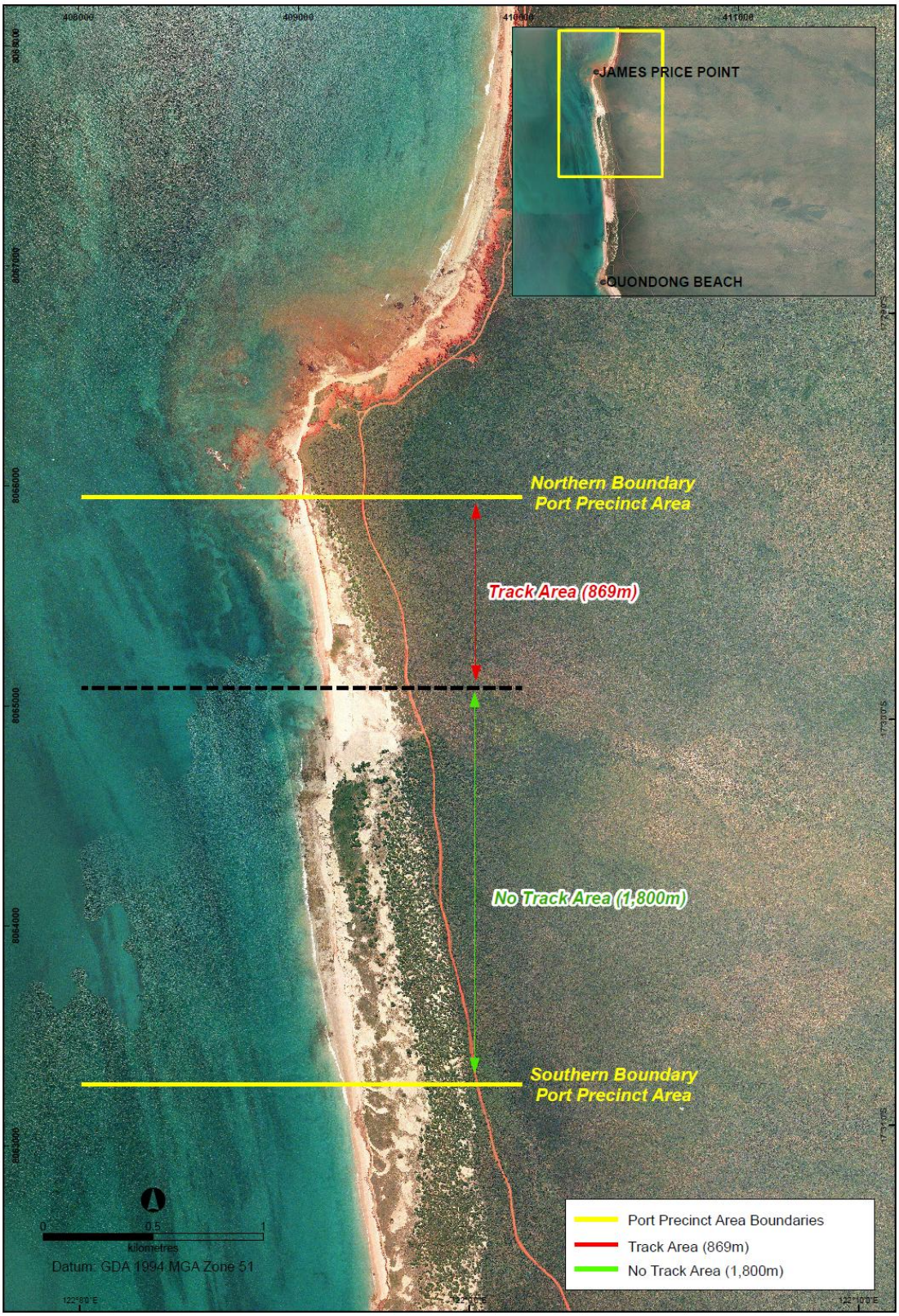

Figure 31 Area at James Price Point with track area and indicative Port boundaries indicated.

4. Discussion

4.1 General observations, local, regional and international context

At the outset we stress that despite our team's ability to survey 58 track-sites at eleven locations, over a period of eleven days (6 days at both morning and afternoon low tides and 5 days at only either morning or afternoon low tides) and during favourable low tides, we cannot claim to have examined every significant track-bearing outcrop either in the direct and indirect impact areas, or in the other areas. Nor did we spend sufficient time at some of the sites to conduct a thorough evaluation. We were accompanied to many of the sites in the direct and indirect impact areas by palaeontologist Steve Salisbury, who has conducted his own, as yet unpublished, surveys in recent months. His guidance and observations were helpful in expediting quick access to some of the more significant sites, and we generally agreed with many of his identifications and interpretations. However we also discovered a few sites which he had not previously recorded (e.g., PORT005) and in some cases our interpretations differed from his.

In order to place our observations in an appropriate context we review our survey results in relation to what has previously been reported in the scientific literature. This exercise quickly reveals that despite the abundance of tracks in the Broome area, rather little has been documented in detail. The only publications of utility to track and dinosaur specialists are the description of the Gantheaume Point theropod tracks (Colbert and Merrilees, 1967), the reports of sauropod tracks (Thulborn et al., 1994) from various unspecified locations from the Riddell Beach and Gantheaume Point locations northwards for about 50 km, into the general area of James Price Point. Thulborn et al. (1994, p. 85) also refer to ornithopod tracks and footprints of "thyreophorans provisionally identified as stegosaurs." The only other available published documentation on the Broome tracks is that found in *Dinosaurs of Australia* (Long 1998) where various track outlines are shown. These sketches constitute the only published illustrations of purported ornithopod and stegosaur tracks from the Broome area. The purported stegosaur tracks achieved local, national and even international notoriety when it was reported that one had been stolen: see Long (2002), for summary, and further discussion below.

Local significance

In this section we outline the significance of tracks found in the entire Broome area. While observations arising from our survey confirm the general conclusions of Thulborn et al. (1994), and the highly simplified summary presented by Long (1998) regarding the occurrence of tracks representing at least four major groups of dinosaurs, the present report affords us the opportunity to detail several dozen locations (total 58: see Table 4) and illustrate a number of representative individual footprints, to which, in some cases we apply different labels and interpretations. This gives us sufficient information to make a preliminary assessment of the significance of the Broome track record (ichnofauna) in relation to others found elsewhere in Australia and around the world: i.e., regionally and internationally. In these comparative analyses we primarily confine ourselves to comparisons between track sites and track site regions of comparable, i.e., Lower Cretaceous age.

As has been intimated above, and in the scant literature available (Thulborn et al., 1994; Long 1998, 2002), the Broome track assemblages (ichnofaunas) are diverse. Moreover, they are significant as the only record of dinosaurs in the area. However, this is by no means a sparse record. The distribution of tracks, found in isolated outcrops over a distance of more than 50 km, constitutes a very significant local

resource. All indications are that local people have repeatedly found tracks in the region since the first tracks were reported at Gantheaume Point in the early 1950s (Glauert, 1952). Such abundant track site occurrences, in a single formation in a well-defined geographical area, invite comparison with occurrences in other areas. Such comparisons traditionally focus on the track nomenclature (ichnotaxonomy), diversity and abundance of tracks.

The following tabulation (**Table 6**) is a preliminary attempt at differentiating the tracks and providing suitable ichnotaxonomic labels and comments on the significance in relation to previous studies and observations made during the present survey.

Table 6. Track types identified during survey with tentative ichnotaxonomic labels and comments

TRACK TYPE	ICHNOTAXONOMIC LABEL	COMMENTS
Small* theropod	"*Wintonopus*" (sensu Long, 1998)	A dubious assignation: the track is probably theropodan (Figure 24)
Medium theropod	*Megalosauropus broomensis* (Colbert & Merrilees 1967)	Distinct from small theropod tracks listed above (Figures 21-23)
Large theropod	cf. *Megalosauripus* (sensu Lessertisseur, 1955) or *Buckeburgichnus* (sensu Kuhn 1958)	Distinct from theropod tracks listed above (Figures 19E and 19 H)
Sauropod track	cf. *Brontopodus*	Ichnogenus name suggested here for wide-gauge trackway
Ornithopod tracks	cf. *Amblydactylus*	Ichnogenus name suggested here for wide tridactyl track
Thyreophoran/ Ankylosaur track	cf. *Tetrapodosauropus*	Ichnogenus name suggested here as alternative to previous label of "stegosaur tracks"

While it is beyond the scope of this report, and indeed beyond the scope of present ichnological knowledge, to provide unequivocal names for most of the track types identified above, or to discuss their significance in detail, we suggest nomenclature (ichnotaxonomy) and interpretations which modify and expand the published record to some degree. In the order of the above tabulation:

Small theropod tracks are arbitrarily defined as being less than 25 cm in length (Thulborn, 1990). Those observed in the present survey have been, in some cases, especially at James Price Point, assigned the label *Wintonopus*, suggesting an affinity to Cretaceous tracks of presumed ornithopod affinity from the Winton Formation Lark Quarry in Queensland. We consider the ornithopod attribution unlikely based on the trackway parameters, and are likewise dubious about the *Wintonopus* label. These tracks could be assigned to a new, or other ichnotaxon based on their robust morphology (e.g. **Figure 19 - B**). For example, we tentatively suggest the label cf. *Irenichnites* could be applied to these smaller tracks (**Figure 24**).

Medium theropod tracks in the arbitrary size range of 25-40 cm include the type material of *Megalosauropus broomensis* (Colbert and Merrilees, 1967: **Figure 19 - G**). This track is controversial for many reasons and has been the subject of protracted discussion because of the nomenclatorial complexities and confusion surrounding the name (Lockley et al., 1996, 2000; Lockley 2000; Thulborn 2001). In short the name *Megalosauripus* (spelled with an 'i') was coined on the basis of entirely different tracks from those described as *Megalosauropus* (spelled with an 'o') by Colbert and Merrilees (1967). Regardless of the arcane issues that arise from such technical academic problems, it is clear that the Broome specimens would benefit from a detailed re-description. For example, it could be that *Megalosauripus broomensis* is a synonym of *Ireniesauripus acutus*, or at least referable to ichnogenus *Irenesauripus*. If this were to be accepted, or introduced into the scientific discussion, it would significantly change the technical debate surrounding the definition of *Megalosauripus*. Our survey confirms that the type material of *Megalosauropus broomensis* is still in place, and that other well-preserved tracks, evidently attributable to the same or similar track makers are available for study at the type locality. In short a significant sample of topotype material awaits further analysis, thus making the locality and sample still relevant and scientifically useful.

Also in the medium-size category are elongate theropod tracks with narrow digit divarication angles and spindle shaped middle digit (digit III) traces, which differ from the tapering morphology associated with the *Megalosauropus* sample. These are potentially another theropod track type distinct from the three listed in **Table 6**.

Large theropod tracks with a foot length of ~50 cm are morphologically distinct (more robust) than those assigned to the small and medium categories, and suggest the potential and need for further study. Such research would help better establish the diversity of tracks in the Broome area.

Sauropod tracks have in some cases been observed in discrete trackways (**Figure 25**). These reveal wide gauge trackway patterns (sensu Farlow 1992; Lockley et al., 1994). This suggests that the ichnogenus name *Brontopodus* can be applied. This conclusion is at variance with that of Thulborn et al., 1994, p. 89) who conclude that most trackways "lack sufficient morphological detail to justify identification at the level of ichnogenus."

Ornithopod tracks identified during the present survey can tentatively be assigned to ichnogenus *Amblydactylus*. This is one of several ornithopod track types (ichnogenera) that mostly differ in subtle detail. We mostly observed isolated tracks blunt-toed tridactyl tracks (**Figure 30**) that ostensibly indicate bipedal track-makers: i.e., we identified no trackways with clearly impressed front footprints. Likewise well-preserved trackways were not identified. The tracks are likely attributable to basal iguanodontians. We observed no very large ornithopod tracks during the course of this survey.

Thyreophoran tracks. The term 'thyreophoran tracks' is used here to indicate the footprints of one or more of the "shield-bearing" dinosaurs. These are traditionally divided into the plated and armored dinosaurs - the stegosaurs and ankylosaurs respectively, as well as some other related groups. Despite a few alternative interpretations, both these well-known groups are viewed as habitual quadrupeds, and both had very similar five toed manus tracks. However, the hind footprints differ significantly with stegosaur tracks being three-toed (tridactyl) and ankylosaurian tracks being four-toed (tetradactyl). These differences are reflected in the ichnogenus

names. *Tetrapodosaurus* is widely used to label ankylosaur tracks (Sternberg, 1932; McCrea et al., 2001), whereas the more recently defined ichnogenus *Deltapodus* is attributed to stegosaurs (Whyte and Romano, 2001). The former is common in the Cretaceous, the later type is more generally confined to the Jurassic. Thus on the basis of two criteria (the four-toed pes and the Lower Cretaceous age) on balance the tracks observed during the survey (**Figure 29**) are interpreted as ichnogenus *Tetrapodosaurus*, of likely ankylosaur affinity.

This conclusion is at variance with anecdotal reports of stegosaur tracks from the Broome Sandstone (Thulborn, 1994; Long, 1998). However, no details are given to support this identification, and we therefore suggest the alternative 'ankylosaurian' interpretation. This does not mean that stegosaurian or other non-ankylosaurian, thyreophoran tracks might not be identified in the Broome area.

Other ichnology of local significance. There are reports of ancient human footprints from the Holocene deposits north of Broome (Long, 2002). Ancient human footprints are very rare in Australia having been reported from only two locations (Belperio and Fotheringham, 1990; Webb et al., 2005), and until recently have been inadequately documented. Documentation of such sites should be of extreme interest to anthropologists and palaeontologists alike. Such sites, if reliably verified, would add significantly to the local significance of the track record in the Broome area. The potential for such finds is indicated by the presence of a fossil arthropod (Decapoda) trackway on cemented dune deposits on Cable Beach which was discovered during the course of this study (**Figure 32**). Indeed, these deposits are rich in fossil remains and have considerable potential for further study.

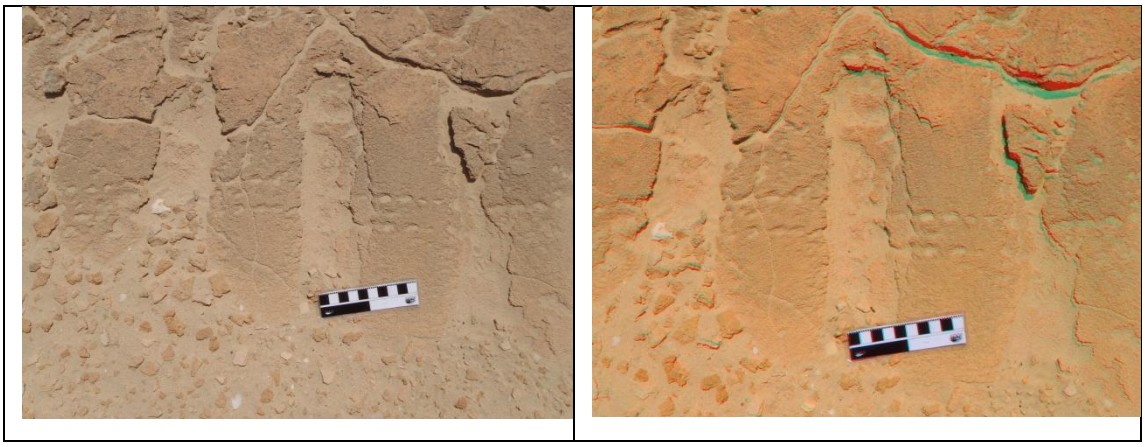

Figure 31 Fossil arthropod (Decapoda) trackway on cemented dune deposits on Cable Beach (left 2d, right 3d)

Regional context

Given the great local significance of the Broome area tracks, by default these same footprints assume considerable regional significance because they are the only dinosaur tracks known from Western Australia. This significance is not diminished by comparison with the sparse track record of Cretaceous dinosaur tracks from eastern Australia, notably those documented from the globally well-known Lark Quarry site in Queensland (Thulborn and Wade, 1984). [Few other dinosaur tracksites are known from Australia, and those of any note are small pre-Cretaceous sites: e.g., Thulborn

(1994), and need not be further considered for comparative purposes]. The Broome track sites differ from the Lark Quarry site in terms of most measurable parameters. For example, unlike the wide distribution of multiple sites in the Broome area, the Lark Quarry site is a single small site, albeit with a high density of tracks. Likewise, whereas the Broome sites have various tracks of large quadrupedal dinosaurs (sauropods and ankylosaurs) the Lark Quarry ichnofauna is dominated by the tracks of predominantly small bipeds. Ostensibly, the Lark Quarry track type *Wintonpus* also occurs at Broome (Long, 1998). However, at the present time it is not possible to compare the tracks of bipeds from the two areas with any confidence. This is because the purported differences between the two Lark Quarry track types (*Wintonopus* and *Skartopus*) have recently been called into question by Romilio and Salisbury (2010). Thus, as there are few obvious similarities between the Cretaceous dinosaur tracks of eastern and western Australia, almost all the information derived from the Broome tracks is additional to anything previously documented from the region.

It has been suggested that the widespread geographical distribution of the Broome tracks makes it an example of a megatracksite or 'dinosaur freeway' which as originally defined is a regionally extensive phenomenon, whereby track-bearing layers accumulate in well-defined and narrow stratigraphic zones over large areas, usually associated with coastal plain systems. This claim has been refuted in various unpublished online blogs and we accept that there is currently insufficient information to either substantiate or refute the "megatracksite" claim. Nevertheless the airing of such questions is symptomatic of an awareness of the extensiveness of the track-bearing units.

International context

There are many regions with Lower Cretaceous dinosaur track-bearing deposits with which the Broome deposits can be compared. However, the scope of this report does not allow for extensive or detailed analysis of the many points of comparison. Recent work on the nomination of dinosaur tracksites for World Heritage (WH) inscription has led to discussion about the criteria that could be used for a systematic comparison. However, while such criteria, numbering up to 35 points of comparison, have been listed in detail in WH nomination documents, they have not been published in the mainstream literature. One attempt was made to compare 10 dinosaur track sites from the USA, using sixteen criteria (Lockley 2010), but in this case individual sites were compared, not track site regions.

The following (**Table 7**) is a brief summary of 7 track site regions with extensive deposits that invite comparison with the Broome region. Points of comparison include diversity of track types, extensiveness of deposits and historical importance including type specimens and extensiveness of scientific literature.

Table 7 Comparison of important Lower Cretaceous Track site regions of Global significance. Eight general track type categories include Theropod (TP), Sauropod (S), Thyreophoran (TH), Ornithopod (O), Bird (B), Pterosaur (P), Crocodile (C), miscellaneous other (mo).

TRACKSITE REGIONS OF GLOBAL SIGNIFICANCE	WELL-DOCUMENTED TRACK TYPES [with approx diversity]	HISTORICAL SIGNIFICANCE (number of type specimens)
Broome: Western Australia*	**TP – S –TH – O – x – x – x – x [4]**	Reported 1950s (1 type)
South America	**TP – S –TH – O – B – P – x – x [6]**	Reported mid 1900s (?types)
China	**TP – S – x – O – B – P – x – x [5]**	Reported 1940s (+5 types)
South Korea	**TP – S – x – O – B – P – x – mo [6]**	Reported 1980s (+5 types)
USA: Texas *	**TP – S – x – x – x – x– x – x – x [2]**	Reported 1930s (3 types)
USA: Colorado*	**TP – x –TH – O – B – P – C – x [6]**	Reported 1930s (4 types)
Western Canada	**TP – S – TH – O – B – x – x – x [5]**	Reported 1980s (4 types)
Western Europe	**TP – S –TH – O – x – P – x – mo [6]**	Reported in 1800s (+5 types)

* refers to tracksite regions associated with a single formation.

Bearing in mind that these comparisons deal only with Lower Cretaceous deposits, and that only the most general criteria are considered, the Broome track sites compare quite favourably with other track site regions in the southern hemisphere including eastern Australia (see above), Africa from which virtually no reliable Cretaceous data is known, and South America for which a modest, but rather obscure literature exists. For historical reasons, the documentation from western Europe and North America is quite extensive and detailed, although some of the most celebrated regions (e.g., Texas) reveal a rather low diversity of documented track types. China and Korea, although increasingly well-documented, evidently lack some of the components found from the Broome area (e.g., Thyreophoran tracks).

It should also be noted that one drawback in this 'broad brush stroke' comparative analysis is that whereas the Broome deposits represent a single formation, and rather specific sedimentary facies, as is the case for the Texas and Colorado track site regions, in the other regions multiple formations and facies are represented, this increasing the potential for a greater cumulative diversity as well as a more extensive literature. Such considerations should be borne in mind when making such generalized comparisons.

4.2 Conclusions

As the science of vertebrate ichnology has matured, efforts to nominate sites and regions for World Heritage status represent just one example of efforts to preserve fossil footprint resources as local, regional or national heritage sites. All such endeavours require evaluation of the resource, along the lines of the effort

undertaken in this survey. This is because local communities and local, regional and national governments need to understand the resources in their areas of jurisdiction in order to make appropriate management decisions. In the case of the Broome region, already part of the larger Kimberly Heritage region, there is no doubt that a significant paleontological resource exists, that has yet to be adequately documented. While there are at least two Australian palaeontologists who have worked on the Broome tracks, their results, with the exception of a preliminary paper (Thulborn et al., 1994) have not been published. Therefore, a thorough evaluation, with appropriate scientific follow through (i.e., publications) is overdue. This report serves only as a first step in stimulating this process. We have no doubt that the present circumstances surrounding the proposed port precinct development have served to generate considerable interest in the tracks and how best to preserve them. For this reason we include a brief set of recommendations as an appendix.

4.3 Recommendations

There are several threats to any track site that is exposed due to natural processes or human activities.

The basic threats are in order:

1. Neglect (if a site is not researched or monitored all other threats continue unimpeded),
2. Natural erosion (pervasive and generally unstoppable),
3. Industrial activity (has potential to be completely destructive, but can also be mitigated),and like natural erosion (2) may bring to light tracks/fossils that would otherwise not be exposed,
4. Human activity (vandalism, theft, etc., can make significant adverse impact).

General steps for mitigation

1. Documentation: Do a thorough scientific survey: with appropriate funding for a team of Australian/international palaeontologists and geologists. Make one of the outcomes of such a survey a requirement for at least one major scientific publication (monograph).

2. Recover original specimens: take a good sample that is representative of the fossil resource and place them in a professionally run museum or other such institution with collections capabilities.

3. Recovering high quality moulds (latex, but silicone is probably better for time constraints caused by tides). Encourage judicious moulding of tracks as a means to preserve them from marine erosion, and as a means to monitor future erosion.

Any of the mitigative steps listed above could be achieved with professionally guided local support and could have a positive benefit for the local community.

Consideration should also be given to dedicate funding for a local museum in the Broome area, which is intelligently planned to serve the community so as to showcase the paleontological and related resources (dinosaurs, geology, Holocene palaeoenvironments, including hominid tracks), as well as offering educational programs for schools and volunteers. Such a museum would also have considerable tourist (and PR) potential.

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Appendices

Appendix 1 – EPA request for additional study

Appendix 2 – Summary of existing knowledge

Appendix 3 – Scope of work and work plan

Appendix 4 – Detailed and site specific geo-referenced findings (to be excluded from publicly available document)

Appendix 5 – Peer review comments and close out letters

Appendix 1 – EPA request for additional study

GOVERNMENT OF WESTERN AUSTRALIA

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Dear Ms McGowan

DINOSAUR FOOTPRINT SURVEY – BROWSE GAS PRECINCT

The Environmental Protection Authority (EPA) is aware of conflicting advice about the presence and significance of dinosaur footprints in the James Price Point area and requires further information to enable it to provide sound advice to Government about this issue when it reports on the Browse Gas Processing Precinct. I note that the issue was identified in the original scope for the assessment of this strategic proposal. The EPA requires the proponent to arrange for the collection of additional information about this issue, according to the normal process for environmental impact assessment in Western Australia provided for under the *Environmental Protection Act (1986)*.

Part of the issue is linked to the absence of definitive location information about footprints reported from the area. The key issue for the EPA's current assessment is to identify the types and precise locations of any prints within the proposed precinct outline and to place this in the context of any similar material in the local area that is not within the project outline.

If footprints are found within the precinct outline, or in a position where project actions are reasonably likely to adversely affect them, then the EPA would like to know of any plans the proponent has to deal with such material to avoid, mitigate, manage or offset any potential impacts.

The EPA requires this information to enable it to determine the significance of any impacts that may occur as a consequence of the proposal on footprints in the area. The EPA considers that this is an important issue that it will need to consider prior to providing its report to Government on the range of key factors associated with this proposal.

The EPA believes that a dedicated ground-based survey, in the appropriate areas under appropriate tidal conditions, is required to inform its consideration of this issue. A draft scope of work for a survey that would assist the EPA is attached.

The EPA is aware that there is a limited pool of experts in Australia (or elsewhere) that would have the experience or would be available to undertake such a survey. The EPA is also aware that the issue of dinosaur footprints in the James Price Point area is somewhat contested by both experts and the community. The EPA does not, however, accredit any particular experts. Accordingly the EPA will require that both the survey design and report on the results be subject to independent peer review, prior to implementation of the survey and before finalisation of the report respectively.

The EPA is aware that publicly identifying the location of any fossilised footprints that are found could put them at risk of unauthorised damage or removal. I would expect an appropriate process to be put in place to ensure that location information is accurately recorded and made available to the EPA on a confidential basis. Location information should be kept confidential and deposited in a secure form with the appropriate government agencies for long term storage, as is normal practice for other heritage information.

At the same time, it is important to the EPA's process that the results of studies that inform the EPA's deliberations are made available to stakeholders and the community in an appropriate and accessible form. The EPA would expect to see and have made publicly available the survey design and any reports produced, including the peer reviewers' comments and responses to those comments. Reports produced for publication should be identical to those provided to the EPA, except that location information that could put footprints at risk of unauthorised damage should be omitted from the published versions. The peer reviewer(s) can be asked to attest that versions of reports produced for the EPA and for publication meet this requirement.

If it is helpful, I would be happy to help broker the engagement of an appropriate expert(s) by explaining what the EPA requires and providing a copy of the scope of work to whoever is capable and available to do it. The Office of the EPA (OEPA) has become aware of a limited number of experts who may be able to undertake this work and staff of the OEPA would be available to discuss these with you if required.

Yours sincerely

Dr Paul Vogel
CHAIRMAN

11 August 2011

Encl. Draft Scope of Work – Browse Precinct Survey for Dinosaur Footprints

cc: Mr Michael Hession – Woodside
Ms Carolyn Cameron – DSEWPaC

Draft Scope of Work – Browse Precinct Survey for Dinosaur Footprints

1. Conduct a ground-based survey of exposed rock strata for fossil dinosaur footprints and other relevant associated fossil material within the outline (see attached figure) of the proposed gas processing precinct near James Price Point, approximately 60km north of Broome, Western Australia.
2. Survey similar strata in similar nearby settings which are outside the outline of the proposed gas processing precinct, to put the data collected under 1 above into an appropriate local context.
3. Use appropriate, professionally recognised search and documentation techniques, including location information collected to an appropriate surveying standard suited to capture on a GIS system compatible with the OEPA system. This should include high resolution digital photographs. The survey should include, where possible, incorporation of local indigenous knowledge of dinosaur footprints.
4. Make the results obtained above available in a report to the EPA and DSEWPaC, with precise location data. This report is to set out the background to the survey, methods used, results and conclusions about the significance of any material found in a local, regional, Australian and international context as appropriate. Conclusions are to be supported by appropriate references to available data, reports and published literature in peer reviewed scientific journals.
5. Make the results obtained above available in an identical report to be made publicly available, with precise location data removed. Removal of location data from this report is necessary to protect any material found from theft or damage.
6. The data collected will be available to the author(s) of the reports produced under 4 and 5 above for publication in peer reviewed journals or other professional forums.
7. The survey design under items 1 to 3 above is to be subject to independent peer review prior to execution of the survey. The peer reviewers' comments are to be addressed and incorporated into the design as appropriate prior to the start of the survey. The peer reviewers' reports will be made available directly to the EPA and DSEWPaC.
8. Reports produced under 4 and 5 above are to be independently peer reviewed prior to completion. The peer reviewers' comments are to be addressed and incorporated as appropriate into the final report.
9. The peer reviewers are to ensure that reports 4 and 5 are identical except for the exclusion of location data from the report prepared under 5 above.
10. Peer reviewers will provide a close-out statement to verify whether the final reports have appropriately dealt with the reviewers' previous comments.
11. Peer reviewers' comments and close out statements will be made publicly available, excluding any precise location information.

Appendix 2 – Summary of existing knowledge

1.1 Previous Palaeontological Research

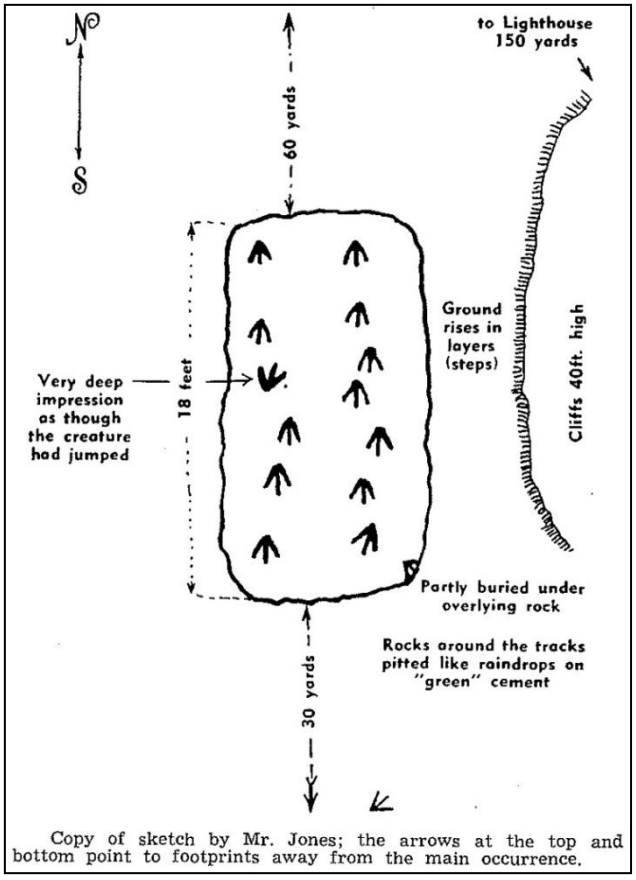
1.1.1 Glauert (1953)

Glauert (1953) reported the discovery by Walter Jones of Broome in 1945 of large impressions "shaped like giant emu tracks", approximately 13 inches (33cm) long, in the Broome sandstone at extreme low spring tide near the Point Gantheaume Lighthouse. Local lore relates that they were originally discovered by a group of Girl Guides in 1935.

Glauert noted:

Although so recently brought to our knowledge the tracks have long been familiar to the aborigines, who have given them the name of warragunna, and who have a legend to account for their origin. The story is that a native walking along the beach noticed the tracks and at once began to follow them. Suddenly a very large bird was seen trying to get across the bay in a southerly direction. When the bird turned and came towards him the native fled, not stopping until he reached "Willy's Creek," where his footprint can be seen. (Glauert 1952: 82-83).

Glauert published a sketch of the tracks, provided Mr Jones (Figure 1), and he based his description on reports, measurements, and a cement cast of one of the prints (Colbert and Merrilees 1967: 21).



Copy of sketch by Mr. Jones; the arrows at the top and bottom point to footprints away from the main occurrence.

Figure 1: Sketch of dinosaur footprints near Point Gantheume Lighthouse (Glauert 1953).

1.1.2 McWhae et al (1958)

The carnosaur tracks from Gantheaume Point were subsequently mentioned briefly by McWhae et al (1958), in their description of the Broome Sandstone:

The unit contains plants with Lower Cretaceous affinities, and is believed to be, in the main, a continental deposit. At Gantheaume Point, well-preserved footprints of a three-toed iguanadont reptile can be seen in the Broome Sandstone when the tide is low. (McWhae et al 1958: 107).

1.1.3 Colbert and Merrilees (1967)

The tracks from Gantheaume Point reported by Glauert (1953) and referred to by McWhae et al (1958) were examined in the field by Colbert and Merrilees in 1964. They described three fossil locations, two at Point Gantheaume and one nearby at Riddell Beach.

Several groups of footprints were observed. One group in rocks exposed near the northwestern end of Riddell Beach consisted of two clearly-defined and one ill-defined print. The second group comprised 10 prints, mostly well defined, about 150 feet seaward of cliffs near the lighthouse at, Gantheaume Point. The third group comprised about 10 ill-defined prints about 200 feet seaward of the same cliff., The geographical distribution of prints of the second group is shown in Figure 1. Print numbers in Figure 1 represent a field system, later shown to be untenable; they may now be taken as arbitrary numbers.

All three groups are normally covered by sea water and are easily accessible only at very low tides. The more seaward group, at Gantheaume point is exposed only at tides of + 1.9 feet or less above the arbitrary datum from which Broome tides are estimated for the North and Northwest Tide Table published by the Harbour and Light Department of Western Australia.

The more landward group at Gantheaume Point is accessible below +2.9 feet. The Riddell Beach group is a little higher. (Colbert and Merrilees 1967: 21).

Figure 2 shows their sketch map of the second group of tracks near the Gantheaume Point lighthouse.

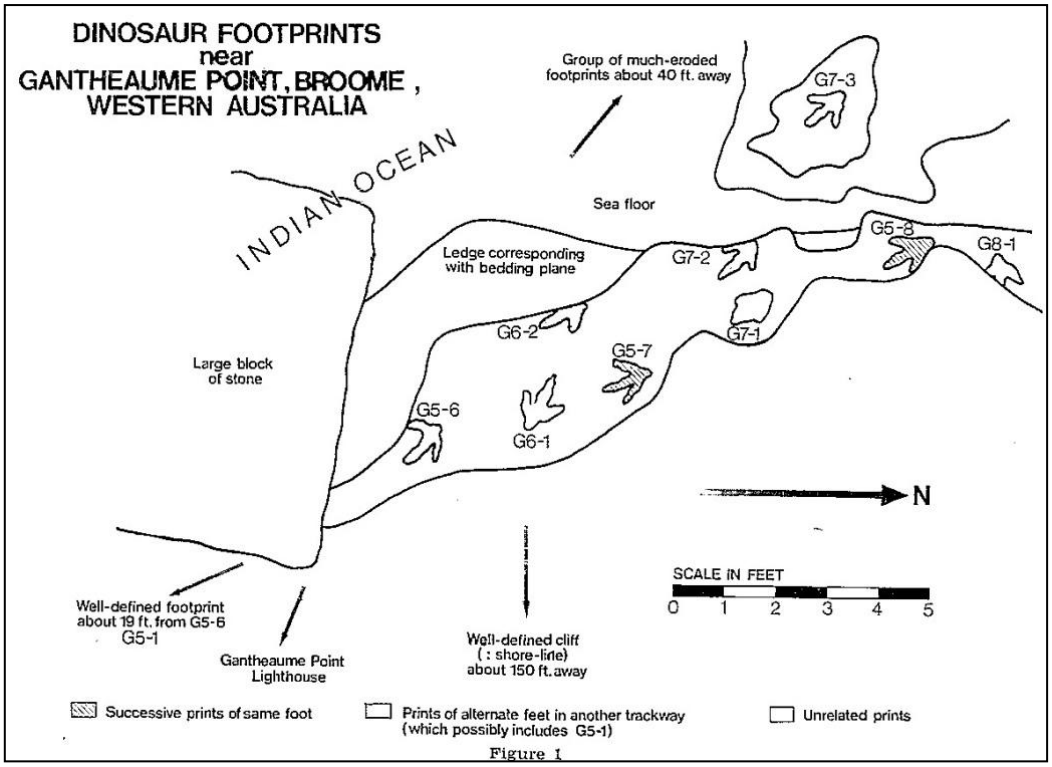


Figure 2 Dinosaur tracks near Cape Gantheaume Lighthouse (Figure 1 from Colbert & Merrilees 1967). Colbert and Merrilees (1967: 23) concluded that all of the prints described belong to Megalosauropus.

From the foregoing description it can be seen that Megalosauropus, as known from trackways exposed at Gantheaume Point near Broome, Western Australia, is a large carnosaurian dinosaur with most of the attributes in the individual footprints and in the trackways that are to be expected in such an animal. Since the Broome Sandstone is now regarded as of early Cretaceous age, being placed well down in the Neocomian (see McWhae et al, 1958) these trackways may be regarded as representative of a large megalosaur, perhaps even of Megalosaurus itself. But since these are only the trackways they have been given a separate designation, for the reasons discussed by Peabody (1940 and 1955) and Baird (1957). They indicate a dinosaur similar to the one (as yet unnamed) that made the Glen Rose trackway, this latter being somewhat later (of Aptian age) than the one in the Broome Sandstone. Finally, the trackways of Megalosauropus broomensis give valuable new evidence as to the world-wide spread of the carnosaurian dinosaurs in early Cretaceous time. (Colbert and Merrilees 1967: 25).

1.1.4 Playford *et al* (1975)

The Geological survey of Western Australia (GSWA) Memoir 2, “The Geology of Western Australia”, contains a brief description of the Broome Sandstone fossils at Gantheaume Point (Playford et al 1975). The fossil plant species recorded by White (1959) are noted (see below), and therapod dinosaur prints are mentioned (citing Colbert and Merrilees 1967) and illustrated (see Figure 3). This is the first published photograph of therapod tracks from Gantheaume Point. Figure 3 shows not the black and white image contained in the publication, but the original colour transparency taken by Phil Playford, who says that they were the only tracks visible at that time,

and very easy to identify (Phil Playford personal communication to Peter Haines, 5th October, 2011).

Figure 3 Photo of therapod tracks (cf. Megalosauropus broomensis) at Gantheaume Point in Playford et al (1975) (Photograph: P. E. Playford, taken 1957).

1.1.5 Long (1998, 2002)

Working from the Western Australian Museum, John Long (now at the Natural History Museum of Los Angeles County, began field studies of the Broome Sandstone in 1990 (Long 2002: 4).

In a general-audience book on the Dinosaurs of Australia and New Zealand, Long (1998: 53) recorded that dinosaur footprints were first recognised in extensive outcrops of Cretaceous rocks in northern WA in the 1940s. He noted he has studied new finds by Paul Foulkes and friends from Broome, revealing at least six different kinds of dinosaur tracks, and that ongoing research by Thulborn, Hamley, and Foulkes is revealing additional types of footprints, *'including some of the world's largest Sauropod tracks'*. Some of these finds, with the researchers, are shown in photographs in the book (see Figures 4 and 5).

Long (1998) produced an outline chart of the basic footprint shapes identified at that time (Figure 6) and an artist's impression of Sauropods 'making tracks' along the Cretaceous coastline near Broome (Figure 7). He also provided short descriptions and illustrations from Broome sandstone examples of the tridactyl (three-toed) print of the therapod *Megalosauropus broomensis* (Long 1998: 127, Figure 8), large sauropod tracks up to 1.5m long (Long 1998: 129-30, Figure 4).

Long described and illustrated possible *Stegosaur* tracks - the only known Australian record of the family *Stegosauridae* (Long 1998: 130; Long 2002, Figure 9). The fossil location is given as Crab Creek (Long 2002: 181-2; Latham vs. the Queen 2010; CNN 1996), which is actually at the coastal end of Crab Creek Road on the northern shore of Roebuck Bay (a locality known as Red Cliffs).

Long also included two forms of ornithopod dinosaur tracks - a medium-sized ornithopod from a trackway near James Price Point that he ascribed to the genus

Wintonopus (Long 1998: 130-1, Figure 10), and a larger ornithopod track about 45cm long, of similar size to *Muttaburrasaurus* (Long 1998 131, Figure 11).

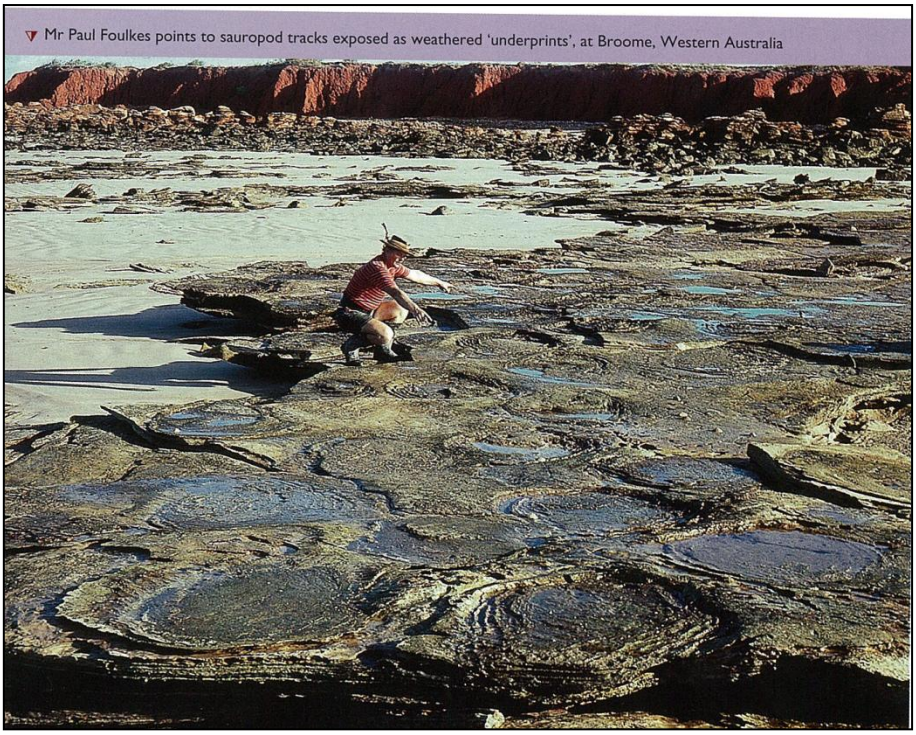


Figure 4 Paul Foulkes with sauropod underprints near Broome (Long 1998)

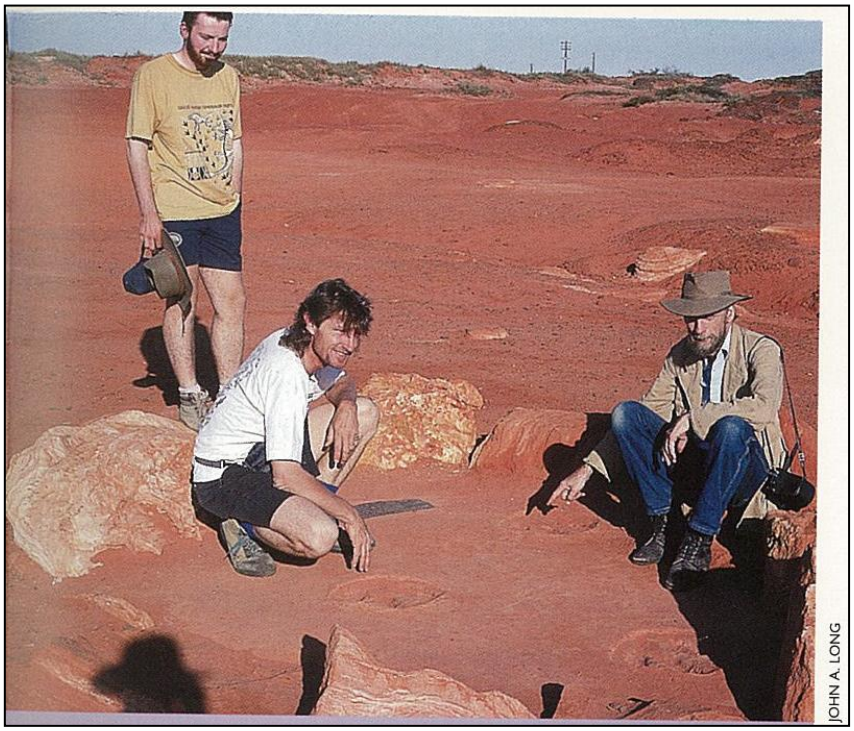


Figure 5 Right to Left: Dr Tony Thulborn, Tim Hamley, Duncan Friend, with dinosaur prints at Gantheaume Point, Broome (Long 1998).

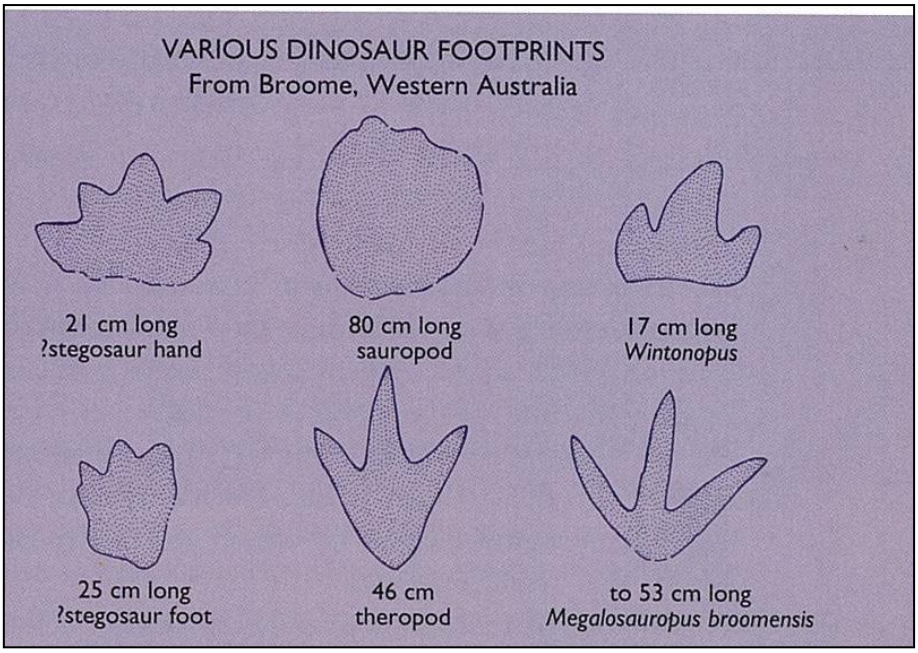


Figure 6 Chart of basic dinosaur footprint types discovered in the Broome sandstone formation (Long 1998).

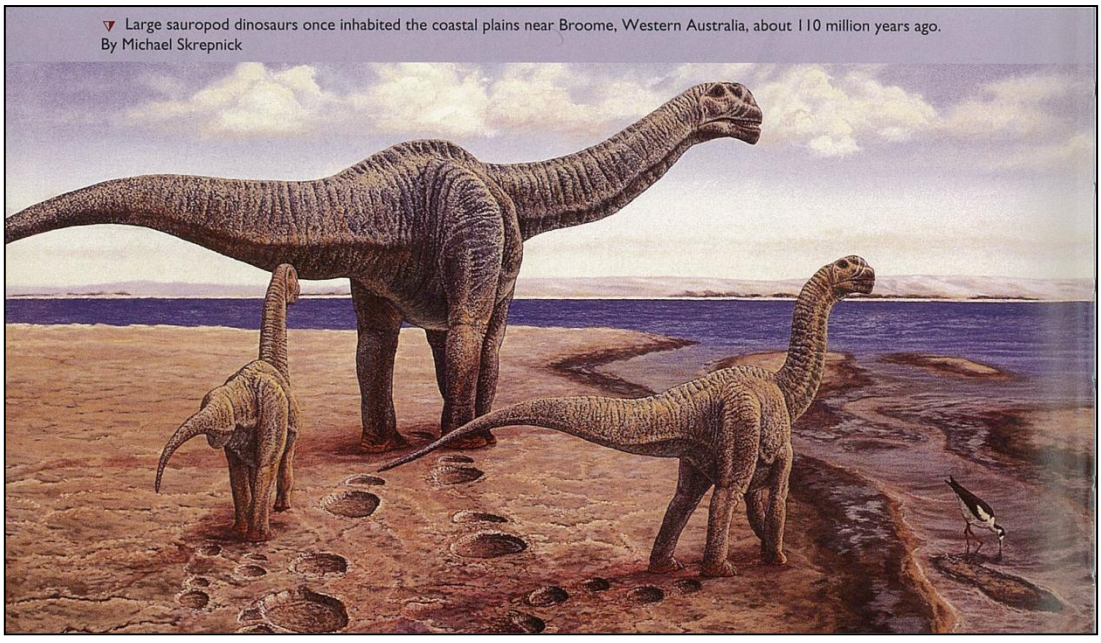


Figure 7 Artist's impression of large sauropod dinosaurs creating tracks along the coast near Broome (Long 1998).

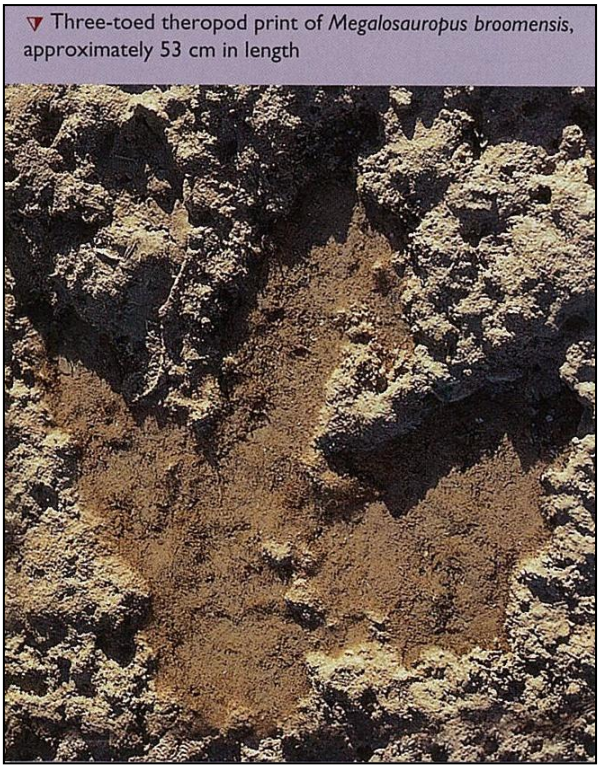


Figure 8 Theropod print of *Megalosauropus* (Long 1998).

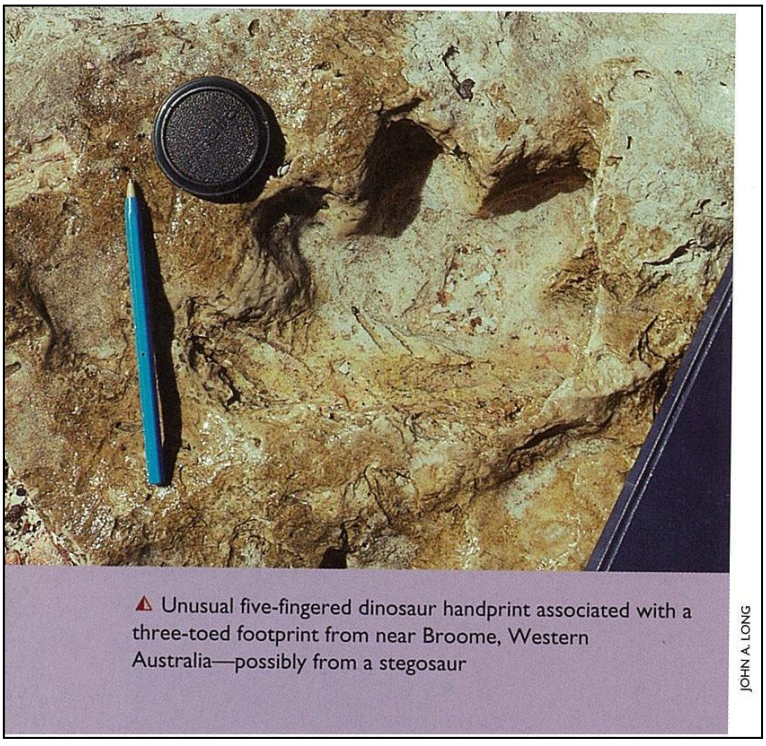


Figure 9 Probable Stegosaur print from Crab Creek (Long 1998).

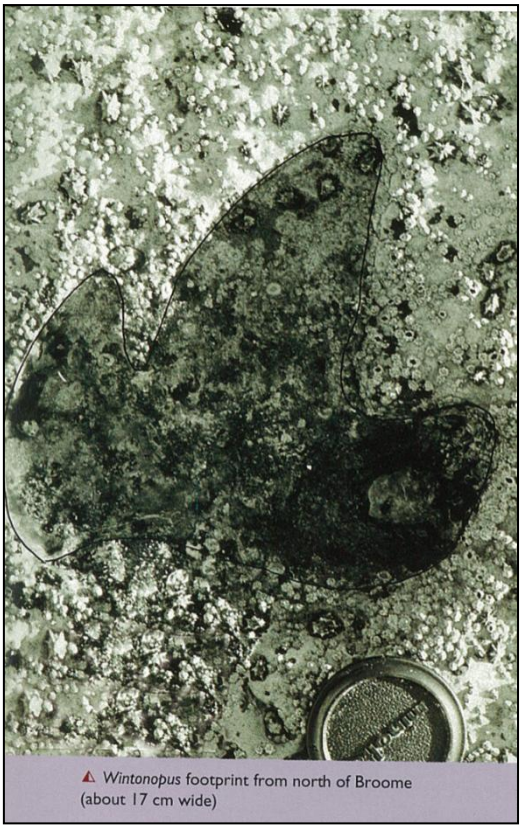


Figure 10 Outlined Ornithopod (cf. Wintonopus sp.) print from the James Price Point area (Long 1998).

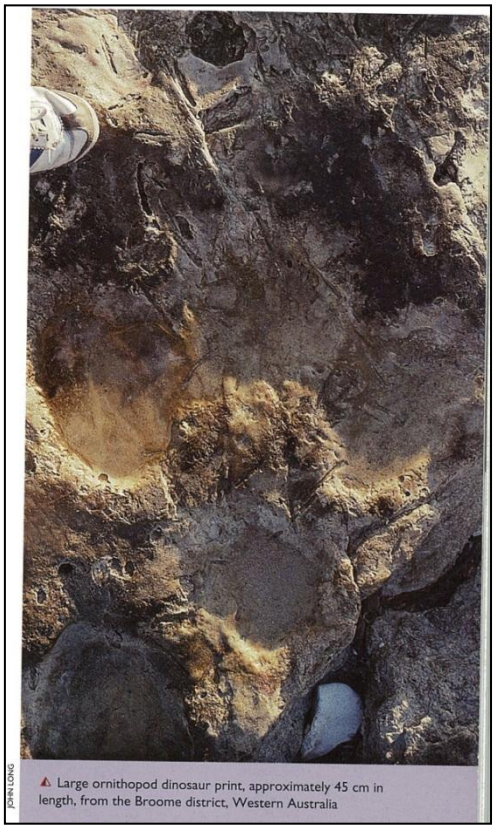


Figure 11 Large Ornithopod track, Broome sandstone (Long 1998).

Long published a summary of his field studies of the Broome Sandstone, and the story of the theft of fossils from the “Crab Creek locality in 1996 in the book *“The Dinosaur Dealers”* (2002), which was paired with a two-part video documentary of the same name (broadcast on SBSD Television). The second episode, 'Stealing Time', focuses on the theft of the probable *Stegosaur* print by 'fossil rustlers'.

Long (2002) refers to his work with local naturalist, Paul Foulkes (who also worked with Thulborn). Long and Foulkes explored several different sites around Broome, “a*s far-ranging as Prices Point [James Price Point], some 70 km north of Broome”.* (Long 2002: 4). Within this 70 km section of coastaline, Long and Foulkes photographed, drew and measured”

"[M]any different kinds of dinosaur tracks, ranging from those of large three-toed meat-eaters (theropods, like Megalosauropus from Gantheaume Point), huge sauropod trackways (from Brontosaurus-like beasts), large and small ornithopods (upright-walking plant-eaters) and the most amazing finds of all, the so-called stegosaur tracks." (Long 2002: 4)

To confirm the type of tracks of the latter, Long contacted Thulborn who was convinced that these footprints were made by a *stegosaur*.

Long states that his field work was undertaken with the permission of ‘Aboriginal leader Paddy Roe’ (Long 2002: 5). This permission was secured through negotiations between Roe and Foulkes.

In 1991, Long undertook further field study at the Broome Sandstone, this time accompanied by members of the Australian Defence Force, Tony Thulborn and Tim Hamley. This field work was the subject of a documentary, 'The Great Aussie Dinosaur Hunt'.

Paddy Roe had given Long permission on the previous field trip to borrow a slab of rock bearing Stegosaur prints so that it could be further analysed in the more conducive environment of the WA Museum. This rock was returned to its find-location in 1994.

Overall, Long concluded:

“*Not only are Broome’s dinosaur footprints well preserved, but the variety of dinosaur tracks identified there by Tony Thulborn and his co-workers makes the Broome sites among the most diverse collection of dinosaur footprints of that age anywhere in the world."* (Long 2002: 9).

Long discussed the aftermath of the two high-profile footprint thefts, in 1996 and 1998. He wrote that the effect was such that Joseph Roe, described as a *‘local Aboriginal leader’* (2002: 11) did not want scientists visiting the footprint sites (2002: 180).

"The whole affair has affected many different groups. The local Aboriginal people are still very sensitive about the theft and will never allow scientists access to the site again. Dr Tony Thulborn, among others, believes the region has a lot of potential for new discoveries, and valuable work could well be ongoing if only permission were forthcoming. Local government and police now have another headache: the worry of whether any more sacred sites will be desecrated…" (Long 2002: 186)

Further information relating to the fossil theft is contained in the court judgement *Latham vs. the Queen* (2010).

1.1.6 Quondong Point (EPA 1991)

The EPA (1991) produced an assessment report and recommendations in relation to a mineral exploration licence application extending inland from Quondong Point (See Map 1). In its summary of the known characteristics of the coastal area, the report noted the presence of dinosaur track fossils at Quondong Point:

"The Western Australian Museum recently reported that there are fossils in a white sandstone rock type at Quondong Point which are of great scientific importance. Dinosaur footprints belonging to at least three different kinds of dinosaurs are preserved as well as some of the best Cretaceous plant fossils recorded in the State. The rock type which contains the fossils is a silcrete or "white sandstone" and the Museum is proposing to conduct a scientific investigation into its extent and fossil content." (EPA 1991: 1).

Outcrops of the Broome Sandstone have been mapped at Quondong Point (Map 1). No further information is available regarding the WA Museum fieldwork referred to above.

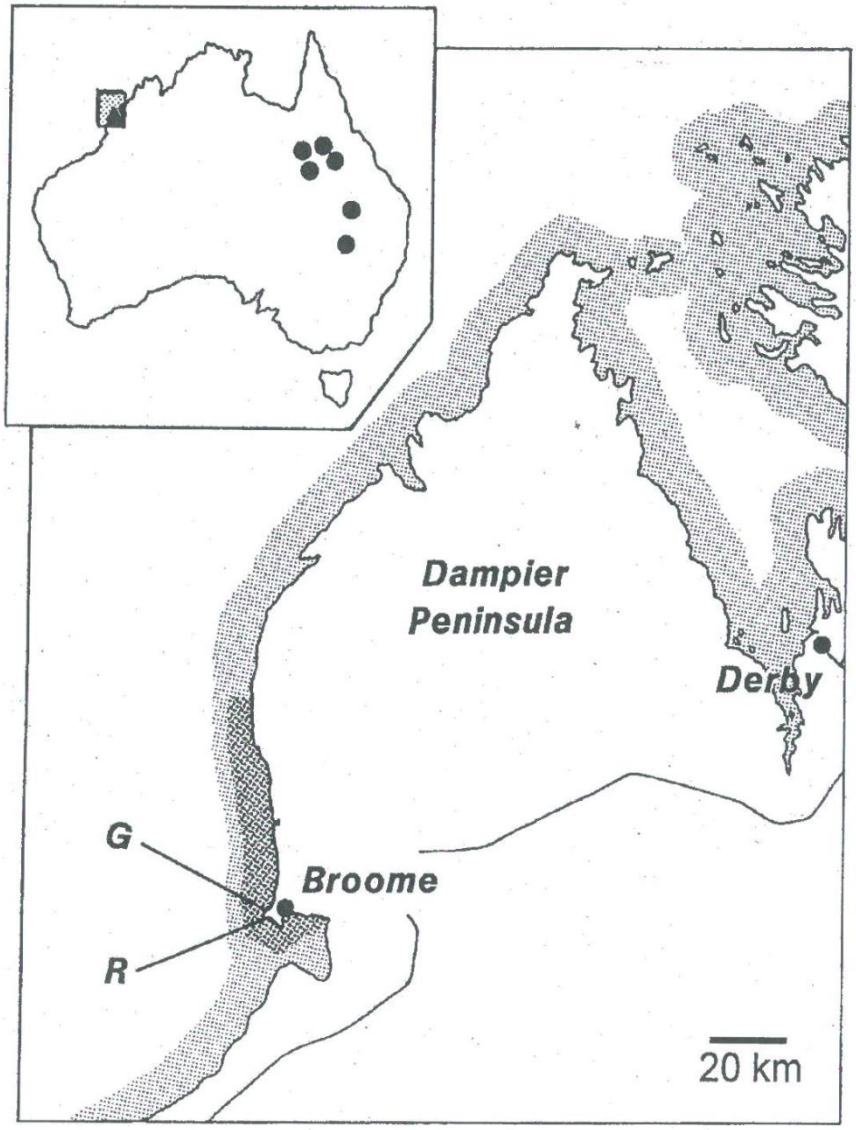
1.1.7 Thulborn *et al* (1994-2009)

Palaeontologist Tony Thulborn (formerly University of Queensland, now Honorary Research Associate, School of Geosciences, Monash University) has undertaken extensive palaeontological investigations of the Broome sandstone, including at James Price Point. Thulborn has produced one academic paper on his preliminary results (Thulborn *et al* 1994), and presented preliminary findings at conferences. He also corresponded on the topic in interviews, on blogs, and on news websites. The latter, informal publications refer to the palaeontological significance of the Broome sandstone as well as the potential impact the Browse LNG development might have on the dinosaur footprints at James Price Point. In 2009, during the 10th International Symposium on Mesozoic Terrestrial Ecosystems and Biota, Thulborn secured signatures for a petition (Thulborn 2009) seeking to stop the construction of the LNG Browse gas hub at James Price Point. Thulborn also mentions in various media interviews that he has made confidential submissions to the Government of Western Australia (and to the Commonwealth Government and Australian Heritage Council in relation to dinosaur tracks and the Strategic Assessment process for the Browse LNG Precinct development.

Tony Thulborn, Tim Hamley (research assistant), and Paul Foulkes (an amateur naturalist in Broome), published a preliminary report on the dinosaur tracks in the Broome sandstone in 1994, outlining the types of footprints found in the sandstone and identifying different environmental settings in which these footprints were made.

"Since 1987 one of the present authors (P.F.) has discovered many more dinosaur footprints in the Broome Sandstone, some of them very different in appearance from Megalosauropus broomensis. It is now apparent that the Broome Sandstone contains a rich dinosaurian ichnofauna, including the tracks of sauropods, theropods, ornithopods and quadrupedal ornithischians. Our preliminary studies have revealed at least 10 distinct morphological types of dinosaur tracks in the Broome Sandstone, some referable to existing ichnogenera and others almost certainly indicative of new ichnotaxa. By world standards this is a remarkably diverse ichnofauna …" (Thulborn, Hamley & Foulkes 1994: 87).

"Complete documentation of the Broome Sandstone ichnofauna will require considerable time. The footprint sites are scattered over more than 80 km of coastline (Fig. 1 {see Map 2]), *and in some instances they are exposed only briefly at extreme low tides."* (Thulborn, Hamley & Foulkes 1994: 87).



Map2 Figure 1 from Thulborn et al (1994), with shaded area showing approximate extent of scattered coastal exposures of sauropod tracks along the west coast of the Dampier Peninsula. G is Gantheaume Point and R is Riddell Beach. Inset map shows distribution of sauropod skeletal fossils.

A local Broome tourism information website (Broome direct n.d.) describes the continuation of this research:

"In late June and early July 1997, Tony Thulborn, Giuseppe Leonardi (Naples) and Tim Hamley (Dr Thulborn's part-time student-assistant) made a trip to Broome, Western Australia, where they discovered thousands of dinosaur footprints in the Lower Cretaceous Broome sandstone along the coastline.

The stretch of coastline had been swept clean by the last cyclone (called a hurricane in the Northern Hemisphere) to reveal an Early Cretaceous land-surface virtually

intact, with the original topography, channels and hillocks, tree-stumps and root systems in their position of growth.

Footprints included sauropods, ornithopods, theropods and some mystery items including supposed stegosaur tracks. Photographs and latex peels were made where possible, although only on a small scale.

A brief summary of the previously known Broome tracks, with emphasis on sauropods, was published in the journal Gaia, volume 10, 1994. Some scientists thought that aspects of the account were exaggerated, such as unusually big sauropod prints (up to 1.5 m long), the exceptional diversity (at least 10 different types of track-makers), and the co-occurrence of sauropod and ornithopod tracks (sometimes thought to be ecologically separated).

On returning to Broome they told the late Paul Foulkes (a naturalist and Broome local) of the sites, who set off to see for himself. He returned, reporting that he'd found even more newly-uncovered tracks.

At a conference in Perth, the following week, the discovery was discussed within earshot of a stray reporter. As a result newspaper reports had the find as a single unbroken dinosaur "highway" 80km long. Although the footprint sites (plural) do extend over 80 to 100 km of coast, it is NOT a single exposure or one continuous track way surface. It is a series of sites, many of them rather small, with (sometimes vast) stretches of beach between them. The sites don't all seem to be at the same stratigraphic level and they appear to represent a variety of environments (forest, swamp, lagoon, fluviatile/deltaic) each with its own distinctive suite of dinosaur track types. The newly-exposed sites seem to represent fairly well-vegetated forest or swamp environments. Sauropod tracks seem to dominate the lagoonal settings."
(http://www.broomedirect.com.au/pdfs/Dinosaur_Footprints_report.pdf).

This account was confirmed by Thulborn in a posting to a Palaeontology chat network.

"Let me straighten out the worst misconception. Yes, the footprint sites (plural) do extend over 80 to 100 km of coast. No, it is NOT a single exposure, NOT one continuous trackway surface. It is a series of sites, many of them rather small, with stretches of beach (and sometimes very long stretches of beach) intervening. The sites aren't all at the same stratigraphic level (so far as we can figure out stratigraphy from disconnected exposures) and they represent a variety of environments (forest, swamp, lagoon, fluviatile/deltaic)... each with its own distinctive suite of dinosaur track types. The newly-exposed sites seem to represent fairly well-vegetated forest or swamp environments. So, despite newspaper reports, it's NOT a single dinosaur trackway, NOR an unbroken dinosaur highway 80 km in length. Even so, it's interesting enough." (Thulborn 1997).

Thulborn's monograph, Dinosaur Tracks (1990: 64) mentions dinosaur footprints in the Broome sandstone. Thulborn et al. (1994) report only that dinosaur tracks are to be found 'at costal exposures over a distance of 80 km' (1994: 89).

In an ABC Kimberley telephone interview (Mills 2010), Thulborn cites two main reasons for not providing locational details for his discoveries: The first reason concerns the difficulty of locating and relocating fossils in the intertidal zone, where they are rarely exposed by extreme low tides, and may be covered or uncovered as tides, currents and storms move sand, mud and loose rock about on the intertidal rocks:

"One year, I went out there with my field assistant. We camped on the top of a cliff. And a site we knew well – we'd seen it four or five times before – we woke up in the morning, looked down on the beach, and it was completely different. What used to be black rock was now yellow, and it was a completely different site…Whether or not you see what you're intending to see depends totally on the conditions…You can't really stick a pin in the map and say, 'This is where the tracks are.'" (Mills 2010)

The second reason provided for not revealing locations is the fear of theft or vandalism of the fossils. (Two cases of fossil theft are documented for this region, an unsolved case in 1996 and a 1998 case in which the perpetrator was caught - see Long 2002; Latham vs the Queen2010). However, later in the same interview, Thulborn was asked if the possibility of theft kept him from providing precise information regarding the location of footprints at James Price Point, to which he responded:

"Not really because as I say, even the experts can walk up and down on the coast scratching their head. In many cases they won't even see the things…" (Mills 2010)

In a letter to *Geology Today*, Thulborn (1998) providede another reason for not providing locational data on dinosaur footprints:

"We are reluctant to do so because that specimen – like various other fossils and geological features at Broome – is of profound cultural and religious significance to the aboriginal community. Some sites are off-limits to women and children, and some sacred items (including certain fossils) are to be seen only by initiated males. The publication of video-footage in the news media may, in some instances, constitute serious affronts. The activities of fossil collectors, journalists, and other visitors (including some professional colleagues) have already provoked consternation, anger, threats of legal action and promises of physical violence. Such affronts to local sensibilities are not to be treated lightly; according to traditional law, serious infringements are punishable by death." (Thulborn 1998:139)

Thulborn has introduced cultural sensitivity as a reason for non-disclosure of locations in other forums. For instance, in a comment posted to a *Nature News* article (Crow 2011a) on the Browse LNG project at James Price Point, Thulborn wrote in relation to the importance of the dinosaur footprints that:

"[T]he cultural connection can hardly be ignored, as the dinosaur tracks and other fossils in the Broome Sandstone are woven into the fabric of aboriginal learning. The most commonly mentioned examples are theropod (predaceous) dinosaur footprints (Megalosauropus broomensis, otherwise known as the tracks of Marella, the sinister emu man who once stalked toese [sic.] remote shores." (Thulborn 2011).

Also in this comment, Thulborn rebukes J. M. Crow, the journalist of the Nature news article, writing that Crow is

"…on shaky ground when he states that the 'aboriginal owners of the land agreed a deal with the state government to allow the development to take place'. There is still no such definite agreement. The 'deal' to which Crow refers was struck between the state government and the Kimberley Land Council and seems to have been reiterated purely for its value as propaganda. However, that Council does not represent the views of all the traditional land-owners. In November 2009 more than 200 of the indigenous traditional owners for Walmadan signed a declaration stating: 'We do not consent to the development of an LNG precinct on our land. As native title claimants, our views, opinions and desires regarding our land and culture have not

been represented. We will not allow our land to be taken from us. We will fight for our land in court.' The resistance is led by Goolarabooloo lawman, Mr Joseph Roe, who is still defiantly rejecting the threats and entreaties of the state government." (Thulborn 2011)

1.1.8 Siversson (2010)

Dr Mikael Siversson, curator of palaeontology, Australian Museum, conducted fieldwork and prepared two reports on dinosaur tracks at James Price Point (Siversson 2010a; 2010b) for the Browse LNG Precinct Strategic Assessment Report.

The first survey was undertaken over a five day period. The majority of footprints identified were found on a single afternoon during a low tide. As with all other investigators studying the dinosaur tracks, Siversson and his team found that the tide largely determined what footprints were available for inspection

"Intertidal outcrops of the Broome Sandstone between 1.2 km and 4.5 km north of James Price Point are poorly exposed during low tide." (Siversson 2010a: 3)
Of the extent and quality of the footprints, Siversson writes:

"The intertidal zone immediately north-east of James Price Point is much degraded and contains no recognisable footprint (with the possible exception of the lowermost part, accessible only during extreme spring tides). Farther north the intertidal zone is largely covered by sand…indicating poor potential for further finds (unless cyclonic storm surges temporarily remove the sand cover)." (Siversson 2010a: 3)

Siversson points out that the Broome Sandstone dinosaur footprint record is unique in Australia, being the most diverse collection so far discovered, and it is the only Australian record of sauropod tracks. Additionally, the sauropod footprints found in the Broome Sandstone may belong to *'the largest known land animals'* (Siversson 2010a: 4).By contrast, the footprints found in the field study at James Price Point are, in his opinion, not impressive. The footprints discovered are described as 'degraded underprints' (Siversson 2010a: 4 – see Figure 12). Siversson writes that

"[T]he sauropod underprints identified within a 280 metres long and 30 metres wide area, approximately 2 km south of James Price Point are not of museum-grade quality. Given that exceptionally well-preserved dinosaur trackway assemblages occur at several locations further south of James Price Point (see Thulborn et al., 1994), the footprints found during the survey are of moderate scientific importance from the Western Australian Museum's viewpoint but may have significant heritage value to the Traditional Owners." (Siversson 2010a: 4)

Siversson also notes that misidentification of fossilised footprints is very common in his experience.

"It is therefore justifiable to approach unpublished/unverified reports of dinosaur footprints around James Price Point with some scepticism. The author of this report has examined a number of photographs depicting alleged dinosaur footprints and even dinosaur remains from the James Price Point area. All of them depict various weathering features of the Broome Sandstone." (Siversson 2010a: 4)

Figure 12 Sauropod "underprint" south of James Price Point (from Siversson 2010a).

Siversson (2010a) also illustrates a feature resembling a three-toed therapod print, which he describes as a pseudo-fossil, because of the intersection of bedding planes with the depression in the rock, but which the Confidential Submission to EPA (2010) considers to be a definite therapod track (see Section 1.1.9 below).

With regard to the impact of development on the footprints he observed, Siversson's assessment is that since the footprints are so degraded (to the point where identification becomes very difficult), that their destruction is *'negligible considering the vastly superior quality of trackways found further south along the coast'* (Siversson 2010a: 5).Finally, He also notes that the development impact could conceivably uncover superior footprints.

Siversson's second survey targeted the two proposed impact areas for the LNG Precinct south of James Price Point, the Port Precinct area (1.2-2.7 km south of JPP) and the Southern Pipeline Crossing area (6.2-7.5 km south of JPP) (Siversson 2002b: i). The field survey was conducted over two days at extreme low tide.

The second report expresses scepticism as to whether the features found were dinosaur footprints, traces of other animal impact, natural erosion, or a combination of the latter two.

"The 280 metre long corridor yielding putative sauropod underprints is right in the middle of the proposed marine infrastructure shore crossing. Construction work is therefore likely to result in the complete destruction of these circular structures. The significance of the structures depends to some extent on their true identity. As sauropod underprints, they are clearly not of museum grade quality (given that excellent indisputable sauropod trackways occur elsewhere in the Broome Sandstone). It is recommended however that a few of the best preserved putative underprints be collected and preserved for further study (long-term storage negotiated between the Traditional Owners and the WAM). This also applies if any evidence arises indicating that some of them are tree stump casts or feeding depressions produced by rays." (Siversson 2010b: 5).

1.1.9 Confidential Submission to EPA (2010)

A confidential submission was made to the WA Environment Protection Agency in 2010, relating to the occurrence of important dinosaur track specimens near James Price Point and calling for their protection within the proposed Kimberley Nation Heritage site listing. Because the EPA process guarantees confidentiality for submissions, this submission must remain anonymous. The submission refers to

three previous reports which describe the geological and palaeontological significance of the James Price Point area. The first of these reports is a short publication on the geology of James Price Point, issued by the Geological Survey of Western Australia (2009).This is essentially a six-page brochure for public information, and not a detailed, scientific field guide or treatise. Consequently, it has only a brief section referring to dinosaur track fossils.

"Dinosaur footprints

Dinosaur impressions are of significant interest to scientists and the general community. This interest has been heightened since the theft of dinosaur footprints from coastal platforms north of Broome in 1966 and the recounting of this event by Long (2003). Only one of the stolen specimens was recovered, and Australian museums only have casts made from outcrops. When the footprints are exposed in the intertidal zones they are subject to wave erosion.

Because of the interest in the dinosaur footprints, any development plan that will impact on the Broome Sandstone should include a detailed site assessment for dinosaur fossils and trace fossils (markings), and a management plan to record and preserve material of interest, including removal to a museum." (GSWA 2009: 6).

The Confidential Submission criticises this general-information brochure for its lack of detail regarding dinosaur tracks:

"[T]he Geological Survey report says remarkably little about dinosaur tracks. In effect, it is silent, as if the authors declined to venture too far into unfamiliar territory." (Confidential Submission to EPA 2010: 7)

The other two reports reviewed in Confidential Submission to EPA (2010) are the two WA Museum survey reports by Siversson (2010a; 2010b). The Confidential Submission contends that the Siversson reports are substantially incorrect, and that the dinosaur tracks in the vicinity of James Price Point are both numerous and highly significant to dinosaurian ichnology (the study of *'trace-fossils of dinosaurs, including their footprints, teeth-marks, droppings, eggs and nests'* - Confidential Submission to EPA 2010: 4).

The Confidential Submission argues that Siversson's (2010a&b) results show a lack of expert knowledge regarding dinosaur tracks, because his expertise is in a different palaeontological specialty (Confidential Submission to EPA 2010: 5).

For example, in his reports Siversson uses the term 'underprint' to cover what the Confidential Submission regards as three different kinds of print. The Confidential Submission claims that most of the prints in Broome sandstone are 'transmitted' prints - prints that are formed through an impact that creates shockwaves deep under the surface of the ground. Through erosion, the transmitted print is then slowly revealed over time.

The Confidential Submission claims that Siversson's photographs and accompanying descriptions are misleading or misidentified – for example, a photograph of 'potholes' which might be mistaken for sauropod prints, which the Confidential Submission (2010: 9) claims are classic sauropod prints, with a detailed discussion of the morphological differences between fossil prints and potholes.

In another case, Siversson presents a photograph that he claims to depict a 'pseudofossil' that might be mistaken for a tridactyl print, but the Confidential

Submission claims that this photograph depicts a *'perfectly good three-toed dinosaur footprint'* (Confidential Submission to EPA 2010: 11). Siversson claims that the 'pseudofossil' cannot be a dinosaur footprint because the toes do not show uniform depth, and the left toe and lower right heel (see Figure 3-12 below) are capped by an undisturbed, overlying stratum (see also Figure 4.4) . The Confidential Submission states that lack of uniform depth in a print is 'perfectly normal' (Confidential Submission to EPA 2010: 11). The controversial imprint is shown in Figures 13 and 14.

Figure 13 Imprint in Broome sandstone near James Price Point interpreted by Siversson (2010a) as a pseudo-fossil, and by Confidential Submission to EPA (2010) as a Therapod print. (Photo: M. Siversson).

Figure 14 Another view of the controversial print shown in Figure 12, showing the overlying stratum over the heel and one digit (Siversson 2010a: Figure 13).

"In fact those photographs show a perfectly good three-toed dinosaur footprint. I'm confident that any of the world's expert dinosaur ichnologists would confirm it. Many

would also confirm that it's a theropod footprint, though some might attribute it to an ornithopod (the distinctions are a subject of endless controversy).

Why did Siversson insist that it was not a footprint? He gave two reasons: the three 'toe-prints' were not uniform in their depth, and the 'heel' region extended beneath a shelf of undisturbed sedimentary rock. Both observations are unimportant. First, it is perfectly normal for the three toe-prints to be impressed to different depths. In fact, this is a useful rule-of-thumb for distinguishing left and right footprints: the medial (inner) toe-print is very frequently the shallowest of the three, whereas the lateral (outer) one is the most deeply impressed (e.g. Figures 16-18).

Second, the 'heel' region extends beneath an undisturbed layer of rock simply because the footprint is slightly eroded. The print penetrates several thin" layers of rock, some more durable and resistant to erosion than others. The 'heel' happens to penetrate a comparatively soft layer which has been slightly scooped out by natural erosion. This differential weathering is universal, seen in countless footprints and in every outcrop of the Broome Sandstone". (Confidential Submission to EPA 2010: 11).

The Confidential Submission also contends that the two Siversson reports differ in that while the first report claimed dinosaur footprints were 'relatively abundant', the second report *'seems to imply that there may be no dinosaur tracks at all!'* (Confidential Submission to EPA 2010: 12).

"This report resembles its predecessor in two respects. First, it says practically nothing about dinosaur tracks (only one of its seven illustrations shows a dinosaur footprint). And, second, what little it does say about dinosaur tracks is demonstrably incorrect". (Confidential Submission to EPA 2010: 12)

The Confidential Submission claims that the conclusion of Siversson's second report expresses a scepticism regarding the existence of dinosaur footprints that is unwarranted.

"[A] reader might suppose that there's no conclusive evidence [for dinosaur tracks] and that the existence of dinosaur tracks at James Price Point remains an open question." (Confidential Submission to EPA 2010: 13)

At the same time, the Confidential Submission notes that field conditions for studying the dinosaur footprints are extremely difficult.

"To reach certain dinosaur tracks one must wait for extreme low tide, and then walk out to the very edge of the shore platform, and sometimes even further, into the water." (Confidential Submission to EPA 2010: 8)

The Confidential Submission states that while the dinosaur footprints are plentiful *'closer to the beach'*, these prints tend to be more degraded and more difficult to identify. It is stated that the best tracks appear to be those which are ordinarily submerged except for extreme low tides, and subject to random exposure of coverage in relation to mobile sand, mud, and rock rubble in the intertidal zone.

The Confidential Submission (2010:3) reports three types of dinosaur footprints at James Price Point - therapod, sauropod, and ornithopod. Sauropod prints are the most common, and the report contends that their abundance means, *'they are likely to be disregarded or misidentified'* (Confidential Submission to EPA 2010: 16). It claims that some of the sauropod prints are in very good condition. The report

suggests that it is possible that the sauropod prints belong to more than one type of animal. There are also theropod prints, including one special track:

"Nearly all the theropod tracks appear to be examples of Megalosauropos, originally described (Colbert & Merrilees 1967) from Gantheaume Point and Riddell Beach, near Broome. However, there is also an unusual form of theropod track which, so far, has only been found at James Price Point. In some respects it resembles the 'classic' North American Ichnogenus Eubrontes: it's the track of a big robust therapod with thick fleshy toes and massive blade-like claws - something a good deal bigger and nastier than Megalosauropus…" Confidential Submission to EPA 2010: 16)

The third category of prints are small ornithopods, which the Confidential Submission says are *'unusually common in the area of James Price Point'* (2010: 16), as well as a few larger ornithopods.

The Confidential Submission makes the following claims for the importance of dinosaur tracks in the Broome sandstone at James Price Point:

- The Broome sandstone is Australia's only known location for sauropod tracks and the sauropod tracks at James Price Point are among the largest yet discovered;
- James Price Point is the location of the track of a very large therapod (resembling Eubrontes sp.) that has not been found elsewhere in the Broome sandstone;
- Small ornithopod tracks are common at James Price Point, but relatively rare at other sites in the Broome sandstone.

Although no actual locations are given, the Confidential Submission states that numerous dinosaur tracks which have not been reported by Siversson (2010a & b) are present at or near James Price Point.

"Figures 9-25 present a sample of the dinosaur tracks and other interesting features so far discovered at James Price Point. Most items are at the point itself; one is at a short distance to the north, and one of the sites illustrated is closer to the 'southern pipeline crossing' mentioned by Siversson. In addition a couple of items from sites elsewhere in the Broome Sandstone are used for purposes of comparison and explanation." (Confidential Submission to EPA 2010: 15).

1.1.10 Salisbury (2011a & b)

Queensland University palaeontologist Dr Steve Salisbury has been a recent participant in the James Price Point fossil debate, and so far his contributions have been informal - that is, comments in media reports and on internet websites. The following statement comes from a recent media release:

"The coastline of the Dampier Peninsula north of Broome in the west Kimberley preserves one the largest and most significant stretches of dinosaur footprints anywhere in the world. The dinosaur tracks occur in coastal exposure of the 130 million year old Broome Sandstone, over 80 km of coastline from Broome to Cape Leveque. There are literally thousands of tracks representing as many as 15 different types of dinosaurs, some of which there is no other record for in Australia. With the exception of a few fragments of bone, these tracks constitute the entire fossil record of dinosaurs in the western half of the Australian continent. Some of the sauropod tracks are up to 1.5m long, and belong to what may have been some of the largest animals to have ever walked the planet (Thulborn et al. 1994; Thulborn 2009).

The Kimberley dinosaur tracks are an important part of Australia's geological heritage, and should be included in the proposed National Heritage listing for the west Kimberley. A final decision on National Heritage listing for the west Kimberley is due before the end of the June 2011.

In 2008, the State Government of Western Australia announced a proposal to exploit natural gas resources of the Browse Basin by installing a pipe-line and gas-processing plant in the region of James Price Point, on the western coast of the Dampier Peninsula. A large number of petroleum companies hold interests in the many gas fields of the Browse Basin. These include Woodside, BP, Chevron, BHP Billiton and Shell. Dinosaur prints at James Price Point will be destroyed if the proposed LNG plant is allowed to go ahead (Siversson 2010). In addition, sand-dredging of channels and the construction of groynes, bulkheads and breakwater structures associated with the LNG plant will result in the re-distribution of sand by longshore currents, which may further impact on dinosaur tracks on other parts of the Dampier Peninsula coastline." (Salisbury 2011).

Salisbury has referred to recent fieldwork documenting sauropod prints and possible stegosaur prints between Broome and James Price Point, and his intention 'to get it published in a peer review journal as quickly as possible' (Weekend Australian Magazine 2011).

Steve Salisbury was interviewed by ABC PM on July 11, 2011, and provided further information on his discoveries at James Price Point:

STEPHEN LONG: In WA, its dinosaur fossils versus development. A palaeontologist has found more dinosaur footprints near James Price Point, north of Broome, where a major gas hub is to be developed. Dr Steve Salisbury, from the University of Queensland, is fighting to protect the prints, he says they're under threat from the gas development. The energy company Woodside started work at the site this week. But Dr Salisbury says the Federal Government should deny the project final approval, until a full assessment of his findings. He spoke to David Weber.

STEVE SALISBURY: I've just been looking at a few areas, there's obviously a lot of ground to cover up here, and nearly everywhere that I've been I've just been blown away by the quality of the prints that are here and the diversity and also the abundance, it's really spectacular. I should have some quite exciting information to share with everyone very soon.

DAVID WEBER: Have you found prints that have not been discovered before?

STEVE SALISBURY: Yes. This area, the rocks that the dinosaur prints are preserved in, they're in the intertidal zone, so I've been up here for the last week during the last week during the spring tides to take advantage of the extreme low tides. And we've been getting out on reefs that are only accessible during the lowest tides and yes, finding lots and lots of prints that haven't been seen before.

DAVID WEBER: How far are they from the gas hub site?

STEVE SALISBURY: There are prints right across that area, at James Price Point, where the gas hub is supposed to go.

DAVID WEBER: Are they where the gas hub site is? Where Woodside's been doing its clearing, presumably you didn't get to go there, or did you get there before the blockade was lifted?

STEVE SALISBURY: I've been inside that area, I was there before all the dramas happened at the blockade. And just been getting out every day, twice with each low tide, looking at stuff and there's just hundreds of prints out in these areas. It's really the spectacular the abundance and diversity.

DAVID WEBER: What types of dinosaurs?

STEVE SALISBURY: The places I've been, at least six different types of dinosaurs in that area, I've seen a few distinct types of sauropod footprints, few different types of ornithopods, the bipedal plant-eating dinosaurs, prints of armoured dinosaurs. The diversity is quite phenomenal.

DAVID WEBER: The Department of State Development has said that the two surveys, in 2009 and 2010 turned up what were not footprints, but depressions left beneath dinosaur tracks, what they describe as fossilised under-prints; could you just explain the difference?

STEVE SALISBURY: Well when a dinosaur leaves a footprint it obviously distorts the ground. So often, you know, sometimes the best case you'll get the footprint and you can see everything around it, but if erosion has occurred then the upper surface of the footprint might be gone and you'll just see the remnants of what was left underneath. So the distorted sediments and the, sort of, shockwaves that have gone through those. I mean I've seen trackways here where at one end, you've got a perfectly preserved footprint but the other end, a few footsteps into the trackway the footprints have deteriorated because they are on the edge of the rock platform or they've been covered in sand.

So really it's that whole coastal strip that should be considered one mega trackway site and that makes it really unique. I mean there's very few places where that's the case.

STEPHEN LONG: Dr Steve Salisbury speaking to David Weber."

The University of Queensland's Vertebrate Palaeontology and Biomechanics Lab website also features the Dampier Peninsula dinosaur tracks (UQ 2011). The "Lab Leader" is Dr Steve Salisbury. The "latest news and results" webpage focuses on "the fight to save dinosaur track-sites in the Kimberley, Western Australia".

"The coastline of the Dampier Peninsula north of Broome in the west Kimberley preserves one the largest and most significant stretches of dinosaur track-sites anywhere in the world. There are literally thousands of footprints and trackways representing as many as 15 different types of dinosaurs, some of which there is no other record for in Australia. With the exception of a few fragments of bone, these tracks constitute the entire fossil record of dinosaurs in the western half of the Australian continent. Some of the sauropod tracks are over 1.5m long, and belong to what may have been some of the largest animals to have ever walked the planet." (UQ 2011).

1.2 Palaeo-environmental Research

The only published record of plant fossils from the Broome sandstones is the summary by White (1959) of specimens collected by D. J. Guppy in 1948 from four locations and from “the lighthouse cliffs at Broome (presumably Gantheaume Point) by Dr. R.O. Brunnschweiler in 1949.

Brunnschweiler conducted a preliminary identification of the fossils he collected and White re-examined the collection and published a revised species list, together with some reference photos.

The Gantheaume Point plant fossils were identified as:
Bed B (top of cliff:
Ptilophyllum pectin (Lindley and Hutton)
Cladophlebis australis (Morris)
Otosamites cf. O. bengalensis (Oldham and Morris)Zamites sp.
Hausmannia sp.
Cycad stom (Bucklandia)

Bed A (bottom of cliff)
Nilsonnia cf. N. schaumbergensis Dunk
Dichopteris delicatula Schward
Walkom
? *Dictyophyllum sp.*
Cladophlebis cf. C. Albertsi (Dunkel)
Taeniopteris cf. T. howardensis Walkom
Nilsonnia sp.

The locations for the Guppy collections were recorded as:

1. Two miles north of Goldwyer Well, 24 miles (approx.. 38.4 km) south of Broome;
2. Cape Leveque;
3. Top of cliff section at Entrance Point, Roebuck Bay, Broome;
4. Top of Section at Hill A, 15 Miles (approx. 24 km) NW from Nillibubbaca Well, on Broome-Derby Road 67 miles (approx. 107.2 km) from Broome.

The Goldwyer Well specimens included *Taeniopteris cf. T. howardensis, Cladophlebis cf. C. Albertsi, Dichopteris delicatula, Pterophyllum sp*., *Sphenopteris cf. S. superba, Pterophyllum (Anomozamites)* or *Nilssonia cf. schaumbergensis. Ptilophyllum pectin, Dictyophyllum cf. davidi.*

The Cape Leveque collection had only one identifiable specimen, of *Cladophlebis Albertsi*.

The Entrance Point, Roebuck Bay specimen was identified as *Otozamites cf. bengalensis*.

The Hill A specimen was *Ptilophyllum pectin*.

1.3 Other Sources of Information

1.3.1 Roebuck Bay (Lambert and Elix (2004)

Lambert and Elix (2004) conducted a values mapping project for Roebuck Bay, just south of Broome, for the National Shorebird Conservation Project. The project extended beyond ecological values, and also considers other aspects, ranging from recreation and tourism to Aboriginal cultural heritage.

One of the people they consulted was hovercraft tour operator Roger Colless, who identified a dinosaur track site at Quarry Beach (Lambert and Elix 2004: viii). This is the main Red Cliffs site, at the end of Crab Creek Road.

1.3.2 The Internet

A wide range of internet sites refer to dinosaur fossils in the Broome Sandstone, sometimes accompanied by photos and location information. These entries include photo-sharing sites such as Web Shots and Flickr (e.g., “retronine” on Web Shots, “Mark Spark” on Flickr). The Australian Conservation Foundation website has photographs; so does St Mary’s College, Broome. There are also blog sites, such as Martin (2011). Where these internet sources include locations, they have been listed above in Table 1.

The Goolarabooloo (2011) website features cultural tourism tours run by the Roe family and the associated Lurujarri Dreaming Trail (Heritage Council of WA 1999), established by well-known Broome Aboriginal identity Paddy Roe (now deceased) in 1987. The tours are now run by his extended family, who called themselves the Goolarabooloo people. They are sometimes in conflict with the local Yawaru traditional owner group at Broome and the Jabirr Jabirr traditional owner group of the James Price Point area regarding issues related to traditional cultural authority along the west coast of the Dampier Peninsula, which has been exacerbated by Jabirr Jabirr and Kimberley Land Council agreement for the Browse LNG Precinct project, and Goolarabooloo/ Roe family opposition to the project. Both Tony Thulborn and Steve Salisbury have close associations with the Roe family and the current protest movement against the Browse project.

The Goolarabooloo (2011) web page *"The Song Cycle"* for the Lurujarri Trail Tours notes that the Ancestral Being "Marella", the emu man, left traces of his creation journey between Minyirr (Broome) and Dugul (Flat Rock, north of James Price Point) in the coastal rocks. His footprints (in his emu form) are the three-toed dinosaur prints, which resemble giant emu tracks (tridactyl prints). Botanical fossils which are identified by Salisbury (2011b) as "fossilised fronds from a cycad-like bennettatalean seed-fern" are regarded as the tail-feathers of Marella (Goolarabooloo 2011) - see Figure 15.

The Aboriginal cultural significance of emu-like therapod tracks from Gantheaume Point recorded by Glauert (1953) is a Yawaru legend, and different from the Goolarabooloo website/ Lurujarri Trail interpretation.

Figure 15: Seed-fern frond fossils interpreted by the Goolarabooloo as Ancestral Emu Being's tail feathers (Salisbury 2011b; Goolarabooloo 2011).

1.4 Kimberley National Heritage List Declaration

On 31st August 2011, Commonwealth Environment Minister Tony Burke announced the West Kimberley National Heritage List declaration, under the terms of the EPBC Act (1999) (see Commonwealth Gazette 2011). The area covered by the declaration is shown in Map 3-3 (SEWPaC 2011a). As shown on this map and the accompanying GIS spatial data included in the Commonwealth Gazette entry, the declaration includes the Broome Sandstone formation along the intertidal zone of the west coast of the Dampier Peninsula. The National Heritage values of this part of the West Kimberley National Heritage Listing are described in the Summary Fact Sheet as:

"Dinosaur footprints on the west coast of the Dampier Peninsula are a remarkable remnant of ancient life in the Kimberley. Vertebrate palaeontologists and trace fossil experts consider that the range of prints and trackways found along the Kimberley coast, together with their environmental settings, is internationally outstanding. Fossil human footprint sites have also been found and are significant for being one of only three documented human track sites in Australia and the only evidence of human tracks in the west coast of Australia". (SEWPaC 2011b).

The Commonwealth Gazette entry lists the Dampier coast dinosaur tracks under the NHL criterion: *'because of the place's possession of uncommon, rare or endangered aspects of Australia's natural and cultural history.'*

"Dampier Coast

The early Cretaceous Broome Sandstone of the Dampier Coast contains the only sauropod prints found in Australia – these are common in the discontinuous outcrops that stretch for up to 200 kilometres along the west coast of the Dampier Peninsula (Molnar 1991; Thulborn et al. 1994; Long 1998). With some hind foot tracks as long as 1.75 metres, the Dampier Coast tracks may be the world's largest sauropod prints. The world's smallest sauropod tracks have also been found here, indicating a

broader population sample than that of any other known sauropod track site. It preserves rare examples of the coexistence of sauropod and ornithopods.
The Dampier Coast is the only site with extensive evidence of western Australian dinosaurs and the large number of tracks provides an otherwise unobtainable census of dinosaur populations and communities. The Dampier Coast dinosaur tracks have outstanding heritage value to the nation under criterion (b) as the best and most extensive evidence of dinosaurs from the western half of the continent, some of which are unknown from body fossils; for the diversity and exceptional sizes of the sauropod prints; and the unique census of the dinosaur community that they provide." (Commonwealth Gazette 2011: 11).

The National Heritage values assessment also refers to palaeoenvironmental data associated with the Dinosaur trace fossils.

"As well as the tracks, sedimentological and palaeobotanical features of the Broome Sandstone allow the palaeoecology of the area during this time period to be reconstructed. Plant macrofossils from this unit were preliminarily described by White (1961) and were reviewed by McLaughlin (1996), though much work remains to be done (Thulborn 2009). The plant and sedimentological evidence allows reconstruction of the environments in which the dinosaurs found here lived and fed, providing a fuller palaeoecological picture of a suite of Cretaceous coastal environments. These range from lagoonal to fluvial/deltaic, with even an estuarine and a swamp/forest region. The dinosaur tracks that occur in each of these differ – the sauropods appear in most environments, though there are different morphological types of sauropod tracks in some. The theropods and larger ornithopods only occur occasionally in the lagoonal environment, the smaller theropods and sauropods not at all. In the more sheltered, forested environments the most diverse fauna is found (Thulborn et al. 1994). The Cretaceous landscapes that occurred here were buried intact and reveal original topography, with soils, leaf litter and even fossils of plants in their growth positions (roots can be seen descending into the substrate). Dinosaur tracks meander around these plants so that one may walk across these ancient landscapes following their paths through clumps of vegetation (Thulborn pers. comm. 2009). The Broome Sandstone coastal exposures of dinosaur tracks and associated fossils therefore tell an integrated story of the animals, plants and physical environment of this area during the Early Cretaceous period, approximately 132 million years ago." (AHC 2011: 163).

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Appendix 3 – Scope of work and work plan

Scope of Works and Survey Design:

Title: Field Survey of Paleontological Features of the James Price Point Coastal Area and other sites on the west coast of the Dampier Peninsula and Roebuck Bay

Overview

The Browse LNG (BLNG) Precinct is currently being assessed as a strategic proposal under State and Commonwealth legislation. The Department of State Development (DSD) is the proponent for the development. Following an extensive site selection process by the State Government, the Browse LNG Precinct location has been identified south of James Price Point on the Dampier Peninsula (approximately 60 km north of Broome).

In 2010, the Western Australian Museum, led by Dr Mikael Siversson, undertook two field surveys of dinosaur footprints in the James Price Point Area (see **Appendix 2** for summary). These studies found numerous degraded sauropod underprints on areas of Broome Sandstone exposed in the intertidal zone of the coastline. These were described as not of 'museum quality'.

A confidential public submission believed to be from a scientist specializing in dinosaur trackways (see **Appendix 2** for summary) reaches a different conclusion. This submission indicates that important fossils of dinosaur footprints and associated features exist in the area. Recent statements purportedly based on field surveys by a University of Queensland palaeontologist have supported this finding.

The intertidal zone between Roebuck Bay and Cape Leveque (excluding the area around Broome township) have recently been included in the National Heritage List for values associated with dinosaur tracks and associated fossil evidence (see **Appendix 2** for summary).

It is important to note that the National Heritage values are associated with the rarity of the suite of dinosaur tracks, and their palaeoecological context, and the insight they provide into dinosaur behaviour, ecology and interaction with the environment. Importance is not necessarily placed on whether prints are 'museum quality' or otherwise.

Recently, the WA Environmental Protection Authority (EPA) requested that the Proponent (DSD) for the Strategic Development undertake a further survey of paleontological features at James Price Point and surrounds to better resolve what potential impacts the proposed development would have upon the dinosaur tracks (see letter from EPA – **Appendix 1**). The overall objective of this field survey is to satisfy the requirements set out in that letter.

As much as practicable, the proposed survey needs to identify all potential fossil features within the Lower Cretaceous Broome Sandstone within the proposed BLNG Precinct footprint at James Price Point. In addition, the field survey should examine other locations on the Dampier Peninsula which are known or likely to have significant dinosaur trace fossils within the region.

The key objectives of the survey are to;

1. Document and geo-reference fossilised dinosaur footprints and other fossil features within the Browse LNG Precinct outline and the wider James Price Point Area, and other areas of the Dampier Peninsula; and,

2. Using data gathered under objective 1 and published and unpublished literature, place the paleontological features that may be impacted by the development into a local, regional, national and international context.

Location:

James Price Point is located 60 km north of Broome. The survey area encompasses all the intertidal areas of Broome Sandstone within the BLNG Precinct and adjacent areas near James Price Point (see Figure 1). In addition, areas outside the BLNG Precinct boundaries will be surveyed in order to provide a regional context. This will include survey at Roebuck Bay, Riddell Beach and Gantheaume Point near Broome and other sites that may be identified by local informants.

The survey strategy provided Table 1 below has been determined following comment received from the EPA and SEWPaC and analysis of high resolution aerial photography and near shore bathymetry by the field survey team comprising expert palaeontologists and geologists.

Field Methodology;

- Using spring low tides in late September/early October survey the paleontological features of the Broome Sandstone.

- Significant features will be be geo-referenced (using qualified surveyor/s or broader location descriptions should there be cultural restriction applied) and high resolution imagery (digital photographs) captured

- Features will be identified (interpreted) to the highest resolution possible

- Provide an account of the stratum within which each paleontological feature is located.

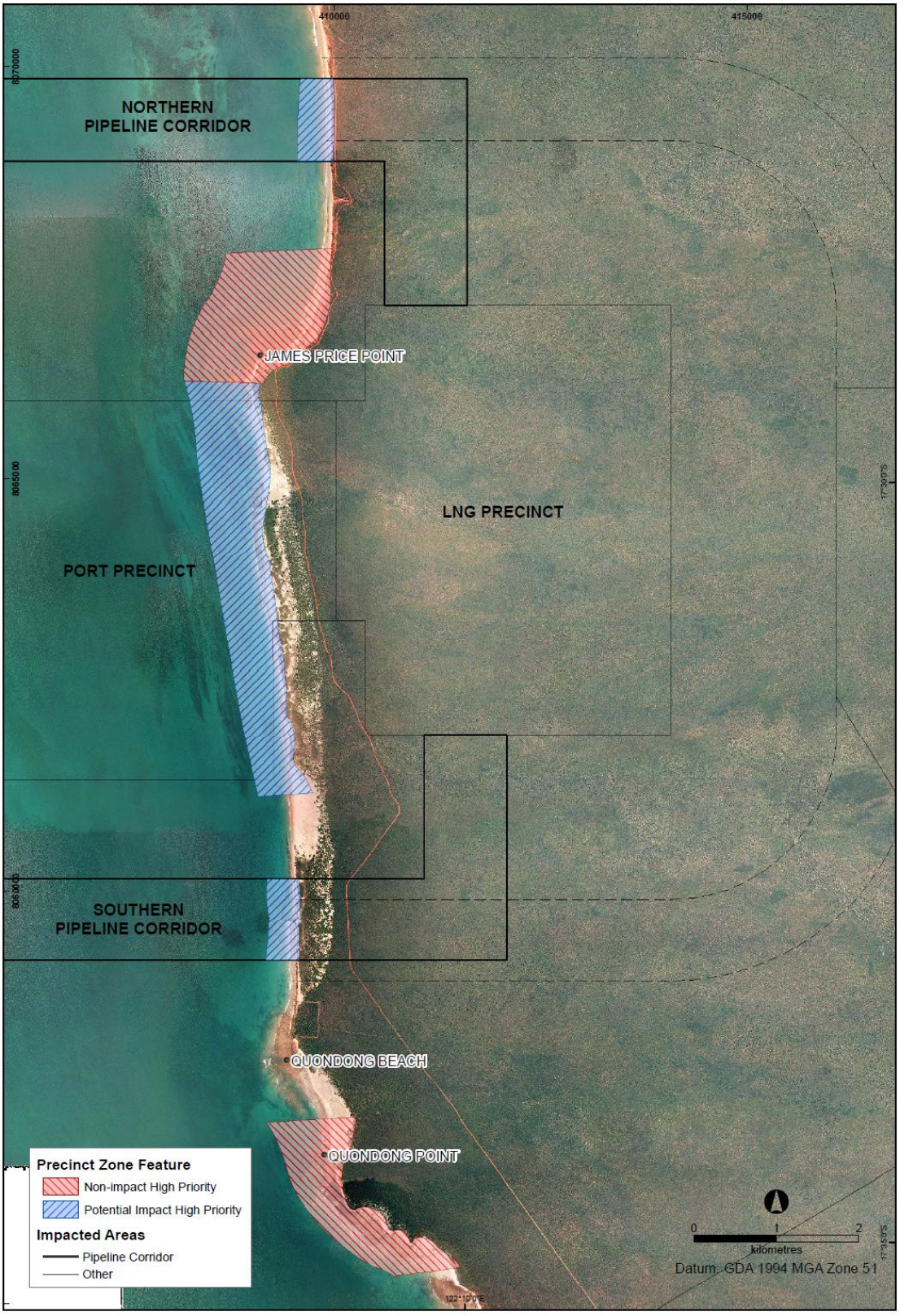
- Two teams will be established to ensure better and more rapid coverage of the selected areas. In most instances these teams will work in close proximity to allow expert consultation on interpretation of features. For further efficiency of coverage teams may sometimes go to different locations.

- Arrangements have been made for a palaeontologist (Steve Salisbury) and local Traditional Owners to guide the teams to areas where significant fossils have been reported which are believed to be at James Price Point. This will save a significant amount of time. Access to information on this knowledge prior to commencing the survey is also continuing to be sought.

- A local tourism operator with knowledge of the locations of features around Broome has also been engaged as a guide to save time in establishing regional context.

- It should be noted that a flexible and adaptive approach is required in this instance as there remain some uncertainties with regard to access to some sites. Accordingly the survey plan provided in Table 1 may be modified in order to maximize the input of the highly specialized skills available to the team. This may include conducting more detailed work in some areas than is anticipated in the survey plan such as more comprehensive cataloguing of sites in Roebuck bay which will help establish the Regional context.
- Consideration may be given to further field data collection between 12-15 October when there are reasonable tides should it be deemed necessary or practicable.

Figure 1 Proposed target areas for survey



- **Table 1 Palaeontological study field survey plan.**
-

Day	MON 26 Sept	TUES 28 Sept	WED 29 Sept	THURS 30 Sept	FRI 1 Oct	SAT 2 Oct	SUN 3 Oct	MON 4 Oct	TUES 5 Oct
Morning time/tide	**0347 2.55**	**0428 1.56**	**0506 0.76**	**0542 0.26**	**0617 0.12**	**0650 0.34**	**0723 0.90**	**0756 1.73**	**0831 2.72**
Evening time/tide	**1609 1.94**	**1646 1.26**	**1722 0.81**	**1756 0.63**	**1829 0.75**	**1900 1.14**	**1932 1.78**	**2003 2.62**	**2038 3.57**
Morning	**Team arrives**	**0930-1130hrs TO - ECHT meeting**	**0500hrs hovercraft Roebuck bay for regional Context DEC Yawuru Rangers 5:00 am to 9:00 am** **0900hrs media**	**JPP south pipeline crossing potential impact (Team 1)** **ML arrives 1220hrs – picked up by local surveyor and brought out to site**	**Joseph Roe/ Salisbury guides to sites at JPP – non-impact local and regional context** **(1)&(2) all day**	**Morning (1)&(2) JPP revisit as necessary and survey Quondong for local and regional context**	**Morning (1)&(2) or split JPP and flat rock (just north of JPP for local Regional context**	**am follow up high up areas – take senior TOs to accessible sites**	**No good tides** **Write up and any follow up meetings with ECHT or others**
Afternoon	**Field planning**	**Afternoon Local sites (Cable Beach? North) DEC Yawuru Rangers 2:00 pm to 5:30 pm**	**Afternoon Riddell Beach, Town Beach and Gantheaume for Regional context DEC Yawuru Rangers 2:00 pm to 5:30**	**Port construction impact crossing and Northern pipeline crossing JPP (team 1 & 2)**	**Joseph Roe/ Salisbury guides to sites at JPP– non-impact local and regional context (1)&(2) all day**	**Afternoon free (bad tides)**	**Afternoon free (v bad tides)**		**Write up and depart evening flight for Perth**

Team Members and Roles:

International expert Palaeontologists (2) – Chief investigators, catalogue key paleontological features, places these features in local, regional, national and international context. Primary authors for reports.

Field survey geologist with local/regional experience (1) – provide expert input into the field survey and report

Field survey geomorphologist with local/regional experience (1) – provide expert input into the field survey and report

Field Surveyors (2): Using DGPS, catalogue and geo-reference significant paleontological features as appropriate (see Appendix 1).

Traditional Owner Representatives (2) – to ensure the survey does not impact on any cultural heritage values.

Team Coordinator (1) – DSD officer to manage and support the teams

Independent Peer Review

The EPA have requested that there be an independent peer review of the survey design with the peer reviewer's comments addressed and incorporated into the design as appropriate prior to the start of the survey. The peer reviewer's comments will be made available directly to the EPA and DSEWPaC.

The same peer reviewer will also review two survey reports. One of these will include geo-referencing of features for the EPA and DSEWPaC and the other, for public release, will exclude precise location information. It is the job of the peer reviewer to ensure they are identical except for the exclusion of location information. Reviewer's comments on these reports are to be addressed and incorporated as appropriate into the final report.

The peer reviewer is to provide a close out statement to verify whether the final reports have appropriately dealt with the reviewers previous comments. Peer reviewer comments and close out statements will be made publicly available, excluding any precise location information.

Assumptions

DSD will;

- provide field logistics (flights, vehicles, field support, communications)
- contract the sedimentologist/geologist, field surveyors and traditional owners separately
- organize pre-departure briefings with EPA and Mikael Siversson
- organize and liaise with the independent peer-reviewer/s.
- provide high resolution aerial images of the survey areas

- produce any spatial maps required for the reports

Office of the Environment Protection Authority (and possibly SEWPaC) will participate in the briefings and field surveys and will receive copies of all independent peer reviewer's reports.

Inputs (provided to Team):

- High resolution map of survey area (8 cm resolution) including indicative infrastructure location where there are likely to be direct or indirect impacts to the coastal zone
- List of known reports and papers, including copies of Siversson reports and confidential public submission
- GPS locations of previous identified features
- Confidential report prepared for DSD which documents formal and informal knowledge of Dampier Peninsula dinosaur footprints and trackways to support the assessment of regional significance

Outputs (Deliverables) to be provided:

1. Scope of Works ensuring the objectives and procedures in the EPA letter (attached) are met (using this document as a guide);

2. Field Report which includes;
- Areas surveyed, including precise description of areas covered/not covered, conditions at the time and methodological approach
- Preliminary overview of results
- Issues encountered
- High level thoughts on any likely key findings

3. Draft Final Report which includes;
- Introduction;
    - Brief summary of the scientific work undertaken to date on paleontological features of the coastal area of the Dampier Peninsula
    - Outline the objectives of study
- Methodology, including descriptions of areas covered/not covered, conditions at the time and methodological approach
- Results
    - What features were found and sample images to indicate the range of features recorded.

- Discuss the spatial distribution of features recorded, noting particularly what was found within and outside the Precinct outline.
- Use diagrams to provide an assessment of track-ways (if any).
- Using an Appendix, provide geo-referenced maps locating each feature recorded with an overlay of the precinct outline and the image catalogue. Each image should have a clear label describing it. *(please note this Appendix will not be made public to avoid the possibility that material may be unlawfully damaged or stolen)*

- Discussion;
  - Discuss the results and place them in a local, regional, national and international context

4. Final Report

- Both the SoW and Draft Report will be reviewed by an independent expert/s. The Final Report should incorporate the comments and suggestions of the reviewer/s.

The schedule for the survey:

Timelines:

Date	Activity/ Deliverable
September 20th – September 25th	Mobilisation, briefings and scope preparation - Perth – Rich McCrea
September 26th – September 28th	Briefings, preparation and survey – Broome – Rich McCrea, Martin Lockley arrives 28th
September 29th - October 3rd	Field Survey and development of field report
October 4th	Morning - briefing to Traditional Owners Return to Perth
October 5th	Field Report presented
October 6th	Briefing and presentation to EPA Report drafting
October 7th	Martin Lockley departs for China
October 7 to 11	Report drafting
October 11	Draft report sent to peer reviewer McCrea available for discussions/questions form peer reviewer, support in developing management plan for footprints/trackways that may be impacted.
October 14	Rich McCrea departs
October 18	Peer review comments received
October 25 (7 days after receiving peer review comments)	Final reports provided to EPA

Appendix 1:

Spatial Datum Requirements

DGPS system capable of precision: Horizontal (2 sigma) +/- 1m, Vertical (2 sigma) +/- 1m, and the contractor should demonstrate that their proposed positioning method will meet the accuracy requirements specified. The spatial data should be GMS-900 standard.

Geodesy & Coordinate System (GMS –900)

DATUM

Name:	Geocentric Datum of Australia 1994 (GDA 94)
Reference Frame:	ITRF92 (International Terrestrial Reference Frame 1992)
Epoch:	1994.0
Ellipsoid:	GRS80
Semi-major axis (a)	6,378,137.0 metres
Inverse flattening (1/f)	298.257222101

GRID PARAMETERS (Downstream)

The Landgate project grid BRO94, which is a local Transverse Mercator projection, shall be used for all 'Downstream' infrastructure at James Price Point.

The area of validity for the BRO94 project grid has been extended to the west and north by Landgate, at the request of WEL. The extension has resulted in a restriction on the use of the BRO94 Grid to areas where the topographic height is less than 130m AHD.

This restriction is imposed on the use of the grid as the accuracy deteriorates to greater than 20ppm in the areas above 130m AHD.

Grid Name:	BRO94
Datum:	Geocentric Datum of Australia 1994 (GDA94)
Projection:	Transverse Mercator (TM)
Central Meridian:	122° 20' 00" East
Central Scale Factor:	1.00000298
False Easting:	50,000.0m
False Northing:	2,200,000.0m
Extent NW Corner:	16° 45' 00" South 122° 05' 00" East
Extent SW Corner:	18° 05' 00" South 122° 37' 00" East
Height Limit:	Less than 130m AHD

Vertical Datum

All heights onshore shall be referenced to the Australian Height Datum (AHD).

Delivery of spatial data in ArcGIS format (Shapefile or geodatabase) with relevant ISO standard Metadata.

Appendix 4 – Detailed and site specific geo-referenced findings (on disc only and excluded from publicly available document)

Appendix 5 – Peer review comments and close out letters

Peer review comments on initial Scope of Works (anonymous)

Peer Review of Scope of Works for "Field Survey of Paleontological Features of the James Price Point Coastal Area and other sites on the west coast of the Dampier Peninsula"

I have read in detail the EPA request to the DSD, the original and SEWPaC-edited versions of the DSD's Scope of Works, and the commissioned reports produced by Mikael Siversson and Australian Cultural Heritage Management. In addition, I have read the Confidential Submission to the EPA on the Broome Trackways, as well as a range of media articles. I therefore feel able to offer the following comments, first of a general contextual nature and second with particular reference to the planned field survey.

The Siversson reports assess the palaeontological significance of the James Price Point Area against that of the surrounding region. The Confidential Submission draws the results and conclusions of the Siversson analysis into question, suggesting that the brevity of the survey, prevailing tidal and other conditions and limited expertise in dinosaur trackway analysis were constraining factors. It may also have been helpful if the information yielded by palaeontological surveys of the region, including the James Price Point Area, over the past two decades had been the subject of more than one preliminary scientific paper (Thulborn et al. 1994) and a series of "patchy and essentially anecdotal and informal reports" (ACHM 2011, p. 47).

Siversson places some considerable emphasis on the poor "museum quality" of footprints in the James Price Point Area, which presumably alludes primarily to their potential as public display items within a museum gallery rather than their scientific significance per se. The Confidential Submission and West Kimberley National Heritage Listing document clearly discuss the broad kinds of scientific information that might be garnered from analyses of all trackways *in situ* and associated geological and other palaeontological features. These extend well beyond museum display value and can only be assessed via a major survey of the area from non-aligned, expert dinosaur trackway specialists. Their scientific value out of field context (e.g., if salvaged) would be greatly diminished. Comments in the Confidential Submission about the fate of dinosaur footprints in museums are sadly rather accurate in my experience due to the severe constraints on space and other resources from which many museums suffer.

Overall, the aims and outline of the survey laid out in the DSD Scope of Works are consistent with the EPA's request, and I agree that it is essential that every effort be made to survey as much of the Broome Sandstone lying outside of the Browse LNG Precinct as possible. There is simply no other way to garner an adequate perspective on the comparative significance of this area. However, I seriously question whether four days are enough to achieve either a detailed survey of the James Price Point Area or the surrounding 100 km or so of coastline. If Salisbury was prepared to make his findings confidentially available to Lockley and McCrea to facilitate their rapid

location and assessment of key sites, this would expedite the process considerably. Salisbury's efforts to get his results published in a peer-reviewed scientific journal would not then be compromised as it would were his findings to be made publicly available beforehand. Still, if the trackways are as extensive and diverse as Salisbury and Thulborn suggest then Lockley and McCrea will have their work cut out for them, even if are not forced to begin their survey from scratch.

I recommend, if it were possible, extending the field survey to seven days, splitting the team into two, one led by Lockley and the other by McCrea, with a surveyor and geologist in each. They could then meet at the end of each day and compare notes, interpretations, etc. With such a large area to cover more eyes on the ground would be greatly beneficial. It would be particularly useful if these field assistants had some experience in identifying fossil footprints, or at the very least a good natural history knowledge, powers of observation and an ability to learn quickly from Lockley and McCrea. If necessary I may be able to suggest some suitably qualified personnel.
I acknowledge that the overall timeframe is tight and that it is now a bit late in the piece to go modifying the schedule in any major way. I also acknowledge that debriefings, presentations and report writing are essential to the process. However, I also believe that the magnitude of the field exercise has been substantially underestimated and that this means there is a real risk that the major overarching objective of the Scope of Works will be incompletely met.

One final point: I recommend that the Scope of Works be modified to state that while location data will not be made publicly available they will be available for suitably qualified and affiliated professionals for future examination and research. Scientific research must be repeatable, verifiable and refutable.

Please contact me if you require further input or clarification of comments in my report.

Peer review comments on draft Report (anonymous)

Received 8 November 2011

Peer review of "Palaeontology Survey of the Broome Sandstone - Browse LNG Precinct Report"

The survey team has done a comprehensive job of responding to the specific requests outlined in the EPA / DSD Scope of Works. It also effectively addressed the two main concerns raised in my initial review, viz. 1) The time period for the field survey was lengthened; 2) Steve Salisbury was enlisted as an advisor.

Given time and other logistic constraints the assessment of the geological context of the trackway assemblage is as detailed as one could reasonably expect. The report makes a number of interesting and unique observations concerning the likely palaeoenvironment and highlights ways forward for future investigations of the locality. It clearly details similarities and differences in the geology between the key areas.

The survey of dinosaur trackways, while preliminary, is impressive in light of the 11-day timeframe for the fieldwork. That the team was able to relocate, document and provisionally identify known tracks in addition to finding numerous new trackways is commendable. The team also provides an effective comparison between the key areas within and immediately outside of the proposed LNG Precinct. It confirms beyond reasonable doubt that in the James Price Point vicinity, most especially the Port Precinct Area, there is a diverse array of well-preserved dinosaur trackways of international importance, although the full significance cannot be appreciated until more comprehensive surveys and analyses are undertaken. The series of recommendations, most especially in relation to mitigation of industrial activity, seem fair and appropriate.

The survey team worked closely with a number of local indigenous groups as part of their assessment of the dinosaur trackways. However, there was no clear evidence in the report of its having directly addressed the EPA request to "include, where possible, incorporation of local indigenous knowledge of dinosaur footprints".

Received 10 November 2011

Close-out Statement Re Query Raised in Peer Review of "Palaeontology Survey of the Broome Sandstone - Browse LNG Precinct Report"

In my peer review I observed that there was "no clear evidence in the report of its having directly addressed the EPA request to "include, where possible, incorporation of local indigenous knowledge of dinosaur footprints"". The report has now been satisfactorily amended to note that this objective was met.

Peer review comments on "Palaeontology Survey of the Broome Sandstone – Browse LNG Precinct Report"

James O. Farlow, Department of Geosciences, Indiana-Purdue University, 2101 East Coliseum Boulevard, Fort Wayne, Indiana 46805 USA; farlow@ipfw.edu

My understanding of my primary task is that I comment on how well the draft report has satisfied the Scope of Works and Survey Plan. Beyond that, I am free to offer my own suggestions for improving the final version of the report, and perhaps to make my own recommendations for long-term study and management of the palaeontology resources specifically in the vicinity of the area affected by the proposed Browse Basin LNG Project (the James Price Point), but also more broadly in the entire region of outcrop of the Broome Sandstone along the west Kimberley coast of Western Australia.

Evaluation of how well the draft report satisfies the Scope of Works and Survey Plan.

First, a general comment: I am **very** impressed by the quality of work that McCrea, Lockley, and others accomplished, on a very tight schedule, under trying field conditions. The document is well written and well illustrated (the 3D anaglyphs are a particularly nice touch), and provides a professional reviewer like myself ample information for evaluation. Because my area of expertise in connection with this report is largely limited to interpretation of the dinosaur tracks, I will mainly comment on the work done by Richard McCrea and Martin Lockley, but I am equally impressed by the work done by the other team participants who contributed to the writing of the draft report.

McCrea and Lockley were tasked with assessing the "rarity of the suite of dinosaur tracks, and their palaeoecological context, and the insight they provide into dinosaur behavior, ecology and interaction with the environment." In addition, they were asked to "better resolve what potential impacts the proposed development would have upon the dinosaur tracks." To accomplish these tasks, they were instructed to "identify all potential fossil features within the Lower Cretaceous Broome Sandstone within the proposed BLNG Precinct footprint at James Price Point" and to "examine other locations on the Dampier Peninsula which are known or likely to have significant dinosaur trace fossils."

A peer reviewer who commented on the initial Scope of Works recommended (Appendix 5, p. 114 of the draft report) that the field survey schedule extend for an entire week. Judging from Table 2 (p. 16), the field surveys came close to following this recommendation, and would easily have done except for interference from protesters. Despite the tight schedule, a broad-brush palaeoenvironmental reconstruction of Broome Sandstone habitats was made (Section 3.1 of the draft report), and a

qualitative assessment of the dinosaur ichnofauna was made (Section 3.2). Dinosaur tracks indeed are widely distributed between James Price Point and Red Cliffs (including the northern portion of the Point Precinct and to a lesser extent the South Pipeline Corridor, but apparently not the North Pipeline Corridor, these being the areas of concern as potential direct impact zones of the Browse LNG project).

Overall, the Broome Sandstone exposures record a remarkably diverse dinosaur ichnofauna, and constitute the only record of dinosaurs in the region. Their potential for ichnological research has thus far barely been tapped. Although the quality of preservation of individual footprints and trackways is highly variable, the sheer quantity of prints over a distance of 50+ km would permit statistical analyses of trackway occurrences at a scale seldom possible. Even poorly preserved prints can be useful for census purposes and for analyzing foot/sediment interactions, a research area of considerable interest among dinosaur ichnologists.

As I understand it, part of my task as peer reviewer of this report is to ensure that the EPA / DSEWPaC and public reports are identical, except that precise location data are not to be included in the latter report. Comparison of Appendix 4 with pages 40-46 allow me to affirm that this condition has been met.

Comments on recommendations of the draft report.

These (Section 4.6) are very appropriate and judicious. The Broome Sandstone dinosaur tracksites deserve thorough documentation, building upon the previous work of Tony Thulborn and Steven Salisbury, and—I would recommend,—involving them, if possible, and presumably McCrea and Lockley, in this endeavor. Removing some of the better or more interesting track specimens, and making high-fidelity casts of others, for a (local?) museum collection, would be of considerable importance. If it is possible to install permanent markers at selected occurrences that can withstand the pounding of surf and storm, and be relocated if buried by shifting sediments, it would be advisable to get some notion of how long particular tracksites survive, once they are exposed.

The draft report recommends that mitigation of economic activities in the Zones of Direct Impact target the northern 900 m section of the Port Precinct. The North and South Pipeline Corridors are considered less significant targets for mitigation. I concur.

In addition to these recommendations of the report, I would also suggest that an appropriate agency be given the task of creating an updatable database of track occurrences. Such a database could be used to combine historic maps, photographs, and other documentation with modern geographic information system locality information, digital photographs, and other records (insofar as this could be accomplished without offending local sensibilities).

Suggestions for improving the draft report.

Although the draft report is very well put together, despite the time constraints in its creation, there are a few points that I would like for McCrea and Lockley to consider as they prepare the final draft. These will be addressed in the order in which they appear in the draft report. I mention these for whatever they are worth. I have only seen pictures of the Broome footprints, not the tracks themselves, and so my interpretations based on those illustrations could be faulty.

1) Figures 19-30 (pp. 31-39): I recommend that, in all of these photos and line drawings of representative tracks, WHICH site they come from, and which footprint they are, be identified in the figure captions or on the figures themselves—unless this would create security problems for the safety of the tracks. Such labeling is done in portions of Figure 19, and I think it a good idea.
2) Figure 21 (p. 33): Is this the footprint that you meant to show here? The caption identifies this as a large theropod print, identified as *Irenesauripus acutus*. However, to my eye it looks less like that ichnotaxon than like the print illustrated in panel G of Figure 19 (p. 31), labeled GSWA, and presumably assigned to *Megalosauropus broomensis*. Furthermore, the illustrated print is not very big—maybe about 37 cm long? Rather smaller than the 50 cm said to characterize large theropod prints from the Broome Sandstone. (Also, note that in Table 6 the large theropod print in Figure 21 is said to be cf. *Megalosauripus*, so whatever it is called needs to be consistent between Figure 21 and Table 6). To me the print in Figure 21 looks a great deal like *Ornithomimipus*, although it seems to be larger than the latter.
3) The sauropod trackway illustrated in Figure 25 (p. 35) is certainly wide gauge, and is assigned to *Brontopodus* (p. 50). I am a little uneasy with this. It does seem as though the name *Brontopodus* has become the default name for wide-gauge sauropod trackways, but I don't see much in the morphology of the individual prints that reminds me strongly of *Brontopodus*, as it occurs in the Glen Rose Formation of Texas, as opposed to other sauropod ichnotaxa. So if it were me, I would call the Broome trackway wide gauge, and leave it at that.
4) Thyreophoran prints (pp. 37-39, Figures 28-29): Did you observe any five-toed manus prints that clearly were part of the same trackway as four-toed pes prints? If so, I would say so explicitly. That would greatly increase confidence in the assignment of the

prints to ankylosaurs. The photo reproduced from Long (p. 69 of the report) suggests that such associations do exist.

5) I take minor exception to the statement (p. 50) that "Based on size the [ornithopod] tracks are likely attributed to *Iguanodon*-sized dinosaurs typical of the Lower Cretaceous: i.e. we observed no very large hadrosaur-like ornithopod tracks characteristic of the Upper Cretaceous were found" (sic—delete the last two words, if you do use this phrase). In fact, *Iguanodon* is a pretty big ornithopod, even if it didn't get as big as the largest hadrosaurids, and many specimens of Late Cretaceous hadrosaurids aren't any bigger than *Iguanodon*. My Figure 1 (below) compares a proxy for footprint length, the aggregate length of the pedal phalanges of the middle toe (digit III), of specimens of *Iguanodon* (mostly from Bernissart, Belgium) with those of several species of hadrosaurids from the Late Cretaceous of western North America. If anything, *Iguanodon* averages larger than the hadrosaurids. So you might argue that Broome ornithopod tracks are more likely to have been made by basal iguanodontians on the basis of stratigraphic occurrence, but I wouldn't try to make the case on the basis of print size.
6) There actually have been two or more dinosaur ichnotaxa named for Glen Rose Formation, not one (Table 7, p. 53). Ellis W. Shuler created two names for the tridactyl prints (the validity of which is at present uncertain), the type specimen for one of which still exists (although it has been badly treated). And of course there is the type specimen of *Brontopodus birdi*. I can cite references for these, but McCrea and Lockley will be familiar with them.

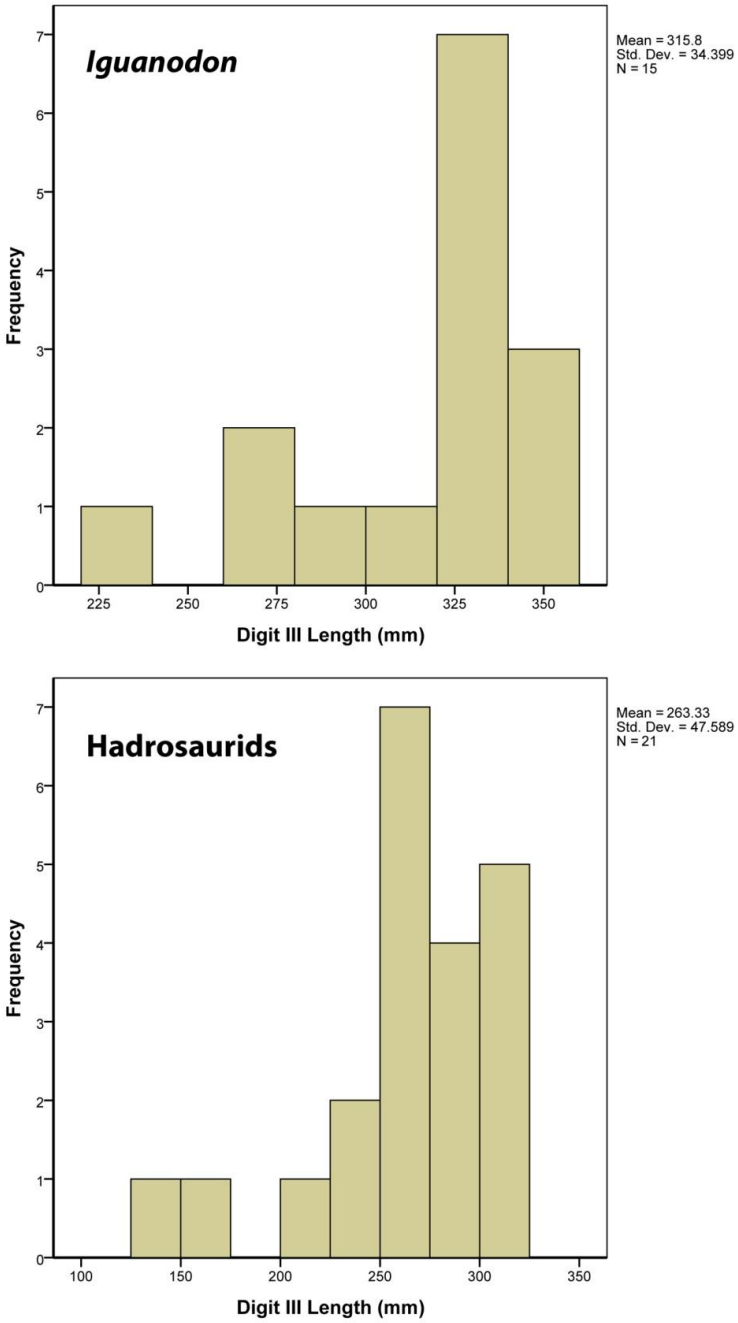


Figure 1. Comparison of the size of a proxy for footprint length, the aggregate length of the four toe bones (phalanges) of the middle toe (digit) III in:
Top panel: *Iguanodon* (mostly *Iguanodon bernissartensis*)
Bottom panel: Various hadrosaurids (*Brachylophosaurus*, *Edmontosaurus*, *Gryposaurus*, *Prosaurolophus*, *Corythosaurus*, *Lambeosaurus*, *Hypacrosaurus*) from the Late Cretaceous of western North America
Data from my unpublished research

Final close out statement from James Farlow following receipt of revised version.

(Note subsequent to this close out statement the caption to Figure 21 was changed to Medium theropod track and consequential amendments were also made in accord with the suggestions below)

-----Original Message-----
From: James Farlow [mailto:farlow@ipfw.edu]
Sent: Thursday, 10 November 2011 10:43 PM
To: BALDWIN, Peter
Cc: rtmccrea@prprc.com
Subject: RE: draft peer review

I think that all of the points I raised have been addressed, with one possible exception:

The caption to Figure 21 (p. 28) identifies the illustrated footprint as being a "large theropod track", but compare the size of this print, relative to its scale, with that of the "medium theropod print" in Figure 22, relative to its scale: Is the print illustrated in Figure 21 in fact bigger than the one illustrated in figure 22?

Both prints are now identified as being _Megalosauropus broomensis_, with which identification I have no quarrel. But in table 6 on page 45, "large" theropod prints from Broome are assigned to _Megalosauripus_, and on p. 46 "large" theropod prints are characterized as being 50 cm or more in length.

So to my mind there is a discrepancy between what is illustrated in Figure 21 and the material on pp. 45 and 46, which is why I asked in my earlier review if the wrong footprint was being illustrated in Figure 21. _Megalosauropus broomensis_ is said by McCrea & Lockley in Table 6 to be a MEDIUM-sized theropod print, NOT a large theropod print, and I don't think the print presently illustrated in Figure 21 would be 50 cm or more in length. So did the authors intend to illustrate a different, presumably bigger, footprint in Figure 21, but mistakenly insert the one that is presently illustrated?

Apart from that I am satisfied with the revised report.

To save time I am CCing this to Rich McCrea.