

The Archaeological Heritage of Oman

# MAGAN - THE LAND OF COPPER

*Prehistoric Metallurgy of Oman*

CLAUDIO GIARDINO



Sultanate of Oman  
Ministry of Heritage and Culture



ARCHAEOPRESS PUBLISHING LTD  
Summertown Pavilion  
18-24 Middle Way  
Summertown  
Oxford OX2 7LG  
[www.archaeopress.com](http://www.archaeopress.com)

© Claudio Giardino 2019

Magan - The Land of Copper, Prehistoric Metallurgy of Oman  
(Includes bibliographical references and index).

1. Arabia. 2. Oman 3. Copper. 4. Prehistory 5. Antiquities.

Cover image: Ceremonial copper axe decorated with a bearded head and a lion found at 'Uqdat Al-Bakrah (photograph by Roman Garba, 2013)

First published in 2017 by the Ministry of Heritage and Culture, Sultanate of Oman, Muscat.

This edition is published by Archaeopress Publishing Ltd in association with the Ministry of Heritage and Culture, Sultanate of Oman.

Printed in England

ISBN 978-1-78969-178-8  
ISBN 978-1-78969-179-5 (e-Pdf)

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective agreements, no reproduction of any part may take place without the written permission of the Ministry of Heritage and Culture, Sultanate of Oman.

Ministry of Heritage and Culture  
Sultanate of Oman, Muscat

P.O. Box 668 P.C. 100  
Khuwair, Muscat  
Phone: +968 24 64 13 00  
Fax: +968 24 64 13 31  
Email: [info@mhc.gov.om](mailto:info@mhc.gov.om)  
Web Site: [www.mhc.gov.om](http://www.mhc.gov.om)

# Contents

<i>List of illustrations and tables</i>	vii
<i>Acknowledgments</i>	xv
<i>Foreword</i>	xvii
<b>1 A country of environmental diversities</b>	1
<b>2 A geological and mineralogical overview</b>	7
<b>3 Basic elements of metallurgy</b>	12
<b>4 Copper for Sumer</b>	20
<b>5 The earliest appearance of metalworking</b>	29
<b>6 Early Bronze Age: the Hafit period, ca. 3200-2800 BC</b>	40
<b>7 Early Bronze Age: the Umm an-Nar period, ca. 2800-2000 BC</b>	63
<b>8 The prehistoric copper mines</b>	84
<b>9 Copper smelting in prehistoric Oman</b>	93
<b>10 Middle and Late Bronze Age: the Wadi Suq period, ca. 2000-1300 BC</b>	106
<b>11 Early Iron Age, ca. 1300-300 BC</b>	114
<b>12 Chemical-Physical Analyses by Energy Dispersive X-Ray Fluorescence (EDXRF)</b> <i>Claudio Giardino and Giovanni Paternoster</i>	139
<i>Bibliographical references</i>	165
<i>Index</i>	175



## List of illustrations and tables

### FIGURES

1.1.	Date palms at the oasis of Bat (photograph by C. Giardino).	2
1.2.	Cliffs at Ras Al-Jinz (photograph by C. Giardino).	3
1.3.	The coast at Ras Al-Hadd (photograph by C. Giardino).	4
1.4.	Mountains near Al-Moyassar (Maysar) (photograph by C. Giardino).	4
1.5.	Landscape of Rub Al-Khali, near 'Uqdat Al-Bakrah (photograph by C. Giardino).	5
1.6.	<i>Acacia</i> tree in the outer margins of the Rub Al-Khali (photograph by C. Giardino).	6
2.1.	Simplified geological map of Oman.	8
2.2.	Copper outcrop inside the Semail Ophiolite at Bilad Al-Maidin (photograph by C. Giardino).	10
3.1.	Photomicrograph of a copper-based object after casting showing a dendritic structure (after etching) (photograph by C. Giardino).	15
3.2.	Photomicrograph of a copper object after casting showing an equiaxial hexagonal grain structure (after etching) (photograph by C. Giardino).	15
3.3.	Photomicrograph of a copper object after hammering and annealing showing twinned grains (after etching) (photograph by C. Giardino).	16
3.4.	Microstructural changes in a metal submitted to mechanical and thermal treatments (after Giardino 2010).	16
3.5.	SEM image with elementary micro-mapping in a micro-structural feature.	18
3.6.	X-Ray Fluorescence portable equipment.	19
4.1.	Trade routes during the 3 <sup>rd</sup> millennium BC, according to the seasonal winds.	21
4.2.	Reconstruction of an Early Bronze Age Magan boat (photograph by Helen Kirkbride, courtesy Oman Maritime Traditional Boat Centre).	24
4.3.	Diorite statue of Gudea of Lagash (courtesy Musée du Louvre).	26
5.1.	Metal objects from Wadi Shab GAS-1 (drawing by L. Tricarico).	32
5.2.	Metal objects from Wadi Shab GAS-1 (drawing by L. Tricarico).	32
5.3.	Ras Al-Hamra RH-10. Multi-tasking tool (DA 2672) (photographs by P. Koch, courtesy Oman National Museum).	34
5.4.	Ras Al-Hamra RH-10. Multi-tasking tool (DA 2672): arrows indicate wear and sharpening traces (drawing by L. Tricarico).	35
5.5.	Ras Al-Hamra RH-10. Detail of the tang of multi-tasking tool (DA 2672).	35
5.6.	Metal objects from Ras Al-Hamra RH-10 (drawing by L. Tricarico).	37
6.1.	Hafit cairn burials from Jebel Misht, Wadi Ayn (photograph by C. Giardino).	40

6.2.	Ras Al-Hadd HD-6. Three-dimensional reconstruction (image by M. Cattani, courtesy Joint Hadd Project).	42
6.3.	Ras Al-Hadd HD-6. Building 1 under excavation (photograph by M. Cattani, courtesy Joint Hadd Project).	42
6.4.	Ras Al-Hadd HD-6. Fishhooks (drawings by L. Tricarico).	46
6.5.	Ras Al-Hadd HD-6. Awls (drawings by L. Tricarico).	46
6.6.	Ras Al-Hadd HD-6. Chisels/punches (drawings by L. Tricarico).	47
6.7.	Ras Al-Hadd HD-6. Drill points (drawings by L. Tricarico).	48
6.8.	Ras Al-Hadd HD-6. Crochets/netting needles (drawings by L. Tricarico).	48
6.9.	Ras Al-Hadd HD-6. Shell-opener (drawings by L. Tricarico).	49
6.10.	Ras Al-Hadd HD-6. Pins (drawings by L. Tricarico).	51
6.11.	Ras Al-Hadd HD-6. Daggers (drawings by L. Tricarico).	52
6.12.	Ras Al-Hadd HD-6. Daggers (photograph by C. Giardino).	53
6.13.	Ras Al-Hadd HD-6. Blocklets/"flat pieces" (drawings by L. Tricarico).	54
6.14.	Ras Al-Hadd HD-6. Fragments for recycling (drawings by L. Tricarico).	55
6.15.	Ras Al-Hadd HD-6. Blocklet DA 16467. Distorted dendrites produced by cold hammering (SEM image).	56
6.16.	Ras Al-Hadd HD-6. Semi-finished pin DA 11585. Distorted dendrites produced by cold hammering (micrograph 5x).	56
6.17.	Ras Al-Hadd HD-6. Awl DA 15684.02. Twinned grains after hammering and annealing (micrograph 200x).	57
6.18.	Ras Al-Hadd HD-6. Whetstone DA 16471 (photograph by C. Giardino).	58
6.19.	Ras Al-Hadd HD-6. Stone-hammer DA 23106 (photograph by C. Giardino).	58
6.20.	Ras Al-Hadd HD-6. Reconstruction of the operative chain (drawings by L. Tricarico).	59
6.21.	Ras Al-Hadd HD-10. Long dagger with straight blade DA 14334 (photograph by P. Koch, courtesy Ministry of Heritage and Culture, Sultanate of Oman).	60
6.22.	Ras Al-Hadd HD-10. Awl DA 10979 (drawings by L. Tricarico).	61
6.23.	Ras Al-Jinz RJ-6. Long pin with small flatted head DA 8621 (photograph by C. Giardino).	61
7.1.	Umm an-Nar cairn burial from Bat (photograph by C. Giardino).	64
7.2.	Ras Al-Jinz, the area of RJ-2 (photograph by C. Giardino).	64
7.3.	Ras Al-Jinz RJ-2. Iron fishhook (DA 10958) (photograph by C. Giardino).	65
7.4.	Ras Al-Hadd HD-5 (surface). Copper seal (DA 12803) (photograph by P. Koch, courtesy Ministry of Heritage and Culture, Sultanate of Oman).	65
7.5.	Ras Al-Jinz RJ-2. Harappan style fishhook (DA 12792).	66
7.6.	Ras Al-Jinz RJ-2. Prehistoric structures and their chronology (image by V. Azzarà, courtesy Ras Al-Jinz Study Program).	67
7.7.	Ras Al-Jinz RJ-2. Flat ingot (DA 8506). Arrows mark the engraved line on its surface.	68
7.8.	Ras Al-Jinz RJ-2. Flat ingot Building I, Room 4 (DA 8506) and flat copper bar from Building I, Room 2 (DA 8366).	68

7.9.	Ras Al-Jinz RJ-2. Crucible fragments (RJ-2: 551,30-551,31). One crucible has its inner surface vitrified and green colored by copper (photograph by C. Giardino).	69
7.10.	Ras Al-Jinz RJ-2. Crucible fragments (RJ-2: 551,32-551,37). The inner surface of the crucible is badly damaged and vitrified by the high temperature of molten metal (photograph by C. Giardino).	69
7.11.	Ras Al-Jinz RJ-2. Small casting residue (DA 12673) (photograph by C. Giardino).	70
7.12.	Ras Al-Jinz RJ-2. ED-XRF spectrum from a crucible fragment (from QDF, U.S. 6062) containing a tin-copper alloy.	70
7.13.	Different fishhooks from Ras Al-Jinz RJ-2.	71
7.14.	Ras Al-Jinz RJ-2. Fishhooks (photograph by C. Giardino).	71
7.15.	Ras Al-Jinz RJ-2. Awls (photograph by C. Giardino).	72
7.16.	Ras Al-Jinz RJ-2. Chisel (photograph by C. Giardino).	73
7.17.	Ras Al-Jinz RJ-2. Crochets/netting needles (photograph by C. Giardino).	73
7.18.	Ras Al-Jinz RJ-2. Shell-openers (photograph by C. Giardino).	74
7.19.	Ras Al-Jinz RJ-2. Knives (photograph by C. Giardino).	75
7.20.	Ras Al-Jinz RJ-2. Flat axes (photograph by C. Giardino).	75
7.21.	Ras Al-Jinz RJ-2. Pins (photograph by C. Giardino).	76
7.22.	Ras Al-Jinz RJ-2. Rings/earrings (photograph by C. Giardino).	77
7.23.	Ras Al-Jinz RJ-2. Razors (photograph by C. Giardino).	78
7.24.	Ras Al-Jinz RJ-2. Necklace from Building VII with indication of the sampling spots for SEM/EDS analysis	78
7.25.	Ras Al-Jinz RJ-2. Blocklets/flat pieces (photograph by C. Giardino).	79
7.26.	Ras Al-Jinz RJ-2. Flat ingots (photograph by C. Giardino).	80
7.27.	Ras Al-Jinz RJ-2. Sheet or blades: fragment for recycling (photograph by C. Giardino).	80
7.28.	Ras Al-Hadd HD-7. Metal finds from tombs 4 and 5 (drawings by L. Tricarico).	81
7.29.	Ras Al-Jinz RJ-2. SEM/EDS spectra of the necklace from Building VII.	82
7.30.	Ras Al-Hadd HD-5. Cockle shell containing a metallic cosmetic amalgam (photograph by C. Giardino).	83
8.1.	Open cast mine at Al-Moyassar (Maysar) filled by mining debris (photograph by C. Giardino).	85
8.2.	Copper workings at Al-Moyassar (Maysar). Collapsed entrance of a mine (photograph by C. Giardino).	86
8.3.	Grooved stone-hammer from the mining area of Al-Moyassar (Maysar) (photograph by C. Giardino).	87
8.4.	Experimental firesetting (photograph by C. Giardino).	88
8.5.	Firesetting in Europe during 16 <sup>th</sup> century (after Georgius Agricola, De Re Metallica Libri XII, Basel 1556).	89
8.6.	Bilad Al-Maidin. Rock cuts and broken ore fragments at a copper ore outcrop (photograph by C. Giardino).	90

8.7.	Linen clothes used as ventilation system in Europe during 16 <sup>th</sup> century (after Georgius Agricola, <i>De Re Metallica Libri XII</i> , Basel 1556).	91
8.8.	Bilad Al-Maidin. Stone mortars and slag fragments scattered on the surface of the site (photograph by C. Giardino).	92
9.1.	Experimental smelting furnace (photograph by C. Giardino).	94
9.2.	Experimental smelting furnace loaded with charcoal (photograph by C. Giardino).	95
9.3.	Tapped slag fragment from Al-Moyassar-1 (DA 2219), with a smooth upper surface characterized by flow patterns (photograph by C. Giardino).	96
9.4.	Bilad Al-Maidin. Tapped slag on the surface of a slag heap (photograph by C. Giardino).	97
9.5.	Bilad Al-Maidin. Stone mortars for crushing slag and ore (photograph by C. Giardino).	97
9.6.	Maysar-1. Landscape (photograph by C. Giardino).	98
9.7.	Photomicrograph of a copper prill (2 mm diameter) imbedded in a slag from Al-Moyassar-1 (photograph by C. Giardino).	99
9.8.	Al-Aqir. Plano-convex ingot (DA 7406) (photograph by C. Giardino).	101
9.9.	Al-Aqir. Section of plano-convex ingot filled with slag (DA 7407) (photograph by C. Giardino).	102
9.10.	Copper ingot from Ras Al-Hadd HD-1 (upper and lower sides) (photograph by C. Giardino).	103
9.11.	Maysar-1. Photomicrograph of copper slag (DA 2219) containing copper prills (20 x) (photograph by C. Giardino).	104
10.1.	Cyprus, Mitsero (Nicosia). Ancient copper mines (photograph by C. Giardino).	107
10.2.	Cyprus, Mitsero (Nicosia). Ancient tapped copper smelting slag (photograph by C. Giardino).	107
10.3.	Plan of Ras Al-Jinz RJ-1 (after Cleuziou and Tosi 2007).	109
10.4.	Ras Al-Jinz RJ-1. Wadi Suq house during excavation (after Cleuziou and Tosi 2007).	110
10.5.	Metal objects from Ras Al-Jinz RJ-1.	111
10.6.	Casting residue from Ras Al-Jinz RJ-1. The arrow shows the cleaned point for the XRF analysis.	112
10.7.	Wadi Suq metal objects from the Al-Wasit grave (after Weisgerber 2007b).	112
11.1.	Metal objects from the tomb of Nizwa (after Al-Shanfari and Weisgerber 1989).	115
11.2.	The site of ‘Uqdat Al-Bakrah in the sands of Rub Al-Khali (photograph by P. Koch).	117
11.3.	Dagger folded up for recycling (# 207): A, frontal view; B, lateral view (photographs by C. Giardino, modified by P. Koch).	118
11.4.	‘Uqdat Al-Bakrah. Charcoal pit.	119
11.5.	‘Uqdat Al-Bakrah. Furnace with stones around the perimeter.	119
11.6.	‘Uqdat Al-Bakrah. Large casting residue that preserved as a cast the inside of a crucible (DA 27317 B (photograph by C. Giardino, modified by P. Koch).	120
11.7.	‘Uqdat Al-Bakrah. Small casting residue (DA 26653.a) (photograph by C. Giardino, modified by P. Koch).	120

11.8.	'Uqdat Al-Bakrah. Semi-finished cast axes (photographs by C. Giardino, modified by P. Koch).	121
11.9.	'Uqdat Al-Bakrah. Dimpled stone tools emerging from the sand.	123
11.10.	'Uqdat Al-Bakrah. Stone anvil from the surface of the site.	123
11.11.	'Uqdat Al-Bakrah. Pierced whetstone (#170); on the left corner, detail of wear traces.	123
11.12.	'Uqdat Al-Bakrah. Fragment of a plano-convex copper ingot (DA 29943) (photograph by C. Giardino, modified by P. Koch).	124
11.13.	'Uqdat Al-Bakrah. Iron blocklets (DA 26655.b) (photographs by C. Giardino, modified by P. Koch).	124
11.14.	'Uqdat Al-Bakrah. Typology of the axes (photographs by C. Giardino, modified by P. Koch).	126
11.15.	'Uqdat Al-Bakrah. Typology of the hammers (photographs by C. Giardino, modified by P. Koch).	128
11.16.	'Uqdat Al-Bakrah. Typology of stakes (photographs by C. Giardino, modified by P. Koch).	130
11.17.	'Uqdat Al-Bakrah. Typology of hoes (photographs by C. Giardino, modified by P. Koch).	130
11.18.	'Uqdat Al-Bakrah. Typology of razors (photographs by C. Giardino, modified by P. Koch).	132
11.19.	'Uqdat Al-Bakrah. Typology of spatulas (photographs by C. Giardino, modified by P. Koch).	133
11.20.	'Uqdat Al-Bakrah. Typology of chisels (photographs by C. Giardino, modified by P. Koch).	134
11.21.	'Uqdat Al-Bakrah. Pair of shallow bowls used as scale plates (DA 29869 A, B) (photograph by C. Giardino) (photographs by C. Giardino, modified by P. Koch).	134
11.22.	'Uqdat Al-Bakrah. Typology of vessels (photographs by C. Giardino, modified by P. Koch).	135
11.23.	'Uqdat Al-Bakrah. Silver finger ring (DA 30197) (photograph by C. Giardino, modified by P. Koch).	136
11.24.	'Uqdat Al-Bakrah. Carnelian bead decorated with gold granulation (DA 26169.m). Top- left corner: micrograph of the granulation (photographs by C. Giardino, modified by P. Koch).	136
11.25.	Metal objects from the hoard of Ibri/Selme (after Weisgerber and Yule 1989; Yule and Weisgerber 2001).	137
12.1.	Schematic plan of the ED-XRF portable apparatus.	140
12.2.	Histogram of presence frequency of analyzed elements in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1.	153
12.3.	Copper concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Jinz RJ-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	153
12.4.	Silver concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-6, analyzed by XRF.	154

<b>12.5.</b>	Zinc concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	154
<b>12.6.</b>	Iron concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	155
<b>12.7.</b>	Cobalt concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	155
<b>12.8.</b>	Arsenic concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	156
<b>12.9.</b>	Arsenic concentrations in tools from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	156
<b>12.10.</b>	Arsenic concentrations in ornaments and weapons from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6 and Ras Al-Jinz RJ-2, analyzed by XRF.	157
<b>12.11.</b>	Arsenic concentrations in semi-finished items from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	157
<b>12.12.</b>	Nickel concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	158
<b>12.13.</b>	Nickel concentrations in tools from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	158
<b>12.14.</b>	Nickel concentrations in ornaments and weapons from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6 and Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	159
<b>12.15.</b>	Nickel concentrations in semi-finished items from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	159
<b>12.16.</b>	Arsenic and nickel in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	160
<b>12.17.</b>	Arsenic and cobalt in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	160
<b>12.18.</b>	Lead concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	161
<b>12.19.</b>	Antimony concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-6, analyzed by XRF.	161

12.20.	Tin concentrations in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-6, analyzed by XRF.	162
12.21.	Tin concentrations in tools from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-6, Ras Al-Jinz RJ-2, analyzed by XRF.	162
12.22.	Tin concentrations in ornaments and weapons from Ras Al-Jinz RJ-2, analyzed by XRF.	163
12.23.	Tin concentrations in semi-finished items from Ras Al-Jinz RJ-2, analyzed by XRF.	163

## TABLES

3.1.	Main alloys used in antiquity.	13
3.2.	Melting point of ancient metals.	14
3.3.	Main analytical techniques for archaeometallurgical studies.	17
6.1.	ED-XRF quantitative and semi-quantitative analyses of Ras Al-Hadd HD-6 metalworks.	44
6.2.	ED-XRF quantitative and semi-quantitative analyses of Ras Al-Hadd HD-6 metalworks. Semi-quantitative composition: MC = main component; ++++++ → + diminishing content; Tr = trace (modified from Giardino <i>et al.</i> 2007).	45
12.1.	Metal finds from Wadi Shab GAS-1. Alloy normalized concentration. MDL (Minimum Detection Limit) and MRE (Minimum Relative Error) are specified for the elements.	145
12.2.	Metal finds from Ras Al-Hamra RH-10. Alloy normalized concentration. MDL (Minimum Detection Limit) and MRE (Minimum Relative Error) are specified for the elements.	146
12.3.	Metal finds from Ras Al-Hadd HD-6. Alloy normalized concentration. MDL (Minimum Detection Limit) and MRE (Minimum Relative Error) are specified for the elements.	147
12.4.	Metal finds from Ras Al-Hadd HD-10. Alloy normalized concentration. MDL (Minimum Detection Limit) and MRE (Minimum Relative Error) are specified for the elements.	148
12.5.	Metal finds from Ras Al-Jinz RJ-2. Alloy normalized concentration. MDL (Minimum Detection Limit) and MRE (Minimum Relative Error) are specified for the elements.	148
12.6.	Metal finds from Ras Al-Hadd HD-5, Ras Al-Jinz RJ-1, Ras Al-Jinz RJ-4, Ras Al-Jinz RJ-6. Alloy normalized concentration. MDL (Minimum Detection Limit) and MRE (Minimum Relative Error) are specified for the elements.	150
12.7.	Average for element in objects from Wadi Shab GAS-1, Ras Al-Hamra RH-10, Ras Al-Hadd HD-6, Ras Al-Hadd HD-10, Ras Al-Jinz RJ-2 and Ras Al-Jinz RJ-1, analyzed by XRF.	151
12.8.	Crucibles from Ras Al-Jinz RJ-2; int.: inside, ext.: outside. Majority elements (maj): + = 1.00%; ++ = 5%; +++ = 15%; ++++ = 30%. Minority elements (min): + = 0.50%; ++ = 5%; +++ = 10%; ++++ = 15%. Trace elements (trace): + = 0.20%; ++ = 1%; +++ = 5%; ++++ = 10%. MDL (Minimum Detection Limit) and MRE (Minimum Relative Error) are specified for the components.	152
12.9.	Metallic cosmetic amalgam inside a cockle shell from Ras Al-Hadd HD-5. MDL (Minimum Detection Limit) and MRE (Minimum Relative Error) are specified for the elements.	152



## Acknowledgments

First of all, I would like to thank His Royal Highness Sayyid Haitham bin Tarik Al Said, Minister of Heritage and Culture of the Sultanate of Oman.

I express my profound gratitude to His Excellency Salim Mohammed Al-Mahrooqi, Undersecretary for Heritage of the Ministry of Heritage and Culture, to His Excellency Hassan Mohammed Ali Al-Lawati, Adviser of His Highness the Minister of Heritage and Culture for Special Projects, and to Mr. Sultan Saif Al-Bakri, Director General for Archaeology of the he Minister of Heritage and Culture, for having put at my disposal the artefacts that I studied.

I thank deeply Prof. Maurizio Tosi, Director of the Italian Archaeological Mission and of the Joint Hadd Project, for involving me in the study of the Omani metals and for the stimulating discussions; he supported this research and provided me with precious information on the early metallurgy of Oman. To him, whose premature disappearance just took place during the final revisions of this volume, I dedicate a grateful and mindful tribute.

I am thankful to Prof. Maurizio Cattani for letting me study the HD-6 metal items and for giving me helpful suggestions. I would like to express my special appreciation to Dr. Alessandra Lazzari for her kind and fundamental collaboration and constant help; to Dr. Francesco Genchi, for sharing his knowledge of the 'Uqdat Al-Bakrah excavation.

Prof. Sobhi Nasir from the Department of Earth Science of the Sultan Qaboos University, who gave me precious help in analyzing the necklace from RJ-2.

I thank Dr. Luigi Tricarico, who made most of the drawings. I am thankful for Dr. Giuseppe Sarcinelli's elaboration of computer graphics. The advice given by Giò Morse in revising the English has been of great help. I am also grateful to Prof. Giovanni Ercole Gigante, to Dr. Giuseppe Guida of the Italian High Institute for Conservation and Restoration (*ISCR Istituto Superiore per la Conservazione e il Restauro*, Rome) and to Dr. Stefano Ridolfi for their invaluable contributions in the scientific analyses of the Omani archaeological materials.

I would like to express my very great appreciation to Dr. Christopher P. Thornton for providing me with the manuscript of his new, precious work on the Bat excavations.

Finally, I would like to express a moving remembrance for Dr. Gert Weisgerber, unforgettable pioneer of the archaeometallurgical research in Oman, who was always generous with advice and information, and who accompanied me on exciting archaeomining surveys.



## Foreword

*“Let the land of Magan [bring for you], hard  
and resistant copper, diorite stones...”*

These poetic words were written in Mesopotamia, in the ancient city of Ur, more than four thousand years ago, when the last king of Larsa was still ruling. They tell us about a country far away from Sumer, Magan, that was fabulously rich in copper: Magan, the land that the last century researchers have identified with modern Oman.

The prehistoric civilizations of Oman are strongly connected with this red, bright and hard metal, which Omani people learned to exploit and trade since very early times. Copper was an urgent need for the proud states of the Near East. Without this metal, it was impossible to produce the weapons for their armies, the ornaments for their aristocrats, the statues of their gods and kings. It is not possible to understand the history of early Oman without taking into account the precious copper that was mined in its mountains.

This book wants to describe and to analyze the prehistory of the country from a metallurgical point of view, starting from the first appearance of copper artefacts – as an intriguing multifunctional tool found in a fishermen village at Ras Al-Hamra RH-10 – up to the mass recycling activity produced in the large Iron Age workshop recently discovered on the border of the desert of the Rub Al-Khali. To accomplish this goal requires to carefully examine the evidence from archaeological excavations, together with the results of scientific analyses carried out on the metal items that were discovered during these excavations.

The book is divided into chapters that reflect the different chronological periods, which characterized the prehistory of Oman. Metallurgy is in fact a science that cannot be really understood without considering the cultural structure of the societies that produced that technology: metal artefacts and metallurgical residues are in fact an excellent tool for understanding the complex interactions between technology and society.



## Chapter 1

# A country of environmental diversities

Oman occupies the southeastern corner of the Arabian Peninsula; it is located on the tropic of Cancer, between 25° and 17° latitude north. It has a total area of 309,500 km<sup>2</sup> and most of central part of the country is covered by a vast gravel desert plain, the Rub Al-Khali (Arabic: “the Empty Quarter”), the largest sand desert in the world. Mountain ranges rise along the north, the Al-Hajar Mountains, while the eastern side of the region is bordered by the sea. Oman has a coastline of almost 3165 km, from the Strait of Hormuz in the north to the borders of the Republic of Yemen in the southwest, overlooking three seas: the Arabian Gulf, the Gulf of Oman and the Arabian Sea.

The country holds a strategically important position, thanks to its geological resources and its location between the sea and the desert, which played a determinant role in Omani civilization and in the spread of metallurgy in the area.

Generally speaking, the Omani climate can be considered to be arid and semi-arid, but it actually differs quite a lot from one region to another. In fact, it is hot and dry in the interior and humid along the coast. The land receives little rainfall except in the mountain areas, where it rains much more. The rainfall changes dramatically within the geographical regions of the country: the average volume of annual rainfall has been estimated at 62 mm, varying from less than 20 mm in the interior desert regions to over 300 mm in the mountain areas (Ministry of Regional Municipalities, Environment and Water Resources 2005). In the north and center of Oman it rains during winter, from November to April, while a seasonal summer monsoon, from June to September, occurs in the southern parts of the country (Dhofar) causing temperature changes. Nevertheless, these atmospheric precipitations allow supplying a large, diffused system of water-bearing layers in the foothill area, which feed the *wadi* basins. Especially in the foothill area, the average rainfall generally has about three peaks that are distributed not only in winter, but also in the summertime (Tosi 1975: 187, fig. 3).

Oman has large amounts of water in aquifers that were replenished when wet climate conditions prevailed, several thousand years ago. Total internal renewable water resources are estimated at 1.4 km<sup>3</sup>/year. About 1.05 km<sup>3</sup> is surface water and 1.3 km<sup>3</sup> groundwater, while 0.95 km<sup>3</sup> is considered to be the overlap between surface water and groundwater (Frenken 2009: 302, tab. 2).

These peculiar climatic characteristics of the country deeply conditioned the exploitation of the local resources. According to archaeological evidence, they have remained substantially the same, at least since the Copper Age.

The availability of water was determinant to permit a diversified flora and fauna, which made possible to develop the exploitation of the local economic resources since prehistory. The presence of bushes and trees in the *Acacia savannah*, especially along the *wadis*, was relevant for the development of early metallurgy, because these plants could be used with profit as a fuel source to feed the furnaces.

Since the 3<sup>rd</sup> millennium BC agriculture was developed in Oman thanks to the oasis system; isolated areas of vegetation in an arid environment created by human ingenuity in the surroundings of a water source. Oases provided habitat for plants, animals and even humans (Figure 1.1).



**Figure 1.1. Date palms at the Bat oasis (photograph by C. Giardino).**

### **The three geographical provinces of Oman**

Geographical criteria allow dividing Oman into three main physiographic provinces: the coast, the mountains and the desert (Frenken 2009: 299). The country is therefore characterized by a large variety of ecosystems that coexist inside its territory; this ecological variability is also increased by the presence of summer monsoons. During prehistory, this variability stimulated different responses by the local communities that developed peculiar specializations in land use and created a mechanism of close interactions and economic integration thanks to the complementary nature of the resources.

*The coast and the coastal plain.* The country has a long coastline of almost 3165 km, it overlooks three seas: the Arabian Gulf, the Gulf of Oman and the Arabian Sea. The elevation ranges between zero near the sea to 500 meters further inland. The coastal area represents a very favorable biotype for sea life. Many types of fish, mollusks, and coelenterates live along the shore, constituting a rich supply for the human settlements. Fishing villages were established in the lagoons with mangroves along the coast of Northern Oman since the Middle Holocene, which used local shells and stones to produce tools and ornaments. Life conditions should have been particularly profitable; in fact, archaeological research discovered more than one hundred settlements dated from the 4<sup>th</sup> millennium BC along the coast between Muscat and Dhofar (Cleuziou and Tosi 2007: 69-70).



**Figure 1.2. Cliffs at Ras Al-Jinz (photograph by C. Giardino).**

These settlements were rather prosperous and had high subsistence levels because they were strongly connected in a network of trades with the other communities spread all over the country. The existence of this network is clearly shown by the presence in one of the fishing sites, at Ras Al-Hamra, of one of the earliest Omani metal objects, a multifunctional tool dating to the end of 4<sup>th</sup> millennium BC. In the sea villages along the coast near Sur many copper tools related to fishing were in use during the Early Bronze Age, in the context of the Umm an-Nar culture. The copper mines, exploited in the productive centers near the outcrops, regularly reached the settlements along the coast. Metal was therefore in use not only for prestigious items, such as daggers or other weapons, but mainly for everyday purposes, as hooks and needles to repairs fishnets or awls for shell craft, which used the local availability of sea snails as *conus*, *strombus*, *cipraea* and *ostrea*. Also in the later periods, the coastal area remains the best place for us to detect metallurgical innovations. At Ras Al-Jinz (Figure 1.2), the easternmost point of the Arabian Peninsula, the earliest evidence of copper melting was recovered; a much more developed technique in comparison with the simple shaping by hammering that took place at the earlier site of Ras Al-Hadd HD-6 (Figure 1.3).

*The mountains.* The mountain ranges occupy 15% of the total area of the country. In the southeastern area, the mountains run from Musandam in the north to the Ras Al-Hadd. Here is located the Jebel Al-Akhdar, with a peak that reaches 3000 meters, near the Al-Batinah Plain. Other mountains are in the Dhofar province, with peaks from 1000 to 2500 meters.



**Figure 1.3. The coast at Ras Al-Hadd (photograph by C. Giardino).**



**Figure 1.4. Mountains near Al-Moyassar (Maysar) (photograph by C. Giardino).**



**Figure 1.5. Rub Al-Khali landscape near 'Uqdat Al-Bakrah (photograph by C. Giardino).**

The average annual rainfall in the mountain areas has been estimated at over 300 mm, which is much more than the general average for the whole country (Frenken 2009). The mountain areas are characterized by the presence of copper ore deposits (Figure 1.4). These deposits have been exploited since prehistory, as indicated by the Bronze Age mines that were identified during archaeological investigations. The metal sources from the mountains contributed in a significant way to the early development of Oman, sustaining middle and long distance trades with other communities and countries. According to Sumerian texts dating back to the 3<sup>rd</sup> millennium BC, copper from the Omani mountains constituted a relevant source for Mesopotamian metallurgy for several centuries.

*The desert.* The interior regions are placed between the coastal plain and the mountains in the north and the south areas; here the elevations do not exceed 500 meters. This area that covers 82 % of Oman is mainly desert, sand and gravel plains. It includes part of the Rub Al-Khali, also known as the Empty Quarter or the Great Sandy Desert (Figure 1.5). The climate is hot with temperature extremes and is decidedly arid with a low and highly erratic rainfall. The region receives extremely little precipitations, generally 20-35 millimeters of average annual rainfall. Rainfall is generally less than 35 mm per annum, and the daily average relative humidity is about 52% in January and 15% in June-July. Daily maximum temperatures average 47 °C in July and August, reaching peaks of 51 °C. The daily minimum average is 12 °C in January and February, although frosts have been recorded (Mandaville 1986; Franken 2009; Llewellyn-Smith 2014). The sands are predominantly silicates, composed of 80 to 90% of quartz and the remainder feldspar (Mandaville 1986). Dune types range from solitary barchan dunes to extensive longitudinal dunes about 300 km long.



Figure 1.6. Acacia tree in the outer margins of the Rub Al-Khali (photograph by C. Giardino).

The Rub Al-Khali has a very limited floristic diversity. There are only 37 species, of which about 17 live mostly around the outer margins; of these, one or two are endemic species (Mandaville 1986; Norton *et al.* 2009). Vegetation may be described as very diffuse, but fairly evenly distributed sand shrub land, interrupted in some parts by near sterile inter-dune floors. Typical plants are *Calligonum crinitum* on dune slopes, saltbush (*Cornulaca arabica*) and tussocks of sedge (*Cyperus conglomeratus*). Other widespread associates are *Dipterygium glaucum*, *Limeum arabicum* and *Zygophyllum mandavillei*. Trees are absent, except around the outer margins, and are typically *Acacia ehrenbergiana* and *Prosopis cineraria* in drainage lines and pans between dunes (Figure 1.6).

In the past, this area was not only a large border, hard to overcome, but also a relevant network of caravan routes that were ideal for communication and trade, connecting Oman with the rest of Arabia. The camel trains were able to withstand harsh conditions: for centuries, they traveled throughout the desert and often carried lucrative goods, such as fine cloth, beautiful textiles, delicious food, useful and precious metals. The peculiar characteristics of this difficult environment made it an ideal location for some specialized metallurgical activities, where the intense use of fire needed a protected location, as it is possible to observe at the Iron Age industrial area of ‘Uqdat Al-Bakrah.