

# Dosariyah

## Reinvestigating a Neolithic coastal community in eastern Arabia

edited by

Philipp Drechsler







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# List of Contributors

*Hilmar Adler*

Institute of Physical and Theoretical Chemistry, Division of Condensed Matter, University of Tübingen, Tübingen, Germany

*Paolo G. Albano*

Department of Paleontology, University of Vienna, Vienna, Austria

*Simon Armitage*

Department of Geography, Royal Holloway, University of London, Egham, UK; SSF Centre for Early Sapiens Behavior (SapienCe), University of Bergen, Norway

*Christoph Berthold*

Applied Mineralogy, Department of Geosciences, University of Tübingen, Tübingen, Germany; Competence Centre Archeometry, Baden-Württemberg (CCA-BW), Germany

*Thomas Chassé*

Institute of Physical and Theoretical Chemistry, Division of Condensed Matter, University of Tübingen, Tübingen, Germany

*Philipp Drechsler*

Institute of Pre- & Protohistory and Medieval Archeology, Early Prehistory and Quaternary Ecology, Department of Geosciences, University of Tübingen, Tübingen, Germany

*Max Engel*

Institute of Geography, University of Cologne, Cologne, Germany

*Georg Häußler*

Institute of Pre- & Protohistory and Medieval Archeology, Early Prehistory and Quaternary Ecology, Department of Geosciences, University of Tübingen, Tübingen, Germany; ArchaeoTask GdR, Engen-Welschingen, Germany

*Shumon Hussein*

Department of World Archeology, Leiden University, Leiden, Netherlands

*Christine Kainert*

Institute of Ancient Near Eastern Archeology, Free University of Berlin, Berlin, Germany

*Steven Karacic*

Department of Classics, Florida State University, Tallahassee, FL, USA

*Corina Knipper*

Curt Engelhorn Centre Archeometry gGmbH, Mannheim, Germany

*Felix Levenson*

Institute of Ancient Near Eastern Archeology, Free University of Berlin, Berlin, Germany

*Bertrand Ligouis*

Institute for Archeological Sciences, Department of Geosciences, University of Tübingen, Tübingen, Germany

*Peter Magee*

Department of Classical and Near Eastern Archeology, Bryn Mawr College, Bryn Mawr, PA, USA

*Michael Maus*

Department of Applied and Analytical Paleontology, Institute of Geosciences, University of Mainz, Mainz, Germany

*Susan M. Mentzer*

Institute for Archeological Sciences, Department of Geosciences, University of Tübingen, Tübingen, Germany;  
Competence Centre Archeometry, Baden-Württemberg (CCA-BW), Germany; The School of Anthropology,  
University of Arizona, Tucson, AZ, USA

*Christopher E. Miller*

Institute for Archeological Sciences, Department of Geosciences, University of Tübingen, Tübingen, Germany;  
Senckenberg Centre for Human Evolution and Paleoenvironment, Frankfurt a. M. and Tübingen, Germany

*Mike W. Morley*

Centre for Archaeological Science, University of Wollongong, Wollongong, Australia

*James Nebelsick*

Department of Geosciences, University of Tübingen, Tübingen, Germany

*Adrian G. Parker*

Human Origins and Palaeoenvironments Research Group, Department of Social Sciences, Oxford Brookes University,  
Oxford, UK

*Ash Parton*

Human Origins and Palaeoenvironments Research Group, Department of Social Sciences, Oxford Brookes University,  
Oxford, UK; Mansfield College, University of Oxford, Oxford, UK

*Martin Posselt*

Posselt & Zickgraf GdR, Mühlthal/Traisa, Germany

*Gareth W. Preston*

Human Origins and Palaeoenvironments Research Group, Department of Social Sciences, Oxford Brookes University,  
UK

*Hannah Russ*

Northern Archaeological Associates, Barnard Castle, County Durham, UK; Faculty of Humanities and Performing  
Arts, University of Wales Trinity Saint David, Ceredigion, UK

*Markus Seil*

Institute for Archeological Sciences, Department of Geosciences, University of Tübingen, Tübingen, Germany

*Hans-Peter Uerpmann*

Institute of Pre- & Protohistory and Medieval Archeology, Early Prehistory and Quaternary Ecology, Department of  
Geosciences, University of Tübingen, Tübingen, Germany

*Margarethe Uerpmann*

Institute of Pre- & Protohistory and Medieval Archeology, Early Prehistory and Quaternary Ecology, Department of  
Geosciences, University of Tübingen, Tübingen, Germany

*Thomas Van de Velde*

Department of Archeology, Ghent University, Ghent, Belgium

## Abstract

Re-investigations at Dosariyah, located in the Eastern Province of Saudi Arabia, took place between 2010 and 2014. They were carried out by the joint German-Saudi Dosariyah Archeological Research Project (DARP). During excavations at different parts of the shallow hill that forms the site, a wealth of material remains was found within almost three metres of anthropogenic deposits. Both radiocarbon dates and comparative studies of artefacts securely date the occupation to the first centuries of the fifth millennium BC. Investigations at the site were supplemented by geomorphological studies and an archeological survey.

The spectrum of material remains excavated at Dosariyah shows unique characteristics. The lithic industry is technologically- and typologically-rooted in the local Arabian Middle Neolithic. Reminiscent of the Arabian Bifacial Tradition (ABT) are bifacially-shaped winged and stemmed arrowheads and bifacial foliates. The poorly-developed primary production is oriented towards the manufacture of flakes although natural pieces of shatter were often used as tool blanks. Production waste proves flint-knapping activities at the site. Likewise, most personal adornment was manufactured in the local tradition. In contrast, large amounts of Black-on-Buff pottery find their closest parallels at Ubaid period settlements in southern Mesopotamia. Other elements of material culture that originate in this cultural sphere are fired-clay objects, shaped bitumen and obsidian artefacts. The absence of related production waste, however, qualifies these objects as imports. Unexplained remains the origin of the Coarse Ware. While evidence for local production at Dosariyah itself is absent, the incised decoration found on one single Coarse Ware vessel is clearly distinct from decorative styles known from southern Mesopotamia.

The mechanisms behind the distribution of foreign materials along the Arabian Gulf coast are still poorly understood. The assumption that Arabian societies were less developed in comparison to societies in Mesopotamia led to the unjustifiable view that foreign traders coming from the upper Gulf were responsible for the appearance of foreign objects in the central Gulf area and beyond. However, the exploitation of marine resources always played a major role for local populations settled along the coasts of the Arabian peninsula. Further, the spectrum of fish remains discovered at Dosariyah includes species that demonstrate the capability for off-shore fishing, while excavations failed to unearth convincing evidence for the presence of Mesopotamian seafarers. It is therefore the central proposition of this book that the local societies living along the shores of the Arabian Gulf coast played an active role in the acquisition of Ubaid pottery and other objects.

In addition to the hunting of a broad spectrum of wild animals and the herding of sheep, goat and cattle, fishing and the gathering of shellfish formed the basis of the diet of the population settled at Dosariyah. Such a broad subsistence base can serve as a protection against environmental crisis, but it also helps to satisfy higher demands for food during short periods of time. As indications for fluctuating occupation densities were likewise observed during excavations, gatherings from time to time of larger groups of people at Dosariyah are plausible.

A predominance of imported objects, considered as 'exotic items', can therewith be understood as integral components of rituals that were part of these gatherings. Based on the material evidence from Dosariyah, such collective social events were embedded in everyday life during the fifth millennium BC.

# Zusammenfassung

Zwischen 2010 und 2014 wurden in Dosariyah, einer an der Küste des Arabischen Golfes in der Eastern Province in Saudi-Arabien gelegenen Fundstelle, neue Forschungen durch das deutsch-saudische Dosariyah Archeological Research Project (DARP) durchgeführt. Während der Ausgrabungen konnte in unterschiedlichen Bereichen der Fundstelle ein breites Spektrum an Funden innerhalb einer bis zu drei Meter mächtigen stratigraphischen Abfolge anthropogener Sedimente dokumentiert werden. Das Alter der Besiedlung wurde sowohl radiometrisch als auch durch vergleichende Artefaktstudien in die ersten Jahrhunderte des 5. Jahrtausends v. Chr. datiert. Ergänzt wurden die Ausgrabungen durch lokale geomorphologische Untersuchungen und einen archäologischen Survey.

Das Spektrum der materiellen Hinterlassenschaften in Dosariyah weist eine Reihe von Besonderheiten auf. Technologische und typologische Charakteristika des Steinartefaktinventars finden ihre Parallelen im Arabischen Mittelneolithikum. Insbesondere bifazial geschlagene, gestielte und geflügelte Pfeilspitzen sowie bifaziale Blattspitzen assoziieren das Inventar mit der *Arabian Bifacial Tradition*. Die auf die Herstellung von Abschlägen ausgerichtete Grundformproduktion ist wenig elaboriert, gleichzeitig finden als Ausgangsform für Werkzeuge häufig natürliche Silex-Trümmer Verwendung. Präparationsabschläge und Kerne geben deutliche Hinweise auf die lokale Herstellung von Steinartefakten an der Fundstelle. Auch Muschel- und Scheibenperlen, welche als persönlicher Schmuck interpretiert werden, zeigen deutliche Bezüge zum Arabischen Neolithikum.

Demgegenüber steht die Herkunft großer Mengen von bemalter Black-on-Buff Keramik, welche sowohl in Gefäßform und Verzierung als auch in der chemischen Zusammensetzung des Tons große Ähnlichkeit mit zeitgleichen Tongefäßen der Ubaid-Kultur Südmesopotamiens aufweist. Andere Aspekte materieller Kultur, welche ebenfalls mit Funden aus Mesopotamien assoziiert werden können, sind Ton- und Bitumenobjekte sowie Obsidianartefakte. Da in Dosariyah Hinweise auf ihre lokale Herstellung fehlen, muss bei diesen Objekten von Importen ausgegangen werden.

Ungeklärt dagegen bleibt der Ursprung der sogenannten Coarse-Ware, welche in Dosariyah mit einem Anteil von ungefähr 20 Prozent gefunden wird. Während auch hier Hinweise für eine lokale Herstellung der Keramik an der Fundstelle fehlen, unterscheidet sich das eingeritzte Dekor eines einzelnen Coarse-Ware Gefäßes sehr deutlich von allen aus Mesopotamien bekannten Verzierungsstilen.

Bis heute können diejenigen kulturellen und sozialen Mechanismen, welche hinter der Verbreitung importierter Objekte entlang der Küste des Arabischen Golfes liegen, noch nicht vollständig nachvollzogen werden. Die Vermutung, dass Arabische Gesellschaften während des Neolithikums im Vergleich zu den Gesellschaften Mesopotamiens nur wenig entwickelt waren, führte lange Zeit zu der unbegründeten Annahme, dass nur Seefahrer aus Mesopotamien für die Verbreitung der Importe im zentralen Golf verantwortlich sein könnten. Forschungen an Küstensiedlungen auf der Arabischen Halbinsel konnten hingegen nachweisen, dass insbesondere die Nutzung mariner Ressourcen eine große Rolle für die lokalen Gesellschaften spielte. Der Nachweis von Fischknochen von Meeresfischen in Dosariyah, welche ausschließlich jenseits der Küste zu finden sind, belegt die Befahrung des offenen Meeres. Demgegenüber gelang es in Dosariyah nicht, die Anwesenheit von Personen aus Mesopotamien eindeutig zu belegen. Als Konsequenz wird im vorliegenden Buch argumentiert, dass nicht mesopotamischen Seefahrern, sondern den Vertretern lokaler Gesellschaften, welche an den Küsten des Arabischen Golfes lebten, eine zentrale Rolle bei der Erlangung und Verbreitung der Ubaid-Keramik und anderer Importe zukam.

Zusätzlich zur Fischerei sowie dem Sammeln von Muscheln, stellte die Jagd auf ein breites Spektrum von Wildtieren sowie die Haltung von Ziegen, Schafen und Rindern einen wichtigen Beitrag zur Ernährung der Einwohner von Dosariyah dar. Eine derartig breite Subsistenzbasis kann als Schutz und Risikominimierung unter schwierigen Umweltbedingungen verstanden werden. Gleichzeitig hilft sie jedoch auch, einen kurzzeitig erhöhten Bedarf an Nahrung zu decken. Da während der Ausgrabungen an der Fundstelle deutliche Hinweise auf eine unterschiedliche Intensität der Besiedlung dokumentiert werden konnten, sind zeitlich begrenzte Zusammenkünfte größerer Bevölkerungsgruppen in Dosariyah denkbar. Die große Zahl importierter Gegenstände, welche als 'exotische Objekte' angesehen werden, können damit als zentrale Komponenten von Ritualen verstanden werden, die Bestandteile dieser Zusammenkünfte waren. Basierend auf den aktuellen Erkenntnissen aus den Forschungen in Dosariyah fanden derartige gemeinschaftliche soziale Ereignisse eingebettet in das tägliche Leben in einer Küstensiedlung des 5. Jt. v. Chr. statt.

## المُلخَص

أجري بحثٌ جديدٌ خلال الفترة بين عامي 2010 و2014 م ضمن إطار مشروع البحث الأثري الألماني السعودي (DARP) في الدوسرية وهي منطقة أثرية تقع على شاطئ الخليج العربي في المنطقة الشرقية من المملكة العربية السعودية. أمكن خلال أعمال التنقيب توثيق تسلسل طبقي للترسبات والبقايا البشرية والعتور على مجموعة واسعة من اللقى في أماكن مختلفة من هذه المنطقة الأثرية على عمق يتراوح من من متر إلى ثلاثة أمتار. تم تأريخ الإستيطان في القرون الأولى من الألف الخامس قبل الميلاد بالإعتماد على المواد المشعة وعلى دراسة تعتمد على مقارنة القطع الأثرية، هذا وقد استكملت أعمال التنقيب بتطبيق دراسة جيومورفولوجية محلّية ومسح أثري.

تمتلك الآثار المادية التي عُثر عليها في الدوسرية العديد من السمات الخاصة، وقد أظهر جرد القطع الأثرية الحجرية خصائصاً تقنية وطبولوجية متشابهة مع مثيلاتها من العصر الحجري الوسيط في المنطقة العربية، مثل العثور على نصل حجري محفور لرأس سهم له جناحين وكذلك أنصال لها شكل ورقة الشجر المسنّنة التي أوجت جميعها بتقليد صناعة النّصل العربي. كانت أشكال المادة الخام الأساسية المستخدمة في الإنتاج غير متطورة، وبنفس الوقت لوحظ استخدام كسرات السليكس الطبيعية كمادة خام لصناعة أدوات العمل. تعطي الأجزاء المشغولة والحبوب التي عُثر عليها مؤشرات واضحة على الإنتاج المحلي لقطع الحجر ضمن المنطقة الأثرية، وكذلك المحار والصدف وقطع اللؤلؤ التي كانت على الأغلب تستخدم كحلي زينة شخصية تملك دلالات واضحة على العصر الحجري الحديث في المنطقة العربية.

ومن ناحية أخرى يعود أصل عدد كبير جداً من رسومات الفخار - المرسومة باللون الأسود على خلفية من اللون البني المصفر - إلى ثقافة عصر الغبيد التي كانت منتشرة جنوبي بلاد الرافدين نظراً لوجود تشابه بأشكال الجرار أو النزيينات أو عن طريق تشابه المكونات الكيميائية للصلصال المستخدم. كذلك الأمر فقد عُثر على مواد أخرى توجي بلقى من بلاد الرافدين بعضها مصنوعة من الصلصال والقيز وكذلك حجر السبيج، ولعدم توفر الدليل الكافي في الدوسرية على أنها منتجات محلية فيعتقد باستيرادهم من مناطق أخرى.

أما أصل المنتجات الفخارية الخشنة والتي عُثر عليها في الدوسرية بنسبة 20% تقريباً بقي غير معروفاً، وعلى الرغم من عدم توافر دلالات على الإنتاج المحلي للفخار هنا فإن الفرق واضح بين المنتجات المزينة بالتحزيز والقطع المزينة من بلاد الرافدين.

لا يمكن حتى اليوم فهم الآلية الثقافية والاجتماعية التي تقف خلف انتشار استيراد العناصر على طول ساحل الخليج العربي. هذا ويعتقد أن المجتمعات العربية خلال العصر الحجري الحديث لم تكن متطورة بشكل كافٍ بالمقارنة مع بلاد الرافدين، مما قاد إلى أن البحارة من بلاد الرافدين فقط هم من كانوا مسؤولين عن التوريد إلى وسط الخليج، وعلى العكس من ذلك فقد أظهرت البحوث المتعلقة بالمستوطنات الساحلية في شبه الجزيرة العربية أن الموارد البحرية كانت تلعب دوراً رئيسياً في حياة السكان المحليين. كما أن العثور على عظام الأسماك البحرية في الدوسرية والتي لا يمكن العثور عليها إلا في الجانب الآخر من الساحل، لهو دليلٌ آخر على استكشاف البحر والوصول إلى هناك، وفي المقابل لم يتسنى إثبات تواجد واضح لأشخاص من بلاد الرافدين في الدوسرية، وكنيجة لذلك يبرهن هذا الكتاب أن الدور الرئيسي لاستيراد ونشر فخار عصر الغبيد وغيرها من الواردات لم يكن لبحارة بلاد الرافدين وإنما قام به مندوبين من سكان محليين مقيمين على ساحل الخليج العربي.

هذا وقد ساهمت تربية الماعز والأعنام والبقير بشكل رئيسي في تأمين المواد الغذائية لشعب الدوسرية بالإضافة إلى الصيد وجمع المحار، ويعد ذلك من عوامل الإكتفاء الذاتي التي تؤمن الحماية وتقلل من المخاطر أثناء الظروف البيئية القاسية، وفي نفس الوقت تساعد على تغطية الحاجات المتزايدة بشكل مفاجئ على مدى قصير، وبما أنه أمكن توثيق أدلة هامة أثناء التنقيبات تثبت إمكانية وجود كثافة استيطانية فقد قاد ذلك إلى التفكير بتجمعات بشرية كبيرة بأوقات متقاربة في الدوسرية يمكن أن يعود إليها عدد كبير من الأشياء المستوردة على أنها «عناصر غريبة نادرة» استخدمت في ممارسة طقوس محددة. استناداً إلى نتائج البحوث الحالية في الدوسرية فقد كانت هناك فعاليات اجتماعية مشتركة تنتمي إلى الحياة اليومية في مستوطنة ساحلية تعود إلى الألف الخامس قبل الميلاد.

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Philipp Drechsler

May, 2018

## Preface

The present monograph on reinvestigations at Dosariyah follows two research objectives. First, it outlines the results of fieldwork at this site and its immediate surroundings in the Eastern Province of the Kingdom of Saudi Arabia and comprehensively documents the range of material culture found during the archeological surveys and excavations. The time span of occupation is closely dated by an extensive series of radiocarbon dates and artefactual analyses which securely place the Neolithic settlement into the first half of the fifth millennium BC. The finds from Dosariyah presented in this book also serve as an important benchmark for less well-dated archeological contexts in eastern Arabia and therefore represent a substantial basis for future research in the region.

Second, this monograph challenges several basic axioms of archeological research in the Arabian Gulf.<sup>1</sup> For decades, the proverbial ‘seafaring merchants of Ur’ — or people from southern Mesopotamia in general — were seen as the driving force behind the distribution of Ubaid pottery and other ‘foreign’ elements of material culture in the Arabian Gulf during the fifth millennium BC. Dosariyah has the distinction of being the site with the highest number of imports, both in terms of counts and diversity of finds, but the presence of southern Mesopotamian people here, or at any other site in this region, remains unproven. Instead arguments are presented which suggest that an indigenous Arabian Neolithic population living along the shores of the central Gulf played an active role in the acquisition of goods from southern Mesopotamia. Being familiar with the exploitation of marine resources from the open sea, these people living at Dosariyah and other contemporaneous settlements along the shores of the Arabian Gulf were plausibly the agents that determined the (re)distribution of material elements of southern Mesopotamian material culture in the central Gulf. Moreover, aspects of environmental conditions, everyday life and material culture are also presented.

The first part of the monograph introduces the site and its immediate surroundings. **Chapter 1** reveals the history of research and contextualizes Dosariyah in terms of its environment and archeology. A more detailed analysis of the site’s environmental history and its change through time is presented in **Chapter 2**. Geomorphological and paleoenvironmental studies focus especially on the fluctuating sea level of the Arabian Gulf during the Holocene, but also consider the development of wide sabkha flats that form a prominent feature in the landscape around Dosariyah. The Dosariyah survey, covering the direct vicinity of the site, is outlined in **Chapter 3**. It takes a diachronic perspective and considers human activities in the wider surroundings from the Neolithic to modern times. Geophysical surveys carried out at Dosariyah are presented in **Chapter 4**. Although not successful in detecting architectural remains, these investigations clearly suggest the presence of anthropogenic accumulations beyond the central fenced area of the site. **Chapter 5** introduces the archeological methodology and excavation techniques, interprets the distribution of finds collected from the surface of the site prior to excavations and describes the excavated stratigraphy and deposits. **Chapter 6** completes this first part of the monograph and compiles all radiometric and archeological data which help to date the occupation at Dosariyah.

The second part of the monograph focuses on the varied material culture recovered from the excavation. Most prominent are finds of thousands of sherds of (partly painted) Ubaid pottery, deriving from vessels imported from southern Mesopotamia. Supplemented by coarse ware of unknown origin, the pottery assemblage from Dosariyah, presented in **Chapter 7**, is the largest excavated in the Arabian Gulf so far. Geochemical analyses of selected pieces of pottery are discussed in **Chapter 8**. **Chapters 9** and **10** describe objects that also fall into the realms of ceramics: reworked pottery and fired clay objects. The spectrum of artefacts made from stone, bone and shell are presented in subsequent Chapters 11 to 15. The lithic industry outlined in **Chapter 11** provides conclusive evidence for the presence of indigenous Arabian populations inhabiting Dosariyah, while a foreign, probably Mesopotamian lithic technology is exclusively restricted to artifacts made from imported raw material. A morphometric study of arrowhead shapes, presented in **Chapter 12**, convincingly documents the morphological homogeneity of arrowheads and suggests occupation by a single, culturally homogeneous, group of people. A group of ground-stone artifacts rarely observed in Neolithic contexts in eastern Arabia are objects made from hematite discussed in **Chapter 13**. While this generally represents a suitable raw material for stone tools, the blood red color that can be obtained from ground hematite might have been used for decorative or ceremonial purposes as well. A rich bone

<sup>1</sup> I am fully aware of the political dispute about the naming of the Persian — or Arabian, depending on one’s point of view — Gulf. According to international organizations including the United Nations and the International Hydrographic Organization and historical sources, the term Persian Gulf is generally preferred. The use of this name, however, would be rejected by the majority of our colleagues from Saudi Arabia. Having taken advantage of their invitation to carry out research in Saudi Arabia and therefore feeling personally committed, I have decided to follow the tradition of archeologists working in the Arabian Peninsula and term the waters ‘Arabian Gulf’.

industry described in **Chapter 14** represents a little-known aspect of Middle Neolithic material culture in Arabia. Repeated finds of production waste prove the on-site production of bone tools while a restricted spectrum of bone tool types suggests a considerable degree of tool standardization. Important indicators for the cultural affiliation of the people settling at Dosariyah are pieces of personal adornment which are presented in **Chapter 15**. **Chapters 16 to 19** consider two unusual groups of artefacts: bitumen objects and pieces of plaster. Detailed morphological studies and a broad range of analytical methods have been employed to analyze their origin and use at Dosariyah. **Chapters 20 to 23** focus on subsistence strategies. The analysis of the zooarcheological assemblage (**Chapter 20**) allows detailed insights into both the terrestrial and marine component of everyday diet. It emphasizes the broad spectrum of exploited animals which include both domesticated and wild species. Additional isotopic analyses of cattle teeth (**Chapter 21**) help to understand patterns of animal husbandry and mobility. These studies are supplemented by analyses of marine shell (**Chapters 22 and 23**) which highlight the importance of this particular marine resource for the inhabitants of the site. Finally, the concluding **Chapter 24** subsumes the results from individual studies with the aim of drawing a comprehensive – though fragmentary – picture of the community living at Dosariyah during the first half of the fifth millennium BC.



# Chapter 1

## The Site and its Context

Philipp Drechsler

### 1 Location

Dosariyah is located 10 km south of the old town of Jubail in the Eastern Province of the Kingdom of Saudi Arabia, approximately 1 km inland from the present shores of the Arabian Gulf (**Figure 1.1**). Surrounded by salt flats (sabkhas), the archeological site is situated within a shallow trough or valley close to the southern edge of a raised area surmounting the sabkhas by up to 14 m. The name of the site refers to the local family of al-Dossary who in the past used the area as a preferred grazing ground.

The immediate surroundings of the site were still wilderness as late as 2008, when only a few tents and small wooden houses used for leisure activities at weekends as well as corrals for sheltering camel, sheep and goat, existed in the area. During archeological fieldwork at the site between 2010 and 2013, however, extensive construction activities were begun to the north of Dosariyah as new residential neighborhoods were built for the growing population of Jubail. The infill of sediment and rubble into the salt flats as well as earth-moving in connection with these construction activities represented major obstacles for both archeological and geomorphological surveys in the area. In 2015, construction work began directly west of the site with heavy bulldozing, which reached the fenced area of the site. It is therefore foreseeable that at least the archeological and geomorphological context of the site will be completely destroyed during the next few years.

### 2 History of Research

The history of research at Dosariyah falls into three different phases: its initial discovery in 1968, archeological excavations and scientific studies during the early 1970s, and the joint Saudi-German Dosariyah Archeological Research Project (DARP) between 2010 and 2014.

#### 2.1 Initial discovery

Dosariyah was initially discovered in 1968 by Grace Burkholder, a school teacher for the Arabian American Oil Company (ARAMCO) in Dhahran, amateur

archeologist and enthusiastic 'pot picker'.<sup>1</sup> While scouting for pottery fragments in the windswept salt flats south of Jubail she came to the site which she named 'site 1' in subsequent publications and maps, stating it was 'carpeted with debris'.<sup>2</sup> Not being familiar with the kind of decorated pottery that was frequent at the site, Burkholder contacted Geoffrey Bibby of the Danish archeological expedition to the Gulf, which was then visiting archeological sites in the Eastern Province of Saudi Arabia.<sup>3</sup> Bibby identified the pottery as Ubaid pottery known from archeological sites in southern Mesopotamia. He further concluded from a short reconnaissance study of the area: 'Here (...) was a strip of low sandy hills fencing the sabkha off from the sea. It must have been a string of islands, I thought, six and seven thousand years ago, when the sabkha was sea. There were no traces of buildings, Grace went on, but there were pieces of plaster showing a smooth face on one side and the impress of bound bundles of reeds on the other'.<sup>4</sup> With an approximate dating to the fifth millennium BC, Burkholder's discovery of Dosariyah extended the 'range of the Ubaid culture by nearly a thousand kilometers', but also 'added a millennium to Saudi Arabia's prehistory'.<sup>5</sup> By 1972, Burkholder had identified as many as 39 locations with fragments of Ubaid pottery, including the sites of Abu Khamis in the Ras al Ghair area (quoted as site 11), and Khursaniyah (quoted as site 2).<sup>6</sup> While most sites with Ubaid pottery that were found by Burkholder north of Jubail are located close to the present-day coast, inland sites also occur towards the south and these are often situated along the edges of sabkhas. In addition, sites identified in al-Hasa oasis and around Ain Dar and Abqaiq also provided pieces of Ubaid pottery. Although Burkholder did not provide a detailed list of objects she collected from the surface of Dosariyah, most of the pieces of jewelry, flint and obsidian implements and of painted Ubaid pottery illustrated in her initial publication are now (2014) on display in the National Museum in Riyadh.<sup>7</sup>

<sup>1</sup> Burkholder 1972: 264.

<sup>2</sup> Burkholder 1972: 264; see also 1984.

<sup>3</sup> Bibby 1970: 376.

<sup>4</sup> Bibby 1970: 376.

<sup>5</sup> Burkholder 1972: 264.

<sup>6</sup> Burkholder 1984: 17.

<sup>7</sup> Cf. Burkholder 1972.

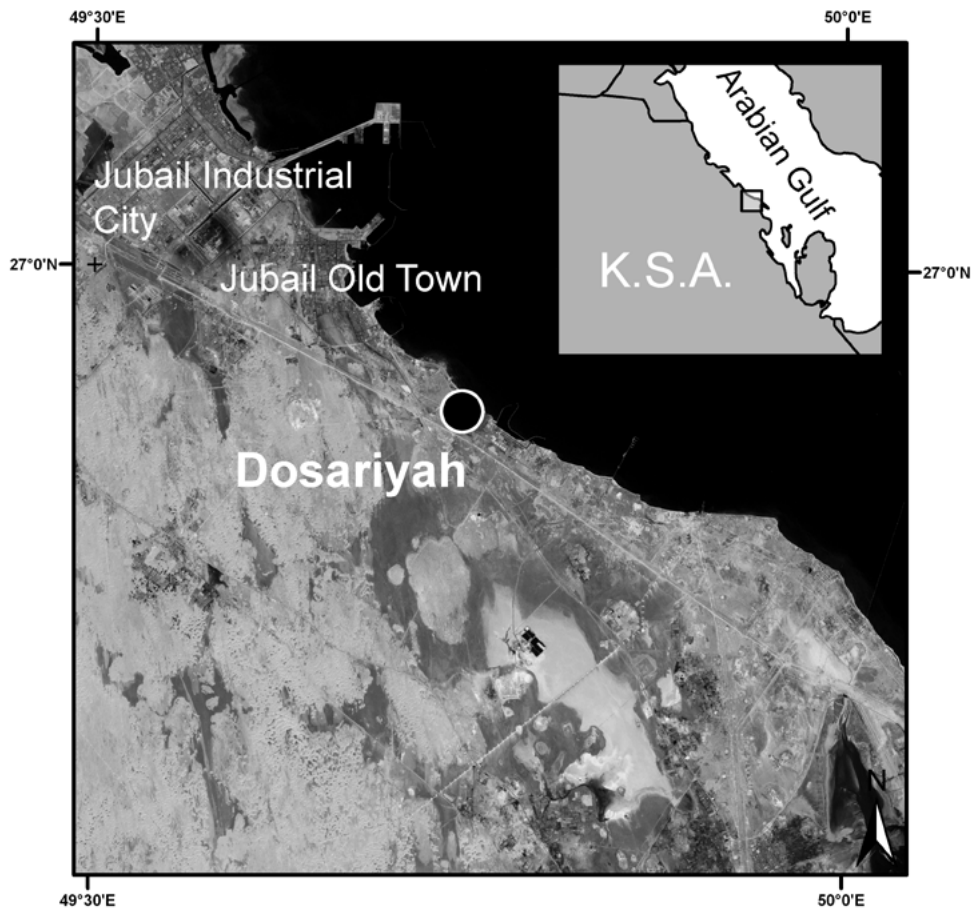


Figure 1.1. Location of Dosariyah south of Jubail Old Town.

## 2.2 First excavations and scientific studies

After examining the pieces of painted Black-on-Buff pottery that Burkholder had collected at Dosariyah and other sites in the Eastern Province, Bibby called for immediate investigations of those findings and of the underlying mechanisms of their distribution. These field investigations were subsequently carried out in spring 1972 by Abdullah Masry, then a PhD student at the Oriental Institute in Chicago and a member of the Saudi Arabian scholarship program for higher studies abroad. Based on this fieldwork, Masry presented his dissertation, which was supervised by Robert McC. Adams and Robert J. Braidwood and entitled *Prehistory in Northeastern Arabia: The Problem of Interregional Interaction*, to the Department of Anthropology at the University of Chicago in June 1973.<sup>8</sup>

Originally planned as a collaborative field project involving four students from Chicago, only Juris Zarins was finally able to take part in the work in Saudi Arabia. The field investigations carried out by this expedition

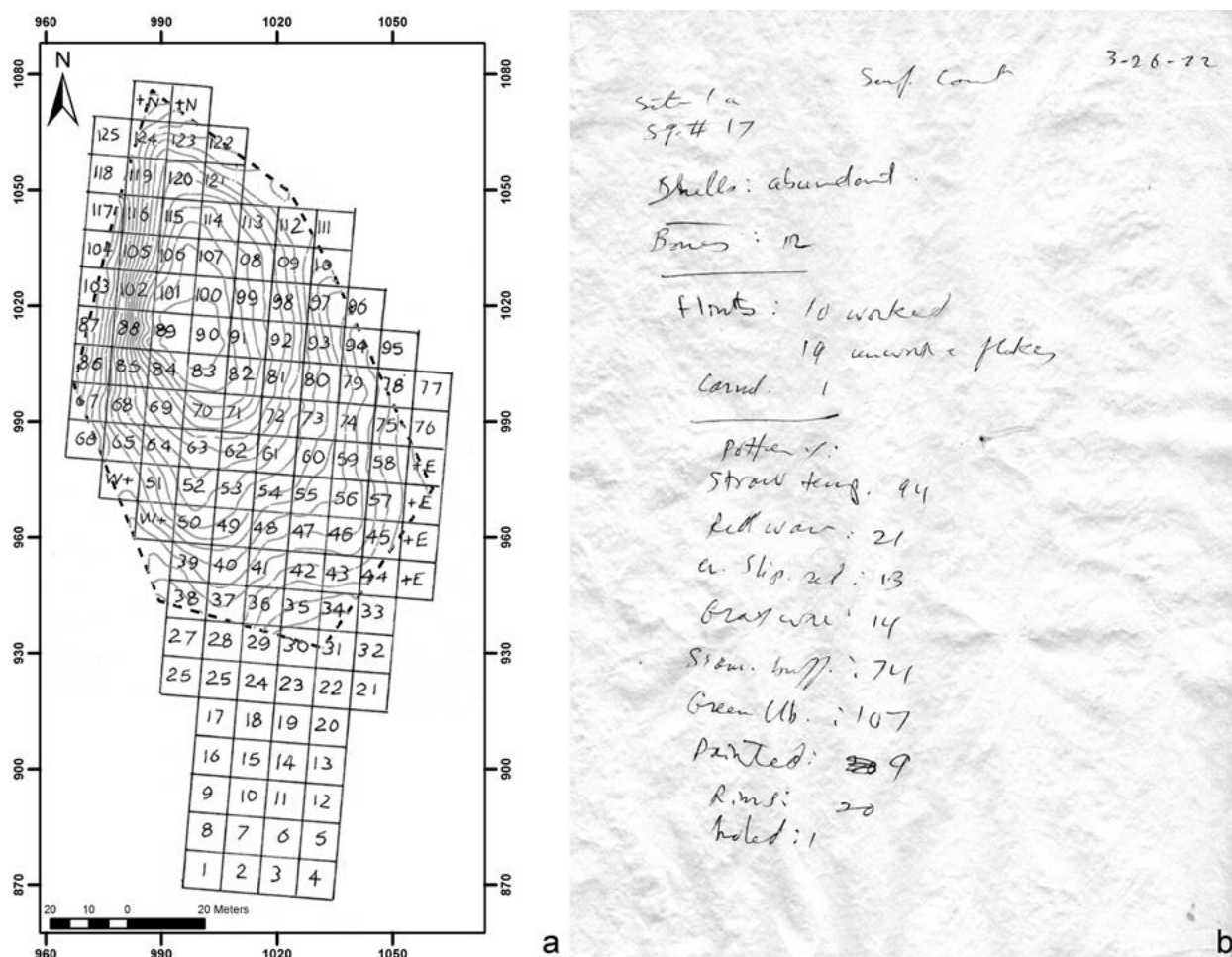
were called 'Al Hasa Expedition – The Ubaid Sites Project. Winter/Spring 1972' and consisted of five main parts: 1) test excavations at Ain Qannas in the Al Hasa area; 2) excavations at Dosariyah and surveys in the surrounding coastal zones; 3) test excavations and surveys around Abu Khamis; 4) excavations at several locations on Tarut island; and 5) surveys in the Jabrin oasis.<sup>9</sup> Over the course of these investigations Masry's field investigations considered all areas and the most substantial sites identified by Burkholder.

The field expedition began on March 1, 1972 when Masry left Riyadh together with four assistants: two field surveyors, a driver and a cook and after nearly two months of 'trials and tribulations involving financial, logistic, personnel and a host of other matters and complications'.<sup>10</sup> After investigations at Ain Qanas (site 18 according to Burkholder's enumeration), Masry and his field team reached Dosariyah on March 23.

<sup>9</sup> Masry 1974: v.

<sup>10</sup> Field notes by A. Masry. The original field notebook as well as all other field documents and photographs have been made accessible to the author by courtesy of A. Masry and are henceforth referred to as Masry 1972.

<sup>8</sup> Masry 1974.



**Figure 1.2.** a Location and orientation of Masry’s surface survey grid in relation to the grid used by the Dosariyah Archeological Research Project. b Field notes from surface sampling (courtesy A. Masry 2013).

Inspections of the site area identified two different parts which were subsequently labelled site 1a (the main site) and a smaller site (site 1b) located approximately 500 m to the north.<sup>11</sup> Also noteworthy was a thick vegetation cover at the site, in sharp contrast to the dune-covered surroundings. As no workmen were available in Jubail, fieldwork at Dosariyah started on March 25 with topographic surveys and collection from the surface of the site. To do this systematically, a square grid measuring 10 x 10 m was established (**Figure 1.2a**) and each square collected separately during the next few days until March 28. Based on the color of paste and treatment, Masry established a ‘rough typology of the pottery’, which was used for the classification of ceramics (**Figure 1.2b**).<sup>12</sup>

Excavations at Dosariyah started on March 28 with sondage I, located in square 89 at the western steep slope of the site and measuring 2 x 2 m (**Figure 1.3**). In

this area, dense and thick layers of shell were unearthed immediately below the surface. According to Masry’s field notes, excavations were carried out in spits measuring between 20 and 40 cm in depth. Down to a depth of 1 m Masry noted: ‘What is remarkable about the finds until now is that they duplicate 1:1 those lying scattered on the surface, in terms of variety’.<sup>13</sup> On the next day, and at a depth of 1.6 m below the surface, the ‘same variety of artefacts and finds’ was noted. At that point, ‘the trench sides fell down before we dug any deeper below [level] 4. The dryness and looseness of sand plus wind blow [one word unreadable] to make of the trench walls a very fragile easily crumbling sides: A level 5 was partially exposed before the trench collapsed’.<sup>14</sup>

Until April 8, a total of seven soundings were excavated in squares 83, 88, 89, 90 and 92, with each sounding measuring 2 x 2 m (**Figure 1.4**). During the excavation of sondages I to IV in squares 88 and 89 at

<sup>11</sup> Site 1b is located only 330 m to the north, measured from the highest point of Dosariyah.

<sup>12</sup> Masry 1972: March 26.

<sup>13</sup> Masry 1972: March 29.

<sup>14</sup> Masry 1972: March 30.



**Figure 1.3.** a Location of soundings in squares 83, 88, 89, 90 and 92. b The beginning of excavations at Dosariyah. c Field notes, March 28, 1972 (courtesy A. Masry 2013).

the westernmost part of the site, Masry noted that the succession of sediment layers did not only dip to the east, but also came increasingly closer to the surface – suggesting a west–east dipping of the underlying paleotopography of the site.<sup>15</sup> Further on, at this early stage of excavations and on the basis of massive layers of shell and the absence of plaster pieces, Masry proposed that the western part of the site once represented a dumping area of a settlement further east.<sup>16</sup>

On April 4 investigations moved temporarily towards site 1b. After surface collection, one sounding (A) was excavated that indicated only a very shallow occupation in this area.<sup>17</sup> As site 1b did not show potential for further work, Masry returned to site 1a and began excavating sondage VII, located in square 92. Excavating this sounding down to a depth of 2.4 m, higher densities of pottery and flint but less dense shell accumulations led him to conclude that ‘It seems that, when in the east side of the site there must have existed more dense occupation than near the shell mound’.<sup>18</sup> In the afternoon of April 8, 1972, after 10 days of field

investigations at Dosariyah, Masry stopped excavations at the site and returned to Dammam the next day.

The results of Masry’s investigations at Dosariyah were published in his dissertation submitted in June 1973.<sup>19</sup> A republication in 1997 uses the original manuscript with some minor changes in both the text and figures.<sup>20</sup>

### 2.3 Dosariyah Archeological Research Project (2010–2014)

The Dosariyah Archeological Project arose from my first visit to the site in October 2008. At that time, I was kindly invited by the Saudi Commission for Tourism and National Heritage (SCTH) to visit Neolithic sites in the Eastern Province for potential joint excavation and research projects. Enthusiastically guided by Abdulhamid al-Hashash, then head of the Dammam Archeological Museum, and Mahmoud al-Hijri, one of his colleagues, we went northwards from Dammam to visit the sites of Dosariyah and Abu Khamis. Although Abu Khamis was much more impressive both in its size and scenery, Dosariyah looked more promising for the study of an Arabian Neolithic coastal community in the

<sup>15</sup> Masry 1972: March 30; 1974: 121.

<sup>16</sup> Masry 1972: March 30.

<sup>17</sup> Masry 1972: April 5.

<sup>18</sup> Masry 1972: April 5.

<sup>19</sup> Masry 1974.

<sup>20</sup> Masry 1997.



**Figure 1.4.** Excavations at Dosariyah, 1972. **a** Sondage II. **b** Sondage IV, level 2. **c** Sondage I: survey engineer Salah al Helwa leaves the trench (courtesy A. Masry 2013).

central Gulf area. The surface of the site was littered with archeological remains, and animal burrows suggested the presence of ashy material indicative of substantial activities all over the well-fenced site. Further on there was no evidence of a later settlement at the site after the Neolithic, but limited amounts of modern rubbish suggested some kind of occupation during the short period of time between Masry's excavations in 1972 and the fencing of the site in the early 1980s.

Although my initial visit did not last longer than 30 minutes, the potential of the site for reinvestigations was clearly evident given its size, preservation conditions and densities of material remains. Masry's previous excavations had furthermore proved the deep stratification of the site that led to my expectation that the occupation at Dosariyah covered at least several centuries. In addition, fieldwork at Dosariyah would provide the opportunity to fill the geographical gap between two other Middle Neolithic sites investigated at that time in the Gulf: H3/As-Sabiyah in Kuwait, excavated by Rob Carter and Harriet Crawford between 1998 and 2004 and finally published in 2010,<sup>21</sup> and Dalma

11 in the Abu Dhabi Emirate, excavated by Katelin Flavin, Elizabeth Shepherd and Mark Beech.<sup>22</sup> A first proposal for the establishment of a joint Saudi-German research project focusing on excavations at Dosariyah was kindly approved by SCTH (formerly SCTA) in 2009 and extended in 2013. A research grant from the Deutsche Forschungsgemeinschaft (DFG) provided the financial background for all investigations.

Investigations of the Dosariyah Archeological Research Project (DARP) were intended to center on four main research questions:

- what are the economic and cultural roots of the Neolithic in the eastern part of Arabia?
- what characteristics of the Arabian Neolithic are the results of economic and social adaptations to local environmental conditions?
- what kinds of resources were used during the Middle Neolithic occupation of eastern Arabia?
- which kinds of relationships existed between the Arabian Neolithic and the Ubaid culture of Mesopotamia?

<sup>21</sup> Carter and Crawford 2010a.

<sup>22</sup> Flavin and Shepherd 1994; Beech and Elders 1999; Beech *et al.* 2000; 2016; Beech and Glover 2005.

To approach these questions, the project was at first planned for three years, with field seasons taking place both in the spring and fall. Nevertheless, uncomfortable climatic conditions with heat and heavy winds during the first fall season forced a change of plan, with only one excavation season per year. It therefore became necessary to extend the project until 2014.

A first field season took place for five weeks in February and March 2010. Together with two archeologists from Dammam Regional Museum, Azzhr al-Toobi and Hassan Hamdoun, three test trenches, measuring 2 x 2 m and 2 x 3 m, were excavated by the German team in the central, southern and eastern part of the site. Although one of the major goals of the campaign, the documentation of the site's complete stratigraphy, was only reached in trench S1 due to the massive collapse of trenches, results from this campaign clearly demonstrated the potential of Dosariyah, especially the high density of finds in all parts of the site and the unexpectedly excellent preservation of fish and mammal remains. In contrast, the absence of any evidence of architectural remains was somewhat disappointing. Datable material was retrieved during excavation and provided the basis for a first series of four AMS radiocarbon dates from *Pinctada radiata* (pearl oyster) shell that all fell within the fifth millennium cal. BC.<sup>23</sup>

The second field season in October and November 2010 suffered from extreme heat. Nevertheless, the start of larger-scale excavations in the southern part of the site was promising as we were able to document a total of 10 natural pearls among many other finds from trench S2. Again, evidence of architecture remained elusive. As in the previous season, Azzhr al-Toobi and Hassan Hamdoun from Dammam Regional Museum joined the excavations.

As a consequence of the first two seasons, the consecutive third field season in spring 2011 started with geophysical investigations aimed at locating architectural remains. Both geomagnetic and georadar measurements were carried out within the fenced area of the site and within a restricted area further south by Martin Posselt from Posselt and Zickgraf GdR. While geomagnetic measurements did not work particularly well due to severe disturbance caused by the metal fence, results from georadar survey indicated several hot spots for potential architecture. Archeological excavations during that season focused on the complete excavation of trench S2 down to the natural soil.

The large number of archeological remains prevented the study of finds during the field seasons. It was therefore decided to reserve the fall 2011 season for analysis and documentation of the objects retrieved

during previous excavation seasons. In addition to laboratory work, one week was spent at the site to test one area (trench N2) suggested by georadar investigations and to trial a new excavation technique that would prevent the collapse of large and deep trenches. In February and March 2012, excavations took place in both the northern and eastern part of the site and these were actively supported by colleagues from Dammam, Riyadh and Doha. The goal to document the full stratigraphic sequences in these parts of the site necessitated the establishment of two large trenches, each measuring 8 x 8 m (E1.1, N3). An additional extension by 2 m to the west became necessary for trench E1.1 due to the presence of a single installation. Towards the end of the season, Robert Carter and Susan Pollock visited the excavations at Dosariyah and during this time, an excursion was organized which led us to Tarut, Al Hasa and Abu Khamis.

A second season that was dedicated to the analysis and documentation of finds took place in October 2012. During a week in the storerooms of the old National Museum in Riyadh, the inventory of objects from Masry's excavations at Dosariyah in 1972 was documented and the finds partly redrawn. During a short meeting with A. Masry permission was kindly granted to study the field notes from his investigations during the next months. Afterwards, the mission moved to Dammam. Kindly hosted by A. al-Hashash at the provisional offices of the Dammam Regional Museum, almost all the objects recovered during the previous field seasons were studied in detail.

A short visit in Riyadh in February 2013 was reserved for the study of Masry's field notebooks and photographs. As the amount of written and photographic record that was available clearly exceeded all my expectations, I obtained permission to make copies of most of the material for subsequent detailed evaluation. In November 2013, intensive foot surveys were carried out in the vicinity of Dosariyah with the aim of contextualizing the site. Short visits in search of flint raw material sources and additional Middle Neolithic sites led the team to Thaj and Khursaniyah. In addition, geomorphological studies were carried out by Adrian Parker and Mike Morley over 10 days.

In parallel with the writing of this monograph, a two-day symposium was held at the University of Tübingen in June 2014 during which contributors of this book and external specialists met for discussions about the essential results of the Dosariyah Archeological Research Project. One major goal of this workshop was to address the research questions formulated at the very beginning of the project in light of the fieldwork results and the study of finds.

<sup>23</sup> Drechsler 2011: 74.

### 3 Environmental Context

Dosariyah is located in the central coastal lowlands of the Eastern Province of Saudi Arabia, about 800 m inland from the present shores of the Arabian Gulf. The central coastal lowlands stretch along the coast approximately between As Saffaniyah in the north to Dhahran in the south, while they are bordered by the northern Summan plateau in the west.<sup>24</sup> They are characterized by moderate relief. The surface is generally covered by sands although limestone exposures are frequent. In the coastal area, wide sabkhas predominate while in the southeast up to Jubail, barren and unstable sand dunes represent the northward extension of the al-Jafurah desert.<sup>25</sup>

#### 3.1 Climate

Today, most parts of the Arabian Peninsula form part of the Old World Dry belt, spanning Mauritania in the west, across North Africa and Arabia and into central Asia. According to the Köppen-Geiger climate classification system, BWh climatic conditions prevail. Precipitation is less than 50% of potential evaporation, with an average annual temperature above 18°C.<sup>26</sup> With its geographical position around 27° northern latitude, Dosariyah is located within the sphere of the northeasterly trade winds, clearly north of the northernmost extension of the Inter Tropical Convergence Zone (ITCZ) during the Boreal summer.

The region has a desert and semi-desert climate, characterized by high summer temperatures and aridity throughout the year (**Figure 1.5a-d**). The mean annual temperatures recorded from the region are 26.5°C (Dhahran) to the south of Jubail,<sup>27</sup> and 26.5°C (Abu Kharuf) and 26.5°C (Abu Ali) to the north.<sup>28</sup> The mean July temperature at Dhahran is 35.8°C and 15.8°C for December. Extreme temperature values range between 49.2°C and 4.1°C at Abu Kharuf and 44.3°C and 12.1°C at Abu Ali. The average annual rainfall for the region is 85 mm with high inter-annual variability (**Figure 1.5e**). Mandaville reported annual rainfall values between 5 and 277 mm at Dhahran which is confined to the winter months from October to early May.<sup>29</sup> Predominant sources of rainfall are Mediterranean depressions<sup>30</sup> supplemented by local convection cells, cyclonic depressions that develop in front of the Zagros Mountains above Iraq and eastern Iran and currents from equatorial areas in Sudan and Ethiopia.<sup>31</sup> Due to high temperatures, evaporation rates range from 35 up

to 100 times the local mean annual rainfall, resulting in a very high water deficit for plants.<sup>32</sup> Dew is an important source of moisture in coastal areas where it occurs at night with up to 0.04 mm per night recorded in the winter months.<sup>33</sup>

Wind patterns play a major role in the natural surface landscape development. Strong shamal winds affect the northern Gulf during the summer months with winds blowing at speeds of 40–50 km/hr, while northwesterlies originating from depressions in the Mediterranean occur from November to February.<sup>34</sup> These winds are primarily responsible for the inland movement of sand across the central Gulf area,<sup>35</sup> but they also transport vast quantities of dust into the lower atmosphere and severely reduce visibility.<sup>36</sup> Wind data for the region indicate that the most important direction is from the north and northwest, with a second southeasterly peak originating offshore.<sup>37</sup> Barth measured mean wind velocities between 12.6 and 24.8 km/hr for the region with gust values exceeding 43.2 km/hr.<sup>38</sup> These winds have a powerful effect on the topography and in particular, the dunes.

Daily wind patterns follow a characteristic time schedule along the coast. In the morning, relatively dry winds blow from inland in the west towards the sea in the east. Heat radiation is higher over land during the night, inducing a gradient in local barometric pressure. Increasing insolation during the day reverses this pattern. An increase in temperature over land benefits the development of low barometric pressure and, as a consequence, humid wind moving from the sea towards the land normally begins blowing before noon and continues until sunset.<sup>39</sup> These coastal convection winds tend to move sand inland before it is transported further south, currently preventing the development of large coastal dunes.<sup>40</sup>

#### 3.2 Geology and geomorphology

Eastern Arabia is part of the Arabian platform, built up by sediments of Paleogene and Neogene age. The strata dip gently away from the edge of the Arabian Shield in the west and form zones of cuesta topography with scarps following the curvature of the eastern edge of the Shield. Towards the Gulf these cuestas become barely perceptible<sup>41</sup> and are often covered by Quaternary deposits.

<sup>24</sup> See Mandaville 1990: 8.

<sup>25</sup> Fryberger *et al.* 1984.

<sup>26</sup> Peel *et al.* 2007: 1641.

<sup>27</sup> Vincent 2008: 74.

<sup>28</sup> Barth 2001.

<sup>29</sup> Mandaville 1990.

<sup>30</sup> Mandaville 1990: 11.

<sup>31</sup> Barth and Steinkohl 2004: 101.

<sup>32</sup> Mandaville 1990: 16.

<sup>33</sup> Barth 2002.

<sup>34</sup> Loughland *et al.* 2012.

<sup>35</sup> Loughland *et al.* 2012: 194.

<sup>36</sup> Vincent 2008.

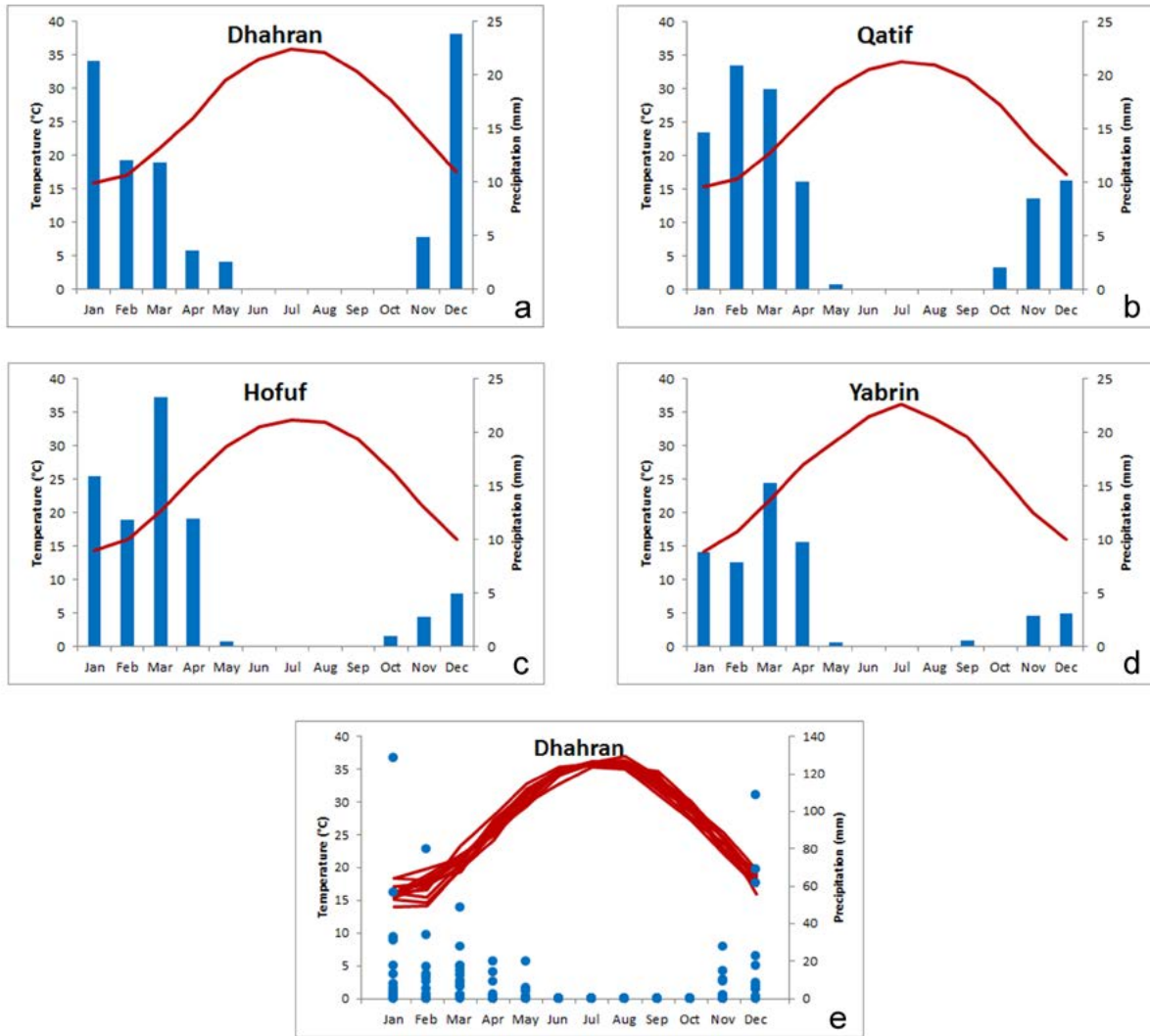
<sup>37</sup> Barth 2002.

<sup>38</sup> Barth 2001.

<sup>39</sup> Personal observation P. Drechsler; see also Vincent 2008: 147.

<sup>40</sup> Loughland *et al.* 2012: 194.

<sup>41</sup> Vincent 2008: 48.



**Figure 1.5.** Climatic charts from **a** Qatif; **b** Dhahran; **c** Hofuf; and **d** Yabrin indicating average monthly temperature and precipitation (data source: Vincent 2008: tables 4.1, 4.3). **e** Climatic chart from Dhahran showing the inter-annual variability of the average monthly temperature and precipitation between January 1949 and March 1963 (data source: [www.ncdc.noaa.gov](http://www.ncdc.noaa.gov); recalculated).

### 3.2.1 Geology

The relief between Dammam and north of Jubail is generally low with a few minor outcrops of Miocene and Pliocene bedrock belonging to the Hadruk and Dam formations. Such outcrops usually occur as minor escarpments (5–20 m high). The Hadruk formation that comprises sandy limestone, marl, gypsum, and beach rock underlies the whole of the Jubail area. One major outcrop occurs at Jebel Barri, 9 km northeast of Dosariyah (N26°53'54" E049°37'52"). In the limestone of the Hadruk formations chert and gypsum layers are prominent. Occasional small outcrops can be found on the surface to the west of Dosariyah.<sup>42</sup> Rock outcrops north of Jubail belong to the Dam formation and

comprise hard limey sandstone, marl, soft sandstone and beach rock.

A number of major structural geological features are found in the region. These include a series of north-south trending anticlinal structures that are oblique to the axis of the Arabian Gulf. Tectonic uplift and folding from the Middle Eocene has led to the development of several large structural anticlines. These include the Qatar and Dukhan anticlines located on the Qatar peninsula and the Bahrain anticline.<sup>43</sup> To the west and southwest of Jubail, the Ghawar anticline is draped over a basement horst structure. It grew initially during the Carboniferous (Hercynian) deformation and was reactivated episodically during the Late Cretaceous.<sup>44</sup>

<sup>42</sup> A. Parker, personal observation, November 2013.

<sup>43</sup> Kassler 1973.

<sup>44</sup> Saner *et al.* 2005.

Kassler postulated that a northwest extension of the Bahrain Ridge passes through the Al Jubail area, parallel to the coastline, and that this tectonic mechanism accounts for the raised beaches observed near Jubail.<sup>45</sup> According to Kassler, the Gulf of Salwah, to the southeast, is believed to be a Late Quaternary structural feature and represents an area of synclinal subsidence.<sup>46</sup> Nevertheless, the raised beaches reported by Holm as far south as Salwah do not conform to this interpretation of the Gulf of Salwah being an area of subsidence.<sup>47</sup>

The anticlines of the Gulf region are of great hydraulic importance. Due to the fractional deformation of the bedded rocks, water flows are generated even through the impervious layers. Artesian springs occur along the anticlines, forming a natural outflow.<sup>48</sup> Hoetzl studied the regional hydrogeology and demonstrated that groundwater sourced from the Umm er Radhuma aquifer feeds spring systems along the Gulf.<sup>49</sup> Aquifer recharge occurred during former humid periods with only a minor recent groundwater recharge component.

In addition to the major anticlinal structures, salt diapirism in the region has led to localized uplift. The Dammam dome, located 70 km to the southeast of Dosariyah, is a salt dome where Eocene age rocks crop out through the surrounding Quaternary sand and sabkha deposits.<sup>50</sup> Modern uplift of the dome occurs at a rate of 0.56 to 0.75 mm per century.<sup>51</sup>

Deflated longitudinal dunes with their axis in a north-northwest-south-southeast direction dominate the Quaternary sediments in the region. In places, secondary dunes reworked by eolian action to form smaller dunes during the Holocene overlie these longitudinal dunes. Sand sheets and barchans cover much of the region. Many barchans are found traversing the sabkhas. At many locations dome dunes likewise occur, which evolve into barchans and vice versa.<sup>52</sup> Sand sheets form flat sandy plains, mostly covered by scattered perennial grasses and other seed-bearing plants. The coastal plain is low lying and in many places the water table is high enough to give rise to extensive sabkhas.<sup>53</sup> In recent times, much of the natural landscape and vegetation has been destroyed by infrastructure developments associated with the oil and gas industry and the rapid population growth of the Eastern Province.

### 3.2.1 The central coastal lowlands

The central coastal lowlands are part of the Al-Jafurah desert that extends along the Arabian Gulf from Kuwait in the north to the Rub' al-Khali in the south, over a distance of almost 800 km.<sup>54</sup> The Al-Jafurah desert itself can be subdivided into three broad zones according to sand budget and wind speed. Within a northern zone, wind velocities are high and deflation predominates. The central zone, where Dosariyah is located, is characterized by dune transport while wind velocities are lower. In the first two zones sand dunes are more or less isolated while extensive sabkha plains exist. The southern zone stretches into the Rub' al-Khali, where wind energies are lower and continuous dune fields predominate. Based on Landsat images, Loughland *et al.* outlined the actual spatial configuration of geomorphologic units of the Eastern Province that provides a general overview of the landscape features in the central coastal lowlands (**Figure 1.6**).<sup>55</sup>

Studies by Anton indicate that the dunes of the Al-Jafurah desert south of Dhahran are not older than 4000 years.<sup>56</sup> They may be the result of a major change in the sand dynamics of the northern regions, triggered by large-scale aridification which started around 5500 BP,<sup>57</sup> followed by degradation of the northern areas.<sup>58</sup> Anton and Vincent suggest that some of the sand in the Al-Jafurah sand sea originates from the major Quaternary fans developed by wadis transporting sands and gravels from the Arabian Shield towards the Gulf.<sup>59</sup> One possible major source is the Ad-Dibdibah plain, a vast fan that was developed by the Wadi al-Batin-Wadi ar-Rumah system in northeastern Saudi Arabia. The Arabian Gulf Basin, which was exposed during periods of low sea level during the Late Pleistocene,<sup>60</sup> represents another sediment source.

### 3.2.2 The landscape around Dosariyah

The wider landscape around Dosariyah is characterized by a narrow coastal strip, dunes, interdune areas, sand sheets and siliciclastic sabkha terrains.<sup>61</sup> Dosariyah itself is located on a raised area build up by eolianites. These fossilized dunes break off rather steeply towards the sea but are increasingly covered by sand sheets as they move inland. Both Pleistocene deflated longitudinal dunes and smaller Holocene dunes overlay the eolianites (see **Chapter 2**). Over wide areas, these

<sup>45</sup> Kassler 1973.

<sup>46</sup> Kassler 1973.

<sup>47</sup> Holm 1960.

<sup>48</sup> Johnson *et al.* 1978.

<sup>49</sup> Hoetzl 1995.

<sup>50</sup> Weijermars 1999.

<sup>51</sup> Hariri 2014.

<sup>52</sup> Fryberger *et al.* 1984.

<sup>53</sup> Anton and Vincent 1986.

<sup>54</sup> Fryberger *et al.* 1984: 413.

<sup>55</sup> Loughland *et al.* 2012.

<sup>56</sup> Anton 1983.

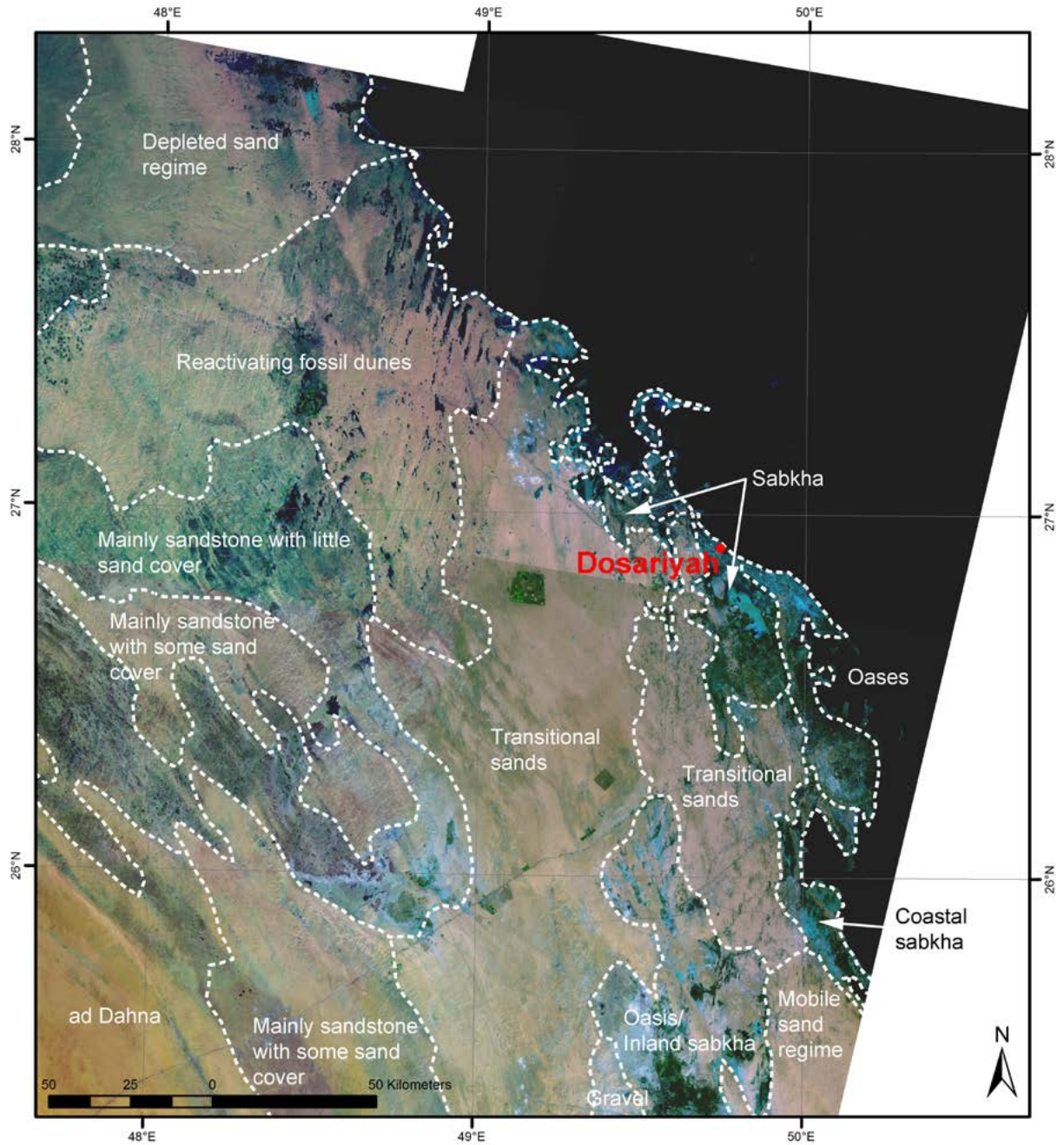
<sup>57</sup> Sirocko 1996.

<sup>58</sup> Barth 2001: 399.

<sup>59</sup> Anton and Vincent 1986.

<sup>60</sup> Lambeck 1996.

<sup>61</sup> Fryberger *et al.* 1984: 413.



**Figure 1.6.** General geomorphological configuration of the central coastal lowlands. Dosariyah is located within a zone dominated by sabkhas (after Loughland *et al.* 2012: 196).

dunes are covered by scattered perennial grasses and other small plants.

The landscape to the west, east and south of Dosariyah is dominated by wide sabkhas of the Sabkhat as-Summ, which constitutes one northern part of the larger Sabkhat ar-Riyas.<sup>62</sup> These sabkhas form a wide arc around the raised area where Dosariyah is located (Figure 1.7a). Shells from the marine snail *Cerithium*

*scabridum* are found on the surface of these sabkhas and indicate that they were once flooded during times of higher sea levels. A series of both active and inactive sand spits along the coast suggest that in the past the sabkhas were connected to the open sea. While clearly of marine origin, the surface morphology and height of the sabkhas is at least partly controlled by the local groundwater level.<sup>63</sup> Strips of wind-blown sand cover part of the sabkha surfaces to the southeast of the

<sup>62</sup> Edgell 2006: 396.

<sup>63</sup> Barth 1998.



**Figure 1.7.** Landscape around Dosariyah indicating the anthropogenic impact on the landscape. **a** 1968: declassified CORONA satellite image; **b** 2006: Google Earth.

raised area. They are both indicative of current sand transport induced by winds from the north-northwest and a comparatively older date of the sabkha itself.

South and west of Sabkhat as-Summ, there are extensive dune fields interrupted by smaller sabkhas (Sabkhat al-Fasl, Sabkhat as-Safi, Sabkhat Mahbulah) and hard rock outcrops (Jebel Barri, Jebel Abu Sharif).<sup>64</sup> Along the western borders of Sabkhat as-Summ and Sabkhat al-Fasl, there are extended palm groves that are no longer under cultivation but which indicate near-surface occurrences of sweet water.

Today, most features of the landscape are widely blurred by infrastructure developments (**Figure 1.7b**). North of Dosariyah, the construction of residential neighborhoods has led to the infill of sabkhas. Further north along the coast, the King Abdul Aziz Naval Base occupies wide areas. Along the southern edge of the sabkha south of the site, an extensive housing complex was built for the Jubail seawater desalination plant run by SWCC (Sea Water Conversion Cooperation). Other major interference is caused by several pipelines crossing the area from northwest to southeast,

connecting the oil and gas extracting areas north of Jubail with the processing and shipping facilities at Ras Tanura.

### 3.2.3 Hydrology

Today, perennial rivers do not exist in eastern Arabia and occurrences of sweet water are therefore restricted to springs and wells fed by (fossil) groundwater, and ponds receiving surface runoff from rainfall. Relict palm stands along the western edges of Sabkhat as-Summ are indicative of extensive subsurface sweet water sources as are several shallow hand-dug wells in the region that once provide relatively good, if brackish, water.<sup>65</sup> Sporadic occurrences of individual date-palm trees in the vicinity of Dosariyah and especially along the edges of the eolianites close to the seashore suggest the presence of sweet water closer to the site as well.

Extensive occurrences of artesian water were observed both within the dune fields and in the sabkhas during geomorphological studies carried out during the planning of the Industrial City north of Jubail and

<sup>64</sup> Defense Mapping Agency 1982.

<sup>65</sup> Mandaville 1990: 8.

approximately 15 km north of Dosariyah.<sup>66</sup> With sodium chloride (NaCl) concentrations down to 0.2%, and gypsum (CaSO<sub>4</sub>) concentrations of 0.07% this water is almost potable.<sup>67</sup> According to James and Little, two different sources for this artesian water exist:<sup>68</sup> extended aquifers which conduct water from distant sources in the west to the springs at Bahrain and Qatif, as well as to submarine springs along the southern shores of the Gulf; it is suggested that a second source of sweet water exists in the dune fields surrounding the sabkhas of the central coastal lowlands themselves. These dunes contain high groundwater tables up to 20 m above the sabkha surfaces. As some pinnacles of the Hadruk formation reach high levels in the dunes, it is possible that water stored at high levels in the dunes enters the Hadruk formation through sub-vertical fissures contributing to artesian pressure beneath the sabkhas.<sup>69</sup>

### 3.2.4 Flora

The flora of the Arabian Gulf coast belongs to the Nubio-Sindian center of endemism,<sup>70</sup> generally characterized by scattered trees of species such as *Aerva javanica* (Arabic: *ra'*), *Acacia tortilis* (Arabic: *samur*), the salt-loving shrub *Halopeplis perfoliata* (Arabic: *khurrayz*) and the grass *Panicum turgidum* (Arabic: *thumam*).<sup>71</sup>

While the wide coastal sabkhas of the central coastal lowlands are devoid of higher plant life, areas covered with fixed sand show denser vegetation and provide the habitat preferred by wild or naturalized date palms and *Tamarix* shrubs.<sup>72</sup> Two trends in the local vegetation can be observed along the central Gulf area: the overall proportion of therophyte elements (annual plants) declines from north to south and this is paralleled by decreasing total species diversity.<sup>73</sup>

Characteristic plant communities for the central coastal lowlands are the *rimth* (dominated by *Haloxylum salicornicum*) saltbush shrubland and the *thumam* (*Panicum turgidum*) grass shrubland. Open *rimth* saltbush shrubland covers major parts of northeast Arabia where it ranges from Iraq in the northeast down into the northern edge of the Rub' al Khali. It is found on sands in wide topographic lows with groundwater not far below the surface. Less salt tolerant than other halophytes, it is not generally found on the highly saline sabkha margins, but dominates areas surrounding such salt-rich lows at only marginally higher elevations.

While generally considered to be of limited value for grazing, *rimth* provides good firewood which is often carried some distance by Bedouins.<sup>74</sup> *Thumam* grass shrubland is found on relatively well-drained sand substratum, although it also occurs on elevated ground near saline terrain. It is widely distributed in the central coastal lowlands where it represents a very important grazing association. *Panicum turgidum* is often found associated with shrubs of *Calligonum comosum* that produces excellent firewood.<sup>75</sup>

In the past, the coastal areas of the central coastal lowlands were comparatively densely vegetated although major grazing activity during the last few decades, and a continuously increasing animal population accompanied by supplemental feeding and trucking of water, have changed the vegetation significantly.<sup>76</sup> Former extensive shrubland communities covering 15–20% of the ground have become degraded *thumam* grasslands that seldom exceed a ground cover of more than 5%.<sup>77</sup>

### 3.2.5 Fauna

The wild fauna of eastern Arabia is heavily affected by human action today. Millennia of intensive hunting as well as recent industrialization and urbanization have had a very strong impact both on the faunal composition and frequencies of wild animals.

The Arabian Peninsula shows a four-fold faunal division between the Afro-tropical, Saharo-Sindian, Palearctic and Oriental Region. Eastern Arabia can be assigned to the Saharo-Sindian region.<sup>78</sup> It is part of a vast region that links the western Sahara to the deserts of Afghanistan and central Asia. Animal species in this region are particularly adapted to arid, dry and desiccated landscapes. Characteristic herbivores of this faunal community in eastern Arabia were the Arabian Oryx (*Oryx leucoryx*), gazelle (*Gazella gazella*) and wild goat (*Capra aegagrus*). Carnivores include the striped hyena (*Hyaena hyaena*), golden jackal (*Canis aureus*), red fox (*Vulpes vulpes*) and caracal (*Caracal caracal*).<sup>79</sup> Lagomorphs and rodents are frequent even today in coastal deserts and plains. Desert reptiles are also frequent, and lizards (*Uromastix* sp.) in particular were the most commonly eaten desert animals until historic times.<sup>80</sup> The bird fauna of eastern Arabia is diverse. In addition to migrant desert and marine birds, partridges, ducks and geese inhabit the reed beds of marshy depressions. Although now extinct, ostrich

<sup>66</sup> James and Little 1994: 88.

<sup>67</sup> James and Little 1994: 90, table 2. The limit of NaCl for potable water is 1000 mg/l by WHO standards. World Health Organization 1984.

<sup>68</sup> James and Little 1994: 92.

<sup>69</sup> James and Little 1994: 92.

<sup>70</sup> White and Leonhard 1991.

<sup>71</sup> Vincent 2008: 174.

<sup>72</sup> Mandaville 1990: 8.

<sup>73</sup> Mandaville 1990: 23.

<sup>74</sup> Mandaville 1990: 28.

<sup>75</sup> Mandaville 1990: 107.

<sup>76</sup> Barth 1998; 1999.

<sup>77</sup> Barth 1998.

<sup>78</sup> Harrison 1964: 10.

<sup>79</sup> Masry 1997: 29.

<sup>80</sup> Masry 1997: 30.

(*Struthio camelus syriacus*) used to be common along the coastal plains and further inland.<sup>81</sup> Along the coast and offshore, a great variety of marine species are still of major economic importance.

#### 4 Cultural Context

A series of radiocarbon dates place Dosariyah at the beginning of the fifth millennium cal. BC. The spectrum of material culture discovered at the site shows affinities with the Arabian Middle Neolithic,<sup>82</sup> but elements of southern Mesopotamian material culture also occur.

##### 4.1 The Arabian Middle Neolithic

The fifth millennium BC represents a flourishing period in prehistoric Arabia. High numbers of archeological sites suggest a rapid growth of human populations, potentially enabled by ameliorating climatic conditions.<sup>83</sup>

###### 4.1.1 Paleoclimatic background

In the southern part of the Arabian Peninsula, a northward shift of the Indian Ocean Monsoon provided higher amounts of precipitation during the mid-Holocene.<sup>84</sup> As a result, dune fields became stabilized and vegetated with  $C_3$  grasslands and scatters of woody vegetation.<sup>85</sup> The lowlands and desert areas were covered by grassland vegetation with woody elements,<sup>86</sup> while grass and scrub vegetation with a higher density of trees predominated in the Yemen highlands.<sup>87</sup>

In the Levant, an increase in precipitation is evident in a dripstone sequence from Soreq Cave located in the Judean Hills, which suggests higher precipitation with rainfall of 675–950 mm/yr between 8000 and 6000 BC. During the fifth millennium BC, rainfall did not exceed present values.<sup>88</sup> While mechanisms of changing climatic conditions during the Late Pleistocene and Holocene are comparatively well understood both in the southern and northern part of Arabia, poorly developed climatic archives in central and eastern Arabia obscure the pattern for these regions.<sup>89</sup> The general absence of dripstones in the central and eastern parts of Arabia that date to the Holocene contradicts the notion of a well-developed mid-Holocene period of moister climatic conditions induced by a northward shift of the Indian Ocean Monsoon beyond 23°–24° north.<sup>90</sup> Nevertheless,

the development of ephemeral lakes in interdunes<sup>91</sup> and endorheic depressions<sup>92</sup> suggest higher amounts of (irregular) precipitation in northern and central Arabia contemporaneous with the Arabian Middle Neolithic.<sup>93</sup>

###### 4.1.2 Settlement and mobility pattern

Neolithic groups whose subsistence was primarily based on domesticated sheep, goat and cattle as well as on hunting a broad range of wild animals benefited from these favorable environmental conditions. The distribution pattern of stylistically similar arrowheads<sup>94</sup> demonstrates the great mobility of these populations. The presence of similar point shapes in the desert interior, coastal regions and mountain ranges suggests the exploitation of all these regions by the same or closely related groups.<sup>95</sup> Further evidence of the mobility of these communities is provided by personal adornments made of marine shell that have been found up to 180 km away from the closest seashore, demonstrating the mobility of the pastoral communities who must regularly have come into contact with coastal communities as part of their annual cycle of migration.<sup>96</sup> Additional evidence of mobility comes in the form of exotic goods such as obsidian in southwest Arabia.<sup>97</sup>

The predominance of a highly mobile way of life in Arabia during the Middle Neolithic constrained the development of settlements with fixed dwellings. Places that were occupied permanently or at least for longer periods of time developed exclusively in those regions where diverse or especially resource-rich environments supported a greater degree of sedentism. This process is documented along the shores of the Peninsula, where such settlements relied on marine resources. Along the coast of the Gulf of Oman, settlements affirm this date to the sixth millennium BC,<sup>98</sup> therefore suggesting a long tradition of marine exploitation in Arabia. Based on the environmental characteristics of the site locations that provided a year-round food supply, it has been suggested that at least semi-sedentary communities settled in this area.<sup>99</sup>

In contrast, comparable settlements along the southern shores of the Arabian Gulf barely predate the fifth millennium BC. Rising sea levels during the Holocene led to the flooding of the Arabian Gulf

<sup>81</sup> Potts 2001a.

<sup>82</sup> Drechsler 2007; 2009: 22; Charpentier 2008: 108.

<sup>83</sup> Parker and Goudie 2008: 467.

<sup>84</sup> Lezine *et al.* 1998; Neff *et al.* 2001; Fleitmann *et al.* 2003.

<sup>85</sup> Parker *et al.* 2004.

<sup>86</sup> Schulz and Whitney 1986; Lézine *et al.* 1998; 2007; Parker *et al.* 2004.

<sup>87</sup> Wilkinson 1997.

<sup>88</sup> Bar-Matthews *et al.* 2003: 3195.

<sup>89</sup> Fleitmann *et al.* 2004: 1.

<sup>90</sup> Fleitmann *et al.* 2004: 20.

<sup>91</sup> Schulz and Whitney 1986: 181.

<sup>92</sup> Garrard *et al.* 1981.

<sup>93</sup> Schulz and Whitney 1986.

<sup>94</sup> Drechsler 2009.

<sup>95</sup> Spoor 1997.

<sup>96</sup> Uerpman M. *et al.* 2000; 2006; Beech *et al.* 2006; Uerpman M. and Uerpman H.-P. 2008.

<sup>97</sup> Edens and Wilkinson 1998.

<sup>98</sup> Uerpman H.-P. and Uerpman M. 2003; Biagi and Nisbet 2006; Charpentier 2008.

<sup>99</sup> Biagi and Nisbet 2006.

basin,<sup>100</sup> preventing the preservation of older sites. In the northern Arabian Gulf, sea level was possibly up to 2.5 m higher during the fifth to the third millennium BC, while thereafter it was relatively stable, close to present-day levels.<sup>101</sup> Coastal settlements along the Gulf are often associated with dense accumulations of shell, suggesting that the collection and consumption of shellfish played a major role in subsistence in addition to the catching of fish.<sup>102</sup> Frequent finds of both wild and domesticated mammals at these coastal sites indicate the exploitation of a broad spectrum of resources for the daily diet. These data suggest a mixed foraging and food-producing strategy prevailing in Arabia during the Middle Neolithic. Significant populations lived across the Arabian Peninsula, practicing a diverse range of subsistence strategies tied to a variety of well-watered or marine habitats (lakes, lagoons, springs, creeks).

Evidence of nucleated, long-term settlements associated with the Arabian Middle Neolithic also comes from the Yemen Plateau, where environmental reconstruction suggests woodland vegetation, generally higher water tables and scattered ponds in many upland basins as a result of higher precipitation during the mid-Holocene.<sup>103</sup>

Similarly, rich habitats that allowed for a year-round settlement included oases along the coast and in the interior of the Arabian landmass. Oases in the interior that are based on fossil groundwater are situated in three major basins in the cuesta (ridge) landscape of the Arabian Shield in central and eastern Arabia, and in the sediment bodies of the northern Arabian Peninsula.<sup>104</sup> The outcrops of the water-bearing formations along the edges of these basins are zones of groundwater recharge during periods of high precipitation, while artesian springs can be found within the centers of the basins. Long intervals between water recharge and discharge which can range up to tens of thousands of years,<sup>105</sup> as well as the distance between recharging and discharging areas, make these water sources independent of prevailing climatic conditions. Accordingly, springs are the origins of oases within the flat desert, as is the case with the Al-Qatif and Al-Hasa oases in the Eastern Province of Saudi Arabia.<sup>106</sup>

The existence of a curving, packed stone and mud wall associated with the Ubaid-related, Middle Neolithic levels 1–4 at Ain Qannas indicates the presence of permanent architecture there.<sup>107</sup> This suggests

intensive use of the rich oasis environment near the site, potentially linked to cultural contacts with southern Mesopotamia, as indicated by the Ubaid pottery found at Ain Qannas. Besides Ain Qannas, evidence of continuously inhabited settlements in inland eastern Arabia during the fifth millennium BC is scarce.

#### 4.1.3 Subsistence

Because conditions for the preservation of animal bones are generally poor in Arabia, the number of archeological sites that provide information on prevailing economic activities is restricted. Until recently archeologists have favored the view that it was predominantly groups of hunter-gatherers who roamed the wide landmass of the Peninsula during the early and mid-Holocene.<sup>108</sup> Although rarely explicitly noted, the assumption of hunting and gathering as the predominant way of life is based on the overwhelming number of arrowheads found at countless locations in the desert interior of Arabia.<sup>109</sup> The comparatively small number of archeological sites with clear evidence of the presence of domesticated animals supported the view that these bones represent an exotic complement to hunting. Nevertheless, a compilation of archeological sites with bone preservation clearly suggests that domesticated animals represent a common element of the zooarcheological assemblages in Arabia during the mid-Holocene.<sup>110</sup> The presence of domesticated sheep, goat and cattle in sixth-millennium BC<sup>111</sup> archeological contexts in southern Arabia indicates that the herding of domesticated animals had a long tradition in Arabia, clearly predating the fifth millennium BC. One can plausibly argue that the question of whether the herding of domesticated animals or the hunting of wild animals was of greater importance finds its answer in the diverse environments of Arabia: whenever possible, herding was supplemented by hunting wild animals and vice versa. Along the coasts, both fishing and the collection of shellfish played a major role in the economy.

#### 4.1.4 Material culture

In contrast to the restricted evidence of places that were permanently occupied, there are numerous sites all across the Arabian Peninsula with evidence of an ephemeral occupation that can be related to the Arabian Middle Neolithic. Characterized by scatters of flint artifacts and in some cases spatially associated with fireplaces, such localities can be interpreted as the remains of short-term occupations of highly mobile societies. The ephemeral character of most

<sup>100</sup> Lambeck 1996.

<sup>101</sup> Al-Asfour 1978; Sanlaville 1989; Engel and Brückner 2014.

<sup>102</sup> Beech 2004.

<sup>103</sup> Fedele and Zaccara 2005; Fedele 2008.

<sup>104</sup> Burdon 1977.

<sup>105</sup> Wushiki 1997.

<sup>106</sup> Hötzel and Zötl 1984.

<sup>107</sup> Masry 1974.

<sup>108</sup> Tosi 1986; Potts 1993: 168; Cleuziou and Tosi 1998: 123; Edens and Wilkinson 1998: 68; Cleuziou *et al.* 2002: 20; McCorriston *et al.* 2002: 83.

<sup>109</sup> Uerpman *et al.* 2000: 321.

<sup>110</sup> Drechsler 2007.

<sup>111</sup> Martin *et al.* 2009.

Arabian Middle Neolithic sites had a major effect on the preservation of material culture. Due to the restricted anthropogenic accumulation of settlement debris and prevailing natural erosion of sediment, flint artifacts constitute the most frequent category of finds. Less resistant material such as pottery often shows heavy traces of weathering, while artifacts made from organic material are preserved only at a very few sites. The defining element for Middle Neolithic artifact assemblages is therefore flint artifacts, supplemented by objects made from other stone.

Characteristic elements of the flint artifact assemblages that date approximately to the fifth millennium BC and therefore fall into the later phase of the Arabian Middle Neolithic,<sup>112</sup> are bifacial forms with an emphasis on stemmed and usually shouldered points and on narrow foliates, supplemented by scrapers and diverse light and heavy-duty tools.<sup>113</sup> While originally defined for the Rub' al Khali, comparable tool types occur in a much broader area defining an 'Arabian bifacial lithic tradition', *sensu* Edens,<sup>114</sup> often referred to as Arabian Bifacial Tradition (ABT). The corresponding primary production is poorly developed, not standardized and highly heterogeneous. It is oriented towards the production of flakes and can best be described as expedient.<sup>115</sup> Despite basic technological and typological similarities, Arabian Middle Neolithic flint artifact assemblages reminiscent of the Arabian Bifacial Tradition show some degree of regional variability.<sup>116</sup> In the western Rub' al Khali, the Eastern Province of Saudi Arabia and Qatar, the assemblages are dominated by stemmed bifacial points.<sup>117</sup> In contrast, sites in eastern Oman show a clear bifacial component while stemmed points are under-represented.<sup>118</sup> Stemmed points also occur in southern Oman, but they are not barbed and tend to show a pronounced triangular cross section. Greater similarities to the Rub' al Khali assemblages exist in the areas west of the Rub' al Khali, in Wadi Dawasir and the Asir highlands as well as in the southern Hejaz and central Nejd in the north.<sup>119</sup>

Regional variability has been explained by the presence of local populations adapted to different regional environments.<sup>120</sup> Beyond differences in the lithic assemblages, these adaptations are also mirrored in differences in the structuring of space on sites, as well as differences in the prevailing economy. While pastoralism predominates in the southern Arabian highlands, the coastal sites of Oman and the Eastern

Province of Saudi Arabia, hunting and gathering is attested in sites in the Rub' al Khali. Although distinguished by these environmental adaptations, the different lithic facies can be seen as formalized due to inter-regional exchange<sup>121</sup> or a common cultural background as the result of the development of the Arabian Middle Neolithic out of refugia during a period of climatic deterioration.<sup>122</sup>

Both technological and typological characteristics of the Middle Neolithic flint industries as well as the spectrum of flint raw material at many sites is characteristic of mobile societies: raw material is often diverse, and even at sites close to raw material outcrops, imported flint occurs regularly.<sup>123</sup> Apparently, pieces of flint were carried along for some time until they were discarded or replaced by a better piece. Despite the presence of bifacial chipping and pressure flaking for the production of bifacial implements, the Arabian Middle Neolithic flint artifact production has been described as opportunistic.<sup>124</sup>

#### 4.2 Beyond the Ubaid phenomenon: life in the central Gulf area during the Middle Neolithic

Evidence of persistent settlement activities comes from a number of Middle Neolithic sites along the shores of the upper and central Gulf, many of which are characterized by architectural remains and a broad spectrum of artifacts (H3/As-Sabiyah,<sup>125</sup> Bahra 1/As-Sabiyah,<sup>126</sup> Marawah 11<sup>127</sup>). Although generally associated with artifact assemblages that show strong affinities with the Arabian Middle Neolithic, the occurrence of Ubaid pottery at these places indicates cultural ties to southern Mesopotamia.<sup>128</sup> In the lower Gulf towards the Strait of Hormuz, contemporaneous sites are often associated with substantial shell middens, but lack any traces of architecture and are characterized by a more restricted spectrum of material remains. They can therefore be considered to be the remains of ephemeral camp sites<sup>129</sup> that were temporarily used by mobile societies during a year-round migration cycle that was well established in southeast Arabia on the Oman peninsula.

##### 4.2.1 Archeological evidence

The Arabian Middle Neolithic is mostly aceramic. With the exception of about 40 archeological sites that are predominantly located along the shores of the Arabian

<sup>112</sup> Charpentier 2008.

<sup>113</sup> Kapel 1967; Tixier 1980; Edens 1982.

<sup>114</sup> Edens 1982: 120.

<sup>115</sup> Nelson 1991: 64.

<sup>116</sup> Spoor 1997.

<sup>117</sup> Edens 1988: 33.

<sup>118</sup> Bergne and Copeland 1976; Uerpman H.-P. *et al.* 2013.

<sup>119</sup> Edens 1988: 34.

<sup>120</sup> Edens 1988: 35; see Spoor 1997.

<sup>121</sup> Edens 1988: 37.

<sup>122</sup> Drechsler 2009; Preston *et al.* 2015.

<sup>123</sup> Uerpman M. *et al.* 2008; Drechsler 2010.

<sup>124</sup> Kallweit and Davies 2010: 105.

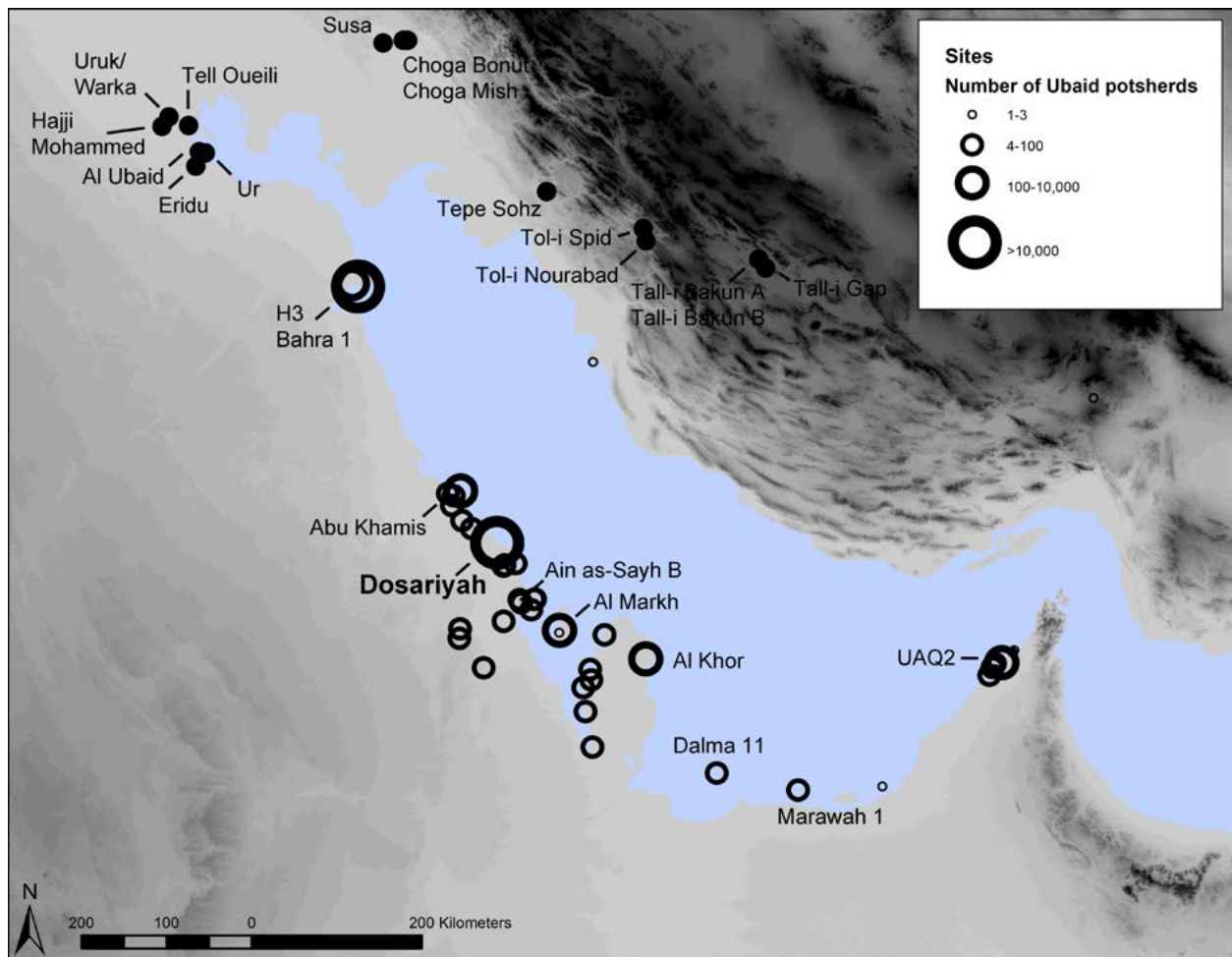
<sup>125</sup> Carter and Crawford 2010a.

<sup>126</sup> Bieliński 2011; 2012.

<sup>127</sup> Beech *et al.* 2005.

<sup>128</sup> Oates J. *et al.* 1977; Roaf and Galbraith 1994.

<sup>129</sup> Uerpman M. and Uerpman H.-P. 1996.



**Figure 1.8.** Sites with Ubaid pottery along the shores of the Arabian Gulf (open circles) and major contemporary sites in southern Mesopotamia and Iran. Shoreline reconstruction for the upper Gulf between c.5300 and 4550 BC (after Pournelle 2003: 123, fig. 44).

Gulf (Figure 1.8), pottery vessels or fired clay objects are known neither from occupation nor from burial or ritual contexts. Only at sites close to the Arabian coast of the Gulf and the Al-Hasa oasis, does pottery occur in the form of painted buff ware and coarse ware. Both vessel shape and decorative style and the chemical composition of the clay suggest an origin of the painted Black-on-Buff ware in southern Mesopotamia and possibly Iran.<sup>130</sup> While the underlying mechanisms of this distribution are unknown, trade or exchange are often invoked as driving forces.<sup>131</sup> The frequency of Ubaid pottery at eastern Arabian sites seems to decrease as the distance from southern Mesopotamia increases.<sup>132</sup>

<sup>130</sup> Bibby 1970; Oates J. *et al.* 1977; Roaf and Galbraith 1994; Beech *et al.* 2005: 46; Carter and Crawford 2010b: 206.

<sup>131</sup> Oates J. *et al.* 1977; Uerpmann M. and Uerpmann H.-P. 1996; Carter and Crawford 2010b; Drechsler 2011.

<sup>132</sup> A small quantity of painted buff ware from sites along the coast of eastern Arabia shows painted decorations that are not commonly associated with Mesopotamian decorative styles. The term 'Ubaid pottery', however, is well established for finds of painted buff ware in the Arabian Gulf. In this volume 'Ubaid pottery' is used in the latter

It occurs in high quantities at Middle Neolithic sites in Kuwait (H3/As Sabiyah, Bahra 1/As-Sabiyah) and in the central Gulf (Abu Khamis, Dosariyah), but was found in significantly lower numbers at several other coastal sites between Ras al-Khaimah and the Qatar peninsula.<sup>133</sup> Stylistically, ceramics from these sites fall within the Ubaid 3 to Ubaid 5 phases,<sup>134</sup> with most assemblages falling in the Ubaid 3 period. Prominent exceptions are H3/As-Sabiyah and Bahra 1/As-Sabiyah, both located in the As-Sabiyah region of present-day Kuwait, where an Ubaid 2 or early Ubaid 3 (Ubaid 2/3) component was documented.<sup>135</sup> Therefore one can argue that the sites with Ubaid pottery and therefore the contacts with southern Mesopotamia did not last

sense as a general term for painted (and unpainted) buff wares found at fifth-millennium BC Arabian Middle Neolithic sites, to avoid the somewhat cumbersome and technical terms 'painted buff ware' or 'Black-on-Buff ware'.

<sup>133</sup> Boucharlat *et al.* 1991; Vogt 1994; Uerpmann M. and Uerpmann H.-P. 1996; Beech *et al.* 2000; Phillips 2002.

<sup>134</sup> Oates J. 1993.

<sup>135</sup> Carter 2010b; Smogorzewska 2013: 556.

longer than a millennium.<sup>136</sup> The location of most sites with Ubaid pottery along the raised shoreline of the Gulf during the fifth millennium BC suggests that contact between southern Mesopotamia and the Gulf was established by seafaring. Direct evidence of boat building was discovered at H3/As-Sabiyah in Kuwait where finds of bitumen fragments with reed impressions and barnacles were interpreted as boat remains.<sup>137</sup> The painting of a boat on a clay disc also discovered at H3/As-Sabiyah proposes the use of the sail in the Gulf at this time.<sup>138</sup>

The role of Ubaid pottery and also of Coarse Ware within the Neolithic societies is still not clear. The spectrum of vessel forms suggests both daily domestic activities (storage jars, cooking pots) and representative items (highly decorated open bowls). Nevertheless, the supply of pottery was marginal at most sites, almost excluding a regular use in daily life. The fact that Ubaid pottery was valuable goods is confirmed by the frequent mending of broken vessels and the reuse of sherds of Ubaid pottery as pendants (see **Chapters 7, 9**).

With the exception of Ain Qannas, located in the northern part of the Al-Hasa oasis in the Eastern Province of Saudi Arabia about 60 km inland, Ubaid pottery was scarcely taken into the interior as the majority of 'inland' sites in the Eastern Province are located at the margins of sabkhas, most likely flooded during the mid-Holocene.<sup>139</sup> In contrast to Ubaid pottery, the occurrence of Arabian Coarse Ware is restricted to the upper and central Gulf where it occurs in lower quantities in comparison to – and always together with – Ubaid pottery. Originally designated as 'simple cooking ware' the broad spectrum of vessel shapes, as well as the presence of decorated vessels,<sup>140</sup> suggests a more diverse use. Although the places of production of this pottery are unknown, the spatial distribution pattern of this kind of pottery suggests a local, Arabian origin. This kind of pottery therefore represents a characteristic element of the Middle Neolithic coastal sites in eastern Arabia.

#### 4.2.2 *Trading networks, exchange patterns or kin relationships?*

The presence of foreign pottery at Middle Holocene sites along the southern shores of the Gulf which originates from different manufacturing locations in southern Mesopotamia suggests a well-established and stable social and/or exchange network during the fifth millennium BC. The underlying mechanisms are, however, poorly understood. Based on his

investigations at Ain Qannas, Dosariyah and Abu Khamis, Masry suggests a common cultural sphere with intense overland contacts or even an origin of the Ubaid 'culture' in eastern Arabia.<sup>141</sup> Excavations at Oueili and the discovery of predecessors of the Ubaid pottery from the central Gulf seized this interpretation.<sup>142</sup> Early levels, designated as Ubaid 0,<sup>143</sup> contain pottery and bricks reminiscent of those from cultural traditions in northern and central Mesopotamia. Subsequent research therefore favored the view of maritime interaction<sup>144</sup> and looked for causes and potential goods for exchange<sup>145</sup> without investigating the fundamental social and economic systems. But is it plausible to argue that communities in southern Mesopotamia, still in the process of state formation, sent out trade expeditions down the Gulf to obtain prestigious goods (i.e. natural pearls)?<sup>146</sup> Or is it likewise reasonable to assume that indigenous eastern Arabian societies who were intimate with seafaring and the exploitation of marine resources sailed in their vessels towards the northwest to obtain pottery?

States with well-developed urban centers and administrative hierarchies potentially able to organize and sustain a trading network did not appear in southern Mesopotamia before the Late Uruk period in c.3000 BC.<sup>147</sup> Although similarities of architecture and painted pottery styles in southern Mesopotamia from the Early Ubaid through the Late Uruk periods suggest a certain degree of demographic and cultural continuity, it is debatable whether later mechanisms of formalized exchange (or trade) can be extrapolated from the more distant past. By the beginning of the Ubaid period (Ubaid 0–1), small villages and towns were common across Mesopotamia. Much of this region was linked through social networks, and similarities in artifacts indicate a widespread exchange of goods and knowledge.<sup>148</sup> At this time, even the larger communities such as Eridu, Ur or Tell al-Ubaid were small, averaging about 1 ha, with estimated populations not exceeding 1000 people. As these small communities were widely dispersed and lacked the linear distribution typical of settlements dependent on irrigation canals,<sup>149</sup> the practice of irrigation agriculture in southern Mesopotamia at that time is questionable. During the Middle Ubaid (Ubaid 2–3), a two-tiered settlement system appeared that often marks the emergence of hierarchically organized, non-state societies.<sup>150</sup> Important centers such as Eridu

<sup>136</sup> Rose 2010: 864.

<sup>137</sup> Carter 2006; Carter and Crawford 2010b.

<sup>138</sup> Carter 2010d: 91.

<sup>139</sup> R. Carter, personal communication.

<sup>140</sup> Kainert and Drechsler 2014.

<sup>141</sup> Masry 1997: 123.

<sup>142</sup> Huot 1989.

<sup>143</sup> Oates J. 2004.

<sup>144</sup> Oates J. *et al.* 1977; Carter 2006; Carter and Crawford 2010b.

<sup>145</sup> Uerpmann M. and Uerpmann H.-P. 1996.

<sup>146</sup> Oates J. *et al.* 1977: 233; Uerpmann M. and Uerpmann H.-P. 1996: 135.

<sup>147</sup> Adams 1981; Nissen 1988; 2001; Pollock 1999; Yoffee 2005.

<sup>148</sup> Kennet D.J. and Kennet J.P. 2006.

<sup>149</sup> Adams 1981: 59.

<sup>150</sup> Wright 1981; Stein 1994.

grew up to 10 ha, with estimated populations of 2000 to 3000.<sup>151</sup> During this period, Ubaid pottery appears in Middle Neolithic settlements along the southern coast of the Arabian Peninsula for the first time. Although an economic and political differentiation is indicated by this hierarchical distribution of settlements in Mesopotamia, little evidence exists to support elite control of long-distance exchange systems and centralized control of high-status craft production.<sup>152</sup> Instead, Ubaid-period societies were centered on the temple complex, and ideology appears to have played an important role in organizing these communities.<sup>153</sup> Only by the end of the Ubaid period were some communities substantially larger than their neighbors, ruled by hereditary leaders and administered by institutionalized administrative organizations.<sup>154</sup> But it was not before the late Uruk period that 'colonists' and/or 'merchants' from southern Mesopotamia were able to gain access to critical material and wealth objects and that the movement of goods to southern cities was facilitated by outposts strategically located in areas containing valuable resources, affording control over the distribution of these materials.<sup>155</sup>

Even if the fifth-millennium BC southern Mesopotamian socio-economic environment did not support regular trade it remains a valid hypothesis that southern Mesopotamian seafarers sporadically traveled down the Gulf to obtain some kind of local products not available in their homeland in exchange for pottery. But what would be appropriate and beneficial targets of this exchange? Copper, the most important export of eastern Arabia during the third millennium BC, can be excluded, as there is no evidence of copper mining during this period. In addition, eastern Arabia in the central Gulf region lacks any copper sources. One possibility that has been repeatedly mentioned is that Ubaid pottery was exchanged for pearls.<sup>156</sup> Although pearl fishing in the Gulf clearly dates back to the fifth or even sixth millennium BC,<sup>157</sup> the use of pearls is most convincingly attested at that time for southeast Arabian societies who used them to adorn their dead.<sup>158</sup> In addition, mother-of-pearl was used for the manufacture of adornment and fishing hooks by local coastal populations.<sup>159</sup> In addition to pearls and shell, the spectrum of potential goods for exchange that has been suggested by different researchers includes

livestock,<sup>160</sup> dried fish,<sup>161</sup> leather and textiles, access to water and a peaceful passage,<sup>162</sup> or marriage partners to encourage a multi-directional network of family connections.<sup>163</sup>

Although plausible to some degree, all these suggestions are difficult to verify based on the archeological record. The question remains open as to what goods or commodities were so important in southern Mesopotamian societies that Mesopotamian seafarers sailed down the Gulf.

While the problem of goods provided for exchange remains, at least the question of impetus for this exchange can be broached if one considers the local Arabian populations living along the shores of the Gulf as the active agents in this kind of exchange; it is not only from mending holes that we know that Ubaid pottery was considered valuable. At Dalma 11, located in the lower Gulf and well beyond the area of the central Gulf that had easier access to southern Mesopotamian pottery, Ubaid pottery was imitated in painted plaster vessels.<sup>164</sup> Clearly, there was a certain need for painted pottery along the Arabian shores of the Gulf but again, the specific character of this need is difficult to demonstrate. Carter suggests that the Ubaid pottery found in Arabian Neolithic contexts was oriented 'towards serving and display, both of the ceramics themselves and of the food served.' He further proposes that 'Ubaid pottery was not only used to present food, but was also redistributed in acts of ceremonial gift-giving or exchange at communal events, perhaps in feasting contexts'.<sup>165</sup>

It is the idea of this feasting context that is further developed by Peter Magee.<sup>166</sup> Following Ibn Khaldun, Magee introduces the idea of *assabiya*, social mechanisms that derived from shared experiences of desert life, as one of the formative elements of Arabian (pre)history.<sup>167</sup> According to Ibn Khaldun, *assabiya* is antithetical to an urban existence based on royalty, wealth and luxury, but emphasizes kin relationships that allow the overcoming of social or environmental challenges. It can be defined as 'a corporate spirit oriented towards obtaining and keeping power' which was 'held together by the sense of common ancestry, whether real or fictitious'.<sup>168</sup> Was the presence of Ubaid pottery in eastern Arabia an integral part of ceremonies that center on social cohesion in this region? During the subsequent fourth millennium

<sup>151</sup> Adams 1981.

<sup>152</sup> Stein 1994.

<sup>153</sup> Hole 1994: 139; Stein 1994.

<sup>154</sup> Kennet and Kennet 2006: 83.

<sup>155</sup> Algaze 2001; Rothman 2001.

<sup>156</sup> Oates J. et al. 1977; Uerpmann M. and Uerpmann H.-P. 1996; Carter and Crawford 2001; Phillips 2002; Carter 2006; Charpentier et al. 2012.

<sup>157</sup> Charpentier et al. 2012.

<sup>158</sup> Kiesewetter et al. 2000; Beauclair 2005; 2008.

<sup>159</sup> Beech and Elders 1999; Méry et al. 2009.

<sup>160</sup> Kallweit 2003: 63.

<sup>161</sup> Uerpmann M. and Uerpmann H.-P. 1996: 139, n. 70.

<sup>162</sup> Carter and Crawford 2010b: 209.

<sup>163</sup> Carter and Crawford 2010b: 210.

<sup>164</sup> Beech et al. 2000; <http://www.adias-uae.com/plaster.html>, accessed 17/09/2014.

<sup>165</sup> Carter 2006: 60.

<sup>166</sup> Magee 2014.

<sup>167</sup> Magee 2014: 11.

<sup>168</sup> Hourani 1992: 2 after Magee 2014: 12.

BC, such social strategies are well attested. While a mound of dugong bones at Akab, Umm al-Quwain, indicates mass slaughter and consumption, potentially in the context of totemism,<sup>169</sup> an oval arrangement of forty cattle skulls that were pushed into the sediment at Kheshiya, Wadi Sana, Yemen,<sup>170</sup> was associated with a collective event that ‘commemorated the convergence of a social group or several social groups whose practice of ritual sacrifice emphasized their community ties’.<sup>171</sup>

Another fundamental characteristic of Arabian societies is the high degree of mobility in view of a diverse spatial distribution of environmental resources. This high degree of mobility was often accompanied – and is traceable through – the displacement of material culture. In addition to an exchange of material goods and ideas, ‘regularized interaction between groups would also have provided an opportunity for the alignment of ideological and social systems across the entire peninsula’.<sup>172</sup> The distribution of soft stone, obsidian, worked stone and shell<sup>173</sup> that were found in distances up to 180 km from their original sources<sup>174</sup> suggests that this kind of mobility was already established in the fifth millennium BC, be it in the form of intense interaction between different population groups or actual movements of people.<sup>175</sup> It is a fascinating and peculiar characteristic of the spatial distribution of Ubaid pottery that – in contrast to many other aspects of material culture – it scarcely found its way inland, but it almost exclusively occurs along the (former) coastline. Although considered a valuable item at coastal sites, it was not distributed further inland. No explanations can be given at present, but it is reasonable to assume that some kind of social mechanisms/restrictions hindered an effective redistribution.<sup>176</sup>

One interesting aspect in the discussion about the distribution of Ubaid pottery along the Gulf coast comes from Rose’s hypothesis of a population refuge in the Arabian Gulf basin (‘Arabo-Persian Gulf Oasis’) that became submerged by rising sea levels until the mid-Holocene.<sup>177</sup> Fed by both allochthonous rivers and groundwater aquifers, favorable environmental conditions are suggested to have existed at times when

precipitation was reduced in the interior. According to Rose, arid conditions during MIS 2 forced nomadic groups to contract toward the Arabian Gulf basin.<sup>178</sup> In contrast, ameliorating climatic conditions in Arabia from the onset of the Holocene onwards, together with the contemporaneous postglacial flooding of the Gulf, drew populations into the hinterland and thus led to a permanent inland shift of the settlements in accordance with the transgressive sea. It has already been argued that the formation of rich coastal zones along the northern shorelines of the Gulf – in southern Mesopotamia – promoted the development of Ubaid communities and played a critical role in the process of state formation.<sup>179</sup>

But what were the consequences of these changing environmental conditions for the populations in eastern Arabia? First of all, an almost dramatic increase in the number of archeological sites can be observed. With the exception of Qatar, sites that are (often only tentatively) dated to the seventh and sixth millennia BC are very rare in eastern Arabia. In contrast, more than 60 sites are known today along the shores of the Gulf that date to the fifth millennium BC, thus coinciding with the final phase of the marine incursion. Further on, the settlements along the shores of the central and lower Gulf seem to lack local ancestors predating the Arabian Middle Neolithic/Ubaid 3 period. The only exception might be Ain Qannas, where Ubaid pottery was found that can be associated with Ubaid 2. The fact that Ain Qannas is located about 60 km inland and on the edge of a well-watered oasis suggests a different mechanism for the establishment of this site. It is therefore conceivable that the present picture of the spatial distribution of sites along the shores of the Gulf is the result of the history of its flooding, with the majority of Middle Neolithic sites located along or close to the shoreline of the mid-Holocene high stand. Contemporaneous with the incursion of the Gulf, populations and their settlements were pushed outwards onto dry land. Such a mechanism would have one further important implication. During the time when the Arabian Gulf basin served as a refugium it might have been occupied by a single population with a common cultural background, consecutively driven apart by the transgression. In that case, did the imports of Ubaid pottery function as a symbol for a common ancestry, as an assurance of shared identity? The early Ubaid settlements in southern Mesopotamia were located on slight rises (‘turtle backs’) within aquatic habitats in the wetlands at the head of the Arabian Gulf.<sup>180</sup> Such locations were at the interface between fresh- and saltwater and were optimal for freshwater

<sup>169</sup> Méry *et al.* 2009.

<sup>170</sup> McCorrison and Martin 2009; McCorrison 2011: 100.

<sup>171</sup> McCorrison and Martin 2009: 246.

<sup>172</sup> Magee 2014: 62.

<sup>173</sup> Edens 1988.

<sup>174</sup> Beech *et al.* 2006: 24.

<sup>175</sup> See Uerpmann M. *et al.* 2000 for year-round migration cycles in southeastern Arabia.

<sup>176</sup> The use of pottery vessels is widely restricted to sedentary communities, while mobile societies often replace pottery by other, less breakable, materials. It is therefore plausible that at first sight the pots did not travel further inland due to the risk of breakage during transport. Nevertheless, if we consider Ubaid pottery in an Arabian Neolithic social context as a valuable or exotic item rather than a functional one, even single – especially painted – potsherds would have kept their essential value.

<sup>177</sup> Rose 2010.

<sup>178</sup> Rose 2010: 854.

<sup>179</sup> Kennet D.J. and Kennet J.P. 2006.

<sup>180</sup> Pournelle 2003.

accessibility, hunting and fishing, and transportation.<sup>181</sup> The settlements in southern Mesopotamia therefore closely mirror the characteristics of the majority of Middle Neolithic settlements along the southern shores of the Gulf, both in their locations on islands or very close to the former sea lines and in characteristic adaptations to marine resources. Are these similarities simply the result of congeneric adaptations to similar environmental conditions? Or are we faced with

developments that find their basis in a common cultural context deeply rooted in both southern Mesopotamian and coastal Arabian societies? The study of material remains excavated at Dosariyah unveiled in the subsequent chapters will try to find answers to these questions, ultimately contributing to a growing body of knowledge about a fascinating facet of the prehistory of the Arabian Peninsula.

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<sup>181</sup> Oates J. 1960.

# Chapter 2

## Geomorphology, Geoarcheology and Paleoenvironments

Adrian G. Parker, Simon J. Armitage, Max Engel, Mike W. Morley, Ash Parton,  
Gareth W. Preston and Hannah Russ

### 1 Introduction

Environmental change during the Holocene in eastern Saudi Arabia is poorly understood. Few detailed records have been examined to date, with limited evidence available from dunes, lakes and sea-level records. While the geomorphological setting of the Jubail region has been described in detail by Barth,<sup>1</sup> the chronology for the development of this landscape is largely unknown. Lacustrine deposits from the Al Sulb Plateau,<sup>2</sup> Al-Hasa,<sup>3</sup> Nafud As Sirr<sup>4</sup> and the southern playa of Bahrain<sup>5</sup> record wetter conditions during the Early to mid-Holocene. These sites have yielded radiocarbon dates between 7900 and 4700 cal. BC (8300–5800 <sup>14</sup>C BP) but no detailed physical, chemical or biological analyses have been conducted. Therefore, the environmental backdrop against which the occupation at Dosariyah can be set is limited.

An area approximately 3 x 2 km was mapped in detail (**Figure 2.1**) to record the geomorphology of the site and its surroundings through field observations, logging of natural and artificial quarry sections, and test pit evaluation to record sub-surface stratigraphy and collect samples for paleoenvironmental analyses. Geomorphological and paleoenvironmental research in the Dosariyah area was conducted over 10 days of field investigation, during which parts of the wider region were also visited. The topography in and around the site is generally low lying, comprising small bedrock outcrops up to 20 m high, eolianites, dune sands, sand sheets, sabkhas and coastal spits, bars and barrier complexes.

### 2 Geomorphology

Along much of the southern coast of the Arabian Gulf extensive outcrops of cemented eolian sands occur. These are the remnants of deflated longitudinal dunes with their axis trending in a north-northwest-south-southeast direction. At Dosariyah two remnant ridges of these deflated eolian sands were mapped, both of

which are orientated parallel to the modern coast and are up to 15 m asl (above mean sea level). The coastal facing side of the ridges is exposed to intensive eolian erosion with exposed eolianite at the surface, while on the landward side younger, secondary dunes have formed on the leeward side of these ridges from the reworking of the primary eolian bedforms (**Figure 2.1**).

To the south of Dosariyah, Hussain refers to deposits of Dammam Eolianite.<sup>6</sup> This eolianite is dominated by carbonate material, comprising mostly oolites, rounded skeletal fragments (coral, shell debris) and peloids, cemented by calcite, aragonite and gypsum. The cemented dunes comprise pale brown-buff calcareous grainstone with over 85% carbonate grains. The Dammam Eolianite is characterized by well-sorted, fine to medium sand-size particles. Glennie noted that carbonate sand grains are eroded by wind action 2–4 times as fast as quartz grains and thus carbonate allochems in eolianite are usually fairly well rounded.<sup>7</sup> Outcrops of Dammam Eolianite are exposed at Dosariyah at the surface along the coastal strip (**Figure 2.1**). They form a resistant cap (**Figure 2.2**), which in places has been faceted by wind action to form yardangs (**Figure 2.3**) or is covered by younger dunes. Goudie notes that yardangs are developed by unidirectional or narrow bimodal wind directions and are often found in areas associated with barchans.<sup>8</sup> In exposed sections, foreset strata dip at varying angles between 9° and 21° while individual laminae are typically 1–3 mm thick, giving rise to well-developed pin-stripe lamination. These laminae are commonly formed by coarser grain flows of larger, well-rounded carbonate grains (oolites, skeletal material and peloids) interbedded with finer-grained carbonate material. Further inland from the coast, the material contains an increasing amount of quartz and other siliciclastic material.

Sections through these cemented dune ridges show they are formed from more than one generation of eolian deposits. Underlying the cemented Dammam Eolianite cap rock several exposures revealed soft, uncemented, well-sorted medium sands comprising ~95% quartz, and less than 1% ooids. Key exposures

<sup>1</sup> Barth 1998; 2002.

<sup>2</sup> Jado and Zötl 1984.

<sup>3</sup> Larsen 1983.

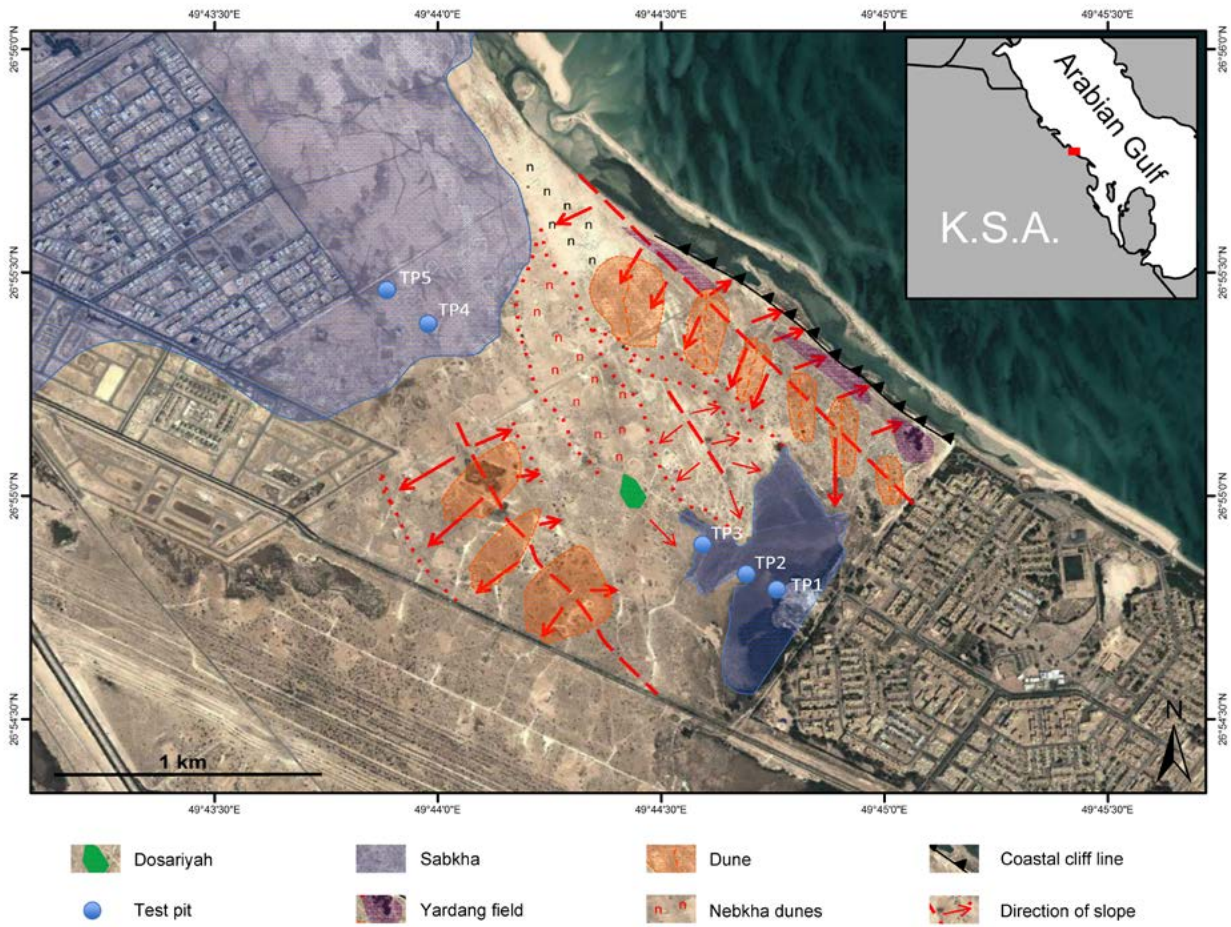
<sup>4</sup> Schulz and Whitney 1986.

<sup>5</sup> Doornkamp *et al.* 1980.

<sup>6</sup> Hussain 2006.

<sup>7</sup> Glennie 1970.

<sup>8</sup> Goudie 2007.



**Figure 2.1.** Geomorphological map of the Dosariyah area (geomorphological mapping: A. Parker and M. Morley).



**Figure 2.2.** Carbonate-rich Dammam Eolianite capping quartz-rich uncemented sand in coastal cliff exposure, Dosariyah. The lower weakly cemented sand unit underlying the carbonate-rich cemented cap unit was OSL dated to  $6.8 \pm 0.5$  ka ( $4.8 \pm 0.5$  ka BC) (photograph: A. Parker).

were noted in a disused quarry section, where up to 8 m of the deposits were exposed beneath a 1 m thick Damman Eolianite cap (N26°54'52.1" E049°44'21.5"), and also in a coastal cliff section (**Figure 2.2**) under a 0.5 m cap (N26°55'34.3" E049°44'30.8").

In the United Arab Emirates carbonate cemented sands, mapped as 'miliolite' by Huntings<sup>9</sup> as they contained many miliolid foraminifera, equate to the Damman Eolianite observed in the eastern coastal region of Saudi Arabia. More recently, however, they have been termed the Ghayathi Formation<sup>10</sup> after a type section at Jabal Marban in Abu Dhabi. The Ghayathi Formation consists of carbonate-dominated paleo-dune sandstones, which form a series of semi-continuous outcrops across the region. These generally occur as extensive deflated sheets occupying low-lying areas. Small isolated outcrops of miliolite draping the older orange quartz-rich sands, which are synonymous with the Madinat Zayed Formation of the UAE,<sup>11</sup> occur locally.

Low dunes, reworked and emplaced during the Holocene, are found superimposed on the main eolianite dunes. They are most conspicuous on the north-northwest-south-southeast trended deflated linear dune closest to the coast. Here they top the summits of the high ground and are draped over the eolianite surface on the landward side. In places these dunes are up to 3 m above the eolianite surface and are whitish in color, having largely been reworked from the Damman Formation. They trend north-northeast-south-southwest, with several wind gaps between the white dune areas. These dunes are covered in scrubby vegetation. Areas of cross-bedded and planar-bedded grainstone occur locally between areas of low dune or sand veneer. These are exposed as corrugated pavements, which are flat in nature due to deflation by wind, which has exposed the bedding planes. Good examples occur at N26°55'11.0" E049°44'42.0" and N26°55'13.6" E049°44'35.5". Within the wind gaps and on the dune flanks of the sabkha areas at Dosariyah extensive areas of low, small scrubby nebkha dunes up to 1 m high occur.

Across much of the desert interior to the northwest and west of the site active transverse barchanoid dunes occur. Driven by the shamal winds, these move at rates of up to 3 m/yr.<sup>12</sup> Barth suggests that overgrazing has reduced the vegetation cover to such an extent that previously stable fossil dunes have once again become active.<sup>13</sup>

Within the southeastern coastal area yardangs are common features of the landscape, often found on

low-lying hills and ridges of the Upper Tertiary Rus, Damman and Hofuf formations, and Quaternary carbonate eolianite formations. At Dosariyah meso-scale yardangs were mapped adjacent to the coast, developed in carbonate-rich eolianites. The yardangs here are up to 1.5 m high, 3 m wide and up to 15 m in length (**Figure 2.3**).

The dominant orientation of the yardangs is to the south-southeast and roughly parallel to the present-day prevailing wind patterns along the Arabian Gulf coastline. Yardangs faceted into Hadruk bedrock were also noted in the vicinity of Jebel Bari (N26°54'26.4" E049°29'59.2"). To the west and northwest of the study site, barchanoid ridges and barchan dunes overlying sabkha deposits are also found. These dunes have migrated across the sabkhas in the same prevailing wind direction.<sup>14</sup> Elsewhere in the Arabian Gulf region meso-scale yardangs up to 10 m high have developed on resistant dolomitic Eocene limestones (Rus Formation) in the southwest corner of the main island of Bahrain's central depression, while yardangs up to 4–6 m high are also found on eroded eolianites on Jiddah Island, off the west coast of Bahrain.<sup>15</sup>

### 3 Coastal Processes

The coastline running south of Jubail to the desalination plant, south of Dosariyah, is dominated by a series of complex coastal barriers, spits, lagoons and sabkhas. The coastal configuration comprises several headlands and embayments, which are heavily influenced by coastal processes, especially tidal patterns, wave refraction and longshore drift. Tidal patterns within the Arabian Gulf are complex with regional variations in tidal range,<sup>16</sup> including two amphidromic points that have been noted where there is no tidal range. The first is located off the northern Saudi Arabian coast to the north of Dosariyah, and the second is located off the western Abu Dhabi coast (UAE). Tidal ranges increase away from these nodes. Over most of the Gulf the tidal range offshore is < 0.6 m but increases to 1–2 m near land.<sup>17</sup> At Jubail the tides mainly follow a semi-diurnal regime with a mean spring tide range of c.1.5 m and a neap tidal range of 0.8 m.<sup>18</sup>

At Ras al Qulay'ah, 15 km southeast of Dosariyah, calculated tidal data for 2016 show a Mean High Water (MHW) of 1.61 m, Mean Low Water (MLW) of 0.55 m and mean tidal range of 1.09 m. Mean Highest High Water (MHHW) was calculated to be 1.70 m and Mean Lowest Low Water (MLLW) to be 0.44 m with a tidal range of 1.26 m. The Highest Astronomical Tide (HAT) was

<sup>9</sup> Huntings 1979.

<sup>10</sup> Hadley *et al.* 1998.

<sup>11</sup> Farrant *et al.* 2012.

<sup>12</sup> Barth 2002.

<sup>13</sup> Barth 1999; for further details see Barth 1998.

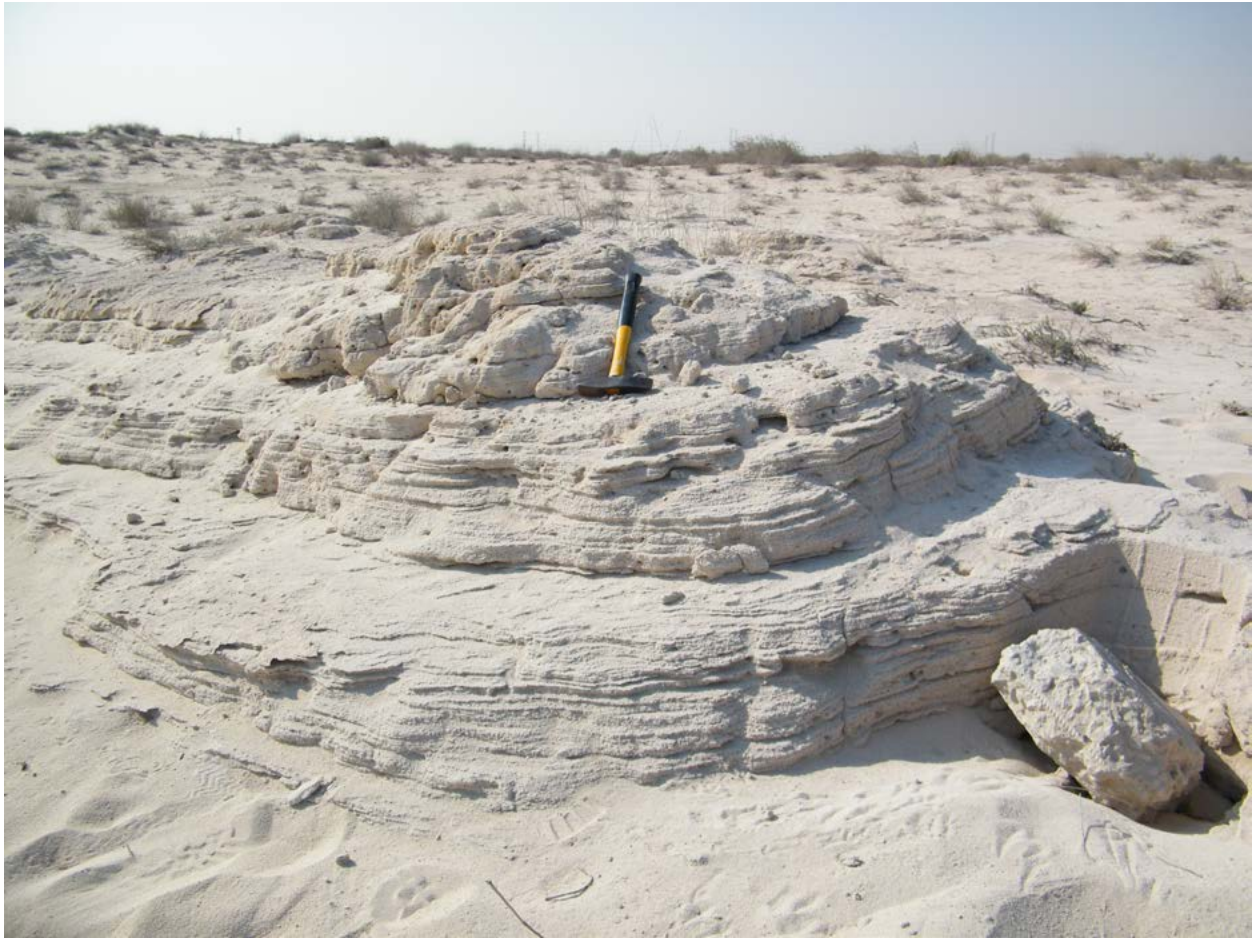
<sup>14</sup> Anton and Vincent 1986; Barth 2002.

<sup>15</sup> Doornkamp *et al.* 1980.

<sup>16</sup> Barth 2002.

<sup>17</sup> Sheppard *et al.* 1992.

<sup>18</sup> Barth 2002.



**Figure 2.3.** Yardang faceted into coastal eolianite, Dosariyah (photograph: A. Parker).

2.05 m and Lowest Astronomical Tide (LAT) 0.09 m. Al-Subhi reported semidiurnal dominance in the region with astronomical tide variation accounting for 90% of the total water variation.<sup>19</sup> The rest of the variation was attributed to atmospheric pressure and water density variations, especially during the winter months. The Gulf coastline in the proximity of Dosariyah thus shows a low tidal range. In addition to the normal tidal range, shamal wind generated high amplitude storm surges, coupled with changes in atmospheric pressure, topography and tidal effects that can lead to significant changes in sea level of several meters.<sup>20</sup> From historical data it has also been suggested that earthquake activity in Iran has led to probable tsunami events in the Arabian Gulf leading to coastal inundation.<sup>21</sup> To date, no (paleo-)tsunami deposits have been reported from the Gulf coast region.

Present-day coastal processes have been severely impacted by development and infrastructure along

the coast, in the form of artificial islands, marinas and groynes, leading to sediment supply and delivery issues. In places this has led to the starvation of sediment resupply leading to erosion of the coastal barrier island and spits. At Dosariyah a coastal barrier-spit complex has developed, behind which a series of lagoons and channels has formed. These coastal features formed across coastal embayments at the mouth of the now dry sabkha inlets. At least two barriers were mapped: the present barrier lies approximately 250 m from the coastal cliff line, while an older, former barrier abuts the land and is clearly visible in the CORONA satellite images (**Figure 2.4**). This feature lies across the entrance to the northern sabkha where it now forms a low dune. The coastal barrier deposits comprise a complex mix of beach, eolian and washover sands. These form complex elongate hooked spits curving inland. Current coastal processes are eroding this feature because of the starvation of new sediment supply due to coastal development and the construction of breakwaters to the north. The spits and barrier islands are aligned parallel to the coast and the coastal barriers are interspersed by intertidal and lagoonal sediments.

<sup>19</sup> Al-Subhi 2010.

<sup>20</sup> El-Sabh and Murty 1989; Thoppil and Hogan 2010.

<sup>21</sup> Bou-Rabee and VanMarcke 2001; Jordan 2008.

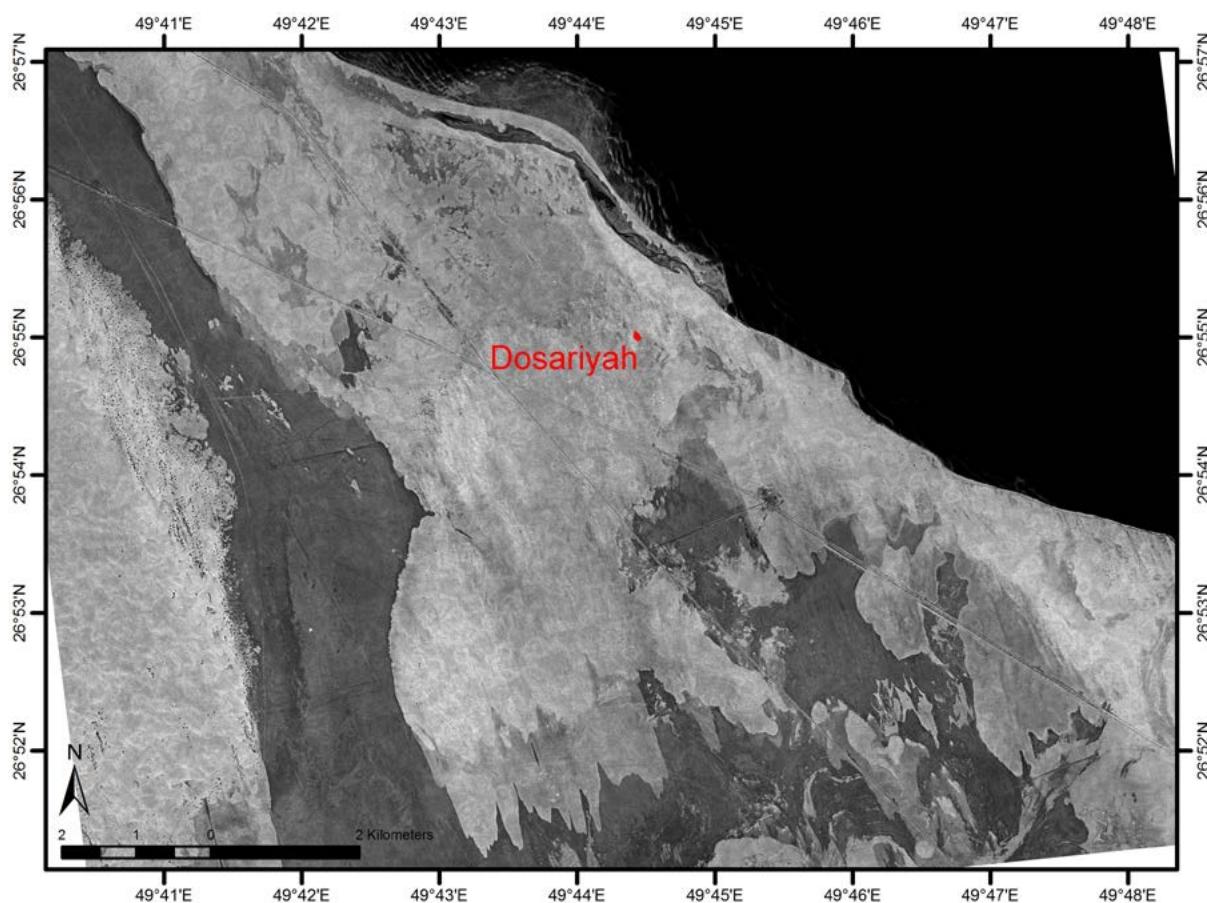


Figure 2.4. CORONA satellite image for the Dosariyah region.

Inland, these features have largely infilled to form extensive sabkha deposits. Compared to the classic barrier-lagoon systems found in the UAE around Abu Dhabi, the Dosariyah system tends to lack carbonate mud and algal mats. This observation was previously noted by James and Little.<sup>22</sup> They suggest that this may be the result of groundwater influences from aquifers within the Pleistocene dune and Miocene Hadrukh bedrock formations. The sabkhas comprise flat areas, partially cemented by salt (sodium chloride) and calcium sulphate (gypsum) often forming pustulose surfaces (Figure 2.5).

Two areas of sabkha are found close to the site at Dosariyah (Figure 2.1), one to the north and the other to the south. The southern sabkha is of particular importance because of its location adjacent to the Neolithic archeological site. In this area three different sabkha levels, representing former sea-level shoreline limits, were mapped at 1.2, 1.5 and 2.0 m asl. A series of test pits (TP 1–5) were dug into the sabkhas. TP1, 2 and 3 were located in the southern sabkha and TP4 and 5 in the northern sabkha. These sections record phases

of development from open water to intertidal flats and finally sabkha development. The sections were sampled for sedimentological and paleoenvironmental analyses and are described below.

#### 4 Methods and Sampling

The Neolithic site of Dosariyah is situated on an area of higher ground, ~5 m asl, surrounded on three sides by low-lying sabkha and to the east by coastal dunes and the Arabian Gulf coastline. The sabkha surface in this area comprises flat, low-lying gypsiferous surfaces with coarse gypsum crystals, medium to coarse sand and abundant relict marine gastropod shells of the genus *Cerithidea*, a mollusk favoring an intertidal environment. The sabkha in this area of Jubail is unusual as it is nourished by artesian groundwater that appears to be important in the maintenance of this area as a salt flat.<sup>23</sup> To the south of the site the sabkha can be broadly divided into an upper, middle and lower elevation surface, with the elevation dropping towards the south away from the site. To the north of the site the higher ground is formed by Pleistocene and Holocene

<sup>22</sup> James and Little 1994.

<sup>23</sup> James and Little 1994.



**Figure 2.5.** Pustulose sabkha surface with salt, southern sabkha, Dosariyah (photograph: A. Parker).

dune systems, and the sabkha appears to comprise one main surface that extends out to the north and west.

Profiles across the site were surveyed using a total station in relation to sea level and these are shown in **Figure 2.6**. Five test pits were excavated into the sabkha deposits located to the north and south of the Dosariyah archeological site. The depths excavated were limited by the modern water table. The sediment sections were logged and described and are shown in m asl (**Figure 2.7**).

#### 4.1 Sedimentology

Profiles within these test pits were recorded and sampled for paleoenvironmental analyses. Mass-specific, low-frequency magnetic susceptibility measurements were made on each sample using a Bartington MS2 meter with a MS2B sensor at 0.1 SI unit sensitivity.<sup>24</sup> Loss-on-ignition analyses followed the method described by Heiri *et al.*<sup>25</sup> Samples of < 2 mm were oven dried at 105°C,

followed by a first combustion at 550°C to remove organic carbon then a second burn at 950°C to drive off carbonates. Results are reported as percentages of the dry weight. To determine grain size, samples of air-dried sediment < 2 mm were gently disaggregated in de-ionized water with 5% Calgon (hexametaphosphate) and analyzed using a Malvern Mastersizer 2000. Grain size statistics are based on the logarithmic graphical measures of the (original) Folk and Ward method for sorting, skewness and kurtosis.<sup>26</sup> The mean particle size calculations are based on the modified Udden-Wentworth scale and are reported in microns (µm).

#### 4.2 Dating

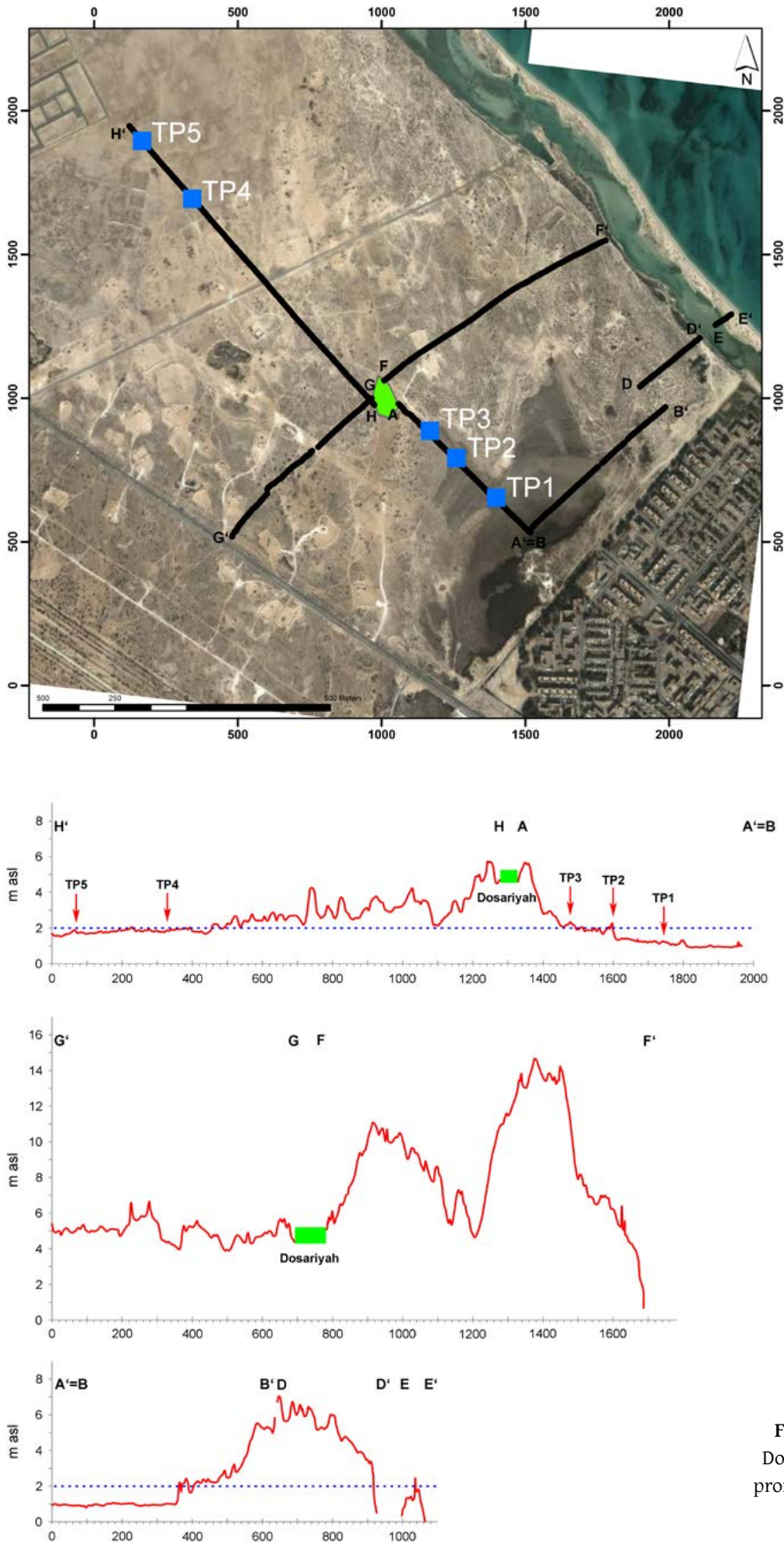
Samples were collected from cleaned sections using black, opaque, light-proof tubes (50 mm diameter x 200 mm length). Sample locations are listed in **Table 2.1**. Using the procedure outlined in Armitage *et al.*<sup>27</sup> 212–180 µm diameter quartz grains were extracted from the sample tubes. Stimulation

<sup>24</sup> Dearing 1999.

<sup>25</sup> Heiri *et al.* 2001.

<sup>26</sup> Folk and Ward 1957.

<sup>27</sup> Armitage *et al.* 2011.



**Figure 2.6.** Cross sections across Dosariyah showing the topographic profiles and locations of the sampling sites.

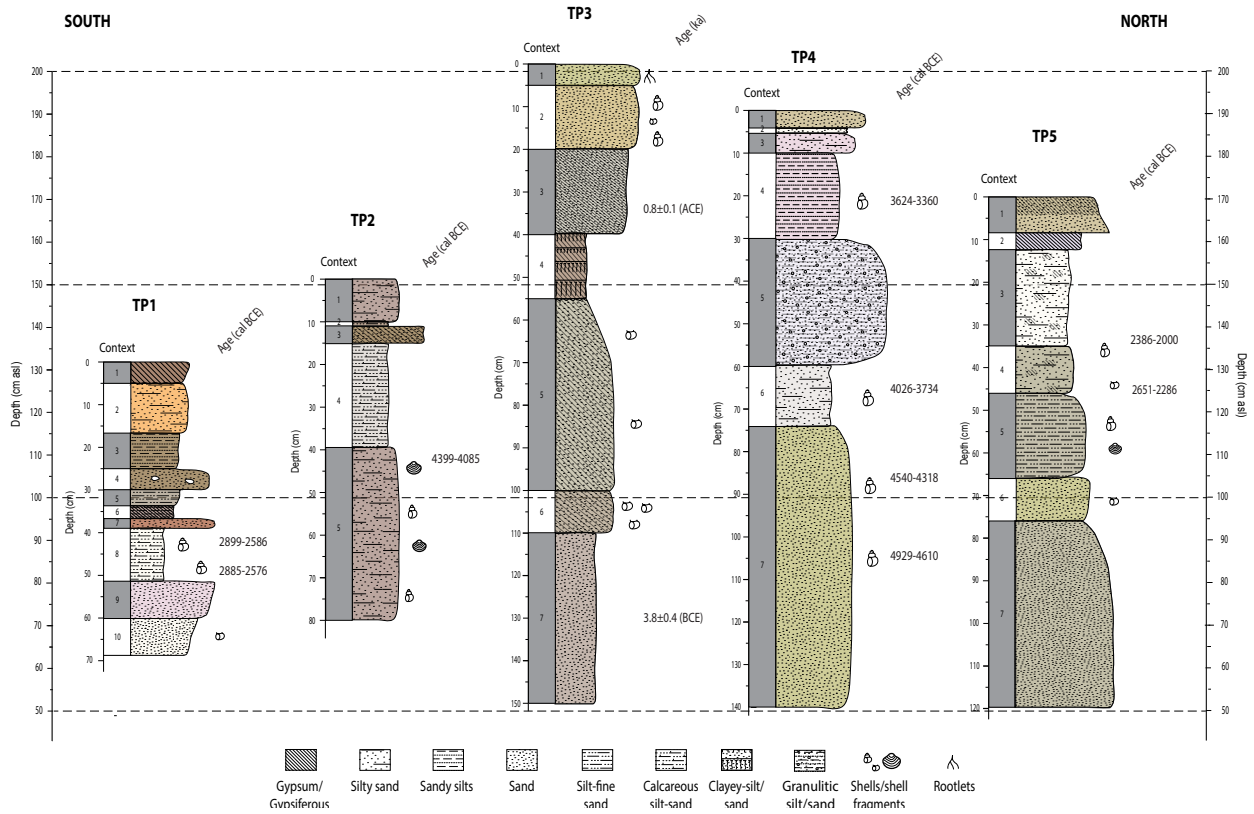


Figure 2.7. Test pit profiles from the southern sabkha (TP1, TP2, TP3) and northern sabkha (TP4, TP5); all sections are presented in m asl.

Table 2.1. Summary dosimetry and OSL dating results.

Sample	Sample details	Radionuclide concentrations			Sample depth (m)	Water content (%)	OSL sample grain size (µm)	Cosmic dose rate (Gy/ka)	Dose rate (Gy/ka)	Equivalent dose (Gy)	n (accept)	Age (ka) <sup>1</sup>
		K (%)	U (ppm)	Th (ppm)								
OSL1	Dosariyah (TP3)	0.90 ± 0.09	0.89 ± 0.09	1.67 ± 0.17	1.3 ± 0.2	5 ± 2.5	212–180	0.169 ± 0.004	1.23 ± 0.07	7.14 ± 0.34	27	5.8 ± 0.4
OSL2	Dosariyah (TP3)	0.41 ± 0.04	2.00 ± 0.20	0.67 ± 0.07	0.35 ± 0.2	5 ± 2.5	212–180	0.212 ± 0.027	1.03 ± 0.05	1.23 ± 0.12	22	1.2 ± 0.1
OSL3	Dosariyah (QP1)	0.34 ± 0.03	1.81 ± 0.18	4.80 ± 0.48	1.1 ± 0.2	5 ± 2.5	212–180	0.173 ± 0.005	1.15 ± 0.05	8.33 ± 0.41	21	7.2 ± 0.5
OSL4	Dosariyah (QP1)	0.47 ± 0.05	1.67 ± 0.17	0.62 ± 0.06	0.5 ± 0.2	5 ± 2.5	212–180	0.199 ± 0.018	0.99 ± 0.05	2.95 ± 0.16	22	3.0 ± 0.2
OSL5	Dosariyah (coastal section)	0.90 ± 0.09	0.74 ± 0.07	1.80 ± 0.18	0.5 ± 0.2	5 ± 2.5	212–180	0.199 ± 0.018	1.23 ± 0.07	8.36 ± 0.33	27	6.8 ± 0.5

<sup>1</sup> Uncertainties are based on the propagation, in quadrature, of errors associated with individual errors for all measured quantities. In addition to uncertainties calculated from counting statistics, errors due to 1) beta source calibration (%) (Armitage and Bailey 2005); 2) ICP-MS calibration (10%); 3) dose rate conversion factors (3%); and 4) attenuation factors (2%) have been included (Murray and Olley 2002).

(60 s at 125°C) was provided by blue LEDs (wavelength 470 nm) and OSL signals, derived from the first 0.5 seconds of stimulation (with a background signal obtained from the last 6 seconds), were detected with an EMI 9235QA photomultiplier tube via 7 mm of Hoya

U-340 optical filter. All equivalent doses (De) were determined using the SAR protocol<sup>28</sup> using small (2 mm) aliquots comprising approximately 150 individual

<sup>28</sup> Murray and Wintle 2000; Murray and Wintle 2003.

**Table 2.2.** Radiocarbon dates from the paleoenvironmental test pits.

Samples			Reconstruction of paleo-sea level band					Lab ID (SUERC)	Material	<sup>14</sup> C BP	δ <sup>13</sup> C (‰)	Calibrated ages	
Sample name	Depth (m b.s.)	Elevation (m a. MSL)	Upper Limit (m a. MSL)	Lower Limit (m a. MSL)	Upper limit paleo-MHHW (m a. MSL)	Upper limit paleo-MSL (m a. MSL)	Lower limit paleo-MSL (m a. MSL)					Age cal. BC (2σ)	Age cal. BP (2σ)
DOS 14/8TP5	0.32	1.39	1.53	-0.44	3.45	2.92	0.95	54501	<i>Pillucina cf. angela</i> / <i>Dosinia alta</i>	4266 ± 30	1.2	2386–2000	3949–4335
DOS 14/9TP5	0.48	1.23	1.53	-0.44	3.29	2.76	0.79	54502	<i>Dosinia cf. alta</i>	4482 ± 30	1.8	2651–2286	4235–4600
DOS 14/2TP1	0.48	0.84	1.53	-0.44	2.90	2.37	0.40	54492	<i>Tellinia incarnata</i> / <i>wallaceae</i>	4690 ± 30	2.9	2885–2576	4525–4834
DOS 14/1TP1	0.42	0.90	1.53	-0.44	2.96	2.43	0.46	54491	<i>Tellinia incarnata</i> / <i>wallaceae</i>	4706 ± 30	2.9	2899–2586	4535–4848
DOS 14/4TP4	0.22	1.69	1.53	-0.44	3.75	3.22	1.25	54497	<i>Dosinia cf. alta</i>	5273 ± 30	2.3	3624–3360	5309–5573
DOS 14/5TP4	0.64	1.27	1.53	-0.44	3.33	2.80	0.83	54498	<i>Dosinia cf. alta</i>	5642 ± 30	2.4	4026–3734	5683–5975
DOS 14/3TP2	0.45	1.09	1.53	-0.44	3.13	2.60	0.63	54496	<i>Pillucina cf. angela</i> / <i>Dosinia alta</i>	5976 ± 30	2.6	4399–4085	6034–6046
DOS 14/6TP4	0.86	1.05	1.53	-0.44	3.11	2.58	0.61	54499	<i>Dosinia cf. alta</i>	6139 ± 30	2.1	4540–4318	6267–6489
DOS 14/7TP4	1.17	0.74	1.53	-0.44	2.80	2.27	0.30	54500	<i>Dosinia cf. alta</i>	6444 ± 31	2.6	4929–4610	6559–6878

grains. Aliquots showing poor OSL characteristics (recycling ratios outside 10% of unity, recuperation > 5% of the natural OSL signal or evidence of feldspar contamination<sup>29</sup>) were rejected from the analysis. At least 22 aliquots passing these rejection criteria were used to determine the sample equivalent dose. Beta and gamma dose rates were calculated for each sample using radioisotope concentrations measured by ICP-MS (U and Th) and ICP-AES (K). Dose rates were corrected using an assumed water content of  $5 \pm 2.5\%$ .

AMS radiocarbon dating was carried out at Scottish Universities Environmental Research Centre (SUERC) and dates were determined on marine shells. Dates were calibrated using the 95% confidence limits in Calib 7.1 using the Marine 13 curve<sup>30</sup> and corrected for the Arabian Gulf Marine reservoir effect using the delta R value of  $180 \pm 53$ .<sup>31</sup> All ages are reported in BC. **Table 2.2** shows the radiocarbon ages for nine samples taken from the test pits.

#### 4.3 Mollusk identification and quantification

Bulk samples (1 kg) were collected and processed for molluscan analysis. Remains were identified using published identification guides and keys.<sup>32</sup> The

assemblages from the five test pits were quantified in terms of number of identified specimens (NISP), minimum number of valves (MNV) and minimum number of individuals (MNI) based on apex and aperture presence for gastropods, and on umbo presence for bivalves. Bivalves were attributed to right or left sides where possible. For bivalves the recorded dimensions (shell size, below) were taken into consideration when calculating MNV and MNI.

Mollusks were measured to the nearest 0.1 mm using Mitutoyo Absolute Digimatic calipers. For bivalves, measurements for valve length (VL) and valve height (VH) were taken, as described by Claassen.<sup>33</sup> Valve depth was also measured in bivalves. For gastropods, shell height (SH) and width was measured, also as described by Claassen.<sup>34</sup> Specimens were not measured if they were not complete (e.g. with missing apex or missing or damaged apertures in the case of gastropods, and absent umbo or margin damage for bivalves).

In addition to recording fragmentation each specimen was subjected to observation for taphonomic impacts. This includes recording any evidence of predation by other animal taxa, hosting for tubeworms (e.g. Vermetidae) or any other surface modification of known or unknown origin.

<sup>29</sup> Duller 2003.

<sup>30</sup> Reimer et al. 2013.

<sup>31</sup> Southon et al. 2002.

<sup>32</sup> Bosch and Bosch 1989; Oliver 1992; Willan 1993; Hasan 1994; Bosch et al. 1995; Glover and Taylor 2001; DuPont and Al Tamimi 2008;

Jahangir et al. 2012.

<sup>33</sup> Claassen 1998: 109.

<sup>34</sup> Claassen 1998: 110.

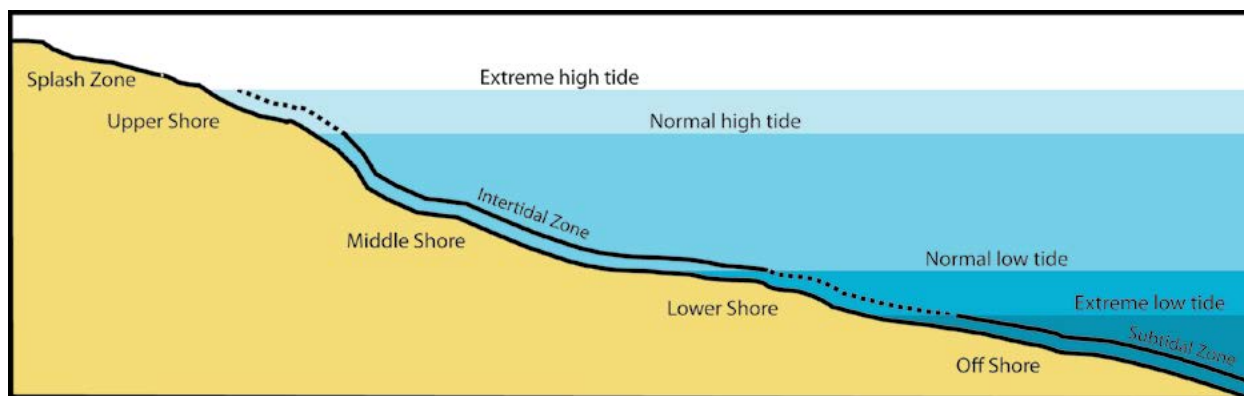


Figure 2.8. Tidal and shore zones.

Molluscan taxa are often highly sensitive to variation in environmental conditions; as such, their presence, absence and relative abundance in stratified sediments can be used to aid reconstruction of past environmental conditions, and changes in these over time and space. Habitats for taxa identified at Dosariyah can be found in **Appendix Table 2.1** and **Figure 2.8** and the species found in **Appendix Table 2.2**.

It is essential in the study of both recent and ancient mollusks that the use of current, accepted taxonomy is ensured. In Arabia, many molluscan taxa remain understudied, and as such, taxonomy is not always agreed upon between specialists. Ensuring a correct taxonomic identification impacts upon the environmental conditions that can be reconstructed using molluscan data. The taxonomy for molluscan species is continuously being updated, and therefore any taxonomic name listed here could be revised in the future. To avoid confusion each identified taxa will include a referral to the published source of its taxonomic description.

#### 4.4 Calculation of relative sea levels (RSL)

Sea-level index points (SLIPS) were used to fix the position of past RSL in time and space<sup>35</sup> and tend to form at or around mean highest high-water tide (MHHWT), rather than at the paleo-mean sea level.<sup>36</sup>

All the <sup>14</sup>C samples dated in this study are considered as primary SLIPS, as their elevations, ages and vertical relationships to contemporaneous tide levels (indicative meaning) can be deduced. The OSL ages are regarded only as secondary SLIPS as they lack indicative meaning values. Horizontal error bars indicate the maximum and minimum ages as determined by the <sup>14</sup>C calibration. The vertical error calculation includes the sum of all

the quantified or estimated height errors, including field levelling, present tide heights and interpretation of indicative meaning ( $\text{total error} = \sqrt{(e_1^2 + e_2^2 + \dots + e_n^2)}$ ).<sup>37</sup> Due to the nature of the sediments and the shallow depths sampled, the effects of compaction and sediment consolidation were regarded as negligible.<sup>38</sup> All ages were made on *Dosinia* sp., *Pillicina* cf. *angela* and *Tellinidae incarnate/wallacea*. Estimation of habitat range for these species was based on El-Sorogy *et al.* and Feulner and Hornby when considering the intertidal plus the uppermost meter of the shallow subtidal range.<sup>39</sup> The upper and lower limits calculated for the paleo-MSL and upper limit for the MHHW are shown alongside the radiocarbon ages in **Table 2.2**.

## 5 Results

### 5.1 Dune sections

The quarry section yielded an age of  $7.2 \pm 0.5$  ka ( $5200 \pm 500$  BC, QP1 OSL3) for the quartz-rich weakly cemented sand unit 1.05 m below the surface. The upper carbonate-rich cemented unit with up to 50% ooids was dated to  $3.0 \pm 0.2$  ka ( $3000 \pm 200$  BC, QP1 OSL4) at 55 cm depth. The quartz-rich sand unit below the carbonate-rich eolianite cap unit from the coastal section (**Figure 2.3**, **Table 2.1**) was dated to  $6.8 \pm 0.5$  ka ( $4800 \pm 500$  BC, Coastal Section OSL5). The ages and differences in the composition of the two sediment units imply that they were formed in two phases of deposition with a break in sedimentation sometime in between. The lower unit is eolian in origin and derived from quartz and other siliciclastic terrestrial sources with minor carbonate elements. The sediments in the upper unit, rich in ooids, were originally derived from a shallow marine origin and transported by eolian processes.

<sup>35</sup> *Sensu* Tooley 1998.

<sup>36</sup> Shennan *et al.* 2002; 2006.

<sup>37</sup> Horton *et al.* 2000.

<sup>38</sup> *Sensu* Lokier *et al.* 2015.

<sup>39</sup> El-Sorogy *et al.* 2016; Feulner and Hornby 2006.

5.2 Southern sabkha, test pit 1 (TP1), N26°54'50.5" E049°44'41.5"

TP1 is situated at a point where a tongue of higher ground forms a low promontory extending out into the northwestern area of the southern sabkha (Figure 2.6a). The surface height was measured at 132 cm asl and the water table was reached at 70 cm below surface (b.s.). TP1 exhibited a very well-defined stratigraphic sequence, with medium to coarse eolian sands (in a lagoonal context) overlying a highly distinctive white

fine silt unit with a sticky consistency and a very pure composition. The sedimentology of TP1 is described in Appendix Table 2.3 and shown in Figure 2.9a. The molluscan assemblage is shown in Figure 2.9b. A total of 119 mollusk shells were recovered from the three samples taken from TP1. These represented six individual gastropods and 113 bivalve valves (Appendix Table 2.4). Gastropods are represented by one taxa of the family Potamididae. Bivalves are represented by at least three taxa, from two families, Ungulinidae and Tellinidae. Bivalves are more frequent than gastropods

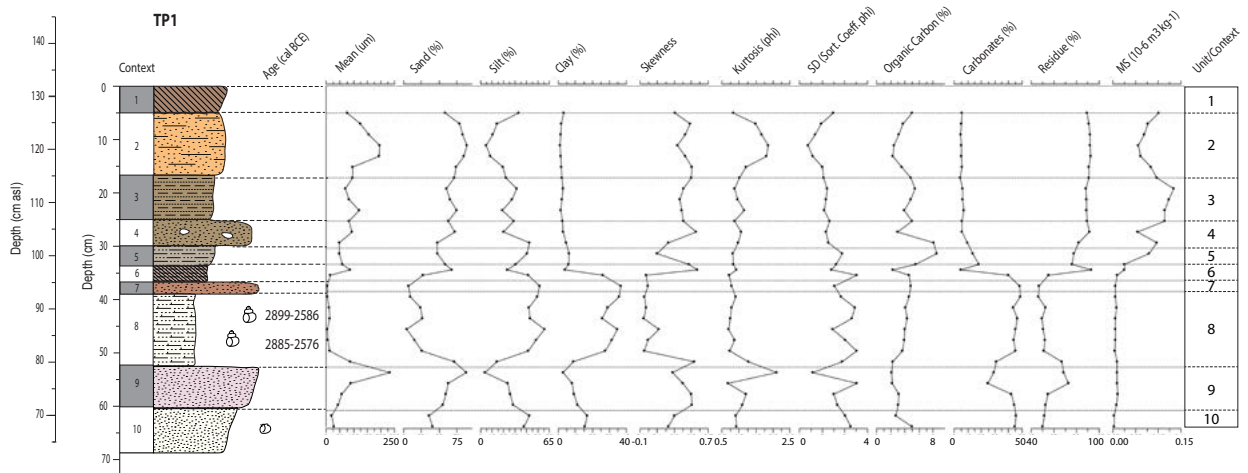


Figure 2.9a. Sedimentology diagram for TP1.

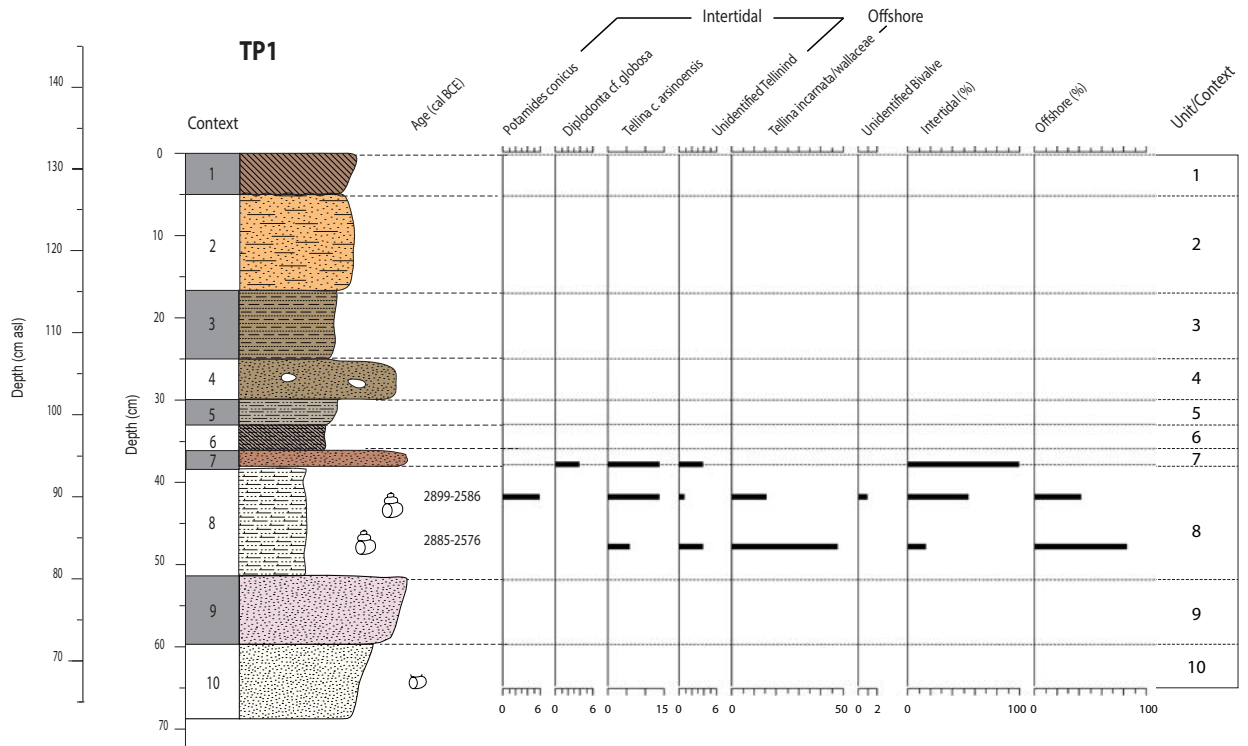


Figure 2.9b. Molluscan diagram from TP1.

in the TP1 sequence, within which *Tellina cf. arsinoensis* and *Tellina incarnata/wallaceae* are most abundant in the assemblage. Unlike the molluscan remains from the other test pits at Dosariyah, those from TP1 included substantial amounts of fragmentary material, especially at 46–50 cm, which contained 127 fragments of unidentified Tellinid remains. Two radiocarbon samples were measured at 90 cm asl (42 cm b.s.) and 84 cm asl (48 cm b.s.) which yielded ages of  $4706 \pm 30$   $^{14}\text{C}$  BP (SUERC-54491, 2899–2586 cal. BC  $2\sigma$ ) and  $4690 \pm 30$   $^{14}\text{C}$  BP (SUERC-54492, 2885–2576 cal. BC  $2\sigma$ ) (Table 2.2).

The sequence in TP1 shows a very marked change in depositional environment from fine-grained silts (less than 50  $\mu\text{m}$ ) in the lowermost Unit 10 (68–60 cm b.s., 66–72 cm asl) to medium- to coarse-grained sands (up to 250  $\mu\text{m}$ ) in Unit 9 (60–52 cm b.s., 72–80 cm asl), returning to fine-grained clays (up to 30%) and silts (up to 50%) in Unit 8 (50–38 cm b.s., 82–94 cm asl) with medium- to coarse-grained sands in the overlying Units 7 to 2. Unit 8, which comprised homogeneous carbonate-rich fine-grained clays and silts, contained mollusks in life position. There is a decline in the proportion of sand (< 10–25%) and increases in silt (~50–60%) and clay (25–35%) in this unit. The silty sediments in Unit 8 and Unit 7 are very poorly sorted, platykurtic and near symmetrical. This unit is indicative of a very low-energy environment where silts and clays have settled out of suspension in a marine-proximal environment with marine shells deposited in life position.

Occasional thin (< 4 cm) lenses and stringers of coarser sands in the lower part of this sequence (e.g. Unit 9) may represent horizons when water depths were shallower. In Unit 8 the layers of abundant marine bivalves in life position mark the stabilization of water levels at a depth conducive to supporting bivalve communities in higher numbers. A deeper water marine environment is suggested by the presence of *Tellina incarnata/wallaceae*, which is the most abundant species in Unit 8. The mollusks present in the upper part of Unit 8 and Unit 7 suggest a shallowing up sequence with an increase in the presence of intertidal species including *Potamides conicus*, *Diplodonta cf. globosa* and *Tellina cf. arsinoensis*. Both radiocarbon dates are statistically identical and place Unit 8 at c.2900–2585 cal. BC. The bulk of the lower Units 10 to 8 were laid down during a marine transgression event when a sufficient water column existed for the deposition of clays and silts.

The sands of Units 6 to 2 indicate a reduction of water depth and the contraction of the lagoonal shoreline allowing sand to be introduced to the lagoonal environment by eolian processes. The sediments coarsen upwards from silts in Unit 6 to fine sand in Unit 2 and change from near symmetrical to strongly fine-skewed, meso/platykurtic to very leptokurtic and very poorly sorted to poorly sorted. Clay content decreases

sharply at 34 cm b.s. (98 cm asl) to ~5%. Organic content increases in Unit 5 and the lower part of Unit 4 to ~8%, declines slightly in the upper part of Unit 4 and increases again in Unit 3 to ~4%. MS values follow the organic curve. There is a steep decline in carbonate content to ~5% in the upper four units. These units represent the development of sabkha deposits. Shell fragments of marine bivalves are found in very low frequencies, usually comprising only small fragments of larger shells, indicating a possible wind-blown origin of these lighter inclusions.

The upper 10 cm of the sabkha profile (Unit 1) and the present-day surface comprises well-cemented gypsiferous sands, gypsum crystals, salt heave features and abundant cerithid shells. The latter are consistent with intertidal sand flats, signifying a coastal marginal environment during the sea-level regressive event.

### 5.3 Southern sabkha, test pit 2 (TP2), N26°54'48.76" E049°44'44.8"

TP2 was located at the northwest margin of the middle sabkha, at the point where this level interdigitates with higher sabkha deposits. The surface was 152 cm asl and a single radiocarbon age determination was made from a sample at 109 cm asl (45 cm b.s.) ( $5976 \pm 30$   $^{14}\text{C}$  BP, SUERC-54496, 4399–4085 cal. BC  $2\sigma$ ) (Table 2.2). The results from the sedimentological analyses are shown in Figure 2.10a and molluscan analysis in Figure 2.10b. The 80 cm deep sequence recorded in TP2 was divided into five units (Appendix Table 2.5). Only 36 mollusk shells were recovered from the eleven samples taken from TP2 (Appendix Table 2.6). These are represented by four individual gastropods and 32 bivalve valves. Gastropods are represented by at least two taxa of two families — Potamididae and Columbella. Bivalves are represented by at least five taxa, from four families — Lucinidae, Tellinidae, Psammobiidae and Veneridae. Bivalves are more frequent than gastropods in the TP2 sequence, within which *Dosinia* sp. and *Tellina cf. arsinoensis* are most abundant in the assemblage, though both are still only present in relatively low numbers.

The oldest, basal context (Unit 5) comprises medium-fine near symmetrical, mesokurtic, moderately sorted eolian sands that have been reworked and deposited into a marine marginal environment, most likely at the fringes of an intertidal flat during a transgressive phase. Fine silts and the presence of a few shells including *Dosinia cf. alta* indicate a shallow to moderate water depth, suggesting a tidal influence close to the site at Dosariyah to the north. Shells are absent between 72 and 50 cm b.s. (80–102 cm asl) suggesting a contraction in marine/lagoonal waters is evident up-profile (Unit 5). The molluscan assemblage records lower shore and intertidal taxa during the main transgression phase in the upper part of Unit 5 between 50 and 39 cm b.s. (102–

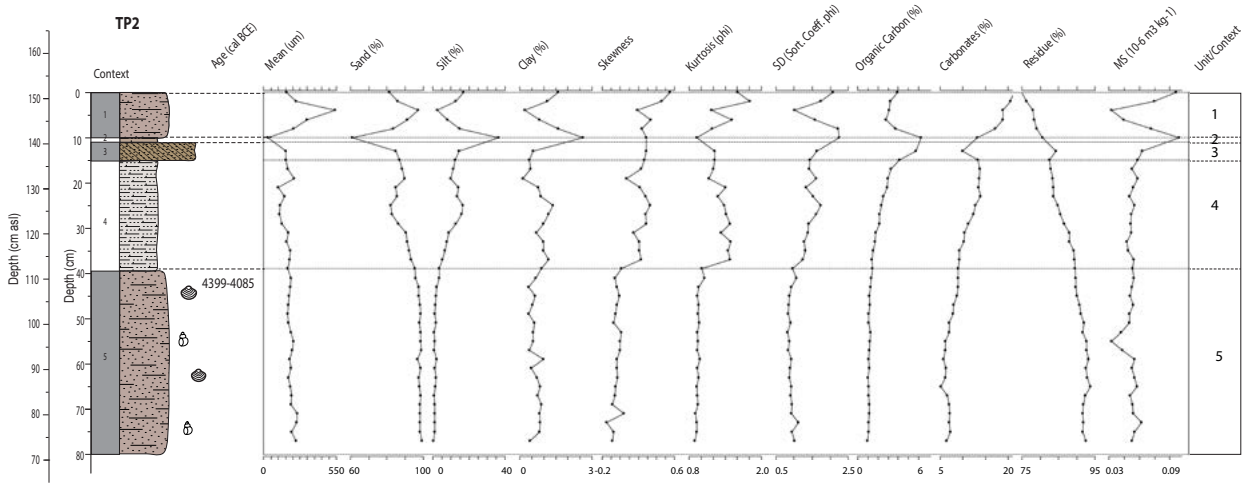


Figure 2.10a. Sedimentology diagram for TP2.

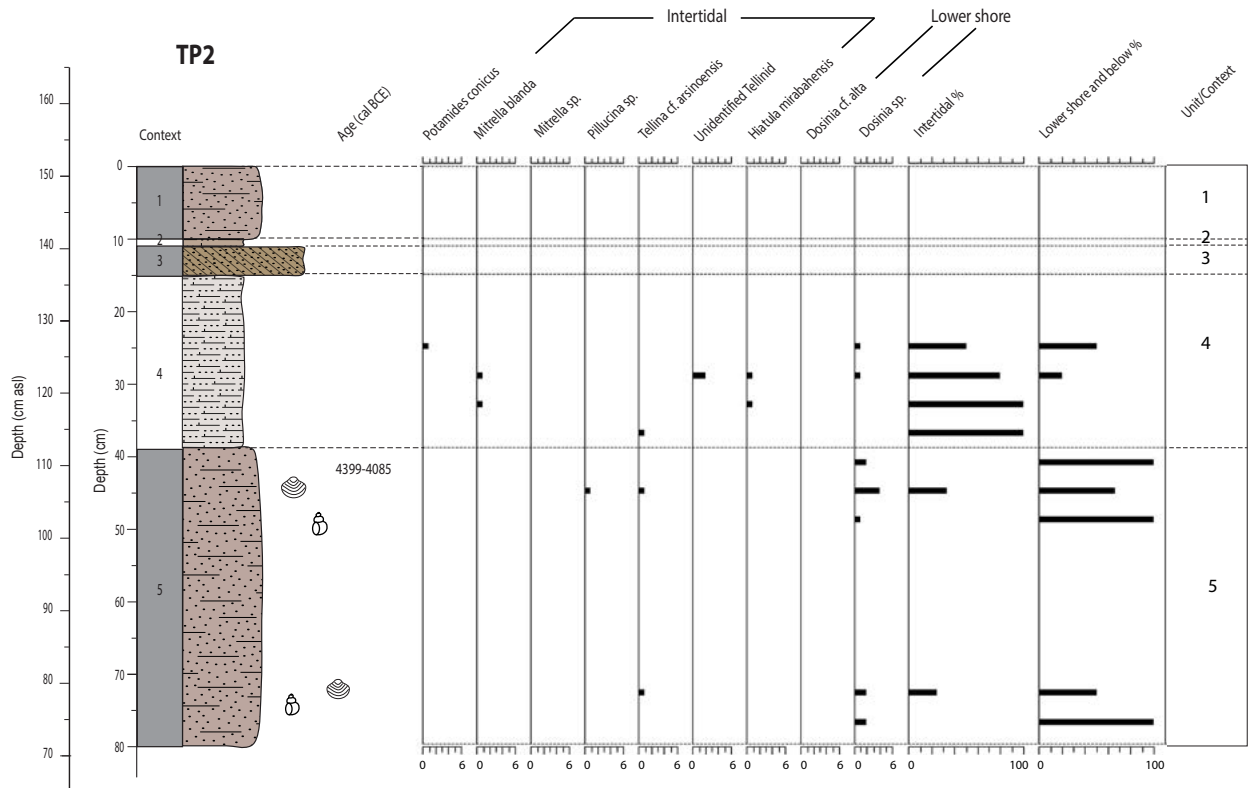


Figure 2.10b. Molluscan diagram from TP2.

113 cm asl) dated to 4399–4085 cal. BC  $2\sigma$  (SUERC-54496, **Table 2.2**) with a change to intertidal taxa in Unit 4 (39–15 cm b.s., 113–137 cm asl). The sediments in Unit 4 change to near fine-skewed, leptokurtic and poorly sorted fine sands and most likely represent sediment infilling and a lateral shift in environment. Unit 3 indicates an intertidal sand flat and the development of a sabkha from ~15 cm b.s. (137 cm asl, Units 3 and 2)

with an increase in magnetic susceptibility and organic carbon values.

The depth for the development of sabkha occurred at 135 cm asl in TP2 and ~138 cm asl in TP4. A switch to eolian dominated sands is seen in Unit 2, with a disturbed upper layer representing recent to sub-recent turbation of the sabkha surface. The presence of

artesian water in the area has resulted in a persistent gypsiferous/halite surface as hydraulic pressure forces (brackish) groundwater up through gypsiferous sediments.

**5.4 Southern sabkha, test pit 3 (TP3), N26°54'56.9" E049°44'33.1"**

TP3 was located at the northern fringes of the upper sabkha surface, closest to the site of Dosariyah. The surface level was at 202 cm asl and a 144 cm deep profile was sampled. No samples were radiocarbon dated from this pit, but two OSL ages were measured (Table 2.1). TP3 OSL1 was sampled at 67 cm asl (135 cm

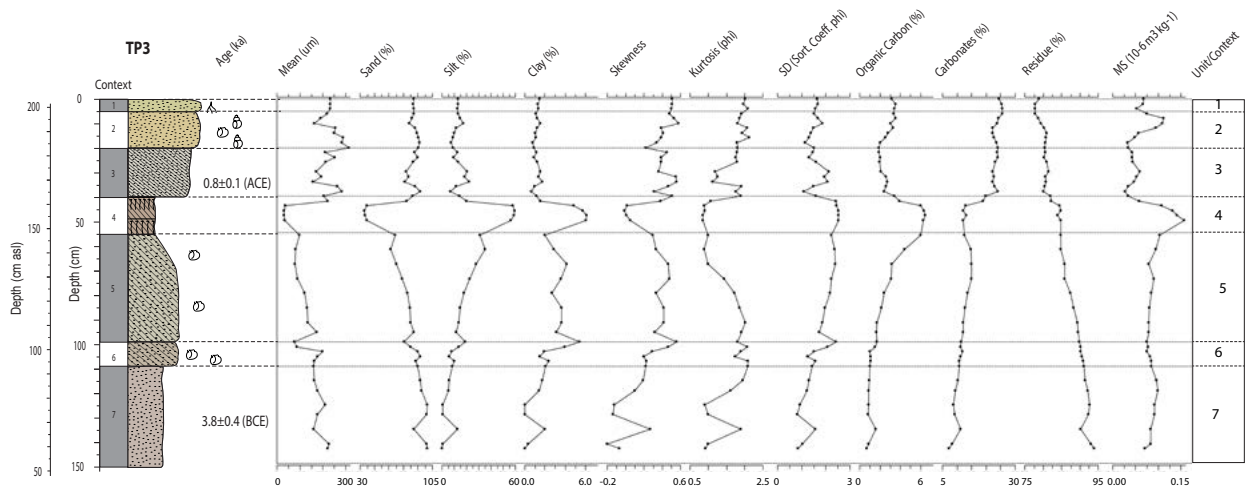


Figure 2.11a. Sedimentology diagram for TP3.

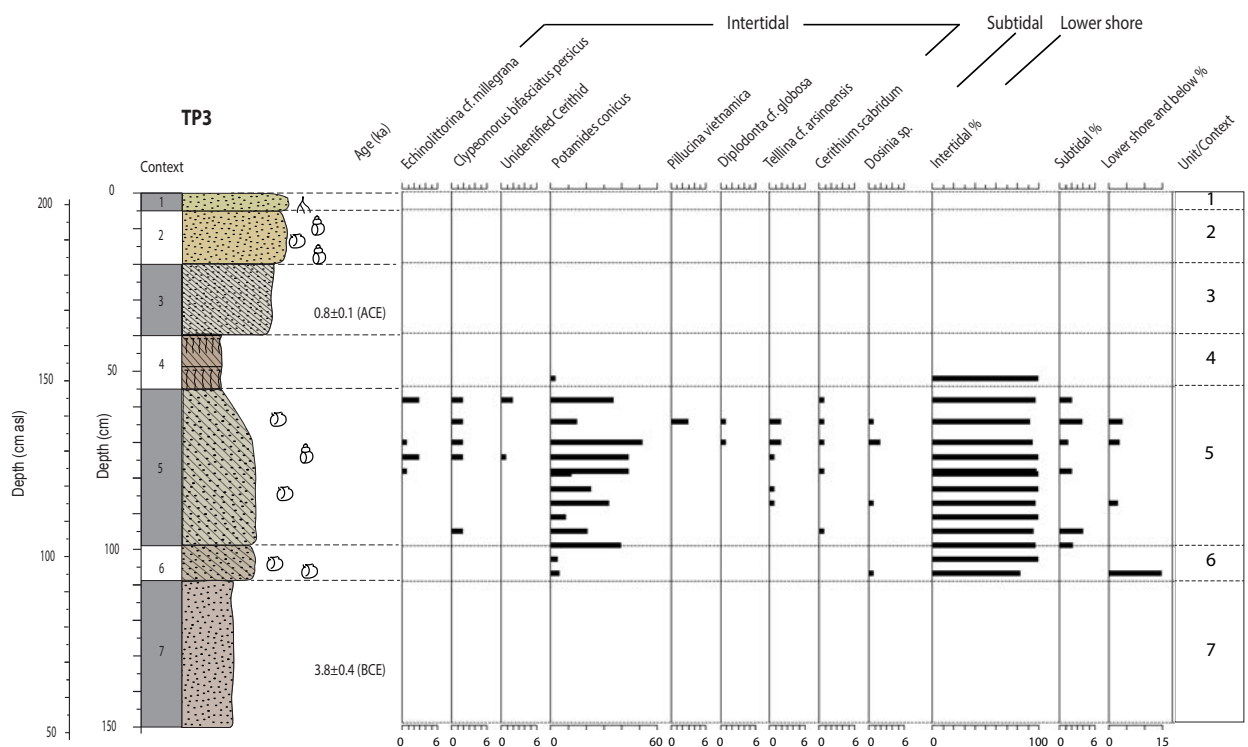


Figure 2.11b. Molluscan diagram from TP3.

b.s.) and yielded an age of  $5.8 \pm 0.4$  ka (4200–3400 BC). TP3 OSL2 at 167 cm asl (35 cm b.s.) provided an age of  $1.2 \pm 0.1$  ka (AD 900–700). The sequence recorded in TP3 shows seven lithological units (**Appendix Table 2.7**) with the area close to the site changing markedly in terms of the environments present and the influence of marine inundation. The sedimentological results are shown in **Figure 2.11a** and the molluscan diagram in **Figure 2.11b**. In total, 387 mollusk and mollusk fragments were recovered from 14 samples taken from TP3. These represented 369 individual gastropods and 18 bivalve valves (**Appendix Table 2.8**). Gastropods are represented by at least five taxa of four families — Litterinidae, Cerithiidae, Potamididae, and Vermetidae. Bivalves are also represented by at least five taxa, but from five families — Lucinidae, Ungulinidae, Tellinidae, Psammobiidae and Veneridae.

The lower part of Unit 7 (150–110 cm b.s., 52–92 cm asl) indicates eolian sedimentation with the deposition of fine, coarse-skewed, mesokurtic, moderately to poorly sorted, sands. These fine up the sequence with a small rise in silt and clay content but these remain low. Organic content is characteristically low at ~1.5%. Mollusks are absent in Unit 7.

At ~110 cm b.s. (92 cm asl) the presence of mollusks occurs from Unit 6 with a continued fining up of sediments and an increase in clays and silts. The sediments are fine-skewed, leptokurtic and poorly sorted fine sands. The gastropod *Potamides conicus* (Potamididae) is by far the most abundant taxa throughout the TP 3 sequence. The molluscan assemblage mainly represents an intertidal environment dominated by *Potamididae conicus* with some subtidal and lower shore elements but these occur in low frequencies. This marks a phase of marine transgression and a switch to an intertidal environment. This continues into Unit 5 until around 60 cm b.s. (142 cm asl). The sediments are fine-skewed to strongly fine-skewed, very leptokurtic and poorly sorted fine to very fine sands. This indicates slow or standing water, probably at the fringes of a lagoon. The subsequent lowering of sea level and the development of a sabkha, as indicated by the increased values for magnetic susceptibility and organic content and the peaks in clay and silt, are shown in Unit 4. The sediments in Unit 4 comprise near symmetrical, platykurtic, very poorly sorted silts. Unit 3 is characterized by a sharp increase in medium-coarse sands, reduction in magnetic susceptibility, organic content and increase in carbonates. The sediments are strongly fine-skewed, very leptokurtic, poorly sorted fine to medium sands. This unit represents the possible interdigitation between wind-blown sands and marginal marine sediments. An OSL date of AD 900–700 was determined from this unit. Unit 2 denotes the development of sabkha while Units 3 and 1 represent wind-blown sands.

#### 5.5 Northern sabkha, test pit 4 (TP4), N26°55'20.6" E49°43'59.6"

TP4 was situated at the southern margin of the northern sabkha 1.91 m asl, where it is overlain by dune sands. Seven lithological units were identified from a 140 cm deep section (**Appendix Table 2.9**). Four radiocarbon dates were measured from marine shell samples of *Dosinia cf. alta* (**Table 2.2**). The sedimentology is shown in **Figure 2.12a** and the molluscan diagram in **Figure 2.12b**. In total, 749 mollusks and mollusk fragments were recovered from 16 samples taken from TP4. These represented 615 individual gastropods and 134 bivalve valves (**Appendix Table 2.10**). Gastropods are represented by at least nine taxa of six families — Trochidae, Littorinidae, Cerithiidae, Potamididae, Columbidae and Olividae. Bivalves are also represented by at least five taxa, but from four families — Lucinidae, Tellinidae, Psammobiidae and Veneridae. The gastropod *Potamides conicus* (Potamididae) is by far the most abundant taxa throughout the TP 4 sequence.

The northern sabkha joins a much larger area of low, flat ground that extends over a very wide area of sabkha to the north and west of Dosariyah. At the base of Unit 7 the sediments comprise homogeneous, fine-skewed, mesokurtic, moderately sorted fine to medium sands. These then become fine to strongly fine-skewed, leptokurtic to very leptokurtic, fine to medium sands with localized iron staining. Organic content is low (~1%) and carbonate content is also low and gently increases up-unit from ~5 to 10%. This unit represents interdigitation between wind-blown sands and marginal marine facies representing the onset of marine transgression. Silt and clay contents are low but increase up-unit. The lowest age from Unit 7 at 74 cm asl (116–118 cm b.s.) gave a date of  $6444 \pm 31$  <sup>14</sup>C BP (SUERC-54500, 4929–4610 cal. BC  $2\sigma$ ) and denotes the onset of transgression. At 105 cm asl (84–88 cm b.s.) the <sup>14</sup>C age of  $6139 \pm 30$  <sup>14</sup>C BP (SUERC-54499, 4540–4318 cal. BC  $2\sigma$ ) occurs during the transgression in Unit 7. The molluscan assemblage records intertidal species dominated by *Potamides conicus*, which accounts for ~20–30% below 95 cm b.s. (96 cm asl) and increases to 60–80% in the upper part of Unit 7. Lower shore and below taxa comprise *Dosinia* sp. and *Dosinia cf. alta*. These account for ~25% of the assemblage in the lower parts of the unit and steadily decrease up-unit to ~5% at the top of Unit 7.

Unit 6 represents a transitional zone represented by finer-grained coarse silts with a mean particle size of ~50  $\mu$ m. Sand decreases to ~71–55% with silts ~23–35% and clays ~6–8%. The facies exhibits strongly fine-skewed, platykurtic, very poorly sorted silts with an increase in carbonate from 18 to 27% and a slight increase in organics to ~3%. There is a slight rise in MS to  $0.04 \times 10^{-6} \text{m}^3 \text{kg}^{-1}$ . Mollusk values decrease in this

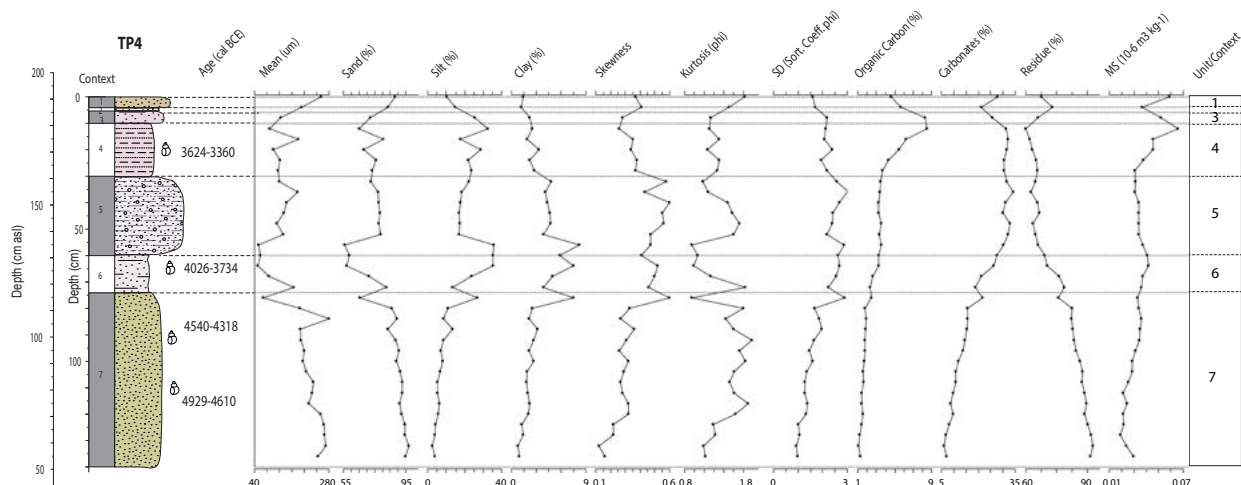


Figure 2.12a. Sedimentology diagram for TP4.

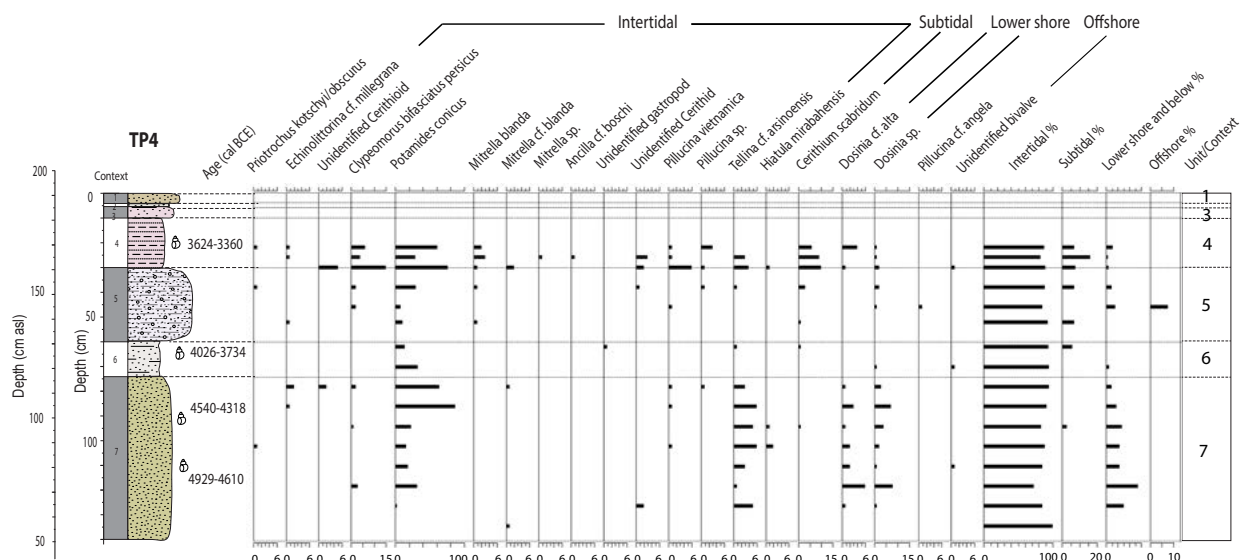


Figure 2.12b. Molluscan diagram from TP4.

unit with the disappearance of lower shore and below species and also a decline in intertidal taxa. *Potamides conicus* values decline to less than 20%. Unit 6 represents the development of lower-energy, tidal flats. A <sup>14</sup>C age of 5642 ± 30 <sup>14</sup>C BP (SUERC-54498, 4026–3734 cal. BC 2σ) dates this phase at 127 cm asl (62–66 cm b.s.).

Units 5 and 4 in the profile show an increase in energy and in marine elements representing a second phase of transgression. Mean particle size values increase to ~130 µm representing fine sands (~80%) with decreases in silt (~15%) and clays (~3%). These sediments are strongly fine-skewed, leptokurtic to mesokurtic, very poorly sorted fine to very fine sands. Carbonate content increases to 34% in Unit 5 and MS values increase slightly when compared to Unit 6 below. The

mollusk assemblage shows very low numbers present in the lower part of Unit 5 but increases towards the top of Unit 5 and into Unit 4. Intertidal taxa dominate in both units with *Potamides conicus* and *Clypepmorus bifasciatus persicus*, the main species represented in Unit 5. In Unit 4 both species increase sharply to 80% and 15% respectively. Other intertidal species that increase in Unit 4 include *Mitrella blanda*, *Pillucina vietnamica*, *Tellina cf. arsinensis* and *Echinolittorina cf. millegrana*. The subtidal species *Cerithium scabridum* appears throughout both units with values increasing to ~10% in Unit 4.

Lower shore and below species reappear from 42 cm b.s. (142 cm asl) with *Dosinia sp.* and *Dosinia cf. alta* present. These taxa are also present in Unit 4 but in lower numbers. The lower part of Unit 5 represents the