



Agent-based Modeling and Simulation of Adaptation and Long-Term Change in Inner Asia (v.0.1)



Smithsonian Institution

C. CIOFFI-REVILLA, S. LUKE, D.C. PARKER, M. TSVETOVAT, *George Mason University*
 J.D. ROGERS, W.W. FITZHUGH, W. HONEYCHURCH, B. FROHLICH, P. DePRIEST, *Smithsonian NMNH*
 R. LATIMER, *T. Jefferson High School of Science* and C. AMARTUVSHIN, *Mongolian Academy of Sciences*
 Student Researchers: G.C. Balan, R. Casstevens, C. Eltrich, J. Harrison, M. Latek, M.M. Rizi, S. Wilcox



MOTIVATION

Main scientific puzzles addressed:

- How do societies evolve or fail when challenged by threats or opportunities?
- How does success or failure in collective action affect social complexity?
- How did polities rise and fall in Inner Asia since ca. 3000 BC?

Main gaps in needed scientific knowledge:

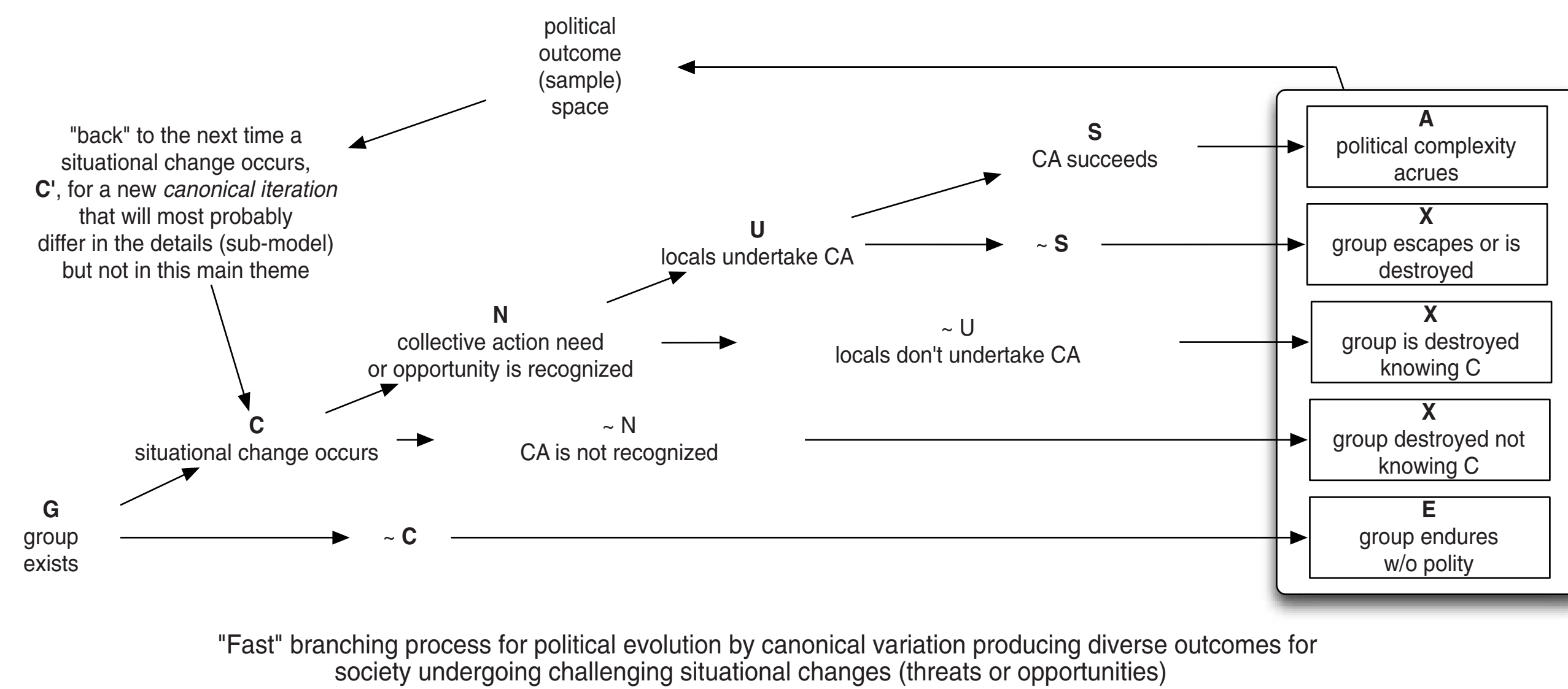
- *Lack of theory:* Needed to advance our understanding of long-term societal dynamics
- *Lack of data:* Needed for knowing the history of when, where, and how polities evolved
- *Lack of models:* Needed for developing validated/calibrated agent-based computational models with sufficiently complex and shifting environments

THEORY AND HYPOTHESES

Polities evolve by a process of "canonical variation" (Cioffi-Revilla 2005), whereby a society increases or decreases its political complexity (overall governance capacity) depending on success or failure in meeting collective action challenges (threats or opportunities).

Sociopolitical evolution by canonical variation occurs on two distinct **time-scales**:

- A **fast process** determines whether a society is successful or not in meeting collective action needs
- A **slow process** determines whether a society develops or declines depending on the cumulative effects of numerous and often parallel fast processes

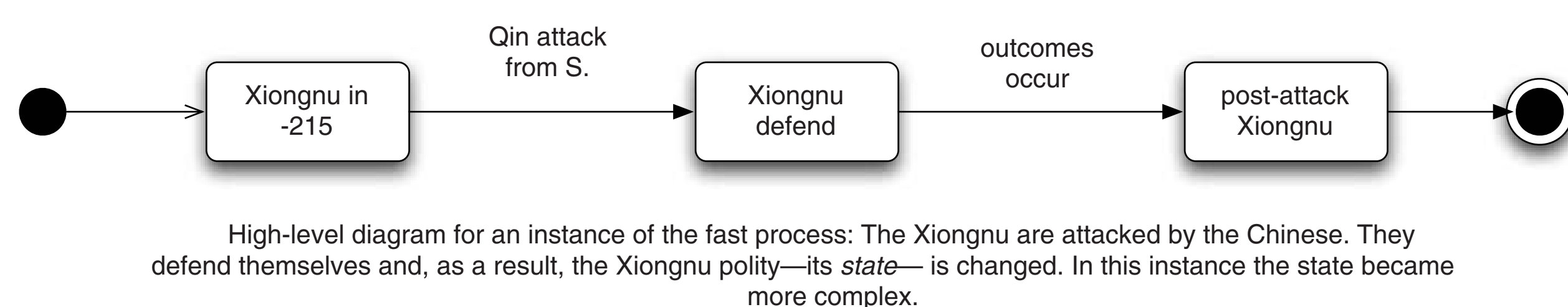
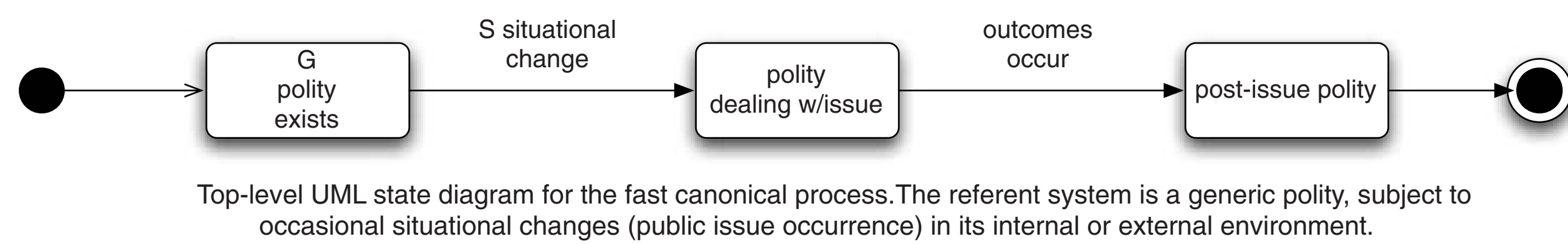


Why is the fast process called "canonical"?

- Because the same common theme in the event sequence G-C-N-U-S re-occurs again and again, throughout history, but with important variations caused by success and failure.

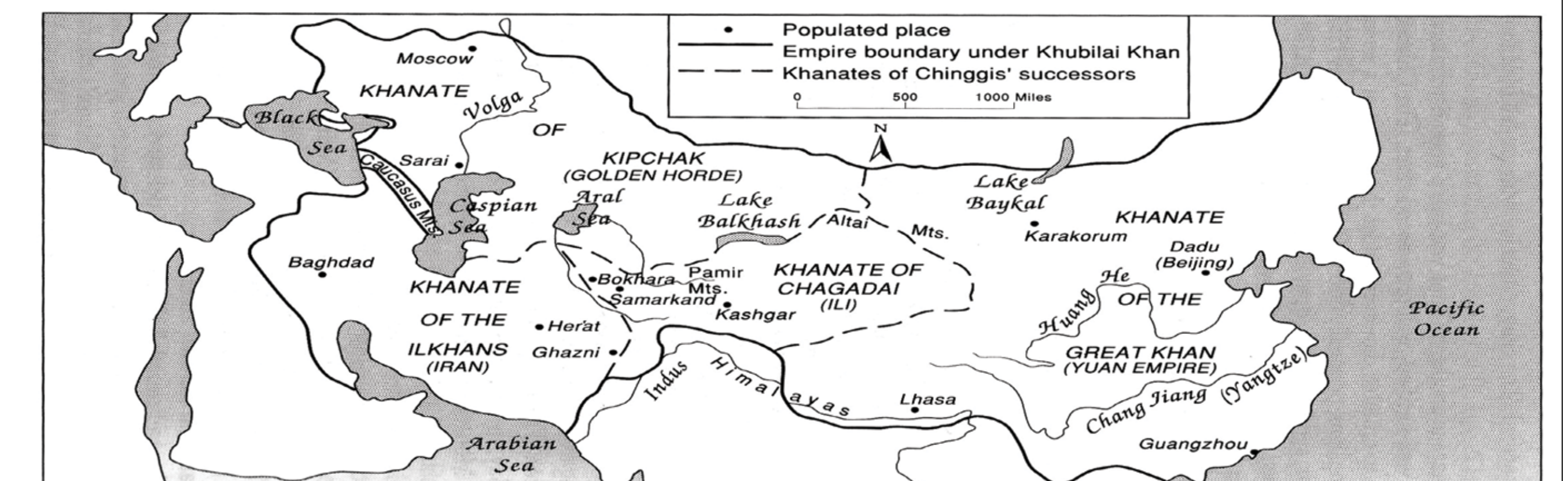
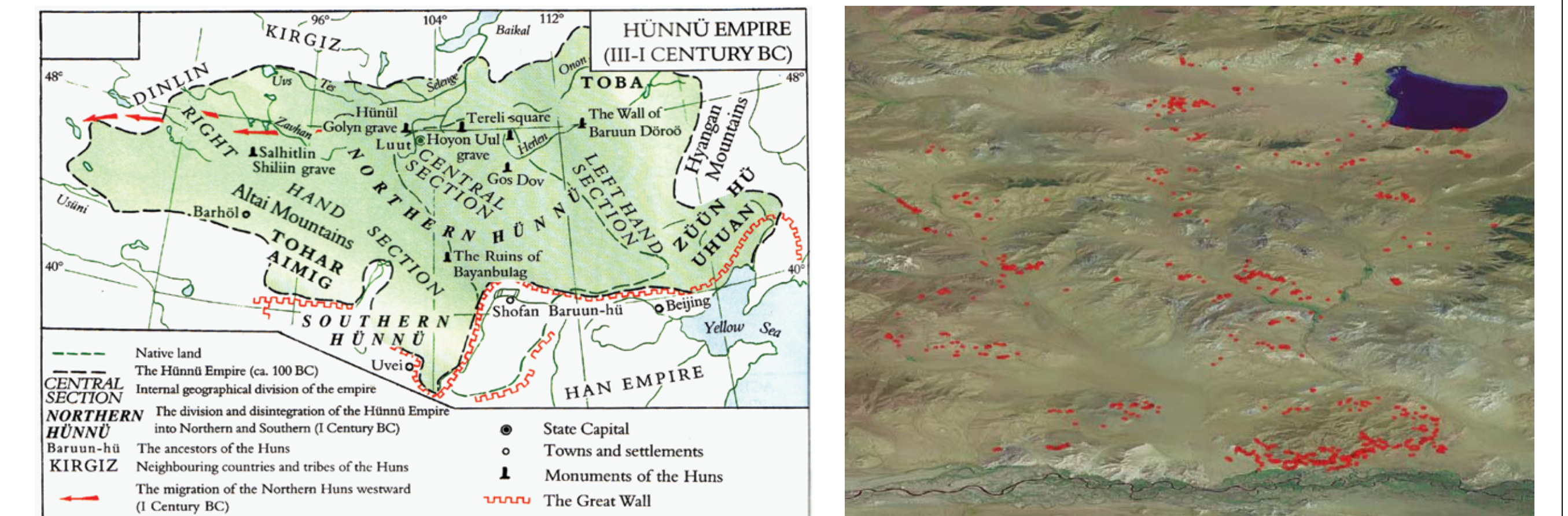
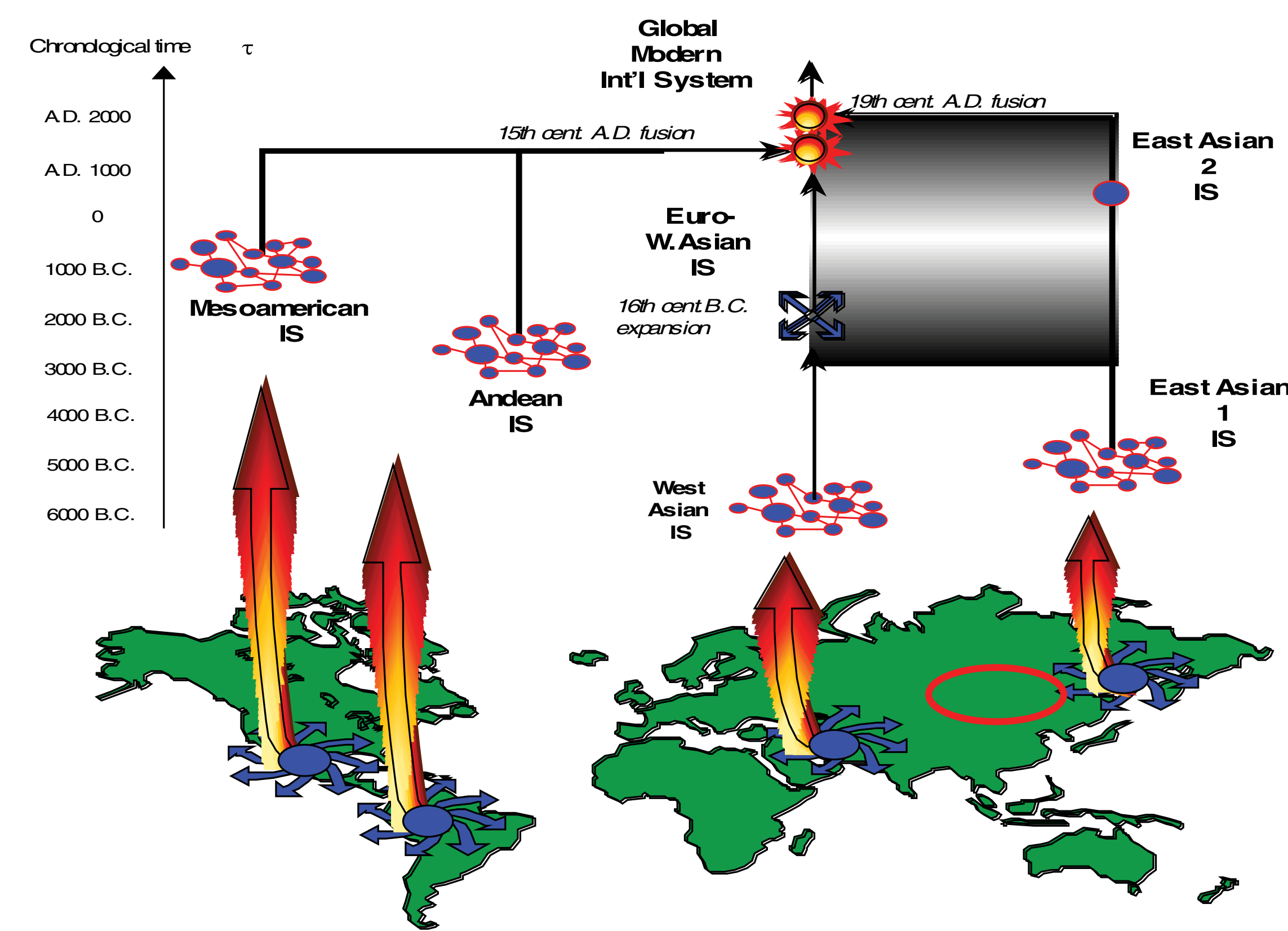
How does the fast process with canonical variations "feed into" the slow process?

- By a mechanism of "credit assignment", whereby different outcomes of the fast process produce positive and negative externalities for governance capacity



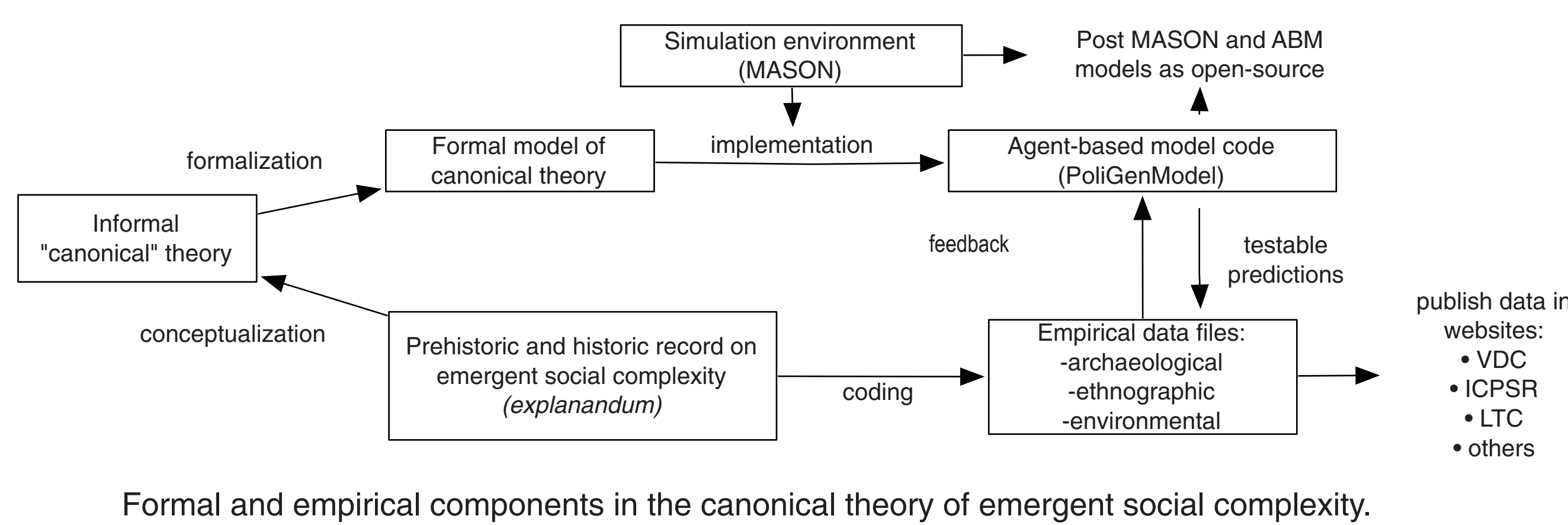
TARGET HISTORICAL SYSTEMS

Inner Asia (red oval) is a region that links the sociopolitically "pristine" regions of East Asia and West Asia after 3000 BC. Source: Cioffi-Revilla (2006).



How did Mongol society develop the largest territorial empire in the world history with only minor social complexity?

RESEARCH METHODOLOGY



EXPECTED PROJECT RESULTS: 2006-09

1. New scientific **concepts, theories, and methods** for understanding long-term societal dynamics in complex and shifting environments.
2. New **databases** on geographic, social, economic, political, military, technological attributes of Inner Asian societies, starting from ca. 3000 BC, including information on their physical environments.
3. New **computational models**—multi-agent systems or agent-based models—of societal evolution and adaptation, using the MASON system and evolutionary computation (see Research Methodology).

PROJECT-RELATED PUBLICATIONS

Cioffi-Revilla, Claudio. 2005. A Canonical Theory of Origins and Development of Social Complexity. *Journal of Mathematical Sociology* 29 (April-June):133-153.

Cioffi-Revilla, C., S. Luke, D. C. Parker, J. D. Rogers, W. W. Fitzhugh, W. Honeychurch, B. Frohlich, P. DePriest, and N. Bazarsad. 2006. Agent-based dynamics of social complexity: Modeling Adaptive Behavior and Long-Term Change in Inner Asia. *Proceedings of the North American Association for Computational Social and Organizational Sciences NAACOS 2006*, June 22-23, Notre Dame, IN, USA.

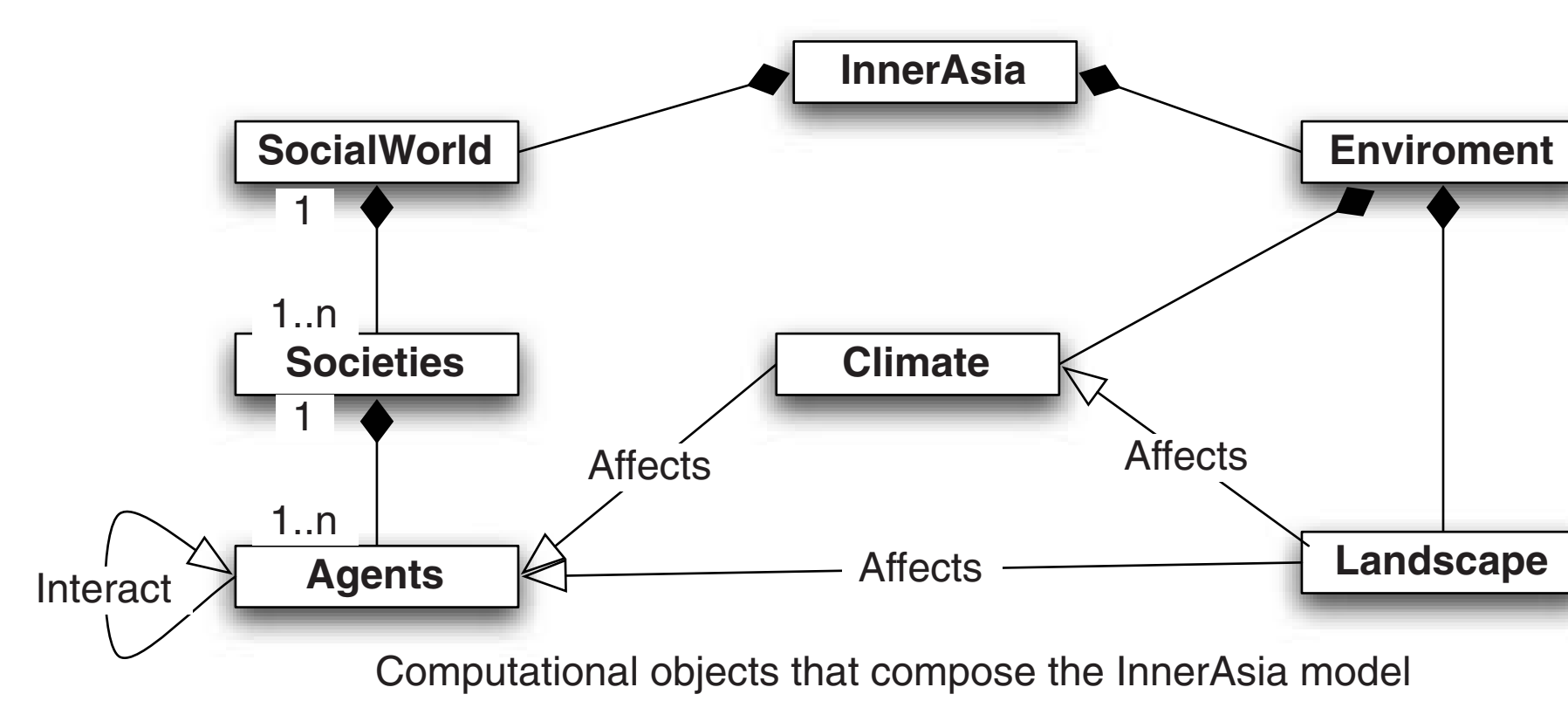
Cioffi-Revilla, C., S. Luke, D. C. Parker, J. D. Rogers, W. W. Fitzhugh, W. Honeychurch, B. Frohlich, P. DePriest, and N. Bazarsad. 2006. Agent-based dynamics of social complexity: Modeling Adaptive Behavior and Long-Term Change in Inner Asia. *Proceedings of 20th World Congress of the International Political Science Association IPSA*, July 9-12, Fukuoka, Japan.

Cioffi-Revilla, C., S. Luke, D. C. Parker, J. D. Rogers, W. W. Fitzhugh, W. Honeychurch, B. Frohlich, P. DePriest, and N. Bazarsad. 2006. Agent-based dynamics of social complexity: Modeling Adaptive Behavior and Long-Term Change in Inner Asia. Paper presented in the *First World Congress of Social Simulation*, August 21-25, Kyoto, Japan.

Powell, Eric A. 2006. Mysterious Mongolia. *Archaeology* 59 (1).

Rogers, J. Daniel, Erdenebat Ulambayar, and Matthew Gallon. 2004. Urban Centers and State Development in Eastern Inner Asia. Washington, DC: Department of Anthropology, National Museum of Natural History, Smithsonian Institution.

Acknowledgements: This project is funded by the U.S. National Science Foundation, Human and Social Dynamics Program, grant no. 0527471.



Main methods employed by our team:

- Interdisciplinary collaboration
- Field research at archaeological sites (see red dots on the top right picture)
- Archival data collection
- GIS, including social and historical
- UML for designing models
- Agent-based modeling using MASON
- Evolutionary computation using ECJ

What Is MASON?

Multi-Agent Simulator of Networks and Neighborhoods

Main features:

- Fast and 100% Java
 - Separable computation - visualization
 - Guaranteed reproducible results
 - Free and open-source
- <http://cs.gmu.edu/~eclab/projects/mason/>