Spatial Environment and Conceptual Design

THE CONCEPT OF SOCIAL ECOLOGY AS A MEANS TO INTEGRATE HUMANITIES AND SCIENCE IN LANDSCAPE ARCHAEOLOGICAL RESEARCH

Daniel Knitter
Wolfram Schier
Brigitta Schütt
(eds.)

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BERLIN STUDIES OF THE ANCIENT WORLD

THE RELATIONSHIP BETWEEN HUMANS, their landscapes, and the natural environment is complex and underlies mutual non-material and material fluxes. Especially challenging is the attempt to reconstruct this relationship in order to understand the role and relevance of Space and Knowledge of Ancient Civilizations, the core theme of the cluster of excellence Exc 264 Topoi, funded from 2007–2019. In this book we present the results of an attempt to use a system-oriented concept of social ecology as tool for interdisciplinary collaboration and integrative research on aspects of human-environmental relationship. In six different interdisciplinary projects the developed social ecological model is applied and critically discussed.

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Claudia Näser, Martin Gussone, Will M. Kennedy, Torsten Klein, Daniel Knitter, Jan Krause, Julia Meister, Stephan G. Schmid, Brigitta Schütt, Wiebke Bebermeier, Iris Gerlach, Kay Kohlmeyer, Dirce Marzoli, Bernd Müller-Neuhof, Philipp von Rummel, Dorothee Sack, Ulrike Wulf-Rheidt

Investigating Marginality within the Framework of Socio-Ecological Interaction Models

Summary

This contribution explores the application of the socio-ecological interaction model proposed by Marina Fischer-Kowalski for an investigation of the colonization of marginal habitats. Central to our approach is the hypothesis that the occupation of areas beyond the 'regular' settlement patterns of (pre)historic, and indeed modern, societies corresponds to colonization processes that reflect specific social strategies and may have stimulated the development of new technological skills. Four case studies from the sites of Resafa (Syria), Petra (Jordan), and Ayamonte (Spain) highlight the potentials, as well as the limits, of applying the socio-ecological model to archaeological material/studies.

Keywords: socio-ecological interaction models; colonization; technical knowledge; marginality; landscape archaeology

Dieser Beitrag untersucht die Anwendbarkeit des Sozialökologischen Interaktionsmodels von Marina Fischer-Kowalski auf/für die Untersuchung der Kolonialisierung von marginalen Räumen. Für unseren Ansatz ist folgende Hypothese zentral: Die Besetzung von Arealen über ‚reguläre' Siedlungsstrukturen (prä-)historischer sowie auch moderner Gesellschaften hinaus stimmt mit Kolonialisierungsprozessen überein, welche spezifische soziale Strategien spiegeln und die Entwicklung von neuen technologischen Fähigkeiten stimuliert haben könnten. Fallstudienzu Resafa (Syrien), Petra (Jordanien) und Ayamonte (Spanien) betonen die Potentiale wie auch die Grenzen der Übertragung des Sozialökologischen Modells auf archäologische Quellen/Studien.

Keywords: Sozialökologisches Interaktionsmodell; Kolonisation; technisches Wissen; marginal Räume; Landschaftsarchäologie

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1 Introduction

1.1 Objectives

The research group 'The Ancient Colonization of Marginal Habitats' (A-1) of the Topoi Excellence Cluster investigates the nexus between environmental requirements for settlement spaces, the cultural acquisition of these spaces, and the development of technical knowledge. The central working hypothesis is that the development and shaping of settlement spaces in past societies was an important engine for the development of technological skills and technical knowledge. This is most plainly evident in places where settlement plans were confronted with disadvantageous environmental conditions. Settling in these places required particular effort with regard to the development and use of technical knowledge and customized settlement strategies.

A major challenge of this research is to reveal the dynamics of the complex processes of settlement from a perspective that is exclusively based on archaeological data. The aim of this contribution is to explore whether, and in which way, the socio-ecological model, which was originally proposed for an integrative research on human-environmental interactions, can be productively adapted in this research context. Based on the socio-ecological model corresponding to Fischer-Kowalski,[1] the authors attempt to draw connections between specific cultural interactions, intentions, and innovations; how this is embedded into the natural environment; how settlement activities adapt to the natural environment; and whether the natural environment triggers technical or social innovations.

The research is being conducted by the interdisciplinary research group 'The Ancient Colonization of Marginal Habitats,' uniting scholars of prehistory, archaeology, building research, and physical geography. The individual research projects build, in part, on preceding studies conducted within the research group 'Central Places and Their Environment' of the EXC 264 Topoi during its first funding phase (2007–2012). Geographically, the eight research projects within the group range from modern Spain to the Jordanian desert and from Turkey to the Ethiopian highlands, thus, covering a different variety of colonized areas and colonizing intentions/settlement strategies (Fig. 1). For each of the case study settlement sites, we attempt to assess the environmental conditions, the motivation, and the process of colonization, as well as its consequences for the natural and built environment. It is evident that only an interdisciplinary approach that comprehensively investigates the history and trajectory of the settlement activities, past environmental conditions, social structures, and technical skills, can yield conclusive

1 Fischer-Kowalski 1998.

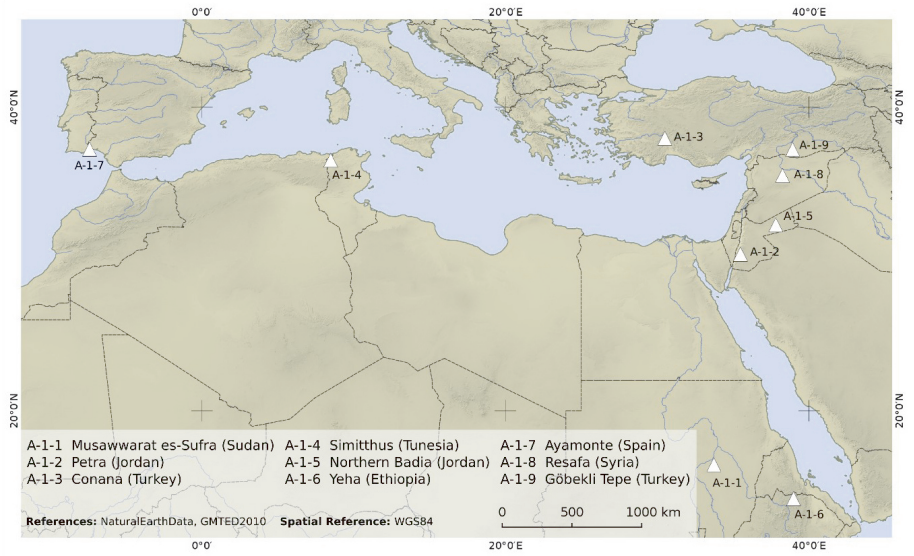

Fig. 1 Location of the study sites of the research group Topoi A-1 *The Ancient Colonization of Marginal Habitats*. Triangles mark the center of the respective region of interest.

results. Further, the work of the research group is not restricted to aspects of socio-ecological marginality, but also deals with aspects of economic and spatial marginality and more.[2]

1.2 The socio-ecological model of Fischer-Kowalski et al. from an archaeological perspective

The socio-ecological model[3] of Fischer-Kowalski et al. (2011) works with a range of aspects/factors that lend themselves as analytical instruments for an archaeological enquiry to a differing degree.[4] The following paragraph will introduce our understanding and partial adaptation of these aspects, and the specific terminology used by Fischer-Kowalski (Fig. 2).[5] We understand *nature* as the environment that is open to human exploration, intervention, and exploitation, while also setting the physical parameters or conditions for human existence. In our perspective, nature is the physical frame of the societal project of colonization. *Labor* is the activity or process of changing nature in order adapt it to human needs or to advance the metabolism between humans and

2 As elaborated in Bebermeier et al. 2016.

3 For a general introduction to this model see the contribution Knitter, Schütt, Schier, Bernbeck (Introduction) in this volume.

4 Fischer-Kowalski, Mayer, and Schaffartzik 2011.

5 Fischer-Kowalski, Mayer, and Schaffartzik 2011.

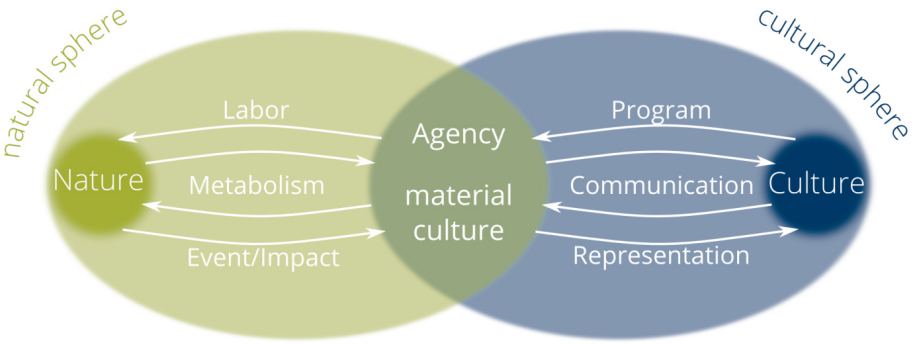

Fig. 2 Adapted version of the socio-ecological model after Fischer-Kowalski, displaying the terms used in the current research.

nature. We define labor as an investment in the environment, thus, appropriating, adjusting, and maintaining it in order to meet the conditions of the colonization project. From the perspective of labor, nature is both a resource, as well as a limiting factor. According to Fischer-Kowalski, *metabolism* is "the most direct connection between society and the material world",[6] and "the acquisition of material and energy as well as their transformation as means for preserving life, enabling labor and finally creating metabolic products".[7] It is the connex/relation "with the shortest cycles […] and when these are interrupted, societal systems are quickly no longer reproductive".[8] However, this conceptualization seems problematic with regard to the differentiation of labor and metabolism. Both involve human actions and social practices – and even the most basic actions are socially conditioned and not a purely metabolic process, in biological terms, as Fischer-Kowalski and Erb concede as well.[9] Thus, labor and actions defined as metabolism differ only by degree, or by the application of arbitrary definitions, e.g. regarding intentionality and range. From an analytical perspective, it seems better to define metabolism as the (continuous) dialectic processes of environmental change, i.e. the actual conversions caused by labor, with labor being defined as any kind of human action or intervention. In contrast to labor, *experience/event/impact* designates all events or impacts of a non-anthropogenic origin that lead to changes in the environment. Obviously, such impacts from natural causes also result in changes in the resource base of the natural environment, which in turn influences social practice.

In the socio-ecological model as it is applied here, *material culture* constitutes the nexus between the spheres of nature and culture. Material culture is one of the most widely discussed terms in social anthropology, archaeology, and the eponymous field

6 Fischer-Kowalski, Mayer, and Schaffartzik 2011.
7 Fischer-Kowalski and Erb 2006.
8 Fischer-Kowalski, Mayer, and Schaffartzik 2011.
9 Fischer-Kowalski and Erb 2006, 42.

of material culture studies,[10] and can be defined as the entirety of all physical objects produced by any given society or social group. Within the perspective of our topic, i.e. colonization, material culture are the material products of the colonization project. Turned into archaeological remains through time, their analysis offers us insights in the particularities of the colonization process, its conditions, trajectories, and consequences. If material culture is both an all-encompassing category, as well as an interpretive battle ground, the same goes for the concept of *culture*. Fischer-Kowalski follow a system theory understanding, as proposed by Niklas Luhmann.[11] For our purposes, it may suffice to define culture as the products of human action and the sustained social communication about them. *Program* is the cultural process that arises from a societal or individual endeavor to master a specific facet of human existence or experience. In this understanding, the colonization of new settlement spaces is a cultural program *par excellence*. As to *communication*, Fischer-Kowalski adhere to a Luhmannian reading of the term, which defines society as a system of recursive communication.[12] Finally, *representation* describes the specific organization of communication, *how* specific experiences, impacts, or programs are communicated. Representation concerns the means as well as the semantics of (symbolic) interaction.

After clarifying the framework of the socio-ecological model, it is necessary to evaluate the database for its archaeological application. Records relating to the *natural sphere* are preserved as, e.g., sediments resulting from soil erosion processes, botanical remains in the form of pollen, or phytoliths act as proxy data for local environmental conditions or topographic features indicating turning active human interventions into natural dynamics. *Material culture*, or more precisely, the physical remains of material culture that have been transformed into archaeological data, form the center of the model, i.e. the 'coupling point' of the two spheres.[13] Thus, archaeology might be in a privileged analytical position, as it operates with data that are central to the dynamics of the model. However, the other aspects of the *cultural sphere*, namely program, communication, and representation, are only indirectly preserved and need to be 'reconstructed', i.e. argued based on their material remains. In many cases, this seems to be straightforward enough; for example, the program of colonizing a new settlement area can be 'read' from the physical result, i.e. settlements in an area previously unoccupied by the given society. However, without additional written records, working from archaeological sources alone, it will be difficult to understand the social motivation and representation of this program. The four case studies in this contribution illustrate this point.

10 See e.g. Hahn 2014; Samida, Eggert, and Hahn 2014; Hicks and Beaudry 2010; Tilley et al. 2006 – to name but four of hundreds of contributions.

11 Fischer-Kowalski, Mayer, and Schaffartzik 2011.

12 Fischer-Kowalski, Mayer, and Schaffartzik 2011, 99.

13 For the concept of 'coupling' see Fischer-Kowalski and Erb 2006, 33, 36, 43.

Another issue is *chronology*. The dialectic, or in the original reading 'causal', relationships of the socio-ecological model imply a processual nature of condition, impact, and consequences or, in short, a diachronic dimension. Such relationships of impact and consequences, and even more so, their social motivation, can be hard to ascertain given the multi-causal conditioning of almost all processes in both the cultural and natural sphere, as well as the patchy archaeological dataset. This observation is also true for the natural sphere: in order to comprehensively reconstruct past environmental conditions and their trajectories, which may allow the identification of the postulated relationships between, e.g. labor and its impact upon the environment, is a real challenge. The following case studies will describe how these challenges are met.

2 Case studies

Colonization and habitation require conditions that are greatly determined by environmental factors. Colonization of unfavorable areas has frequently been accompanied by the development of techniques to overcome natural limitations, such as techniques for storing food and water, or, particularly in drylands, water harvesting, water storing, and water direction.[14] Natural environments changed in conjunction with colonization; natural landscapes were transformed into *cultural landscapes,* with the sediment balance, and water budget, as well as the nutrient fluxes altered. Non-sustainable settlement and land use strategies resulted in land degradation, frequently leading to the deterioration of other site-related factors.

The case studies are geographically widely dispersed across the Mediterranean, and all together they encompass a broad time span, ranging from the 5th millennium BCE to the 1st millennium CE. All of the case studies adhere to a settlement-archaeological approach and apply similar methodologies. At present, the natural environments of the case study sites have a dryland character, ranging from semi-arid to dry-sub humid. As a consequence, the availability of water plays a major role in all cases for all kinds of settlement activities. Moreover, especially in marginal habitats, the exploitation and utilization of building material and the transfer, adaption, and advancement of each kind of engineering process are of heightened interest.

14 Beckers, Berking, and Schütt 2012; Beckers and Schütt 2013; Näser and Scheibner 2013.

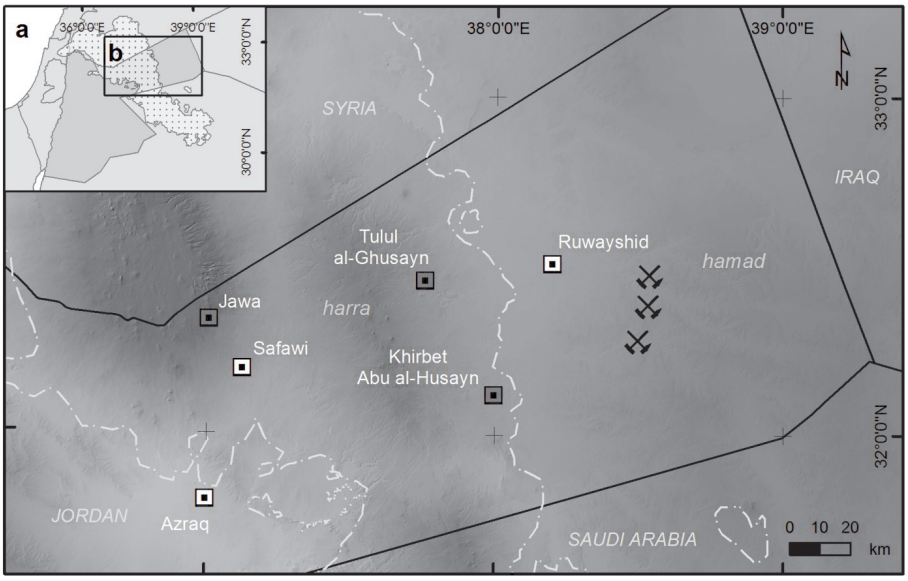

Fig. 3 a) Location of the 'Harrat Ash Shaam' basaltic region within Jordan and neighboring countries. b) Location of modern settlements (white rectangle), C/EBA fortified sites (grey rectangle) and flint mining regions (mine symbol) (after Müller-Neuhof 2014a) within northeastern Jordan.

2.1 The Early Bronze Age settlement of Jawa and its hinterland, the Northern Badia

The Jordanian Northern Badia is a vast steppe desert that is located between Southern Mesopotamia and the Southern Levant (Fig. 3). The region is characterized by a limestone steppe desert in the east (*hamad*) and a basalt steppe desert in the west (*harra*). Recent research has shown intensive anthropogenic activities, especially during late prehistoric times, lasting from the 7th to the 4th millennium BCE.[15] The geoarchaeological project chronologically focusses on the Chalcolithic and the Early Bronze Ages (the 5th to the 3rd millennium BCE). It is motivated by the fact that early complex societies evolved at the same time in the neighboring regions of Southern Mesopotamia and the Southern Levant, a process with possible effects on the socio economy of the centrally located but arid Northern Badia. The project's major aims are the identification of evidence of Chalcolithic/Early Bronze Age socioeconomic activities in the Northern Badia, the evaluation of the character and scope of these activities, and their possible external relations.

The central research outcomes of the project are:

15 C.f. Akkermans, Huigens, and Brüning 2014; Betts et al. 2013; Müller-Neuhof 2014a; Rollefson, Rowan, and Wasse 2014.

1. In the limestone steppe desert (*hamad*), large opencast flint mines and cortical tool blank production sites adjacent to the mines have been identified. Several millions of these typical Chalcolithic/Early Bronze Age tool blanks were produced in this mining region.[16]

2. In the basalt steppe (*harra*), a large number of clustered enclosure sites along wadis have been recorded, attesting to an intensive utilization of this area by nomadic pastoralists.[17] Parts of theses clustered enclosures are dated to the Chalcolithic/Early Bronze Age.[18]

3. In the vicinity of the Early Bronze Age settlement of Jawa, one of the major towns in the Middle East during the 4th millennium BCE, irrigated agricultural terrace systems were discovered, which are so far the oldest known artificially irrigated terrace systems.[19] The site is located in the western part of the basalt desert steppe.

2.1.1 Nature

Northeastern Jordan can be divided geologically into two main areas: the *hamad*, is composed of limestone of a cretaceous and tertiary age, covered by chert gravels,[20] and the basaltic *harra* is part of the North Arabian Volcanic Province 'Harrat ash shaam' that extends from Southern Syria to Saudi Arabia, consisting of several Quaternary and Neogene volcanic basalt lava flows.[21] The surface of the *harra* is covered with extensive basalt stone pavements resulting from the weathering of the volcanic rocks.[22]

The local topography is dominated by a gently undulating plain declining from north to south, with elevations ranging between ca. 1200 and 400 meters asl.[23] Within the basalt plateau, depressions filled with fine-grained sediment deposits are common, locally called *Qa'a*.[24] The natural vegetation cover around Jawa is patchy – occurring as grasses, herbs, and shrubs – and classified as part of the Saharo-Arabian plant region.[25]

Climatically, today the Northern Badia is located in the transition zone between the Mediterranean environment and the fully arid zone of the Syrian Desert.[26] Following the Köppen-Geiger classification, the area is classified as a hot desert climate,[27] characterized by marked seasonal variations, with hot, dry summers and cool, moist winters.[28]

16 Müller-Neuhof 2006; Müller-Neuhof 2013; Müller-Neuhof 2014a.
17 Meister, Knitter, et al. 2019.
18 Müller-Neuhof, L. Abu-Azizeh, et al. 2013; Müller-Neuhof 2014a.
19 Meister, Krause, et al. 2017; Müller-Neuhof 2012; Müller-Neuhof 2014b.
20 Bender 1968.
21 Allison et al. 2000; Bender 1968; Taqieddin et al. 1995.
22 Allison et al. 2000.
23 Allison et al. 2000.
24 Al-Homoud et al. 1996.
25 Al-Eisawì 1996.
26 Al-Homoud et al. 1996.
27 BWh; Kottek et al. 2006.
28 Allison et al. 2000.

In the northwest of the study area, average rainfall rates exceed 150 mm due to its westerly location and the orographic effects of the Jebel Druze. Towards the south and east, rainfall rates decline, reaching less than 50 mm in the southern regions.[29]

Rainfall occurs mainly between November and March; at Jawa it averages about 115 mm.[30] Based on the isotope records from the Soreq Caves, it is assumed that, in general, climatic conditions in the Eastern Mediterranean region have been similar to those of the present for about seven thousand years. The Early Bronze Age I is characterized by small fluctuations, where moist conditions alternated with drier periods.[31] Since there is a lack of high-resolution proxy records in the Northern Badia,[32] detailed paleoenvironmental reconstructions for the Holocene are missing.

2.1.2 *Labor*

For the ancient settlement of Jawa and its hinterland, the Northern Badia, there are four main fields of labor 'activities':

1. Exploitation of mineral resources: In the *hamad*, evidence of C/EBA mining of flint is documented.[33] The exploitation activities were undertaken in order to detect high-quality raw material, sinking pits and trenches in the surface, quarrying the flint nodules, splitting the flint nodules, preparing knapping platforms, and detaching palm sized flat cortical flakes from these flint nodules. Production output (unretouched cortical flakes) were, thereupon, exported to consumer regions.

2. Usage of natural basalt stones: In the *harra*, weathered basalt stones are ubiquitous and in a good shape to be used as a building material. One dominant architectural structure, are the widely spread clustered enclosures[34] that were supposedly used as campsites and/or as animal corrals of herders.[35]

3. Settlements: The ancient settlement of Jawa was built as a fortified settlement. Next to the fortification itself, its natural position on a plateau improves its defensive character. Next to Jawa, other (smaller) fortified settlements are documented in the *harra*.[36]

29 Tansey 1999.
30 Meister, Rettig, and Schütt 2018.
31 Bar-Matthews et al. 1999.
32 C.f. Finné et al. 2011; Rambeau 2010.
33 Müller-Neuhof 2006; Müller-Neuhof 2013; Müller-Neuhof 2014a.
34 Meister, Knitter, et al. 2019.
35 Betts 1982.
36 C.f. Müller-Neuhof 2014a; Müller-Neuhof, L. Abu-Azizeh, et al. 2013; Müller-Neuhof and W. Abu-Azizeh 2016.

4. Water harvesting systems: At the EBA site of Jawa, the water management systems contain multiple elements, such as canals, deflection canals, dams, water reservoirs, spillways, overflows, and agricultural terraces that were used in other to manage and control the water. For water collection, surface runoff and wadi runoff were used. The collected water was directed to water reservoirs and agricultural fields.[37] On the agricultural terraces, next to water storage enhanced sediment, accumulation improves the agricultural use of cultivation areas.[38] Further terraced gardens have been identified at two other LC/EBA settlements in the Badia.[39]

2.1.3 Metabolism

The complex water harvesting and agricultural terrace systems point to the metabolism of this area. Nevertheless, the exact energetic demand of people during Early Bronze Age is not known. Crop yield simulations of the floodwater/runoff irrigated agricultural terrace systems around Jawa provide the first insights into potential crop yields and, thus, their energy production.[40] The complex water harvesting systems also document the need for drinking water for people and livestock. The clustered enclosures in the *harra* point to the metabolic usage of breeding animals for diet.

2.1.4 Impact/Event

Today, the region is characterized as arid, with very high rainfall variability, erratic rainfalls, and, subsequently, short and intensive runoff events.[41] Interannual precipitation variability might be recognized as having an impact on water availability and security and, therewith, also food security. Extreme runoff or longer droughts might have occurred as catastrophic events.

2.1.5 Material Culture

Within the project, artefacts are grouped into three different classes: architectural remains, archaeological surface finds, and geographical archives. The most prominent architectural remains are the remnants of permanent fortified settlements, such as ancient Jawa.[42] The remnants of water harvesting systems such as dams, reservoirs, pools, canals, spillways, overflows, deflection walls, and agricultural terraces, however, are also documented artefacts.[43] Clustered enclosures, potentially used for pastoral activities, are

37 Helms 1981; Meister, Krause, et al. 2017; Müller-Neuhof 2014b.
38 Meister, Rettig, and Schütt 2018.
39 Müller-Neuhof, L. Abu-Azizeh, et al. 2013; Müller-Neuhof and W. Abu-Azizeh 2016.
40 Meister, Rettig, and Schütt 2018.
41 Meister, Rettig, and Schütt 2018.
42 Helms 1981; Müller-Neuhof 2014a.
43 Helms 1981; Meister, Krause, et al. 2017; Müller-Neuhof 2014b.

architectural remains spread all over the basalt desert of the *harra*.[44] Archaeological finds are mostly lithic artefacts and some pottery remains, but also petroglyphs and archaeobotanical material.[45] The examined geographic archives act as artefacts, if the sediment deposition is driven by human activity. Based on short sediment profiles within the agricultural terraces, various proxies, such as geochemistry and phytolith analysis, have been investigated.[46] All 'objects' (artefacts) of the material culture of the above named classes have been taken for interpretation, which is documented in the marked papers.

2.1.6 Culture

For the Chalcolithic/Early Bronze Age, written sources are lacking. Thus, no detailed information on the culture of the inhabitants of ancient Jawa and the people migrating to the study area can be given.

2.1.7 Program

The cultural processes that arise from the societal or individual endeavor of the inhabitants of ancient Jawa and its hinterland form cultural programs that can be grouped into three major classes: resources (excluding water), settling, and water harvesting.

- Resources program: In the *hamad*, the natural mineral resources of flint were detected for systematic mining purposes. A differentiation of the flint layers by means of the quality of the resulting products was established. This means that knowledge of flint formation, with a focus on the resulting tools, was established in the entire mining area. Different types of mining are documented as well.[47] Animals as resources can be differentiated by use in terms of game hunting and animal husbandry. Clustered enclosures (campsites, animal corrals) spread throughout the entire *harra*, document early transhumance pastoral activity. The trading activities of these resources cannot be clearly proved, but has to be assumed.

- Settling program: In the vast arid region, the detection of favorable sites for establishing settlements can be named as part of the program. The settling strategy might have been directly linked to the water harvesting strategy, but this cannot be clearly proven. Further, expansion and fortification of settlements belong to the program of the societal group. If the settling program were directly linked to the resources, and thus to exchange and trade, remains unclear, but can be assumed.

44 Meister, Knitter, et al. 2019.

45 Müller-Neuhof, L. Abu-Azizeh, et al. 2013; Müller-Neuhof and W. Abu-Azizeh 2016.

46 Meister, Krause, et al. 2017.

47 Müller-Neuhof 2013.

– Water harvesting program: The implementation of water diversion and storage systems, described above (labor), secured water availability for people and livestock.[48] The construction of irrigated agricultural terrace systems enhanced and secured the crop yields for the inhabitants of ancient Jawa.[49]

2.1.8 Communication

Disentangling the modes of recursive communication of the societal groups, or individuals of the study area, is at the present hampered due to the complete lack of written sources. However, communication within the region and probably also with external communities is assumed to have been carried out via communication routes. In the almost inaccessible environment of the basalt steppe desert, such communication routes run along wadis and mudpans. Imported artefacts and exported goods (e.g. cortical scrapers) are archaeological evidence of such communication.

2.1.9 Representation

The given artefacts within this project do not allow us to understand the specific organization of communication. A reconstruction of the structural functioning of certain architectural remains might be a first step towards gaining insights into interactions.

2.1.10 Conclusions

For the given project setting and its emerging results, it can be stated that most of the terms of the adapted version of the socio-ecological model based on Fischer-Kowalski's work can be filled with content.[50] The main field of research in the model is the central part named 'material culture', or in this case more precisely, 'artefact'. With the research on architectural remains, archaeological surface finds and geographical archives generated by the project provide an idea of the chain of action of the inhabitants of the Early Bronze Age region of Jawa and its hinterland, Northern Badia. The different programs, derived from the artefact information, lead to a differentiation of the fields of labor, in this case, the exploitation of mineral resources, the usage of natural basalt stones, and the implementation of water harvesting systems. In particular, the crop yield simulations of the irrigated agricultural terrace systems around Jawa provide a first idea about the energy potential of these systems, thus, a first step towards quantifying the energetic metabolism for Early Bronze Age Jawa. Only little information can be given regarding communication and representation in this area at this time.

48 Helms 1981.
49 Meister, Rettig, and Schütt 2018.
50 Fischer-Kowalski, Mayer, and Schaffartzik 2011.

The adapted version of Fischer-Kowalski's socio-ecological model helps to incorporate the research from the different disciplines into one culture-nature framework.[51] It shows the systematic connections and, thus, the logical connections between the research carried out. The model can be used as a common container or communication basis. As described, not all terms can be elaborated within one project setting, but knowledge of the relation to the missing links is crucial for gaining results without disciplinary blinkers.

2.2 Petra/ Jordan

The Nabataean capital, Petra (Jordan; ca. 100 BCE–106 CE; Fig. 4), has been researched in terms of the organizational and technological efforts and innovations needed in order to facilitate a permanent and representative settlement within an unfavorable natural environment.[52] In addition to its arid climate, with an average precipitation of 180 mm (1951–2000),[53] Petra is most striking due to its strategically disadvantageous location in a steep valley that is vulnerable to uncontrolled flashfloods. Belonging to the Jordanian Highlands east of the Wadi 'Arabah floor and lying on a heavily mountainous ridge, Petra is situated within the most rugged landscape in modern-day Jordan, with a difference in elevation of up to 1500 m over only a few kilometers.[54] This terrain was caused by extreme uplifting and tilting.[55] Furthermore, the Petra Valley is flanked north-south by the down-sloping al-Quwayra Fault in the west and the up-sloping al-Mataha Fault in the east.[56] While the al-Mataha Fault consists of various limestone formations (Jabal as-Sharra),[57] the al-Quwayra Fault contains parts of the extensive Ahaymir Volcanic Suite, which extends even farther westwards.[58] Not only is this volcanic igneous rock extremely difficult or even impossible to pass by foot, donkey, or camel, it is also along this volcanic suite that the topography drops suddenly and dramatically several hundred meters towards the Wadi 'Arabah in the west.[59] Only the Petra Valley itself consists of the soft Cambrian-Ordivician sandstone that is good as a building material.[60]

Nevertheless, in the course of the Hellenistic Period (323–330 BCE), the Nabataeans gained control of the Arabian incense trade, turning from their originally nomadic traditions and gradually shifting into a state-like entity, with Petra as the heart of the

51 Fischer-Kowalski, Mayer, and Schaffartzik 2011.

52 The timeframe explored here is based on the archaeologically evidenced monumentalization of urban Petra in the first century BCE until the Roman annexation of the Nabataean realm on 106 CE (compare, e.g. Schmid 2012, 138–141).

53 Beckers, Schütt, et al. 2013; Kouki and Tenhunen 2013, 56–57.

54 Barjous 2013, 51–52; Besançon 2010.

55 Barjous 2013, 51.

56 Barjous 2013, 51.

57 Barjous 2013, 43.

58 Barjous 2013, 44, 51.

59 Kennedy 2016a.

60 Barjous 2013; Besançon 2010.

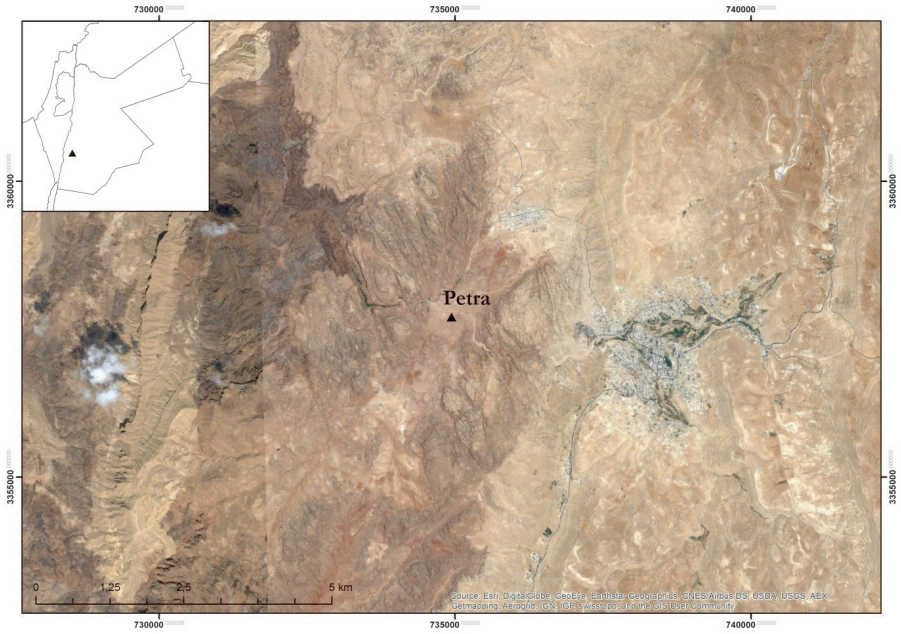

Fig. 4 Petra and its hinterland.

Nabataean Kingdom.[61] Petra developed into an important central place, particularly famous for its monumental funerary architecture, amalgamating oriental and Graeco-Roman traditions.[62]

However, Petra's hinterland remains less monumental and more affected by natural landscape factors, reflecting still persisting semi-nomadic traditions within Nabataean culture.[63] In Petra's immediate environment, there is archaeological evidence of both temporary tent-like structures, thus, being more 'mobile architecture' pertaining to a more nomadic way of life, as well as well-built and more substantial structures that represent a more sedentary aspect of Nabataean society.[64] It may be argued that Petra´s extreme natural settings played a central role in shaping and determining Nabataean culture.[65]

Assessing the interdependencies between the natural environment and Nabataean culture is, therefore, not only vital for comprehensively understanding the landscape organization and spatial strategies of rural Petra, but also for grasping Nabataean society in its entirety. The social ecology model proposed by Fischer-Kowalski recognizes these

61 Wenning 2013; Schmid 2008; Schmid 2001.
62 Schmid 2012; Schmid 2009; Schmid 2007.
63 Kennedy 2016a; Kouki 2012; Lindner 2003.
64 Kennedy 2016a.
65 Kennedy 2016a.

intricate mutual relations between natural and cultural processes.[66] Derived from sociological and ecological theory, the model does not aim to achieve a universally applicable position on nature–culture relations, but rather to present a concept for comprehensively understanding societies. Within the Petra case study, the model is adapted to the archaeological research questions and is used as a tool in order to simply organize the vast data available for both the natural and cultural sphere, as well as the indicative area termed here as material culture at first. By doing so, it is then possible to highlight specific causal connections from the otherwise indistinct blur of complex nature–culture relations.

2.2.1 Natural Sphere

For Petra and its hinterland, the natural settings (*nature*) are, at first glance, extremely disadvantageous, affecting ways of human adaptation (labor) to nature significantly. This includes the lack of water[67] and other natural resources such as wood[68] and metal deposits,[69] little agricultural possibilities,[70] and the arid climate,[71] as well as the generally unfavorable topographical and geological settings (see above).[72]

Labor entails (a) the exploitation of and reaction to the natural, i.e. untouched nature, determining very specific spatial strategies (e.g. the selective placement of strategically important watch posts),[73] but also (b) the exploitation of nature primarily for economic purposes (mining, foresting, modification of water sources, etc.).[74] The numerous agricultural terraces on the western slopes of the Jabal as-Sharra in the hinterland of Petra are good examples of Nabataean changes to the natural landscape (see above).[75]

Metabolism includes (in hierarchical order): (a) the water supply (constant maintenance of water sources),[76] (b) pastoralism (constant care of livestock etc.),[77] (c) agriculture,[78] (d) the supply of raw materials for singular human needs (e.g. wood for simple structures (tents), or as burning material), and, finally, (e) the industrial processing of

66 Fischer-Kowalski, Mayer, and Schaffartzik 2011; Fischer-Kowalski and Erb 2006; Fischer-Kowalski and Haberl 1998.

67 Bellwald 2012; Ortloff 2005.

68 Kouki and Tenhunen 2013, 60–62; Lindner 1997; Kühne and Wanke 1989.

69 Lindner 2003, 96–98; Lindner 1997, 34–35.

70 Lavento, Silvonen, and Kouki 2013, 213–229; Al-Salameen 2005; Lindner 1997, 31–32.

71 Beckers, Schütt, et al. 2013; Kouki and Tenhunen 2013.

72 Kennedy 2016a; Barjous 2013; Besançon 2010. It should be noted, however, that while the eastern ascent to the eastern highlands through the Jabal as-Sharra poses topographical difficulties, this region is also characterized by its comparatively high rainfall rates, and was extensively exploited for agricultural purposes in antiquity.

73 Kennedy 2016b; Kennedy 2013.

74 Lavento, Silvonen, and Kouki 2013; Ortloff 2005; Lindner 1997.

75 Beckers, Schütt, et al. 2013.

76 See e.g. the measures taken not only to divert fresh water into the city, but also to control potential flash floods: Bellwald 2012; Ortloff 2005; Ruben and Bellwald 2003.

77 Rosen 2007.

78 Lavento, Silvonen, and Kouki 2013.

raw materials for production and trade (copper, bitumen, incense, and spices).[79] While the latter does not necessarily fall within the exact study area, it is nevertheless important for understanding the overall metabolic strategies of the Nabataeans on a larger scale.

Impact entails the very particular and, at first glance, disadvantageous natural landscape settings of the Petra region, which affected spatial strategies greatly.[80] For example, the lack of water in the region called for technological and infrastructural advances that, in effect, ensured a permanent living environment.[81] Also, certain geological and topographical features (e.g. disadvantageous volcanic formations, in combination with steep slopes, see above) impacted settlement choices or means of communication significantly.[82] Finally, natural landscape factors greatly affected the economic system as well, and determined the adaptation of an agricultural and/or pastoral system.[83]

2.2.2 *Material Culture*

All types of archaeological evidence within the study area, i.e. military, religious, funerary and commemorative structures, exploitation/industrial sites, settlements, and communication infrastructures, as well as archaeologically unspecified structures and features with their particular subcategories make up the *material culture*. All types of archaeological evidence are closely intertwined with the natural and cultural spheres, and express human adaptations to both spheres within the archaeological record.

2.2.3 *Cultural Sphere*

Culture encompasses the aspect of (semi-)nomadism and a sedentary lifestyle, as well as the mixture of oriental and more Graeco-Roman cultural traditions, which is vital for understanding Nabataean society.[84] Nabataean culture was significantly defined by these two contrasting societal structures and can be observed in the political, economic, military, and administrative organization and the kingdom's religious beliefs, as well as Nabataean funerary customs.[85]

Program describes the endeavors of a Nabataean elite to shift from a fully nomadic lifestyle organized by tribal laws and regulations, into a state-like, sedentary entity with a ruling monarch. While this shift might be explained with the growing political and economic power of the Nabataeans, core tribal elements of societal organization were nevertheless maintained.[86]

79 Schmid 2001.
80 Kennedy 2016a.
81 Ortloff 2014.
82 Kennedy 2016a.
83 Lavento, Silvonen, and Kouki 2013; Rosen 2007.
84 Schmid 2001.
85 Schmid 2001.
86 Kennedy 2016a; Nehmé 2013; Schmid 2001.

Communication may entail (legal) regulations of water distribution, division of land-ownership, or the interaction between the semi-nomadic and sedentary populations of Petra and its hinterland in general.

Representation can most prominently be exemplified by Nabataean funerary customs. The famous façade decorations of Nabataean tomb complexes in Petra took over architectural and spatial designs from both oriental as well as typical Graeco-Roman luxury architecture.[87] These tomb complexes however, were exclusive spaces and were reserved only for a specific family or clan. The persisting tribal structure of Nabataean society is, thus, monumentalized in prominent (sedentary) funerary architecture. In contrast however, the adaptation to disadvantageous natural settings in the form of more mobile architecture (e.g. tent-like installations) in Petra's immediate environment, can be argued to be an expression of the more semi-nomadic aspect of Nabataean society.[88]

2.2.4 Conclusions

As mentioned above, the social-ecology model helps to organize the archaeological and environmental data available for both the natural and cultural sphere. Furthermore, however, the Petra project is a good example of the adaptation of the model. It was shown that the very specific natural environment of the Petra region was a major factor in both determining Nabataean spatial organization, as well as shaping the semi-nomadic and sedentary side of Nabataean culture. For example, although the impact of the extreme topographical conditions of the Petra area first seem disadvantageous for extensive regional control, the Nabataeans managed to use this as an advantage by placing watch posts at selected highpoints and even exploiting untouched nature, thus, falling back on more nomadic traditions. On the other hand, however, the successful and technologically innovative water management system enabled the permanent and sedentary colonization of the city of Petra itself. This constant metabolic interaction between the cultural and natural sphere, as proposed by Fischer-Kowalski, may in fact be a valid explanatory model for the advancement of Nabataean society as a whole. However, considering the overall immense effort put into building the most important central place of the Nabataeans, we still do not fully understand why, precisely, the 'marginal' location of Petra was chosen. In order to provide a fitting explanation, we probably have to take other elements into consideration as well.

87 Schmid 2009; Schmid 2007.

88 Kennedy 2016a.

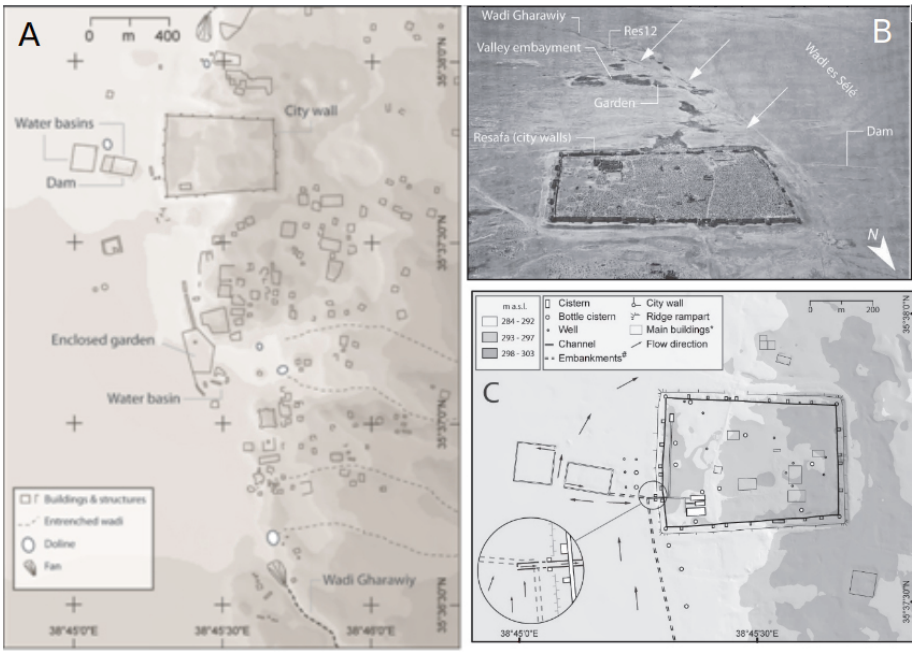

Fig. 5 A: Map of the archaeological finds, basic hydrography and topography of Resafa. B: Edited aerial picture of Resafa and surrounding; the arrows indicate the location of the assumed embankment (copy from Poidebard SJ) C: Detail sketch of the floodwater harvesting system of Resafa. The dashed line indicates the assumed embankments in the northern part. Note that the number of cisterns and wells intra muros is not correct. However we lacked information on the location of some of the structures.

2.3 Resafa-Sergiupolis – Rusafat Hisham /Syria

Resafa, in Northern Syria, lies in the semiarid steppe zone approximately 25 km south of the Euphrates (Fig. 5). Despite difficult environmental conditions, a settlement was founded here and later enlarged several times: built at the site of a former Roman castrum of the Eastern Limes, a pilgrimage city developed in Late Antiquity and a caliphal residence in the early Islamic period. This is testified by archaeological remains, proving a continuous settlement from the middle of the 1st century CE, until its abandonment in the last third of the 13th century CE.[89] To allow the survival of the settlement, the site had to be 'customized' with substantial effort to cover the needs of its inhabitants in the respective stages. Thus, several adaptation processes to cope with the natural conditions are clearly visible in the archaeological record.

89 C.f. Sack, Gussone, and Mollenhauer 2013.

One of the main research topics of the so-called 'Resafa Project' is the analysis of urban development.[90] This colonization of a marginal habitat and its determining factors are the focus of the research.[91] The socio-ecological interaction model of Fischer-Kowalski is discussed here in order to evaluate whether its application can be made productive for the understanding of the site.[92]

2.3.1 *Nature*

The environmental conditions of Resafa were unfavorable for the foundation of a large city. Integral parts of the natural resources of Resafa include the parent bedrock composed of gypsum and clay, which was exploited for the built environment.[93] The settlement is located on a plateau-like land surface at the edge of the Wadi es Sélé (Fig. 6). Perennial water sources providing year-round freshwater are lacking, with only brackish groundwater, unsuitable for drinking, accessible through wells.[94] Furthermore, the site is situated in a semiarid climate zone where rainfall occurs mainly in the cold winter months (October – March), while the summers are hot and dry, with no rainfall at all. The average annual precipitation is about 150 mm, with a minimum of 100 mm, which on the gypsum plateaus, allows rain-fed agriculture only in years with an above-average amount of rainfall.[95] In contrast, the alluvial plain of the Wadi es Sédé is periodically flown through by runoff water originating from the headwater areas in the southward located Jabal Abu Rujmayn and Jabal Bishri.[96] As a consequence, water harvesting measures in the alluvial plain allowed a reliable yearly harvest from irrigation agriculture.[97]

2.3.2 *Labor*

Regarding the settlement of Resafa, the category *labor* was realized in the efforts made to build the urban fabric and the infrastructure system that served the city and its inhabitants. To provide drinking water for the inhabitants and visitors of the city, the seasonal runoff was collected and stored.[98] This process of exploitation of the natural resources for building material, the collection of the seasonal runoff with several water harvesting methods, and the related sophisticated water supply system, represent the relation between the *natural condition* and the *material culture* of Resafa.

90 Sack, Gussone, and Kurapkat 2014; c.f. Sack and Gussone 2015.
91 Bebermeier et al. 2016.
92 Fischer-Kowalski 1998.
93 Bessac, Abdul Massih, and Valat 1997.
94 Wolfart 1966, 35; Wirth 1971, 442.
95 Wolfart 1966, 28; Wirth 1971, 88–93; current statistic: Berking, Beckers, and Schütt 2010, 819–820.
96 Beckers and Schütt 2013.
97 Berking, Beckers, and Schütt 2010.
98 Brinker 1991, 135–136; Garbrecht 1991, 239–241; Beckers, Berking, and Schütt 2012.

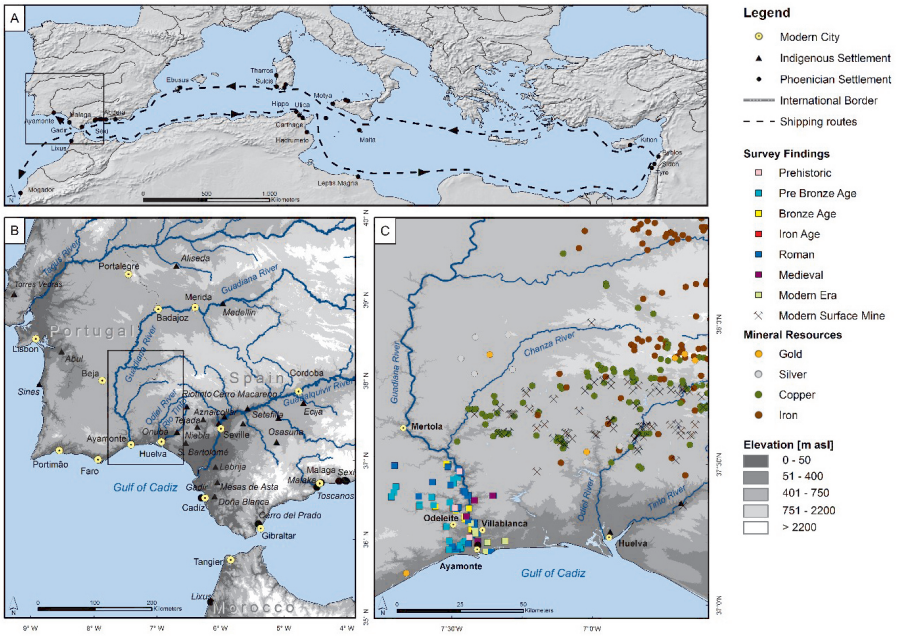

Fig. 6 Supraregional distribution of Phoenician settlements in the Mediterranean. A: Phoenician settlements and trading routes of the Mediterranean; B: Phoenician and indigenous settlements of Southwest Iberia; and C: locations of archaeological survey findings and mineral resources in the wider area of the two prehistoric settlements Ayamonte and Onuba.

2.3.3 *Metabolism*

If we understand *metabolism* as the basic relationship between the unconscious use of a certain site and its resources, we can describe this process for Resafa; for example, the everyday consumption of water and food, or the transport of goods from other places to Resafa using tracks, which caused beaten tracks or hollow ways that are visible in the surroundings. This process could also be seen as the direct or causal interrelationship of natural resources of a specific site, e.g. the gypsum bedrock or the clay and the material culture that is produced, such as the buildings that were erected from the material quarried here. However, if supply from outwards was brought to Resafa, we have to take into account the material flows and their balance on a larger scale – in respect to the socio-ecological, as well as the cultural and economic.[99]

99 Gussone and Sack 2013.

2.3.4 Event/impact

The intervention into the environment of Resafa changed the natural condition to a certain degree, thus, creating a significant *impact* on its *material culture.* A geo-archaeological investigation of the water harvesting system at Resafa[100] provides data on the amount and the sources of water, its collection, and its storing measures, as well as an analysis of the natural preconditions for, the functioning of, and the reliability of the water harvesting system. It emphasizes the 'relative reliability' of the system, which even in dry periods allowed the city-cisterns to be filled at least once every 13 to 14 months, providing drinking water for the inhabitants of the town.[101]

It has to be stated that the success of these ventures – *labor* and appropriate reactions to the challenges of a site, namely the unfavorable *natural conditions* and their *impact* – to a great extent depend on a society with highly developed organizational skills and technical specialization. It seems desirable that this inevitable precondition would be reflected more clearly in this model (as actually generalized, presented in Fig. 2). The same is true for the interaction of antagonistic stakeholders, both on an intra- and intersocietal level.

2.3.5 Material culture/agency

The intermediate position of the *material culture* of Resafa between the *impact* of its *natural resources* and the influences of the *cultural sphere* is clearly visible. During a research history of approximately 100 years, a large amount of archaeological data has been collected at Resafa. There is a wide range of artifacts, ranging from monumental architectural remains like the impressive city wall, five large churches, and the caliphal residence in the surroundings, up to pottery sherds and small finds.[102] The relationship between the preserved monuments and the available natural resources is obvious as, "the city is rising above its own building material",[103] which is recognizable from several quarries and the use of the specific gypsum stone for the churches[104] and the city wall,[105] along with the use of mudbricks for the palaces of the caliphal residence.[106] The *natural resources* of the site were used in both cases, but the changing preferences for the one (gypsum bedrock) or the other (mudbricks) through time are probably explained by varying strategies of usage and changing orientations to different *cultural* backgrounds. The impact of the *cultural sphere* upon the *material culture* of Resafa can be deduced from

100 Beckers and Schütt 2013; Beckers, Berking, and Schütt 2012; Berking, Beckers, and Schütt 2010.
101 Beckers and Schütt 2013; Beckers, Berking, and Schütt 2012.
102 Sack, Gussone, and Mollenhauer 2013 with further literature.
103 Schiller 1977.
104 Brands 2002.
105 Karnapp 1976.
106 Konrad 2016.

the rich archaeological record, which shows a great variety of influences and modes of receptions throughout its history.[107]

Also visible in the *material culture* are several phases of enlargement of the settlement, as well as modifications of the water harvesting methods towards an elaborate supply system,[108] which corresponds first to the political will to install a large city in this place and second to the ability to react to the challenges of a disadvantageous environment. Thus, the growing size of the cisterns and the development of a more sophisticated water supply system seem to be an indication of a successful adaptation to the requirements of the *natural condition*.

Using the socio-ecological model as a working tool, the question arises of how to evaluate a balance between the different parameters of the model, e.g. which amount of building material and what workforce (and how much supply for the workforce) were necessary to produce the constructions, whose remains allow the calculation of their former extent.

2.3.6 Cultural sphere

The area in which Resafa was founded, as a military station, was perceived at that time as a 'Barbarian plain', a remote place at the eastern border of the Roman empire, situated in a conflict area between Rome and the Eastern empires, where political and military considerations were relevant issues.[109] In the Byzantine/Sasanian era, the political and military sphere continued to be dominant, which is reflected by imperial patronage of construction activities and several military campaigns in Resafa's surroundings. In addition to this, however, the religious sphere gained greater significance when Resafa also became an important Christian pilgrimage city, due to the veneration of S. Sergios.[110] Artistic and architectonic discourses are recognizable in the *material culture*. In the early Islamic period, the place still functioned as a place of veneration, whereas the military aspect was less important. In contrast, aspects of political representation became more pronounced due to the city's function as the caliphal residence.[111] Later on, in the 12th and 13th centuries, Resafa flourished as a commercial center with production facilities on a smaller scale,[112] before it was abandoned in the aftermath of the Mongolic invasion, when the Euphrates became the border between the Mamluk and the Ilkhanid empires.[113]

The existence of Resafa spans a period of approximately 1200 years, with a complex historical, intellectual, and *cultural background* that is partly comprehensible through

107 Gussone and Sack 2013.
108 Brinker 1991; Westphalen and Peter 2004.
109 Fowden 1999.
110 Sack 2014.
111 Sack, Becker, et al. 2004; Gussone 2016.
112 Gussone and Müller-Wiener 2012.
113 Sack 1996.

a broad base of data from written sources.[114] In contrast to the comparatively stable environmental conditions, these processes are very dynamic.

2.3.7 Program

The *program* that was to be mastered at Resafa was actually four cultural societal endeavors that were developed successively: first, the function of the settlement as a fortified station on the Eastern Limes; second, the pilgrimage city; third, the caliphal residence; and, finally, a minor commercial and production center. These four different functions entail strategic, urbanistic, and architectural considerations and concepts. The transmission of technological knowledge, e.g. the implementation of fortification guidelines or the installation of the water supply infrastructure, is an important dimension of these strategies.

2.3.8 Communication

Equivalent to *metabolism* in the *natural sphere*, *communication* is understood as the direct, uncontrolled relation between the cultural sphere and material culture, reflected in the techniques and typo-morphological repertoire of traditional craftsmanship. Thus, the city wall of Resafa shows a significant variation in the execution of the masonry and construction details, indicating the activity of different workgroups.[115]

2.3.9 Representation

There is a certain vagueness in this category, as this aspect of *representation* seems to be similar to the process of 'unintentional interaction' of the category of *communication*. Whereas communication hints, e.g., at 'unconscious' cultural techniques such as traditional craftsmanship, the category *representation* corresponds to *material culture* as a source for general *cultural* concepts of a society.

The *material culture* of an archaeological site is always informed by its *cultural background*, which is also reflected in the respective *material culture*. Regarding the case of Resafa, for example, the churches represent the religious as well as the architectural discourses of their period. The design and furnishings refer to liturgical procedures,[116] their decoration signify the activity of different workgroups of varying (*cultural*) provenance.[117] Another example is pottery evidence that comprises types that are clearly related to Iraqi traditions of pottery production, thus, indicating processes of trans-

114 Late antiquity: Fowden 1999; Brands 2002. Early Islamic: Kellner-Heinkele 1996; Müller-Wiener 2016b.
115 Hof 2010.
116 Schuhmann 2016.
117 Brands 2002.

regional and, at the same time, intercultural exchange during the late Umayyad period.[118]

2.3.10 Conclusions

The impulse to settle in Resafa came from the *cultural sphere*: strategic considerations led to the colonization of a site that would not have been chosen otherwise, due to its unfavorable *natural condition*. It is obvious that the foundation of Resafa, its phases of growth, as well as its end have been steered by outside political powers (*cultural sphere*), and was independent from advantages or disadvantages of the *natural condition* of the site.

The *natural conditions* of Resafa and its surroundings were gradually altered into a cultural landscape – for example, the skillful exploitation of water harvesting (*labor*), or by sedimentary processes (*impact*) – but the basic conditions remained relatively stable in the long term. This refers to the topographic position, the availability of building material, and – most important of all – the semi-arid climate (rainfall variability) that was nearly the same for the last 1500 years.[119] To grasp these dynamics in the model of Fischer-Kowalski is problematic, as it does not differentiate between *nature* or *natural conditions* and *cultural landscape*, provided that *cultural landscape* is not considered as being a part of the *material culture.*[120]

To allow survival at this place, *labor* was invested to exploit the *natural resources* of the site. Based on the preconditions of the *natural resources* and the *cultural background* of the respective period, a rich *material culture* was created by actors with highly developed technological skills and a complex social organization. The application of the socio-ecological model of Fischer-Kowalski to the pilgrimage city of Resafa and the caliphal residence in its surroundings, leads to the conclusion that this societal organization and the dynamics of the colonization processes is only partly represented by this model.[121] A further modification of this model should be considered in order to represent the complex societal adaptation strategies used for the colonization of marginal habitats more adequately.

2.4 Ayamonte/Spain

The aim of this contribution is to explore whether the socio-ecological model of Fischer-Kowalski can be adapted to landscape archaeological research on a Phoenician settlement in the politically and economically margins of the Phoenician sphere of influence

118 Müller-Wiener 2016a.

119 Beckers and Schütt 2013; Beckers, Berking, and Schütt 2012.

120 Fischer-Kowalski 1998.

121 Fischer-Kowalski, Mayer, and Schaffartzik 2011.

(Fig. 6). The socio-ecological model of Fischer-Kowalski was originally proposed as a concept for integrative sociological research; it was adapted to present based geographical human-environment research by Weichhart & Wardenga.[122] However, the basic approach of the socio-ecological model in general relies on in-depth socio-scientific observations and data. The landscape archaeological research on the Phoenician settlement Ayamonte, in its current status, includes: (a) an initial archaeological survey of the Phoenician and Roman settlement of Ayamonte and some burial grounds in its vicinity[123] and (b) detailed geomorphological, sedimentological, and geophysical studies in the environs of Ayamonte.[124] As a consequence of the fragmentary archaeological knowledge on Phoenician settlement activities, this reflection on the applicability of the socio-economic model focuses on the natural sphere, the use of landscape, and its direct and indirect shaping by human impact, as defined by Schütt.[125]

Previous studies show that the Phoenicians colonists preferred specific locations for establishing their harbors. In Levantine Sidon and Tyre, the Phoenician homeland, islands or coastal promontories guaranteed protection from weather-driven events.[126] Phoenician settlements along the coast of the Gulf of Cadiz show properties very similar to those of their homeland. Generally, the most important Phoenician settlements are located close to estuaries and alluvial plains of major rivers.[127]

Prior to the discovery of the Phoenician settlement and necropolis in the modern town of Ayamonte in 2007, the Guadiana estuary was a *terra incognita* in terms of Phoenician settlement activity. Results of the archaeological excavation of the necropolis and the remains of the Phoenician settlement are manifold, but remain preliminary, due to missing current research activities.

2.4.1 Nature

The natural characteristic of the settlement site at the Guadiana estuary were of crucial importance for the Phoenicians. The topography of Ayamonte and its surroundings met the needs of the Phoenician traders: the isolated settlement-hill allowed a settlement secure from floods and invaders, with water-bearing coves that offered sheltered anchorage grounds that were renowned throughout the Mediterranean. Already known quarries in the hinterland, where ore-deposits were mined, were unequivocally of major relevance, expanding the Phoenician settlement network of intra-Mediterranean trade to the East (Fig. 6).

122 Fischer-Kowalski 1998; Wardenga and Weichhart 2006; Wardenga and Weichhart 2007.
123 E.g. Marzoli et al. 2014.
124 Klein et al. 2016.
125 Schütt 2006.
126 Marriner and Morhange 2006; Marriner, Morhange, Boudagher-Fadel, et al. 2005; Marriner, Morhange, and Doumet-Serhal 2006.
127 Aubet 2001.

2.4.2 *Labor*

During the Phoenician settlement phase, the major structures of the natural environment of Ayamonte were already set, as the post-glacial sea level rise had ended. Natural matter flows included (a) the discharge of the Guadiana River and its sediment load, with maximum amounts during the winter and spring,[128] and (b) a daily alteration of the high tide, pushing salty sea water into the Guadiana Estuary up to 50 km inland[129] and a mean tidal range of 2.0 m, causing the deposition of bars.[130] With the Phoenician settlement, increased human impact on the environment resulted in significant changes of the estuary and coastal landscape close to the Guadiana River mouth. Post-Phoenician examples include the erection of tidal mills, the construction of salines, and the development of numerous reservoir dams. Increased soil erosion in the hinterland of the Estuario de la Nao caused its siltation; as a consequence, the former anchorage site today is under agricultural use.[131]

The sediments in the vicinity of Ayamonte provide only few direct proofs of the 'material culture', as artefact findings are rarely in the sediments and generally are relocated. Rather, characters of the extracted artefacts in the sediments provide clear evidence of human impact. This includes increased concentrations of lead and other heavy metals identified in slope deposits, giving the indication of ore processing in the catchment and the accompanied waste production,[132] documenting a direct intervention in the balance and flow of matter. In contrast, increased deposition rates of detritals provide evidence of human impact on the factors controlling surface runoff and erosion (corresponding to the balance and flow of matter) and, thus, are understood as indirect influence.

2.4.3 *Metabolism*

Since ancient times, humans have made efforts necessary to maintain living conditions in the environs of the estuary. Access to waters rich in fish and the combination of a flat surface topography with strong summer insolation and evaporation, facilitates the production of salines and the subsequent export of transportable and durable fish products. The seafaring identity and the maritime know-how, complemented by the special topography, resulted in the establishment and usage of marine infrastructure. The situation is similar with the occurrence and management of mineral resources. The availability of

128 González et al. 2004; Camacho et al. 2014.
129 Fletcher 2005.
130 Borrego, Morales, and Pendon 1995; Morales 1997.
131 Klein et al. 2016.
132 Thorsten Klein (and others). "Human-Environment Interactions at the Phoenician Site of Ayamonte (Huelva/Spain): Insights from Terrestrial Borehole Data". *Zeitschrift für Geomorphologie* (submitted) and Torsten Klein. "Geoarchaeological Case Studies at the Lower Guadiana Estuary:Paleogeographic Development and Human-Environment Interactions at the Phoenician Site of Ayamonte (SW-Andalusia/Spain)". Dissertation FU Berlin 2018 (https://refubium.fu-berlin.de/bitstream/handle/fub188/23488/Dissertation_Klein.pdf?sequence=4&isAllowed=y; last visited 09/06/2020).

metallic ores and water supported the establishment of metallurgy workshops and the processing and export of high-quality goods.

2.4.4 Impact

Human actions were strongly affected by natural processes and unintentional human impacts. A relatively stable sea-level from around 6000 years BP and increasing erosion rates in the Guadiana drainage basin, resulted in increased sediment load and increased siltation of alluvial loam, reducing the navigable open lagoonal waterbodies and number of favorable anchorages.[133] Natural processes, in particular, were of relevance for the population when they faced extreme events; a particularly dramatic moment resulted from a tsunami, which generated the Great Lisbon earthquake on November 1, 1755.[134] For the environs of Ayamonte, about 1000 deaths related to this tsunami are presumed.[135]

2.4.5 Material Culture

The archaeological knowledge about the Phoenician settlement(s) in Ayamonte and its environs are exclusively based on archaeological surveys, while extensive excavations had not been conducted until recently. Archaeological evidence for the Phoenician period in the environs of Ayamonte comprises fragments of Phoenician pottery, remains of metallurgic furnaces, remains of Phoenician houses, and remains of a metallurgic workshop. Recently discovered materials include fragments of a Phoenician vessel and amphorae. Excavations in nearby Phoenician tombs have revealed numerous mortal remains, with precious grave goods and traces of an *ustrinum*.[136]

2.4.6 Culture

The local cultural interpretation regarding the Phoenician population in the environs of Ayamonte, is primarily obtained by the composition and presentation of burial equipment.[137] The Phoenician community at the Guadiana Estuary buried the deceased essentially with the same ritual that they practiced in the Levantine motherland.[138] However, some peculiarities within several tombs occurred, indicating different traditions, chronologies, and/or societal affiliations. An intermixture between the Phoenician and local population in Ayamonte and other necropolises of the Iberian Peninsula have not been observed until now.[139]

133 Klein et al. 2016.
134 Andrade 1992; Gupta and Gahalaut 2013; Klein et al. 2016; Lario et al. 2011.
135 Álvarez 2007.
136 Teyssandier and Marzoli 2014.
137 Teyssandier and Marzoli 2014.
138 Teyssandier and Marzoli 2014.
139 Teyssandier and Marzoli 2014.

2.4.7 Program

The cultural program regarding the Phoenician population in the environs of Ayamonte producing artifacts or spatial structures can be – due to the current fragmentary character of the archaeological knowledge – described best by the burial rites. Habits and practices were launched with the immigration of the Phoenicians, which remodeled or replaced habits and practices of the local, original inhabitants.[140] Achieving cultural continuity by traditional burial rite were, especially for early cultures, of central importance for cultural development.[141] Traditional elements maintained the awareness of a 'Phoenician identity', united in the form of a community within a Mediterranean diaspora.[142] Further archaeological studies have to prove if preliminary observations of a cultural connection to Carthage and Sardinia can be confirmed.[143]

2.4.8 Communication

Disentangling modes of communication of the Phoenicians settling in the environs of Ayamonte is at the present hampered, due to the complete lack of written sources.

2.4.9 Representation

The 'Phoenician architecture' within Ayamonte and its surroundings is badly preserved, and at the present provides only a rudimentary understanding and reconstruction of the structural functioning.

2.4.10 Conclusions

The archaeological research on the Phoenician settlement of Ayamonte is still in its initial stage, with only few archaeological surveys conducted.[144] The reconstruction of past environmental conditions and their trajectories clearly indicate human impact in the drainage basin. During the settlement phase, increased deposition rates of sediments and the increased heavy metal concentrations (metabolism) in the sediments point to settlement activities in the hinterland. They are indirect indicators, and document a changing environment (labor) coinciding to human settlement activities – and, thus, have been attributed to it. Direct indicators of human impact on the landscape, such as a constructed environment, have not yet been investigated. Sedimentological investigations also provide clear evidence on the 1755 tsunami triggered by the Lisbon

140 Teyssandier and Marzoli 2014.
141 Teyssandier and Marzoli 2014.
142 Marzoli et al. 2014.
143 Teyssandier and Marzoli 2014.
144 Teyssandier and Marzoli 2014; Cabaco Encinas 2011; Pérez Macías, Cabaco Encinas, and García Teyssandier 2012; García Teyssandier and Cabaco Encinas 2009; Elisabet García Teyssandier. Memoria Preliminar de la Actividad Arqueológica de Urgencia en el Plan Parcial, Sector 12, ›Nuevo Parque‹ del Término Municipal de Ayamonte (unpublished).

earthquake (event/impact) at least. However, the short-term impact on livelihoods and the long-term impact on, e.g., settlement strategies can only be assumed. Some general investigations on adaption and mitigation strategies referring to the 1755 Lisbon earthquake were conducted, but predominantly focused on governmental aspects.[145] A compilation on the structural changes that occurred in Lisbon itself is presented by Pais.[146]

3 Insights

In the introduction to this paper, we raised the issue of differentiating between labor and metabolism, as defined by Fischer-Kowalski.[147] The point is made particularly clear by scenarios involving societies or groups who leave relatively few physical imprints in/on the environment, e.g. foragers or nomadic groups, as their socioeconomic and sociocultural strategies, i.e. programs, are often not designed to change nature, but rather to interact with it in a way which leaves few physical traces. The Petra case study highlights these aspects nicely. It was made clear that the particular environmental factors of the Petra region impacted the structural appropriation of Petra's environs significantly, therefore, influencing societal developments greatly as well. On the one hand, the unfavorable geological and topographical settings of the region allowed only limited movement through the landscape and the erection of structures of temporary use only. This may, therefore, reflect the persisting semi-nomadic aspect of Nabataean society. On the other hand, very specific natural landscape factors also offered good conditions for permanent structures and settlements that represent a more sedentary lifestyle in Petra's hinterland. Finally, the climax of the colonization of a marginal habitat with permanent structures lasted for a comparably short time, and within a wider cultural-political environment favorable to such massive efforts in order to dominate the unfavorable natural setting.

The dynamics that led to these efforts can clearly be localized within the cultural sphere, driven mostly, though not exclusively, by aspects of representation. The contribution of the Badia case study has also show how to gain an idea of the chain of action of the inhabitants of the Early Bronze Age region of Jawa and its hinterland, Northern Badia, based on the research carried out on architectural remains, archaeological surface finds, and geographical archives. Derived from the information gained from the artefacts, three different fields of labor 'activities' – the 'exploitation of mineral resources', 'usage of natural basalt stones', and 'implementation of water harvesting systems' – were

145 Mendes-Victor et al. 2008; Mullin 1992.
146 Pais 2009.
147 Fischer-Kowalski, Mayer, and Schaffartzik 2011.

distinguished. With the crop yield simulations of the irrigated agricultural terrace systems around Jawa, a first understanding about the energy potential of these systems and, thus, a first step towards quantifying the energetic metabolism for Early Bronze Age Jawa can be derived. The cultural processes that arise from the societal or individual endeavors of the inhabitants of ancient Jawa and its hinterland, form cultural programs that can be grouped into three major classes: resources program (excluding water), settling program, and water harvesting program.

In contrast, the case of Resafa shows that significant efforts were undertaken to customize the natural setting of the semi-arid Syrian desert-steppe to collect seasonal run off that allowed the existence of a large settlement in an unfavorable natural area. Nevertheless, a close interrelation between the natural resources and the material cultural of the site shows a clear dependency on both parameters.

A further result is that the reasons for interventions in an unfavorable setting, as well as the complex requirements to maintain the installations, can only be explained through inter-societal processes. It has been realized that the model does not consider these inter-societal processes adequately. However, these processes are vital for research on colonization that brings two or more societies into contact and results in regular interaction.

Here, the socio-ecological model provides a tool to calculate the requirements of interaction between the natural and cultural spheres, which both influence the material culture of archaeological sites. An opportunity of the model is its systemic approach, to see singular phenomena not as static, isolated relics, but as a part of an evolving, processual entity, whose components have to be balanced.

Despite the fact that the exploration of Ayamonte is still at its beginning, some interesting aspects, nevertheless, stand out. Here, the Phoenician settlers found a favorable environment that was, in some points, similar to their homeland. The major challenge, in terms of marginality, must have been the distance to their cultural base, no matter whether we consider this to have been rooted in Phoenicia or Carthage. The interaction between the natural and the cultural sphere seems to have been driven by the aim to exploit natural resources. This, in the long run, apparently led to a certain deterioration of the initially favorable setting, provoking the need for new settlement strategies. Hence, the socio-ecological interaction clearly plays an important role, but in order to be able to more explicitly comment on the applicability of the model discussed here, more data has to be collected.

All in all, the model offers a comprehensive framework for analyzing human interactions with nature, illustrating the dialectic processes arising from this interaction in a systematic way. From an archaeological perspective, however, its application is hampered by the fact that much data of explicit past interactions, which constitutes the main parameters of the model, are not available in the archaeological record. There-

fore, reconstructing causal relationships between the various elements of the model may appear very speculative and argumentative. One crucial point, in this regard, is the diachronic resolution and ordering of data obtained for both environmental conditions and changes, as well as events or processes of human impact. Another point concerns facets of societal communication and (symbolic) representation, which cannot be 'read' directly from material culture remains.

Thus, while a comprehensive reconstruction of past socio-ecological dynamics based on Fischer-Kowalski's[148] model has proven to be problematic, at best, it is still deemed fruitful to alter the analytical orientation of the model and its resolution. As a more abstract tool, the model can help to plot possible interactions and interrelations between different phenomena of the natural and cultural spheres and to identify specific data one may want to look for and identify in one's material: as illustrated in the case studies, the model can, in this sense, act as a heuristic devise.

148 Fischer-Kowalski 1998.

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