MASON HIERARCHIES: A LONG-RANGE AGENT MODEL OF POWER, CONFLICT, AND ENVIRONMENT IN INNER ASIA

Claudio Cioffi-Revilla, William Honeychurch, J. Daniel Rogers

Recent advances in computational social science, primarily through use of agent-based models (known as "multi-agent systems" in computer science), now permit the first simulations of large-scale complex adaptive social systems, including spatial dimensions, network-based organizational hierarchies, and culturally-grounded social institutions in changing natural environments. This paper presents the "Hierarchies" model of the Mason-Smithsonian Joint Project on Inner Asia (Cioffi-Revilla et al. 2007), which is a computational agent-based model developed with the MASON computational toolkit. We report three sets of computer-generated results indicating close similarity between real history and simulation runs produced by the Hierarchies model, specifically in terms of confederations of tribes[1] (i.e., *aimags* in Mongolian) and warfare through conquest, rebellion, and polity disintegration in the steppes of Inner Asia. These results are encouraging for developing more insightful models of long-range socio-natural dynamics that include politics based on real-world historical observation.

This chapter contains four sections. First, we provide an introduction with motivation and background on the Hierarchies model, with emphasis on research questions addressed by the model and earlier relevant literature. The second section describes the methodological procedure used for creating the model in terms of main developmental stages, from initial conceptualization (research questions and abstracting relevant features of Inner Asia) to technical computational stages (design and implementation) and simulation results. The third presents a set of results intended to demonstrate significant functional features and the model's empirical validity. Finally, the fourth section provides a discussion of the model, broader implications in terms of extant literature, and directions for future research.

Introduction

Why investigate social complexity using computer models?

Understanding long-range dynamics of societies and polities in their natural environments is an enduring and difficult interdisciplinary challenge in social science, a puzzle that cannot be solved without multi-disciplinary research (Lightfoot et al. 2009). This scientific challenge is conspicuous in the context of Inner Asia (Fig. 1) and Eurasia, a quasi-continental region of the world considered to be

[1] The term "tribe" is used in this chapter to indicate a polity based on inequality and lineage-corporate governance institutions.

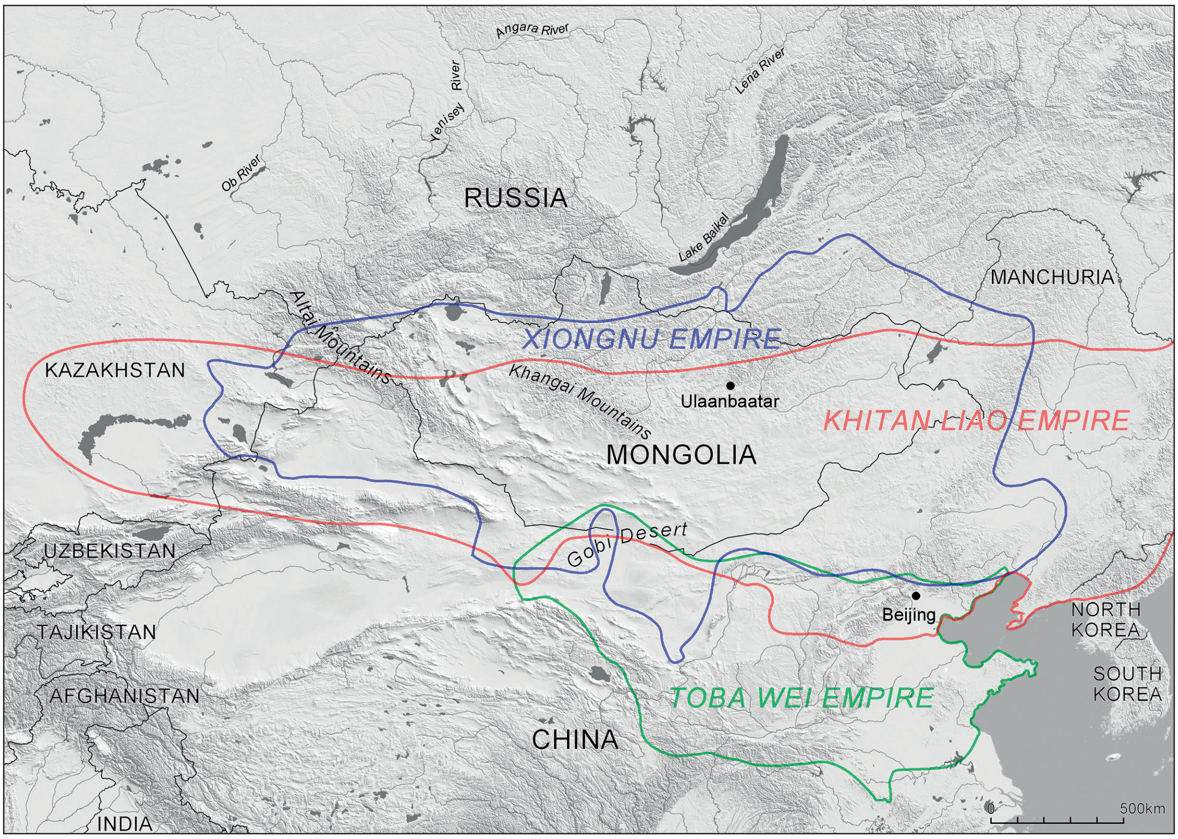

Fig. 1. Map of Inner Asia. The dark blue circled area represents the approximate territorial extent of the Hünnü (Xiongnu in Mandarin) polity at its maximal size, ca. 150 BCE, considered the first state-level society in Inner Asia. Numerous subsequent societies followed (Toba Wei Empire – green circled; Khitan Empire – red circled) (Cioffi-Revilla et al. 2011; Rogers 2012). MASON Hierarchies is a spatial agent-based model of the rise and fall of polities within the region shown here (source: J. Daniel Rogers, Smithsonian National Museum of Natural History, Washington, DC).

the heartland of the Old World, a "bridge" linking Asia and Europe across an expansive steppe land[2]. One methodological approach to investigating these complex systems is through spatial agent-based modeling and simulation, methods that are capable of representing natural and social dynamics within an integrated computational framework.

Modeling long-term sociopolitical change – how polities in the real world form, adapt, evolve, and change throughout history – remains an enduring challenge in social science for at least three reasons. First, the underlying causal processes involve networks of human actors endowed with intentionality and decisional capacity, not just material or physical causality. Second, the actors are situated in social and natural environments, spanning interdependent, multi-level phenomena that range from cognitive to ecological (Liu et al. 2007). Third, the main result of these complex processes, the ontology they produce from an aggregate social perspective, generates emergent systems of governance and other intangible entities – i.e., "social objects" or "constructs" in the form of institutions, norms, and the like, which are neither values of variables nor solutions to equations. Consequently, previous scientific efforts to solve this problem by traditional approaches

[2] Bemmann et al. 2009; Di Cosmo 1999; Fitzhugh et al. 2009; Honeychurch/Amartuvshin 2006; Rogers 2007; 2012.

alone – namely using classical mathematical or statistical approaches (e.g., game-theoretic or econometric models) – have fallen short, although such models have improved our understanding. For example, classical mathematical approaches are invaluable for understanding demographic dynamics (Tuma/Hannan 1984), social networks (Wasserman/Faust 1994), and conflict processes (Zagare/Kilgour 2000). Similarly, statistical models are essential for understanding spatial patterns (Ward/Gleditsch 2008), size distributions (Kleiber/Kotz 2003), and other key empirical features. However, neither mathematical nor statistical models alone are capable of modeling the life cycles of spatially-situated social entities – i.e., groups, organizations, and societies – as complex, adaptive, dynamical systems (Arrow et al. 2000) situated in a natural environment.

Using an object-oriented computational simulation approach to address these problems, we present an agent-based model where political hierarchies – a defining feature of many societies in the real world – emerge under a variety of conditions (Epstein 2006; Gilbert 2008). Hierarchical organization, a variant of "inequality" in complex social systems, is a set of ordered social relations that occurs in many forms: rulers and ruled, elite and commoners, leaders and followers, powerful and weak, rich and poor, skilled and unskilled labor, hegemons and subordinates, literate and illiterate. The emergence of hierarchical organization in social and socio-natural computational simulations[3] is also insightful for understanding institutions and governance (Lichbach 1996), as well as patterns of cooperation and conflict (Midlarsky 1999).

Relevant background literature

Related literature that is relevant to this study comes from several fields, including Inner Asian studies and spatial agent-based computational models of socio-natural dynamics. Numerous studies show that Inner Asia has a rich and long history, offering a valuable laboratory for understanding long-term social and political adaptations in the face of great challenges, including climate change (Sinor 1990). Traditional sinocentric theories about the rise of early nomadic confederations in Inner Asia (e.g., Barfield 2001; Di Cosmo 1999) postulate the Chinese state as the main causal driver of socio-political complexity in neighboring regions. However, archaeological findings have brought greater time and geographical depth to the scientific investigation of political processes on the Inner Asian steppe, suggesting alternative non-sinocentric mechanisms for understanding the emergence of regional political integration[4]. A powerful Chinese polity to the south did provide one of several stimuli for political development – the emergent formation, evolution, and decline – in the steppe polities to the north, but so did other processes endogenous and exogenous to the polities themselves.

Spatial agent-based models that investigate territorial competition, politico-military change, and historical dynamics on empirically realistic (i.e., not abstract or notional) geographic space are still few, given the interdisciplinary and technical challenges. An et al. (2005), Kohler and van der Leeuw (2007), Liu et al. (2007), and Walker and Janssen (2002) demonstrate significant advances in modeling socio-environmental systems. However, historically calibrated politico-military dynamics are not explicitly represented. Agent-based models by de Marchi (2005), Laver (2005), and Laver and Sergenti (2012), among others, are about political coalition dynamics, but not about Asia or other spatially situated polities. Several spatial agent-based models have addressed research questions about politico-military dynamics, starting with the pioneering

[3] Kohler/van der Leeuw 2007; Liu et al. 2007; Kuznar 2006; Laver 2005; Laver/Sergenti 2012.

[4] Cioffi-Revilla et al. 2011; Honeychurch/Amartuvshin 2006; Sneath 2006; Rogers 2007; Kradin 2011.

model of Bremer and Mihalka (1977)[5], but by using abstract spaces that do not claim to provide empirical geographic or country-specific references, to Asia or elsewhere. Lowe's (1985) earlier dynamical model on the rise and fall of Maya polities had a concrete historical context, but lacked spatial representation and pre-dates the object-orientation to computational modeling, as do other earlier models by Benson (1963), Natalicchi (1994), Hughes and Hillebrand (2006), and others. Kuznar and Sedlmeyer's (2005) model of conflict and environment in Darfur, Sudan, does have explicit geographic space, but is focused on pastoralist conflicts, not territorial competition on the scale of the rise and fall of polities from a long-range perspective.

The Canonical Theory of sociopolitical complexity[6] explains the emergence, evolution, and decline of complex polities in Inner Asia (as elsewhere) as resulting from a long-term cumulative process of collective action responses to social and/or environmental changes. Figure 2 illustrates the main causal mechanism by a process that unfolds along the top tree branch: Given a societal group in a given state **G** of social complexity (initially simple), a threat or opportunity may or may not occur (situational change **C**). If one does, then the society may or may not recognize a need for collective action (events **N** and **U**). If it does, then collective action may succeed (**S**) or fail. When it succeeds, social complexity increases from the consequences of success (outcome **A** in green). (Conversely, failures in responding to changes produce loss of social complexity; i.e., outcomes **X**.) Here we use the Canonical Theory to endogenize the socio-environmental dynamics of Inner Asian polities. This positive, non-sinocentric theory, formalized by the spatial agent-based model described below, emphasizes differential political sustainability and susceptibility to collapse among multiple steppe confederations composed of tethered mobile pastoral groups (tribes) involved in long-distance networks of contacts and exchange. Our approach provides a different explanation of the rise and fall of polities among northern pastoral nomads – by proposing a new, positive theory formalized by a computational agent-based model.

Methodology of Computational Modeling

In this section we describe the method with specific procedures used to develop the Hierarchies model in terms of main conceptual and computational stages, starting from core research questions, which are followed by the focal system of reference, model design or specification, implementation, verification, validation, and analysis leading to the generation of illustrative simulation results. We follow current criteria for verification and validation emerging in the field of Computational Social Science[7], as detailed below. The main purpose of this section is to provide a descriptive, functional-operational explanation of the computational model to assist understanding and replication. MASON Hierarchies was initially developed over a period of two years, from formulation of the first research questions to obtaining the first results. The interdisciplinary team of social scientists, computer scientists, and environmental scientists included approximately ten collaborators (faculty and graduate students) led by the co-authors.

5 See also Bearce/Fisher 2002; Min 2002; Turchin 2003; Cederman 2003; Majeski 2004; Gavrilets et al. 2010.

6 Cioffi-Revilla 2005; 2012; Rogers/Cioffi-Revilla 2009.

7 Cioffi-Revilla 2002; 2010; 2014; Macal 2005; Gilbert/Troitzsch 2005; Sargent 2004; Ozik et al. 2008.

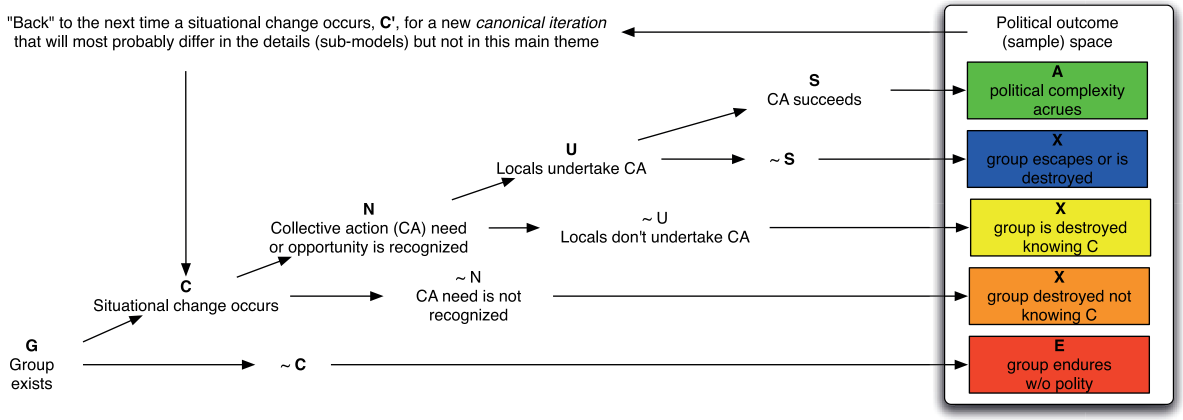

Fig. 2. Tree diagram representing the "fast" branching process of the Canonical Theory of sociopolitical complexity. During this relatively short-term, high-frequency process, actors produce different path-dependent outcomes for a society challenged by situational changes (threats or opportunities), depending on successes or failures in undertaking collective action (CA). Outcomes subsequently accrue to the structure and knowledge of society, during a relatively "slow" process of institutional development or decay (contingent on fast processes), resulting in long-term political evolution by canonical variations. Adapted from Cioffi-Revilla 2005.

Main research questions

Hierarchies is a spatial agent-based computational model designed to investigate a broad class of research questions, including simulated replication of observed historical patterns, testing theoretical hypotheses, exploration, and – something very appealing but normally unavailable in most areas of social science – conducting controlled experiments[8]. The main research questions investigated by the Hierarchies model are:

1. How did historical Inner Asian political coalitions emerge from among unequal potential allies?
2. Specifically, how did confederations (hierarchical polities) – the prevailing organizational form of polity in Inner Asia, including the Mongol Empire – form on repeated occasions?
3. Can historical polities and warfare dynamics that are known with increasing accuracy be approximated by computational models that provide new explanations of human and social dynamics based on the Canonical Theory?

Answers to these and related questions would provide new insights and scientific understanding of long-term change and adaptation in Inner Asia, with implications for other socio-natural regions. Interestingly, these research questions are typically intractable using traditional mathematical or statistical methods (i.e., dynamical systems, game-theoretic models, econometric models, or other equation-based models). By contrast, Hierarchies is a computational object-oriented model, so all the necessary variables, states, and dynamics (i.e., the *explanans*) are "encapsulated" within social and natural entities that comprise the "target" or "focal" system (*explanandum*).

[8] Axelrod 1997; Bainbridge 2007; Cioffi-Revilla 2002; Epstein 2006; Gilbert 1999.

Focal system

Given the above research questions, the next specification consists of the focal spatio-temporal system being modeled. In this case the focal or referent system of primary interest consists of the geographic region of Inner Asia beginning in the first millennium BCE, as shown in Figure 1. It is a relatively large socio-environmental region consisting of the territories of modern-day Mongolia, northern China, eastern Manchuria, southern Siberia, and eastern Kazakhstan, demarcated approximately by the following coordinates: 35° to 55° N and 50° to 120° E. Deserts, mountains, forests, and vast grassland steppes comprise the diverse ecosystems of this region, spanning approximately 30 million km^2 [9]. The climate within this region is driven by weather from three neighboring climate systems: Siberia, the Indian Ocean, and the Pacific Ocean.

The human population within the broader focal system of Inner Asia delineated in Figure 1 consisted of approximately 7.5 million inhabitants at any given time (ca. 500 BCE to ca. 1300 CE), distributed as follows: Mongolia 2 million (by ca. 1200 CE), northeastern China 0.5 million (Manchuria), northern China 3 million (including Beijing), northwestern China 0.5 million (Xinjiang), eastern Kazakhstan 1.5 million, and southern Siberia 0.5 million[10].

Within the broader system of Inner Asia, Hierarchies represents a smaller geographic area, but one that is still sufficiently large to generate confederations with significant territorial scope and size distributions.

MODEL DESIGN

Overall design

Hierarchies' overall design consists of (1) a foundation provided by the MASON HouseholdsWorld model of Inner Asian pastoralists, including weather events (Cioffi-Revilla et al. 2010; Rogers et al. 2011); and (2) a system of politico-military dynamics generated by decision-making on the part of autonomous tribal agents in the face of challenges (threats and opportunities), based on the Canonical Theory. Although autonomous, the tribal agents belong to the same regional cultural sphere (i.e., pastoralists of the steppes of Inner Asia), so tribes follow similar decision-making rules, as detailed below. The size of the territory represented is intentionally small, albeit realistic, to allow for detailed investigation of coalition dynamics and related historical patterns.

Weather events drive biomass distribution in the landscape (main environmental component), just as in the earlier HouseholdsWorld model. In turn, biomass distribution drives herd demographics and animal behavior, which – in turn – drive human household behaviors. Each household represents approximately six to eight persons. Households aggregate by clans that form tribes *(aimags)* which, in turn, aggregate forming hierarchical coalitions (alliance confederations). Camps are mobile and consist of households from only one clan.

[9] The east-west width of the region in Fig. 1 at 35° N is approximately 10,000 km or 6,200 miles.

[10] We are grateful to Sarah Flores for assistance in providing these estimates (Rogers et al. 2011).

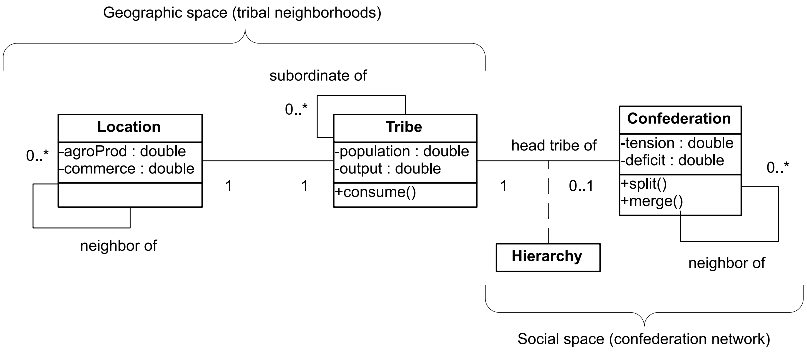

Fig. 3. Design overview and main architecture of the MASON Hierarchies model. Social structure and emergent organization include (from left to right) tribes situated at geographic locations in a natural geophysical landscape, and emergent hierarchy resulting in tribal confederations. Tribes are composed of households (not shown here).

Each household has an amount of wealth used as proxy for food. A hierarchy or alliance consists of groups of clans or tribes. One clan will be the top clan with others subservient to it. A subservient clan, in turn, may have other subservient clans. A lower tribe pays tribute in the form of wealth to its superiors, who pay wealth to their superiors, and so on. The strength of a confederation as a whole reflects the overall health of its constituent households. Each household can belong to only one tribe.

From the most general, high-level ontological perspective, the MASON Hierarchies model is constituted by three classes of entities. These classes are based on Herbert A. Simon's (1996) initial theoretical paradigm on social complexity and adaptation, as well as more recent formal development through the Canonical Theory[11]:

1. Natural landscape: Biophysical systems, including topography, water, ground cover (biomass distribution), animal herds, and weather. This first class consists exclusively of entities belonging to Nature without humans or their artifacts.
2. Humans and kin-based groups: Households, with clan membership, consisting of individuals with values and social norms that enable decisions that, in turn, produce behavior. This second class contains no organizations beyond households.
3. Artificial systems: Camps, tribes, and federations as emergent phenomena generated by the complex adaptive system consisting of natural and human components in interaction with one another. This third class comprises the built environment, be it social (organizations such as tribes, federations, polities) or physical (only camps and neighboring boundaries, as Hierarchies lacks any other kind of built environment).

Figure 3 provides an overview and main architecture of the Hierarchies model, showing the principal entities (classes of objects) and relations (associations among classes) using a class diagram in Universal Modeling Language (UML). The basic components of the Hierarchies model are nomadic tribes, indexed as $\theta \in \Theta$, which are composed of households. Each tribe occupies a specific spatial location ("site") in geographic space, with topology being either a regular lattice (e.g., rectangular or hexagonal) or based on a GIS (Geographic Information System database) vector shape file. Attributes of a tribe θ include the number of able-bodied men (M_θ) as basic military capability and a scalar value of economic output (E_θ).

11 Cioffi-Revilla 2005; 2012; Rogers/Cioffi-Revilla 2009.

Tribes and tribal capabilities

A set of nomadic tribes $\{\theta\}$ forms a hierarchical confederation $h \in H$. Thus, each tribe $\theta \in h$ has a set of subordinate tribes, denoted by $\text{sub}_h(\theta)$, as well as a superior set of tribes, denoted as $\text{sup}_h(\theta)$. For the leading tribe of a given confederation, denoted by root_h, the operator $\text{sup}_h(\text{root}_h)$ returns ø (null). Similarly, for tribes at the lowest levels of a confederation (leaf tribes), $\text{sub}_h(\theta) =$ null. Peers having equal rank have the same number of superior levels above them.

A tribal leader can effectively manage only up to τ subordinate tribes. Let $|A|$ denote the "cardinality" of some set A, or number of elements in A. When $|\text{sub}_h(\theta)| > \tau$, the effectiveness of tribe θ's military capability decreases. This assumption – consistent with the concept of a minimal winning coalition (MWC) in the sense of Riker (1962) – is formalized by the following recursive equation describing the military capability $\text{mil}_h(\theta)$ of tribe θ and its subordinates:

$$\text{mil}_h(\theta) = M_\theta + \left\{ \frac{1}{1 + I_{|\text{sub}_h(\theta)|>\tau} \left[|\text{sub}_h(\theta)| - \tau \right]} \right\} \sum_{i \in \text{sub}_h(\theta)} \text{mil}_h(i).$$

Wealth flows as tribute from subordinate to superior tribes, losing a fixed proportion a of value when crossing each hierarchical level. The amount of wealth that a tribe can pass to its superior is given by a similar recursive equation:

$$\text{econ}_h(\theta) = E_\theta + \alpha \sum_{i \in \text{sub}_h(\theta)} \text{econ}_h(i).$$

After circulating up as tribute, wealth is redistributed down from the top tribes to satisfy demands by subordinates (coalition side-payments, in the sense of Riker). For any tribe θ, its demand $\text{dem}_h(\theta)$ for wealth payments is proportional to its military contribution weighted by a factor β, so $\text{dem}_h(\theta) = \beta\, \text{mil}_h(\theta)$. Therefore, the amount of redistributed wealth that a subordinate (i.e., non-leader) tribe θ can expect (red_h) within a given hierarchy h and superior $s = \text{sup}_h(\theta)$, is given by:

$$\text{red}_h(\theta) = \max \left\{ \frac{\text{mil}_h(\theta)}{\text{mil}_h(s)} \left[\text{red}_h(s) - \text{dem}_h(s) \right], 0 \right\}.$$

The next section describes how the above functions are used in the decision-making process of tribal leaders when situational changes cause the stress level of a tribe to rise.

Tribal decision-making and behavior

If a tribe fails to secure a desirable amount of wealth, or if the hierarchical structure (coalition) is such that some of the tribes are under stress, then the confederation as a whole is stressed and tension increases – consistent with the known behavior of Inner Asian tribes, based on historical and ethnographic data[12]. Using the previously defined functions, the tension or stress of tribe θ, denoted by $\text{ten}_h(\theta)$, is defined by the difference between expected and actual wealth received:

$$\text{ten}_h(\theta) = \min \left\{ \max \left[\frac{\text{red}_h(\theta) - \text{dem}_h(\theta)}{\text{dem}_h(\theta)}, 0 \right], 1 \right\}.$$

12 Barfield 1981; 2001; Bold 2001; Sneath 2006.

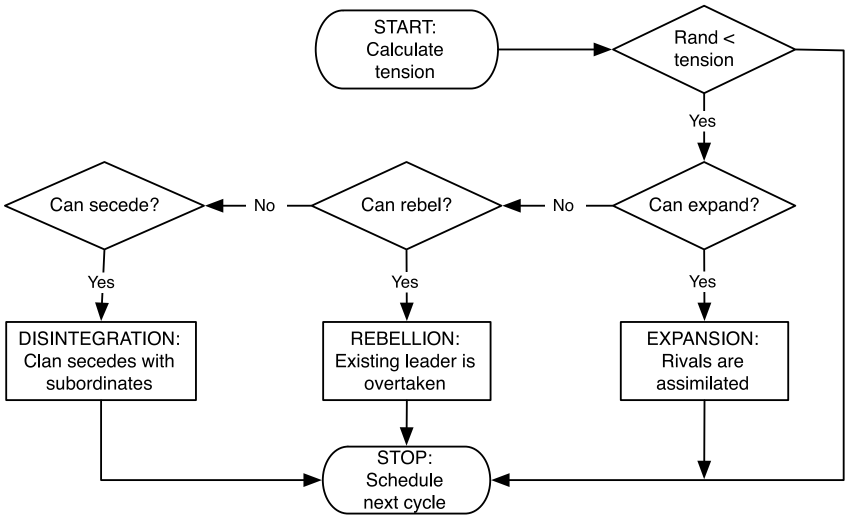

Fig. 4. Flowchart describing a tribe's decision-making process in the main simulation cycle. Actions available to confederation members include outward expansion (by conquest), coup d'ètat (by rebellion), and secession (by disintegration). The exact action chosen depends on the tribe's capability as determined by geographic location and placement within the confederation's hierarchy.

In turn (see Fig. 4), tension or stress produces one of three changes in a tribe:

1. Expansion. If there is a weaker confederation in the immediate neighborhood, the stronger confederation leader will attempt to conquer it, following a Lanchester-type sub-model for military force interactions with appropriate parameters for steppe warfare (e.g., Barfield 1994). If successful, the conquered hierarchy is integrated as a new sub-tree attached to the tribe of the conquering polity, with preference given to the victorious leader and subordinate tribes.
2. Rebellion. If there are no weaker confederations in the immediate neighborhood, or if they possess greater military capabilities, then subordinate tribes within a confederation may attempt a coup d'ètat. Successful rebellion requires accumulating enough power in parts of the hierarchy under rebel control to overtake the remainder of the confederation controlled by the incumbent leader higher up.
3. Disintegration. Finally, a tribe may attempt to secede from its present confederation to form and lead a new confederation, resulting in political disintegration.

The design of Hierarchies is intended to cover a significant variety of decision-making situations and resulting behaviors. From a state machine (Markovian) perspective, member tribes, coalition leaders, and an entire coalition as a whole, have available finite sets of states. For example, as suggested by Figure 4, a coalition leader can transition through various states characterized by tension (e.g., induced by the growth of neighboring threats), expansion (opportunities offered by perceived neighboring weakness), and rebellion (opportunities posed by perceived leader weakness), resembling valid parallels in historically documented states.

Implementation

The model was implemented in MASON (Luke et al. 2005; Luke 2011), version 12. While other agent-based simulation toolkits exist (Nikolai/Maddey 2009), MASON provides a set of desirable features with respect to our research questions, referent system, and overall design. Among the most important features are MASON's ability to produce exactly replicable results across platforms; its separation between computation and visualization to significantly increase speed and enable other functionalities (e.g., checkpoint results for separate analysis); and MASON's convenient interphase with ECJ (Luke 2010) for subsequent research using evolutionary computation. Our research team is experienced with MASON, having produced several earlier models directly relevant to Hierarchies (e.g., Wetlands [Cioffi-Revilla et al. 2004] and HouseholdsWorld [Cioffi-Revilla et al. 2010], among others).

The following standard legacy features of MASON played a significant role in the implementation of Hierarchies[13]:

`Schedule:` MASON's efficient scheduler for implementing discrete events on the main loop, such as tribal decision-making processes illustrated in Figure 4 above and other algorithms.

`AsynchronousSteppable:` MASON's basic implementation of the Asynchronous interface, used for implementing Hierarchies' highly fluid and combinatorial political process of alignment and re-alignment among tribes.

`Continuous2D:` Already used to implement HouseholdsWorld (and therefore also part of Hierarchies), this feature was used to instantiate parts of the landscape.

`SparseGrid2D:` Similarly, also used to instantiate the landscape taking advantage of sparse features in the referent focal system, using hash tables rather than arrays to store a sparse number of objects spread over a large area.

`Network:` Used for neighborhood topology and coalition structures.

`NetworkPortrayal2D:` Similar, for visualization of coalition hierarchies and for mapping the political geography of tribes on the Hierarchies landscape.

`doLoop()` method: Used throughout, such as in implementing agent decision-making.

GUI: Similar use as in previous MASON models, for visualizing simulation runs.

Console: Used as a dashboard to select model parameters in various runs when running from a .jar file.

The main new feature in MASON v.12 that played a significant role in the implementation of Hierarchies was the JUNG (Java Universal Network/Graph) library for visualizing networks. JUNG was used for visualizing two network structures that emerge and evolve in Hierarchies: the political geography of tribal history using "policharts" (Cioffi-Revilla 2007); and the composition of coalition structures (see Fig. 9).

Verification

The model was verified and debugged to ascertain internal validity. Model verification consists of a set of methodological procedures to ensure that the model performs as intended (Macal 2005). Static verification consisted of a code walk-through, ensuring that the main specification of the model's design had been properly implemented in code. Dynamic verification consisted of conducting parameter sweeps, calibration of key parameters, exploration of the parameter space, and sensitivity analysis with respect to main parameters. The full-sized world model

[13] An overview of the complete MASON Class and other documentation is found at: http://cs.gmu.edu/~eclab/projects/mason/docs/overview.html

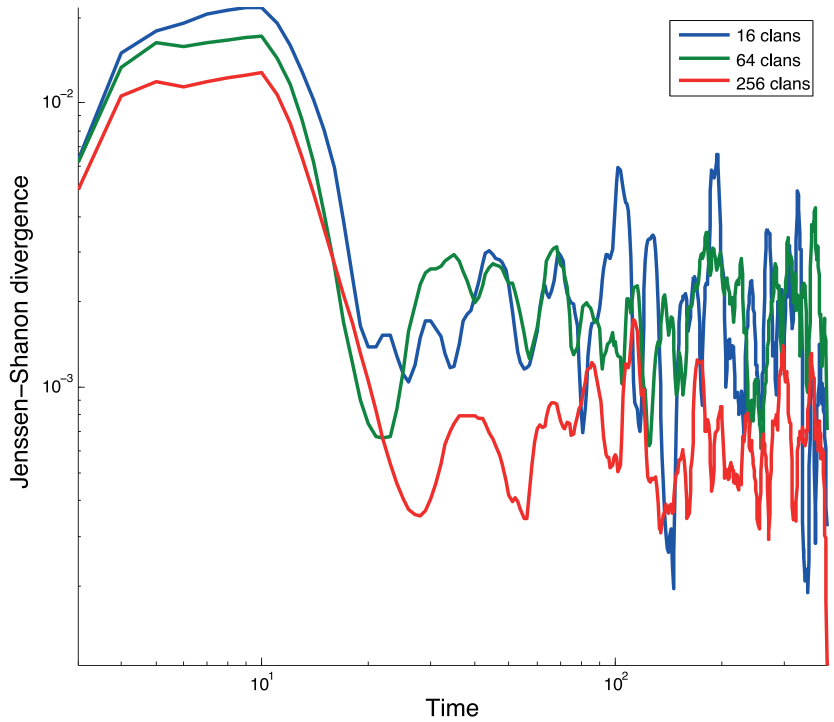

Fig. 5. Jensen-Shannon divergence measure parametricised by number of groups (aimags) in the simulation.

(HierarchiesWithUI) runs relatively fast, avoiding the need to run smaller world "windows" or "patches" consisting of geographic sub-regions for initial testing purposes. Specifically,

Code walk-through: No major re-coding was necessary as a result of several thorough code walk-throughs.

Profiling results: Profiling was performed using Eclipse. Calls on methods were observed and no anomalies were found after the initial test runs.

Calibration: Significant effort went into calibrating Hierarchies, and its predecessor HouseholdsWorld, to reflect the empirical realities of Inner Asia as these are known through archaeological, historical, and ethnographic data. An analogous model of pastoralist tribes and coalition dynamics for a different spatio-temporal region of the world would require a different calibration of numerous parameters.

Parameter sweeps: Several parameter sweeps were conducted, including but not limited to variations on household size (6 to 12 members/household), number of households, and number of clans (16, 64, and 256). For example, the Jensen-Shannon divergence (Grosse et al. 2002) across coalition size distributions with various numbers of clans showed comparable behavior, as shown in Figure 5[14].

Sensitivity analysis: An initial set of sensitivity analysis tests was conducted, primarily for the purpose of ascertaining whether the model was significantly brittle in some respect. Results failed to show any areas of particular concern.

[14] The so-called "Jensen-Shannon divergence" is an information-theoretic measure of the degree of similarity (correlation) between two ordered sets of symbols. It is used here to measure divergence of simulation runs with different numbers of sub-polity groups (clans, tribes).

Validation

Model validation assessed the degree of fit between model outputs from simulation runs and empirically observed or recorded patterns from the focal system in Inner Asia, based on available archaeological, historical, or ethnographic data. A test of face validity showed credible overall qualitative results after initial code debugging. More quantitative validation procedures included three sets of tests: comparing simulated and empirical frequency distributions, time-series, and chronological event patterns.

Distributions: The main distributions selected for validation purposes pertained to emergent phenomena generated by the model, namely coalition or confederation size, tension across tribes, effective coalition power, and coalition duration.

Time-series: Hierarchies generates numerous time-series; too many to report here due to space limitations. The main time-series examined for validation purposes included territorial size of confederations, membership size of coalitions, tribal tension of coalition members, and the Jensen-Shannon divergence as a function of time. Additional time-series of interest are reported in the next section (Simulation Results).

Events chronologies patterns: The simulation generates an event chronology or "virtual history," which we compared with the real politico-military history of Inner Asia as known today. We believe this test of model validity is original and was performed on Hierarchies for the first time.

Other validation tests: Additional tests of validity were conducted. For example, temporal features in the rates of growth and decline were compared, showing similarity between simulated and real patterns.

These and other results are reported in the next section. In the discussion section we mention additional possibilities in terms of validation tests.

Generating illustrative runs

The main purpose in this chapter is to illustrate the functionality and behavioral range of the Hierarchies model, not to report on specific computational experiments. Accordingly, a set of simulated runs was generated for illustrative purposes, as reported in the next section.

Simulation Results

The Hierarchies model is capable of generating sociopolitical processes that are qualitatively and quantitatively similar to those observed in the recorded history of Inner Asia. Here we demonstrate instances of model dynamics focused on two types of virtual simulated reconstructions of known historical processes: specific event sequences in the evolution of confederations and, more specifically, patterns in the rise and fall of confederation polities. These two sets of results represent "fast" (synchronic) and "slow" (diachronic) processes in the evolution of Inner Asian polities, in the sense of Canonical Theory. The third set of results focuses on the size of confederations and related variables. Other results are available using different parameter settings or by varying the input design.

Real vs. simulated historical event processes

In terms of the first simulated reconstruction, Table 1 shows a side-by-side comparison of a series of historical and simulated event sequences (fast processes). These results demonstrate how the real historical contested evolution of polities in Inner Asia (left) between the year 376 CE (Fu Chien's conquest of the first Tuoba state) and year 531 (disintegration of the Tuoba-Wei state) bears strong behavioral, qualitative, and overall quantitative resemblance to a sample simulation run of the Hierarchies model from simulated time cycle 1 ("confederation 1144" [this could well be the Tuoba state in the historical sequence] forms by conquest) and time cycle 45 (the Hierarchies model confederation disintegrates).

Exchanging proper nouns and numeric codes between processes such as these – similar to a Turing test – would render the two sequences indistinguishable from each other. The main narrative of interest in both instances is a complex process involving conquest, rebellion, and secession in the evolution of polities; the sociopolitical grammar of these two processes is analogous. Further research is also under way to ascertain quantitative properties (e.g., measuring Jensen-Shannon divergence), based on these computational qualitative results.

Year	Real History: The Tuoba-Wei polity in Inner Asia	Cycle	Simulation: Confederation 1144 in the model
376	Fu Chien conquers the first Tuoba state or Tai state, which formed in 338. The Tai king dies in exile.	14	Confederation 1144 is created, led by Tribe 33456 as a splinter group from Confederation 15224.
386	Tuoba, a leading tribe of the Xianbei, establishes a second Tuoba state.	15	Confederation 1144 encounters rival Confederation 13972.
391	Tuoba Gui attacks Jujan and reportedly captured half; others flee.	15–20	1144 conducts victorious wars and disintegrates, growing fivefold.
396	Tuoba Gui, Xianbei leader, proclaimed emperor of Wei.	19	Confederation 1144 conquers Confederation 13972.
396	Tuoba captures Ye, capital of the former Yan dynasty.	21	Tribe 22980 revolts and takes over Confederation 1144.
399	Tuoba-Wei defeats a major northern tribe (the . Kao-che), taking 90,000 captives	22	Confederation 1144 reaches its maximal power becoming the largest polity in the system.
423	Tuoba-Wei captures the city of Lo-yang, exploiting inter-state wars.	28	Tribe 43908 secedes from 1144 and forms a new Confederation.
430	Tuoba captures the city of Chang-an, effectively ending the Hsia dynasty.	28–34	Tribe 43908's secession causes 1144 to lose integrity; multiple secessions.
439	Tuoba-Wei conquers the last border state and controls all of N. China.	34	A series of secessions decrease the power of 1144 to 3.6.
494	Tuoba-Wei moves its capital south to Lo-yang, distancing the court from the steppe and reducing the power and financial support to many tribes.	32	Numerous small wars destabilize the system. Confederation 922, the second largest in the system, disintegrates.
523	The Jujan polity attacks and is counterattacked.	38	1144 reconquers losses, in particular it subjugates Tribe 43908.
524	Tuoba-Wei frontier troops (mostly pastoralists) revolt across the frontier.	41	The original size and territorial extent of Confederation 1144 are restored.
528	Tuoba-Wei's capital is captured by a tribal leader, executing the court.	41–45	Confederation 1144 dominates the international system during this period.
530	The Tuoba-Wei state divides into Western and Eastern Wei.	45	A major secession halves the size of Confederation 1144.

Tab. 1. Comparison of historical and simulated processes. The color of the year denotes the type of outcome (and therefore path through branching tree) in the fast branching process in Figure 2. The colored numbers of simulated confederations correspond to colors of polity trajectories in Figure 6.

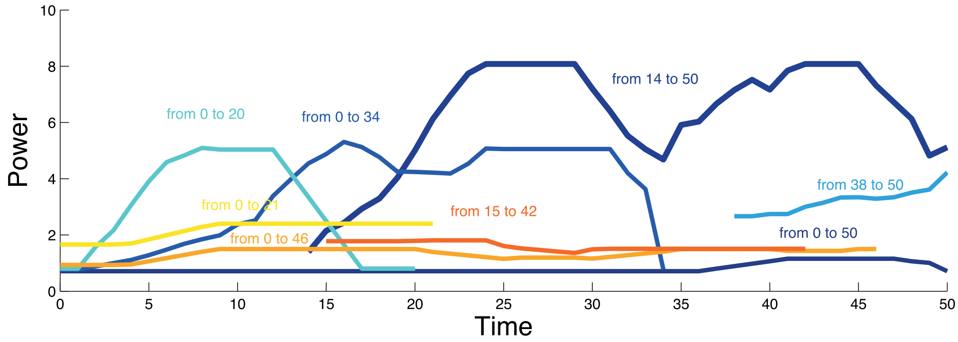

Fig. 6. Rise and fall of polities (tribal confederations) as generated by the Hierarchies model.

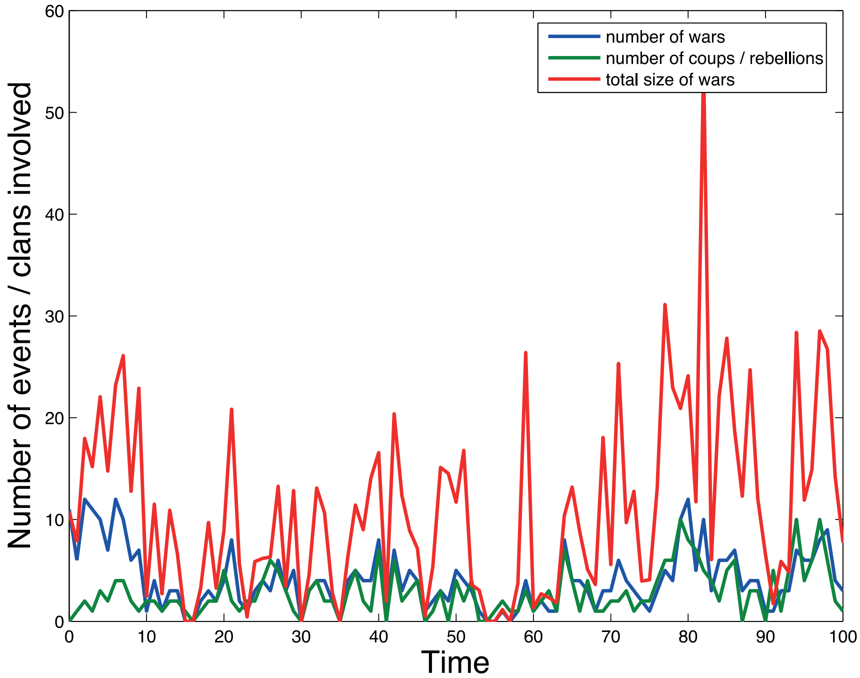

Fig. 7. War dynamics as generated by the Hierarchies model.

The recorded history of the Türk polity provides another and perhaps even closer match to the artificial computational history of the Hierarchies 1144 confederated polity (Honeychurch 2008).

Rise and fall of polities

In the second set of simulated historical reconstructions, via time-series of politico-military dynamics, Figure 6 shows patterns of virtual history in the rise and fall of sets of polities (confederation of *aimags*). The multiple time-series graph shows eight confederation polities rising, fluctuating, and declining as a result of conquests, rebellions, and secessions among *aimag* members. These patterns also are similar to those observed for Asia and elsewhere in the world (Taagepera 1978). Although small differences exist between simulated trajectories in Figure 6 and those of real historical polities, the emergent qualitative and quantitative patterns are similar.

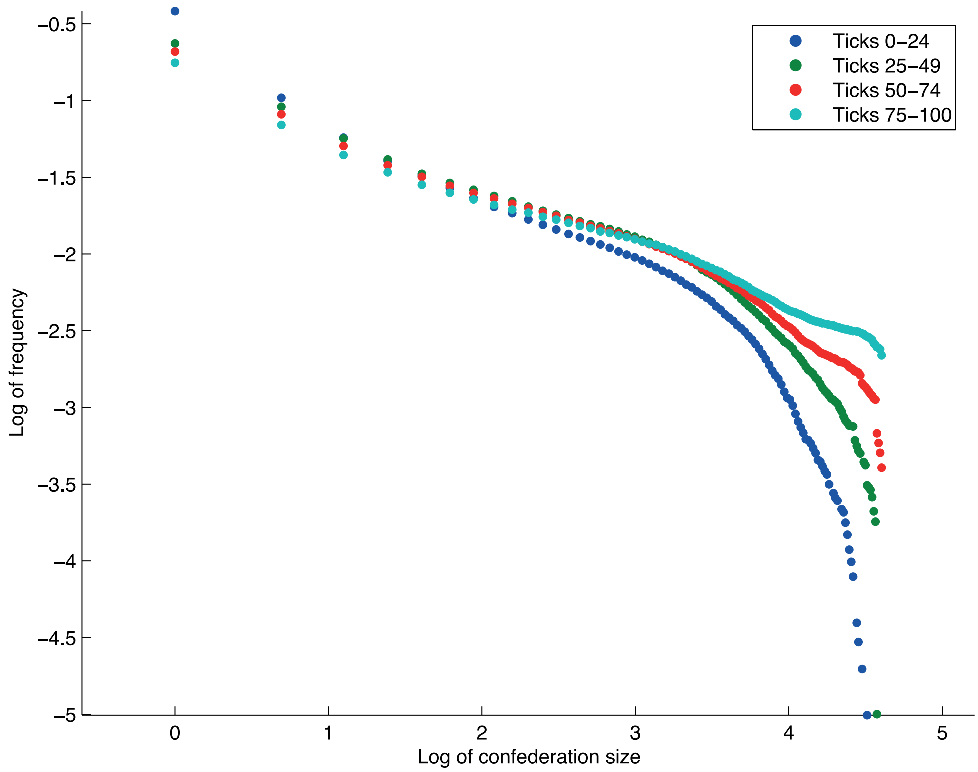

Fig. 8. Evolution of the distribution of coalition size, from early (ticks 0–24) to late epochs of the simulation (ticks 75–100).

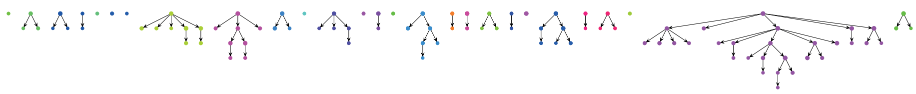

Fig. 9. Evolution of the distribution of coalition size, from early (ticks 0–24) to late epochs of the simulation (ticks 75–100).

Some noteworthy features include: (i) contemporaneous polities evolving in the same epoch (not one-at-a-time), as in a polycentric or multipolar system; (ii) relatively high and long-range temporal correlations (negligible volatility); (iii) longer formation phase relative to decline; and (iv) most polities are small and tend to last longer than the largest polities (Gleditsch/Ward 1999).

Another type of relevant politico-military time-series produced by the model concerns the onset and severity of wars, both international and internal, as shown in Figure 7. In this case the graphs show considerable variability, or high volatility, comparable to patterns of warfare in the international system for different epochs and regions (e.g., Cioffi-Revilla/Lai 1995; Reid-Sarkees/Wayman 2010).

Coalition Size Distributions

A third set of illustrative results is provided by distribution plots. Figure 8 illustrates the size distribution of confederations, parametricised by phase in the simulation run. Size distribution is shown to evolve from exponential or relatively light-tailed to power-law or heavy-tailed as the simulation evolves.

As a sample run, one of these coalition landscapes would look like Figure 9, which shows a multipolar arrangement after 30 simulation cycles (ticks), or within the range of the green data in Figure 8.

Figure 10 shows the evolution of other average distributions, namely confederation size (upper left), tension (upper right), confederation effective power (lower left), and confederation duration (lower right). These results are averaged over 20 runs each. Two sets of simulated data are shown, for early (ticks 0–20) and late epochs (> 20 ticks).

Finally, Figure 11 shows the temporal evolution of coalition "power" measured by a multiplicative indicator of military capability and territorial size. Average effective power shows mostly stationary behavior with low variability, whereas maximal effective power shows significantly greater variability. These results are highly consistent with known empirical patterns, whereby average coalition size will change much less than maximal size. This is because the territorial size of polities has log-normal, non-equilibrium distribution (Russett 1968), whereas the size distribution of winning coalitions has less variability.

Discussion

The MASON Hierarchies model

Results reported in the previous section show general qualitative agreement and several quantitative matches between simulated data and observed empirical patterns of politico-military dynamics. Such patterns included a significant set of known features, including: (1) the rise and fall of polities (Fig. 6); (2) time-series of the onset and severity of internal and international war (Fig. 7); and (3) distribution patterns on the size and duration of politico-military coalitions (Figs. 8 and 10). In addition, the chronological match between simulated history and real history (reported in Tab. 1) seems especially noteworthy. Social simulations have not previously demonstrated this kind of narrative replication of politico-military history. Clearly, further analysis of these narrative texts (artificial and real) is warranted. These results constitute four significant clusters of qualitatively and quantitatively valid results. Taken together, these constitute the main results that lend credence to the validity of the Hierarchies model and provide impetus and hope for further investigations.

Obviously, additional quantitative analysis is required to determine fitness in more exact ways. However, considering the unavoidable presence of measurement error in the extant empirical data (data collected from simulation runs is error-free), one would not expect strong inconsistency between simulated results obtained thus far and empirical data from standard sources (e.g., Reid-Sarkees/Wayman 2010). More likely, measurable quantitative differences will lead to further calibration and improvements of the model, not to its falsification, given the strength of these illustrative results.

Replication is a significant activity in social science simulation research (Altman et al. 2001; Edmonds/Hales 2003). The following are special features or considerations to bear in mind for purposes of replicating the Hierarchies model, whether in MASON, other simulation toolkits (e.g., RePast), or native code:

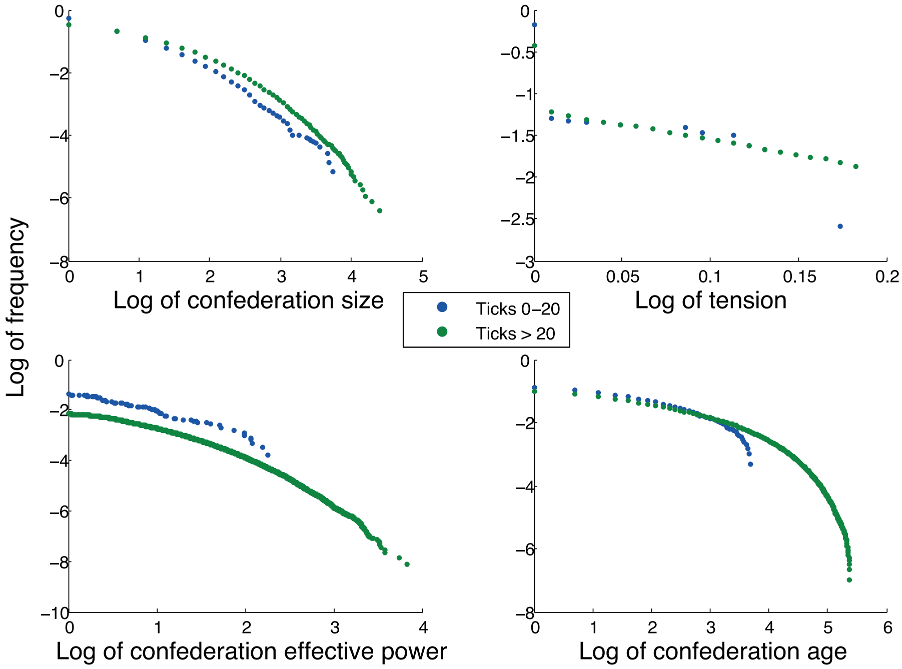

Fig. 10. Rise and fall of simulated polities (tribal confederations) in a sample run of the Hierarchies model.

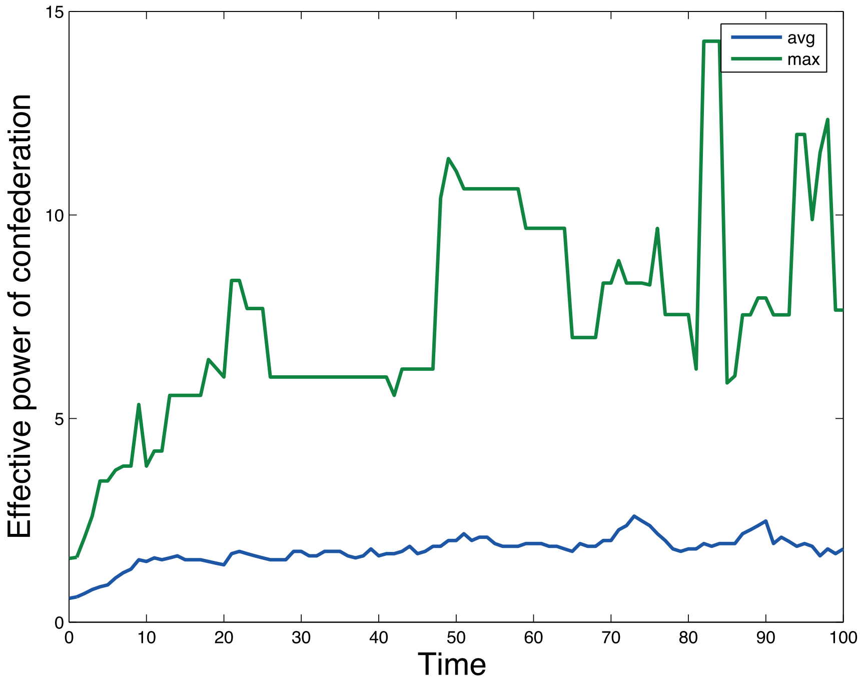

Fig. 11. Rise and fall of simulated polities (tribal confederations) in the Hierarchies model.

1. The general computational dependence of the model is from environment to agents that generate coalitions, consistent with a bottom-up approach. Coalitions are generated by the model as a result of decision-making (as in the real world), not derived from hard-wired processes, consistent with the generative methodological approach (Epstein 2006).

2. The parsing of tribal decisional alternatives in terms of rebellion, conquest, and secession is important and documented by historical and ethnographic sources; it is not arbitrary or artificially construed to produce results. Hence, this "menu for choice" (Russett et al. 2000) should not be changed in a significant way to allow for other alternatives, such as submission, migration away from the region, or other modes of "exit, voice, and loyalty" (Hirschman 1970).
3. Much more data collection from simulation runs is feasible. The data collection reported here is meant for illustrative purposes only.
4. The (pseudo) random number generator (RNG) used by MASON is the Mersenne Twister, which has many positive features. Other RNGs are not guaranteed to produce the same results.

Broader implications

Earlier computational models of sociopolitical dynamics – social simulations focused specifically on the evolution of polities – have progressed through procedural language simulations[15], to replicator dynamics (Bremer/Mihalka 1977; Turchin 2003), to the more recent generation of abstract agent-based simulations that are not geographically or temporally calibrated. Accordingly, the MASON Hierarchies model represents a promising advance with respect to earlier computational models of polity dynamics that have lacked several of its key features.

First, Hierarchies integrates sociopolitical {and} natural dynamics, including realistic decision-making associated with domestic coalition politics within a polity. This is also consistent with current theory and research on hierarchies and organizational adaptation (Carley/Svoboda 1996).

Second, when calibrated for specific environments in Inner Asia, such as between the Xiongnu and the post-Mongol epoch (ca. 300 BCE to 1400 CE), the model generates polity trajectories and chronological histories that bear striking qualitative and quantitative resemblance to the known history of the region – including patterns of multipolarity (competing polities with major and minor regional powers), long-range evolution (relatively slow change and rare volatility in the rise and fall of polities), and other well-documented features of Inner Asia and other regions of the international system.

Third, the spatial dimension of the Hierarchies model – its geospatial foundations – also enables integration with extant models of nomad subsistence. Whereas earlier agent-based models of world politics have remained close to their cellular automata roots, Hierarchies draws on GIS and spatial data on natural and built environments to provide an increasingly realistic representation of the world.

Finally, the model has relevant micro-foundations, because the decision process is explicit and detailed about confederation leaders facing a multi-criteria optimization problem: maximizing the coalition size and resources they control, while minimizing the tension or stress caused by unfulfilled resource acquisitions. The decision algorithm is simple, but not simpler than required for representing the relevant politics of the situation. Earlier models have implemented more limited decisional algorithms resulting in simpler emergent dynamics.

15 E.g., Benson 1963; Natalicchi 1994; Lowe 1985.

Future research

MASON Hierarchies is a rich model amenable to a variety of future research efforts. Two research directions seem particularly promising, based on extant research and feasible opportunities.

First, the current model will be investigated through a variety of computational experiments designed to address a set of research questions. For example, Hierarchies can be used to investigate the effects of climate change on coalition dynamics and polity trajectories, an important topic that has resisted earlier methodological approaches. The model can also be used to investigate hypotheses concerning the stability of polities as a function of their levels of hierarchy (Crumley 2001). Adaptive cycles (Holling 1973; Gunderson/Holling 2002) can also be investigated using the Hierarchies model. Similarly, computational experiments can be designed to analyze "what if" scenarios, to better understand real history when compared to what may have happened (Waugh/Greenberg 1986).

Second, Hierarchies will be extended to create a large-scale model of the entire region of Inner Asia (Fig. 1), including weather. A prototype model of such a large-scale model is currently being developed and is tentatively called MASON HünnüLand. Such a model will mark the final model in the sequence of agent-based models produced by the NSF-funded Mason-Smithsonian Joint Project on Inner Asia. HünnüLand and its predecessors will provide foundations for the new Mason-Smithsonian Joint Project on Climate Change and Society, under funding from the National Science Foundation's Cyber-Enabled Discovery and Innovation (CDI) Program[16].

Finally, Hierarchies was inspired by the political landscape of Inner Asia, consisting of social entities with terms such as clans and tribes. Exchanging these local anthropological terms for more general terms, such as simple/small and complex/large polities, or other more interdisciplinary and less disciplinary terms, would enable Hierarchies to become a more general model of universal, cross-cultural politico-military processes that would still be situated in natural environments. The Canonical Theory is not scaled to specific forms of social relations and organizations, such as clans, tribes, or states. Rather, it applies to polities at any and multiple scales, as well as to polyarchic or polycentric polities with competing authorities (Cioffi-Revilla 2011), as is typical of complex polities. So the MASON Hierarchies model could be used to simulate a range of polities, including states and empires.

Summary

Advances in computational social science, mainly using multi-agent systems or agent-based models, now permit the first simulations of complex adaptive social systems with empirically referenced spatial dimensions, including organizational hierarchies and social institutions with conflict dynamics, in changing natural environments. This paper presented Hierarchies, a computational agent-based model implemented in the MASON system. We reported computational results indicating close similarity between real history and simulation runs, specifically in terms of con-

16 The initial version of the MASON HünnüLand model was designed by C. Cioffi and J. D. Rogers and implemented by Sarah Wise.

federations of tribal *(aimags)* alliances and warfare through conquest, rebellion, and polity disintegration in the steppes of Inner Asia. These results are encouraging for developing more insightful models of long-range socio-natural dynamics based on real world historical observation.

Acknowledgements

MASON Hierarchies was designed by Claudio Cioffi-Revilla, William Honeychurch, and J. Daniel Rogers. It was implemented by Maciej Latek, whom the authors thank for assistance with programing. The authors also thank Maksim Tsvetovat and members of the Mason-Smithsonian Joint Project on Inner Asia, especially Sean Luke, as well as comments received from D. Tseveendorzh of the Mongolian Academy of Sciences' Institute of Archaeology in Ulaanbaatar, Peter Turchin, Nikolai Kradin, Ray Dacey, Michael Mousseau, Ursula Brosseder, Bryan Miller, and Jan Bemmann. Meghan Mulkerin provided valuable assistance in the final preparation of the manuscript. Funding for the Mason-Smithsonian Joint Project on Inner Asia (Cioffi-Revilla et al. 2007) was provided by the Center for Social Complexity at George Mason University and by grant no. BCS–0527471 from the National Science Foundation, Human and Social Dynamics Program, Dr. Thomas J. Baerwald, Program Officer. Funding for developing the MASON system has been provided by grants from the Defense Advanced Research Projects Agency (DARPA), the National Science Foundation (NSF), the Office of Naval Research (ONR), and the Center for Social Complexity at George Mason University. The MASON Project is directed by Sean Luke (Principal Investigator) and Claudio Cioffi-Revilla. Earlier versions of this paper were presented at the International Conference on History and Mathematics, Russian Academy of Sciences, Urals Branch, Yekaterinburg, Russian Federation, December 20–23, 2009; the Eurasian Peace Science Conference, Istanbul, Turkey, January 13–14, 2012; the International Conference on "The Complexity of Interaction Along the Eurasian Steppe Zone in the First Millennium AD: Empires, Cities, Nomads, and Farmers", February 9–12, 2012, Bonn, Germany; and the 54th Annual Convention of the International Studies Association, San Diego, California, USA, April 1, 2012. The authors are solely responsible for any errors in this study.

References

Altman et al. 2001
M. Altman/L. Andreev/M. Diggory/G. King/S. Verba/D. L. Kiskis/M. Krot, A digital library for the dissemination and replication of quantitative social science research: The Virtual Data Center. Social Science Computer Review 19, 4, 2001, 458–470.

An et al. 2005
L. An/M. Linderman/J. Qi/A. Shortridge J. Liu, Exploring Complexity in a Human-Environment System. An Agent-Based Spatial Model for Multidisciplinary and Multiscale Integration. Annals of the Association of American Geographers 95, 1, 2005, 54–79.

Arrow et al. 2000
H. Arrow/J. E. McGrath/J. L. Berdahl, Small Groups as Complex Systems. Formation, Coordination, Development and Adaptation (Thousand Oaks/CA, London, New Dehli 2000).

Axelrod 1997
R. Axelrod, Advancing the art of simulation in the social sciences. Complexity 3, 2, 1997, 193–99.

Bainbridge 2007
W. S. Bainbridge, The Scientific Research Potential of Virtual Worlds. Science 317, 2007, 472–476.
Barfield 1981
Th. J. Barfield, The Hsiung-nu Imperial Confederacy: Organization and Foreign Policy. Journal of Asian Studies 41, 1, 1981, 45–61.
Barfield 1994
Th. J. Barfield, The Devil's Horsemen. Steppe Nomadic Warfare in Historical Perspective. In: S. P. Reyna/R. E. Downs (eds.), Studying War: Anthropological Perspectives. War and Society 2 (Langhorne/PA 1994) 157–184.
Barfield 2001
Th. J. Barfield, The Shadow Empires. Imperial State Formation along the Chinese – Nomad Frontier. In: S. E. Alcock/T. N. D'Altroy/K. D. Morrison/C. M. Sinopoli (eds.), Empires. Perspectives from Archaeology and History. Conference "Imperial Designs: Comparative Dynamics of Early Empires", held in Mijas, Spain, in the autumn of 1997 (Cambridge 2001) 10–41.
Bearce/Fisher 2002
D. H. Bearce/E. O'N. Fisher, Economic Geography, Trade, and War. Journal of Conflict Resolution 46, 3, 2002, 365–393.
Bemmann et al. 2009
J. Bemmann/H. Parzinger/E. Pohl/D. Tseveendorzh (eds.), Current Archaeological Research in Mongolia. Papers from the First International Conference on "Archaeological Research in Mongolia" held in Ulaanbaatar, August 19th–23rd, 2007. Bonn Contributions to Asian Archaeology 4 (Bonn 2009).
Benson 1963
O. Benson, Simulation in International Relations and Diplomacy. In: H. Borko (ed.), Computer Applications in Political Science (Englewood Cliffs/NJ 1963) 574–595.
Bold 2001
B.-O. Bold, Mongolian Nomadic Society. A Reconstruction of the 'Medieval' History of Mongolia (London 2001).
Bremer/Mihalka 1977
St. A. Bremer/M. Mihalka, Machiavelli in machina: Or politics among hexagons. In: K. W. Deutsch (ed.), Problems in World Modeling. Political and Social Implications (Boston 1977) 303–337.
Brosseder/Miller 2011
U. Brosseder/B. K. Miller (eds.), Xiongnu Archaeology: Multidisciplinary Perspectives of the First Steppe Empire in Inner Asia. Bonn Contributions to Asian Archaeology 5 (Bonn 2011).
Carley/Svoboda 1996
K. M. Carley/D. M. Svoboda, Modeling Organizational Adaptation as a Simulated Annealing Process. Sociological Methods & Research 25, 1, 1996, 138–168.
Cederman 2003
L.-E. Cederman, Modeling the size of wars: From billiard balls to sandpiles. American Political Science Review 97, 1, 2003, 135–150.
Cioffi-Revilla 2002
C. Cioffi-Revilla, Invariance and universality in social agent-based simulations. Proceedings of the National Academy of Science of the U.S.A. 99, 14 (Supp. 3), 2002, 7314–7316.
Cioffi-Revilla 2005
C. Cioffi-Revilla, A Canonical Theory of Origins and Development of Social Complexity. Journal of Mathematical Sociology 29, April–June, 2005, 133–153.
Cioffi-Revilla 2007
C. Cioffi-Revilla, Polichart Analysis of Global Issues in Human and Social Dynamics. Proceedings of the Annual Meeting of the Association of American Geographers, San Francisco/CA 2007.
Cioffi-Revilla 2010
C. Cioffi-Revilla, On the Methodology of Complex Social Simulations. Journal of Artificial Societies and Social Simulations 13, 1, 2010, 7. http://jasss.soc.surrey.ac.uk/13/1/7.html
Cioffi-Revilla 2011
C. Cioffi-Revilla, Complex Polities in the Age of Modern States. Paper presented at the International Studies Association Annual Conference "Global Governance: Political Authority in Transition", Le Centre Sheraton Montreal Hotel, Montreal, Quebec, Canada, March 16, 2011. On-

line available: http://citation.allacademic.com//meta/p_mla_apa_research_citation/5/0/0/9/9/pages500995/p500995-1.php

Cioffi-Revilla 2012
C. Cioffi-Revilla, A Formal Theory of Politogenesis: Towards an Agent Simulation of Social Complexity Origins. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2429322

Cioffi-Revilla 2014
C. Cioffi-Revilla, Introduction to Computational Social Science: Principles and Applications (London, Heidelberg 2014).

Cioffi-Revilla/Lai 1995
C. Cioffi-Revilla/D. Lai, War and Politics in Ancient China, 2700–722 B.C. Measurement and Comparative Analysis. Journal of Conflict Resolution 39, 3, 1995, 467–494.

Cioffi-Revilla et al. 2004
C. Cioffi-Revilla/S. Paus/S. Luke/J. L. Olds/J. Thomas, Mnemonic Structure and Sociality: A Computational Agent-Based Simulation Model. In: D. Sallach/Ch. Macal (eds.), Proceedings of the Agent 2004 Conference on Social Dynamics: Interaction, Reflexivity and Emergence. Chicago, IL: Argonne National Laboratory and University of Chicago, Illinois, October 7–9. Online available: http://cs.gmu.edu/~sean/papers/siena.pdf

Cioffi-Revilla et al. 2007
C. Cioffi-Revilla/S. Luke/D. C. Parker/J. D. Rogers/W. W. Fitzhugh/W. Honeychurch/B. Frohlich/P. DePriest/Ch. Amartuvshin, Agent-based Modeling Simulation of Social Adaptation and Long-Term Change in Inner Asia. In: Sh. Takahashi/D. Sallach/J. Rouchier (eds.), Advancing Social Simulation. The First World Congress in Social Simulation (Tokyo, New York, Heidelberg 2007) 189–200.

Cioffi-Revilla et al. 2010
C. Cioffi-Revilla/D. J. Rogers/M. Latek, The MASON HouseholdsWorld Model of Pastoral Nomad Societies. In: K. Takadama/C. Cioffi-Revilla/G. Deffaunt (eds.), Simulating Interacting Agents and Social Phenomena. Post-Proceedings of the Second World Congress on Social Simulation (WCSS '08) held at George Mason University in the United States, 14–17 July 2008. Agent-based Social Systems 7 (Tokyo, New York, Berlin 2010) 193–204.

Cioffi-Revilla et al. 2011
Cl. Cioffi-Revilla/J. D. Rogers/St. Wilcox/J. Alterman, Computing the Steppes: Data Analysis for Agent-Based Models of Polities in Inner Asia. In: Brosseder/Miller 2011, 97–110.

Crumley 2001
C. L. Crumley, Communication, Holism, and the Evolution of Sociopolitical Complexity. In: J. Haas (ed.), From Leaders to Rulers. Fundamental Issues in Archaeology (New York 2001) 19–36.

Di Cosmo 1999
N. Di Cosmo, The Northern Frontier in Pre-Imperial China. In: M. Loewe/E. L. Shaughnessy (eds.), The Cambridge History of Ancient China. From the Origins of Civilization to 221 B.C. (Cambridge 1999) 885–966.

Edmonds/Hales 2003
B. Edmonds/D. Hales, Replication, Replication and Replication: Some Hard Lessons from Model Alignment. Journal of Artificial Societies and Social Systems 6, 4, 2003. http://jasss.soc.surrey.ac.uk/6/4/11.html

Epstein 2006
J. Epstein, Generative Social Science: Studies in Agent-Based Computational Modeling. Princeton Studies in Complexity (Princeton/NJ 2006).

Fitzhugh et al. 2009
W. W. Fitzhugh/M. Rossabi/W. Honeychurch (eds.), Genghis Khan and the Mongol Empire (Seattle/WA 2009).

Gavrilets et al. 2010
S. Gavrilets/D. Anderson/P. Turchin, Cycling in the Complexity of Early Societies. Cliodynamics: Journal of Theoretical and Mathematical History 1, 1, 2010, 58–80.

Gilbert 1999
N. Gilbert, Computer Simulation in the Social Sciences. 42nd ed. (Thousand Oaks/CA 1999).

Gilbert 2008
N. Gilbert, Agent-Based Models. Quantitative Applications in the Social Sciences 153 (Thousand Oaks/CA 2008).

Gilbert/Troitzsch 2005
N. Gilbert/K. Troitzsch, Simulation for the Social Scientist. 2nd ed. (Maidenhead 2005).
Gleditsch/Ward 1999
K. S. Gleditsch/M. D. Ward, Interstate System Membership. A Revised List of the Independent States since 1816. International Interactions 24, 4, 1999, 393–413.
Grosse et al. 2002
I. Grosse/P. Bernaola-Galván/P. Carpena/R. Román-Roldán/J. Oliver/H. E. Stanley, Analysis of symbolic sequences using the Jensen-Shannon divergence. Physical Review E 65, April 2002, 041905.
Gunderson/Holling 2002
L. H. Gunderson/C. S. Holling (eds.), Panarchy: Understanding Transformations in Human and Natural Systems (Washington/DC 2002).
Hirschman 1970
A. O. Hirschman, Exit, Voice, and Loyalty: Responses to Decline in Firms, Organizations, and States (Cambridge/MA 1970).
Holling 1973
C. S. Holling, Resilience and Stability of Ecological Systems. Annual Review of Ecology and Systematics 4, 1973, 1–23.
Honeychurch 2008
W. Honeychurch, Research Memo on the Turk Polity. Mason-Smithsonian Joint Project on Inner Asia, Washington, DC, 2008.
Honeychurch/Amartuvshin 2006
W. Honeychurch/Ch. H. Amartuvshin, States on Horseback: The Rise of Inner Asian Confederations and Empires. In: M. T. Stark (ed.), Archaeology of Asia. Blackwell Studies in Global Archaeology 7 (Malden/MA 2006) 255–278.
Hughes/Hillebrand 2006
B. B. Hughes/E. E. Hillebrand, Exploring and Shaping International Futures (Boulder/CO 2006).
Kleiber/Kotz 2003
Ch. Kleiber/S. Kotz, Statistical Size Distributions in Economics and Actuarial Sciences. Wiley Series in Probability and Statistics (Hoboken/NJ 2003).
Kohler/van der Leeuw 2007
T. A. Kohler/S. E. van der Leeuw (eds.), The Model-Based Archaeology of Socionatural Systems (Santa Fe/NM 2007).
Kradin 2011
N. N. Kradin, Stateless Empire: The Structure of the Xiongnu Nomadic Super-Complex Chiefdom. In: Brosseder/Miller 2011, 77–96.
Kuznar 2006
L. A. Kuznar, High-Fidelity Computational Social Science in Anthropology. Social Science Computer Review 24, 1, 2006, 15–29.
Kuznar/Sedlmeyer 2005
L. A. Kuznar/R. Sedlmeyer, Collective Violence in Darfur. An Agent-Based Model of Pastoral Nomad/Sedentary Peasant Interaction. Mathematical Anthropology and Cultural Theory: An International Journal 1, 4, 2005. http://mathematicalanthropology.org/PDF/Kuznar-Sedlmeyer1005.pdf
Laver 2005
M. Laver, Policy and the Dynamics of Political Competition. American Political Science Review 99, 2, 2005, 263–281.
Laver/Sergenti 2012
M. Laver/E. Sergenti, Party Competition: An Agent-Based Model. Princeton Studies in Complexity (Princeton/NJ 2012).
Lichbach 1996
M. I. Lichbach, The Cooperator's Dilemma. Economic, Cognition and Society (Ann Arbor/MI 1996).
Lightfoot et al. 2009
D. W. Lightfoot/Ch. Bachrach/D. Abrams/J. Kielman/M. Weiss, Social, Behavioral, and Economic Research in the Federal Context. National Science and Technology Council, Subcommittee on Social, Behavioral and Economic Sciences, Washington/DC, 2009. ebook.
Liu et al. 2007
J. Liu/Th. Dietz/St. R. Carpenter/M. Alberti/C. Folke/E. Moran/A. N. Pell/P. Deadman/T. Kratz/J. Lubchenco/E. Ostrom/Zh. Ouyang/W. Provencher/Ch. L. Redman/St. H. Schneider/W. W. A. Taylor, Complexity of Coupled Human and Natural Systems. Science 317 (5844), 2007, 1513–1516.
Lowe 1985
J. W. G. Lowe, The Dynamics of Apocalypse:

A Systems Simulation of the Classic Mayan Collapse (Albuquerque/NM 1985).

Luke 2010
S. Luke, ECJ: A Java-based Evolutionary Computation Research System. Evolutionary Computation Laboratory, George Mason University. http://cs.gmu.edu/~eclab/projects/ecj

Luke 2011
S. Luke, Multiagent Simulation and the MASON Library. Fairfax, Virginia. http://cs.gmu.edu/~eclab/projects/mason/manual.pdf

Luke et al. 2005
S. Luke/C. Cioffi-Revilla/L. Panait/K. Sullivan, MASON: A Java Multi-Agent Simulation Environment. Simulation: Transactions of the Society for Modeling and Simulation International 81, 7, 2005, 517–527. http://cs.gmu.edu/~eclab/projects/mason

Macal 2005
Ch. Macal, Model Verification and Validation. Paper presented at the Workshop on Threat Anticipation: Social Science, The University of Chicago and Argonne Laboratory, Chicago, IL, April 7–9, 2005, The University of Chicago and Argonne Laboratory, Chicago, IL.

Majeski 2004
St. J. Majeski, Asymmetric Power among Agents and the Generation and Maintenance of Cooperation in International Relations. International Studies Quarterly 48, 2, 2004, 455–470.

de Marchi 2005
S. de Marchi, Computational and Mathematical Modeling in the Social Sciences (Cambridge 2005).

Midlarsky 1999
M. I. Midlarsky, The Evolution of Inequality. War, State Survival, and Democracy in comparative Perspective (Stanford/CA 1999).

Min 2002
B. W. Min, Trade and War in Cellular Automata Worlds: A Computer Simulation of Interstate Interactions. Ph.D. dissertation Ohio State University 2002.

Natalicchi 1994
G. Natalicchi, Modelli Simulativi nelle Scienze Sociali: Applicazioni alle Relazioni Internazionali. Collana di scienza politica e relazioni internazionali 20 (Milano 1994).

Nikolai/Maddey 2009
C. Nikolai/G. Maddey, Tools of the Trade: A Survey of Various Agent Based Modeling Platforms. Journal of Artificial Societies and Social Simulations 12 (2) 2, 2009. http://jasss.soc.surrey.ac.uk/12/2/2.html

Ozik et al. 2008
J. Ozik/D. L. Sallach/Ch. M. Macal, Modeling Dynamic Multiscale Social Processes in Agent-Based Models. IEEE Intelligent Systems 23, 4, 2008, 36–42.

Reid-Sarkees/Wayman 2010
M. Reid-Sarkees/F. W. Wayman, Resort to War: A Data Guide to Inter-State, Extra-State, Intra-State, and Non-State Wars, 1816–2007. Correlates of War Series (Washington/DC 2010).

Riker 1962
W. H. Riker, The Theory of Political Coalitions (New Haven/CT 1962).

Rogers 2007
J. D. Rogers, The Contingencies of State Formation in Eastern Inner Asia. Asian Perspectives 46, 2, 2007, 249–274.

Rogers 2012
J. D. Rogers, Inner Asian States and Empires: Theories and Synthesis. Journal of Archaeological Research 20, 2012, 205–256.

Rogers/Cioffi-Revilla 2009
J. D. Rogers/C. Cioffi-Revilla, Expanding Empires and the Analysis of Change. In: Bemmann et al. 2009, 445–459.

Rogers et al. 2011
J. D. Rogers/T. Nichols/M. Latek/C. Cioffi-Revilla, Modeling Scale and Variability in Human-Environmental Interactions in Inner Asia. Ecological Modeling 241, 2011, 5–14.

Russett 1968
B. M. Russett, Is there a long-run trend toward concentration in the international system? In: B. M. Russett (ed.), Economic Theories of International Politics. Markham Political Science Series (Chicago 1968) 304–321.

Russett et al. 2000
B. M. Russett/H. Starr/D. Kinsella, World Po-

litics: The Menu for Choice. 6th ed. (Boston 2005).

Sargent 2004
R. G. Sargent, Verification and Validation of Simulation Models. In: S. G. Henderson/B. Biller/M. H. Hsieh/J. Shortle/J. D. Tew/R. R. Barton (eds.), Proceedings of the 2007 Winter Simulation Conference, December 9–12, 2007, Washington, DC (New York 2007).

Simon 1996
H. A. Simon, The Sciences of the Artificial. 3rd ed. (Cambridge/MA 1996).

Sinor 1990
D. Sinor (ed.), The Cambridge History of Early Inner Asia (Cambridge, New York, Melbourne 1990).

Sneath 2006
LD. Sneath (ed.), Imperial Statecraft: Political Forms and Techniques of Governance in Inner Asia, Sixth–twentieth Centuries. Studies on East Asia 26 (Bellingham/WA 2006).

Taagepera 1978
R. Taagepera, Size and duration of empires: growth-decline curves, 3000 to 600 BC. Social Science Research 7, 1, 1978, 180–96.

Tuma/Hannan 1984
N. Tuma/M. T. Hannan, Social Dynamics: Models and Methods. Quantitative Studies in Social Relations (Orlando/FL 1984).

Turchin 2003
P. Turchin, Historical dynamics: Why states rise and fall. Princeton Studies in Complexity (Princeton/NJ 2003).

Walker/Janssen 2002
B. H. Walker/M. A. Janssen, Rangelands, Pastoralists and Governments: Interlinked Systems of People and Nature. Philosophical Transactions: Biological Sciences 357 (1421), 2002, 719–725.

Ward/Gleditsch 2008
M. D. Ward/K. S. Gleditsch, Spatial Regression Models. Sage University Papers Series. Quantitative Applications in the Social Science 155 (Thousand Oaks/CA 2008).

Wasserman/Faust 1994
St. Wasserman/K. Faust, Social Network Analysis. Structural Analysis in the Social Sciences (Cambridge 1994).

Waugh/Greenberg 1986
Ch. G. Waugh/M. H. Greenberg (eds.), Alternative Histories: Eleven Stories of the World as it might have been. Garland Reference Library of the Humanities 623 (New York 1986).

Zagare/Kilgour 2000
F. C. Zagare/D. M. Kilgour, Perfect Deterrence. Cambridge Studies in International Relations 72 (Cambridge 2000).

COMPLEXITY OF INTERACTION ALONG THE EURASIAN STEPPE ZONE IN THE FIRST MILLENNIUM CE

Bonn Contributions to Asian Archaeology

Volume 7

Edited by

Jan Bemmann

COMPLEXITY OF INTERACTION ALONG THE EURASIAN STEPPE ZONE IN THE FIRST MILLENNIUM CE

Edited by
Jan Bemmann, Michael Schmauder

2015
Vor- und Frühgeschichtliche Archäologie
Rheinische Friedrich-Wilhelms-Universität Bonn

708 pages, 176 figures, 12 tables

The conference and the publication were generously financed by
Gerda Henkel Stiftung
Landschaftsverband Rheinland mit LVR-Landesmuseum Bonn

The conference was co-organized and the book is co-edited by
Ursula Brosseder, Susanne Reichert, and Timo Stickler

Ein Titelsatz ist bei der Deutschen Bibliothek erhältlich
(http://www.ddb.de)

Desktop Publishing and Design: Matthias Weis
Translations: Authors, Daniel C. Waugh
English language editors: Alicia Ventresca Miller, Susanne Reichert
Image editing: Gisela Höhn, Matthias Weis
Final editing: Ute Arents, Güde Bemmann
Printing and binding:
DDD DigitalDruck Deutschland GmbH & Co. KG – Aalen
Printed in Germany

Cover illustration: Martin Pütz

ISBN 978-3-936490-14-7

CONTENTS

NOMADIC INTERACTION WITH THE ROMAN AND BYZANTINE WEST

PREFACE

This volume combines contributions to a conference of the same title which was held February 9 to 11, 2012, in Bonn. Idea and format of the meeting had been developed through a process of intensive discussions among the editors in close cooperation with Dieter Quast, RGZM Mainz. Our original intention was to organize a conference with a focus on archaeology, bearing in mind questions concerning mobility and communication or – stated differently – exchange patterns in Eurasia. After having recognized that research in Eurasia is still dominated by site centric approaches which makes vast overviews as we imagined them somewhat cumbersome we deviated from our first outline.

As a consequence, we broadened the field for two further aspects which had been nearly neglected thus far. First, there are West–East ranging communications in the Eurasian steppe zone which lie beyond the overarching term "Silk Roads". As written sources rarely throw light on interactions among steppe polities, these interactions are markedly less frequently subject to scientific discussions. This question is best approached via archaeological analyses with a wide focus in geographical terms. North–South contacts are by far more commonly discussed than West–East communications, as they encompass interactions between states with foremost sedentary population and nomads who live north of these territories. As a rule, it is the sedentary viewpoint which is being told, as these cultures opposed to the nomads left numerous written accounts[1]. At the same time we wanted to encourage comparative perspectives. Characteristics often assumed to be typical of the relations between sedentary people and nomads are also true in comparable measures of those between Rome/Byzantium and their "barbaric" neighbors. What they all have in common is at least a distinct mobility in space, even though to varying forms and degrees. Furthermore, questions and themes long discussed in European archaeology and history entered the research of Inner Asia and Central Asia only recently, as, for example, identity, the emergence of new ethnic groups, frontiers, frontier societies, contact zones, elites, economies of prestige goods. We therefore wanted to invite colleagues of different disciplines and regions to join in a scientific dispute. Lively discussions during the conference and positive feedback by attendees show that this idea was appreciated.

The second aspect to be included can be summarized under the term "complexity", which in this context should not be understood as a concept from the social sciences but metaphorically. Over long periods of time simple explanations of cultural phenomena were favored, be it statements on pure and poor nomads, the dependency theory or the bad habit of explaining every cultural change with large-scale migrations. "Complexity" is meant as a signal and reminder that the simplest explanations are not always the best, which is reflected by the contributions in this volume.

[1] Numerous projects within the framework of the Collaborative Research Center (Sonderforschungsbereich) 586 "Difference and Integration" at the University Leipzig and the Martin-Luther University Halle-Wittenberg dealt intensively with interactions between nomads and settled people, a good overview of publications thus far is given by the center's website http://nomadsed.de/home/.

We consciously limited the temporal scope of the papers to the time after the Scyths and before the Mongols, somewhat clumsily described as the "first millennium CE", because these two eras have been traditionally paid enormous attention to and are represented in a corresponding flood of publications[2]. At the same time interactions in the steppe zone witnessed only during the centuries around the turn of the era a hitherto unknown rise in intensity and dynamics.

Not all of the works presented at the conference are included in this volume as they were already noted for publications elsewhere. This applies to the presentations given by Enno Giele, Valentina Mordvintseva, and Matthias Pfisterer. However, other colleagues who could not attend the conference were invited to hand in manuscripts. All contributions were revised and partly expanded, which to our delight resulted in this comprehensive volume. We would have loved to have included a paper on the consequences of climate change and meteorological events on the polities of the Eurasian steppe as such conditions win more and more popularity as *explanans* of significant changes[3], but it did not work out. To our dismay and because of different reasons the western steppes and Central Asia are less represented than we wished for.

We subdivided the contributions into four parts: "Nomadic Empires – Modes of Analysis" encompasses highly different approaches to interpretations and analyses of nomadic empires, ranging from computational agent-based models, over anthropological to historical methodology. Better than any perfect introduction this multi-facetted research shows how exciting it is to deal with this area much neglected in World History. Although the section "Xiongnu, the Han Empire and the Oriental Koine" assembles merely three contributions, it covers more than 260 pages. If nothing else, this certainly echoes the boom of Xiongnu archaeology of the past decades. By taking into account enormous amounts of archaeological, art historical, and written sources the authors surmount traditional and often too static schemes of interpretation. These new analyses detect an astonishing variety of interactions during the centuries around the turn of the era, which broadens our understanding of this epoch and provides new avenues for other regions and periods at the same time. In the third section, "Inner and Central Asia from the Türks to the Mongols", nine contributions exemplify a multicolored and almost continuously changing picture of languages, ethnicities, and political affinities for Inner and Central Asia from the sixth to the twelfth centuries. Political affinities, however, were changing so quickly due to situational demands as to almost refute all efforts to retrace them within the archaeological record. Decision makers were astonishingly well informed about even distant regions and they acted accordingly over vast distances. The studies at hand analyze exchange processes on varying

2 See for the Scyths for example W. Menghin/H. Parzinger/A. Nagler/M. Nawroth (eds.), Im Zeichen des goldenen Greifen. Königsgräber der Skythen. Begleitband zur gleichnamigen Ausstellung: Berlin, Martin-Gropius-Bau, 6. Juli – 1. Oktober 2007; München, Kunsthalle der Hypo-Kulturstiftung, 26. Oktober 2007 – 20. Januar 2008; Hamburg, Museum für Kunst und Gewerbe Hamburg, 15. Februar – 25. Mai 2008 (München, Berlin 2007); H. Parzinger, Die Skythen. 3rd ed. (München 2009); J. Aruz (ed.), The Golden Deer of Eurasia: Scythian and Sarmatian Treasures from the Russian Steppes (New York, New Haven 2000); J. Aruz/A. Farkas/A. Alekseev/E. Korolkova (eds.), The Golden Deer of Eurasia. Perspectives on the Steppe Nomads of the Ancient World. The Metropolitan Museum of Art Symposia (New Haven 2006). See for the Mongol period Dschingis Khan und seine Erben. Das Weltreich der Mongolen (2005); W. W. Fitzhugh/M. Rossabi/W. Honeychurch (eds.), Genghis Khan and the Mongol Empire (Seattle 2009); see also the website of the European Research Council Grant "Mobility, Empire and Cross Cultural Contacts in Mongol Eurasia" http://mongol.huji.ac.il/, which provides an extensive bibliography.

3 N. Pederson/A. Hessl/N. Baatarbileg/K. Anchukaitis/N. Di Cosmo, Pluvials, Droughts, the Mongol Empire, and Modern Mongolia. Proceedings of the National Academy of Sciences 111, 2014, 4375–4379; J. Fei/J. Zhou/Y. Hou, Circa A.D. 626 Volcanic Eruption, Climatic Cooling, and the Collapse of the Eastern Turkic Empire. Climatic Change 81, 2007, 469–475.

levels – from language to embassies – as well as aspects of mobility, from the integration of foreign symbols of power to large-scale migrations, or methods of state-building to the strategic destruction of complex states. The last section combines papers that focus on "Nomadic Interaction with the Roman and Byzantine West" traversing the Eurasian steppe zone from east to west. These case studies, either already comparative or suitable for further comparisons, give reason to assume that although there are certain encompassing communalities every conquest and struggle with the empires of the West is historically unique. At the same time it becomes apparent that the knowledge base of the decision makers in the Roman Empire had been greater than hitherto thought.

The variety of studies assembled in this volume leaves no doubt as to how dynamically and diversely the interactions, processes, and transformations developed in the Eurasian steppe zone. These changes cannot be studied under common schemes of interpretation which are more often than not inseparable from overcome clichés.

Chinese names and terms have been transliterated according to the Pinyin system, Russian names and references according to the system of the Library of Congress. Arabic, Persian, and Turkic names and terms appear in the form chosen by the authors of the individual chapters.

Acknowledgements

The conference had been jointly prepared and organized together with Ursula Brosseder and Timo Stickler. We thank both of them for their cordial and companionable collaboration. Susanne Reichert engaged to such an extent in the editing work of the papers that it was a delight for us to include her as co-editor. The edition of this volume in addition to ongoing obligations and projects could only be managed as a team.

Our heartfelt thanks also goes to Daniel Waugh, Seattle, who has helped us now repeatedly with translations and language editing. Without his honorary efforts we would never have been able to integrate Sergey Vasyutin's thoughts in this book. Thanks to his enormous overview and language knowledge Peter Golden saved us from mistakes concerning the correct transliteration of names in the contributions of Tatiana Skrynnikova and Sergey Vasyutin. Image editing lay in Gisela Höhn's sterling hands. She also promoted to create – as far as possible – a unified map basis for all contributions as to facilitate visualizing the different regions. Editing work was done by the proven team Ute Arents and Güde Bemmann, substantially supported by Susanne Reichert. We owe Alicia Ventresca Miller, Kiel, as a native speaker many suggestions for improvement and stimuli. All authors and editors highly appreciate their painstaking efforts. For desktop publishing, which in the face of a multitude of different scripts demands unconventional solutions, we were able to win Matthias Weis. If not stated otherwise, images were provided by the authors and merely serve to illustrate.

The conference was made possible by the generous financial support from the Gerda Henkel Foundation. As always, it was our delight to collaborate with the foundation, a cooperation characterized by mutual trust. The meeting took place in the LVR-LandesMuseum Bonn, which during the same time displayed the exhibition "Steppe Warriors – Nomads on Horseback of Mongolia from the 7th to 14th centuries" ("Steppenkrieger – Reiternomaden des 7.–14. Jahrhunderts aus der Mongolei"). Thus the participants had the opportunity to get insight into an on-

going cooperation between the Institute of Archaeology of the Mongolian Academy of Sciences, the Department of Prehistory and Early Historical Archaeology of the University of Bonn, and the LVR-LandesMuseum Bonn. We thank the State Association of the Rhineland (Landschaftverband Rheinland) for the use of rooms and technical equipment of the museum and the financial support in printing this volume.

Our sincere thanks is owed to everyone who contributed to the success of the conference and the resulting book. With great joy we remember the inspiring and cordial atmosphere during the meeting.

Jan Bemmann, Michael Schmauder March 2015

INDEX OF AUTHORS

Prof. Dr. Jan Bemmann
Prehistory and Early Historical Archaeology
University of Bonn
Regina-Pacis-Weg 7
53113 Bonn, Germany
E-Mail: jan.bemmann@uni-bonn.de

Prof. Dr. Michal Biran
Institute of Asian and African Studies
The Louis Frieberg Center for East Asian Studies
The Hebrew University of Jerusalem
Mt. Scopus
Jerusalem, 91905, Israel
E-Mail: biranm@mail.huji.ac.il

Dr. Ursula B. Brosseder
Prehistory and Early Historical Archaeology
University of Bonn
Regina-Pacis-Weg 7
53113 Bonn, Germany
E-Mail: ursula.brosseder@uni-bonn.de

Prof. Dr. Claudio Cioffi-Revilla
Krasnow Institute for Advanced Study
Computational Social Science, Center for Social Complexity
George Mason University
Research-1 Bldg MS 6B2,
4400 University Drive
Fairfax, VA 22030, USA
E-Mail: ccioffi@gmu.edu

Prof. Dr. Nicola Di Cosmo
Henry Luce Foundation Professor of East Asian Studies
School of Historical Studies
Institute for Advanced Study
Einstein Drive
Princeton, NJ 08540, USA
E-Mail: ndc@ias.edu

Prof. Dr. Michael R. Drompp
Department of History
Rhodes College
2000 North Parkway
Memphis, TN 38112, USA
E-Mail: drompp@rhodes.edu

Prof. Dr. Peter B. Golden
Center for Middle Eastern Studies
Rutgers University
Lucy Stone Hall B-316
54 Joyce Kilmer Avenue
Piscataway, NJ 08854, USA
E-Mail: pgolden@andromeda.rutgers.edu

Prof. Dr. Thomas O. Höllmann
Institute for Chinese Studies
Ludwig-Maximilians-University Munich
Kaulbachstr. 51a
80539 München, Germany
E-Mail: thomas.hoellmann@lrz.uni-muenchen.de

Ass. Prof. Dr. William Honeychurch
Department of Anthropology
Yale University
51 Hillhouse Avenue
New Haven, CN 06511, USA
E-Mail: william.honeychurch@yale.edu

Prof. Dr. Nikolai N. Kradin
Russian Academy of Sciences,
Far Eastern Branch
Institute of History, Archaeology and Ethnography
Pushkinskaia Ul. 10
Vladivostok, 690950, Russia
E-Mail: kradin@mail.ru

Prof. Dr. Étienne de la Vaissière
École des hautes études en sciences sociales (EHESS)
Centre d'Études Turques, Ottomanes, Balkaniques et Centrasiatiques (CETOBaC)
190–198, Avenue de France
75244 Paris Cedex 13, France
E-Mail: vaissier@ens.fr

Prof. Dr. Mischa Meier
Department of History
University of Tübingen
Wilhelmstr. 36
72074 Tübingen, Germany
E-Mail: mischa.meier@uni-tuebingen.de

Dr. Bryan K. Miller
Faculty of History
University of Oxford
George Street
Oxford OX1 2RL, United Kingdom
E-Mail: millerbryank@gmail.com

Prof. Dr. Marek Jan Olbrycht
Institute of History
University of Rzeszów
Ul. Rejtana 16c
35-959 Rzeszów, Poland
E-Mail: marekolbrycht@wp.pl

Prof. Dr. Jürgen Paul
Institute for Oriental Studies
Martin-Luther-University Halle-Wittenberg
Mühlweg 15
06114 Halle/Saale, Germany
E-Mail: juergen.paul@orientphil.uni-halle.de

Prof. Dr. Walter Pohl
Institute for Medieval Research
Austrian Academy of Sciences
Wohllebengasse 12-14
1040 Wien, Austria
E-Mail: walter.pohl@oeaw.ac.at

Dr. J. Daniel Rogers
Smithsonian Institution
National Museum of Natural History
Department of Anthropology, NHB 112
PO Box 37012
Washington, DC 20013, USA
E-Mail: rogersd@si.edu

Prof. Dr. Michael Schmauder
LVR-LandesMuseum Bonn
Colmantstr. 14-16
53115 Bonn, Germany
E-Mail: michael.schmauder@lvr.de

Prof. Dr. Tatiana Skrynnikova
The Department of Central Asian and South Asian Studies
Institute of Oriental Manuscripts
Russian Academy of Sciences
Dvortsovaya Emb. 18
Sankt-Petersburg 191186, Russia
E-Mail: skryta999@mail.ru

Ass. Prof. Dr. Sören Stark
Institute for the Study of the Ancient World
New York University
15 East 84th St.
New York City, NY 10028, USA
E-Mail: soeren.stark@nyu.edu

Prof. Dr. Timo Stickler
Department of Ancient Studies
Friedrich Schiller University Jena
Fürstengraben 1
07743 Jena, Germany
E-Mail: timo.stickler@uni-jena.de

Prof. Dr. Pavel E. Tarasov
Institute of Geological Sciences, Palaeontology
Freie Universität Berlin
Malteserstr. 74-100, Haus D
12249 Berlin, Germany
E-Mail: ptarasov@zedat.fu-berlin.de

Dr. Sergey Aleksandrovich Vasyutin
Department of the History of Civilizations and Socio-Cultural Communications
Kemerovo State University
Krasnya 6
650043 Kemerovo, Russia
E-Mail: vasutin2012@list.ru

Prof. Dr. Mayke Wagner
Branch office of the Eurasia Department in Beijing
German Archaeological Institute
Im Dol 2-6, Haus II
14195 Berlin, Germany
E-Mail: mwa@zedat.fu-berlin.de; mw@eurasien.dainst.de

BONN CONTRIBUTIONS TO ASIAN ARCHAEOLOGY

Edited by Jan Bemmann

1. H. Roth / U. Erdenebat / E. Nagel / E. Pohl (eds.),
Qara Qorum City (Mongolei) 1.
Bonn Contributions to Asian Archaeology, Volume 1 (Bonn 2002).
Out of print – ISBN 3-936490-01-5

2. J. Bemmann / U. Erdenebat / E. Pohl (eds.),
Mongolian-German Karakorum-Expedition, Volume 1.
Excavations in the Craftsmen-Quarter at the Main Road.
Forschungen zur Archäologie Außereuropäischer Kulturen 8 =
Bonn Contributions to Asian Archaeology, Volume 2 (Wiesbaden 2009).
€ 98,00 – ISBN 978-3-89500-697-5

3. P. B. Konovalov,
The Burial Vault of a Xiongnu Prince at Sudzha (Il'movaia pad', Transbaikalia).
Bonn Contributions to Asian Archaeology, Volume 3 (Bonn 2008).
€ 13,90 – ISBN 3-936490-29-5

4. J. Bemmann / H. Parzinger / E. Pohl / D. Tseveendorzh (eds.),
Current Archaeological Research in Mongolia. Papers from the First International
Conference on "Archaeological Research in Mongolia", held in Ulaanbaatar,
August 19th–23rd, 2007.
Bonn Contributions to Asian Archaeology, Volume 4 (Bonn 2009).
€ 74,00 – ISBN 978-3-936490-31-2

5. Ursula Brosseder / Bryan K. Miller (eds.),
Xiongnu Archaeology. Multidisciplinary Perspectives of the
First Steppe Empire in Inner Asia.
Bonn Contributions to Asian Archaeology, Volume 5 (Bonn 2011).
€ 80,00 – ISBN 978-3-936490-14-7

6. Catrin Kost,
The practice of imagery in the northern Chinese steppe (5th – 1st centuries BCE).
Bonn Contributions to Asian Archaeology, Volume 6 (Bonn 2014).
€ 98,00 – ISBN 978-3-936490-32-9

7. J. Bemmann/M. Schmauder (eds.),
Complexity of Interaction along the Eurasian Steppe Zone in the first Millennium CE
Bonn Contributions to Asian Archaeology, Volume 7 (Bonn 2015).
€ 111,00 – ISBN 978-3-936490-14-7

Orders and information: sekretariat.vfgarch@uni-bonn.de (1, 3–7), info@reichert-verlag.de (2)