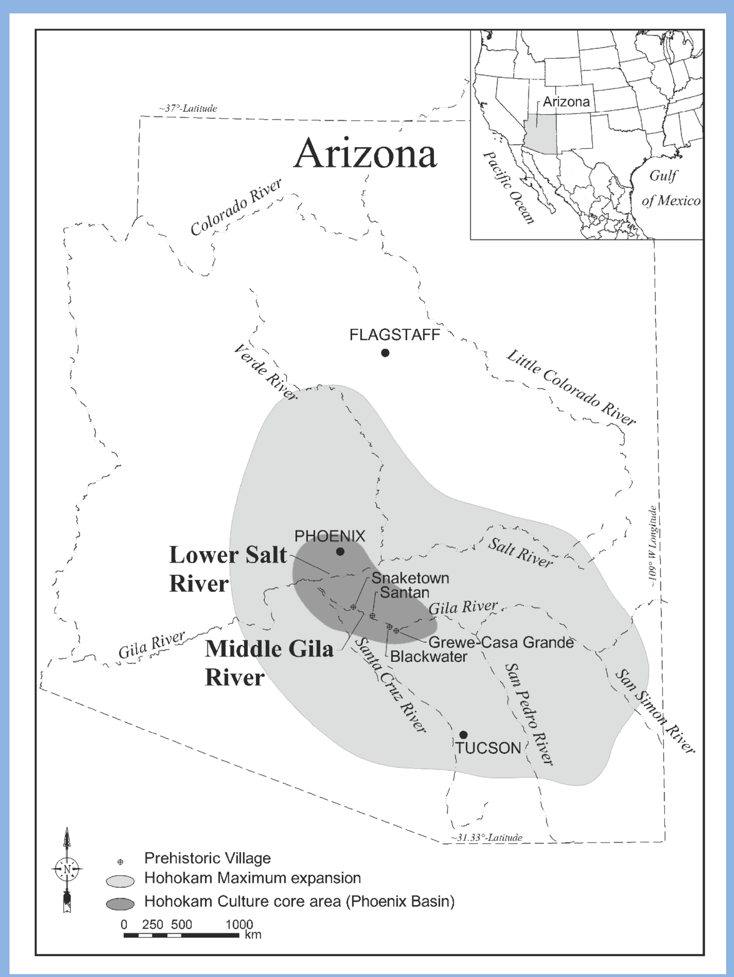
Anthropogenic Soil Formation During a Millennium of Prehistoric Irrigation Agriculture in the Gila River Valley, Arizona

J. Sandor (Iowa State Univ.), K. Woodson (Gila River Indian Community), C. Strawhacker (Natl. Snow & Ice Data Center), & W. Miles (Gila River Indian Community)

Introduction

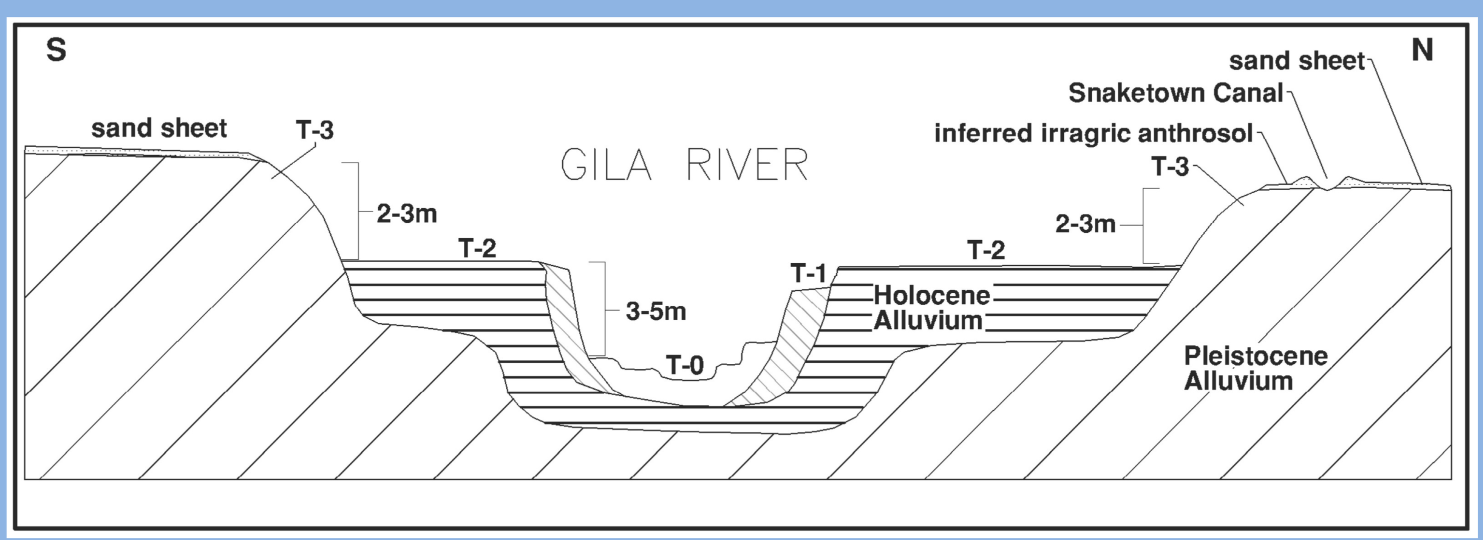
Agriculture has profoundly altered soils world-wide over thousands of years, both through deliberate management, and unintentionally. Ancient agricultural soils are long-term sources of data on anthropogenic soil change and processes. One kind of agricultural soil transformation is the development of irragric soils, which result from prolonged deposition and accumulation of fine sediments from irrigation water. Ancient irragric soils centuries to millennia old occur in several world regions, especially in arid environments of Asia and the Americas. Sediment deposition associated with irrigation agriculture greatly influences soil properties and agricultural productivity. We present evidence for an ancient irragric anthrosol in the American Southwest, along the Snaketown Canal–Field System in the middle Gila River Valley, Arizona. This soil formed during a millennium of irrigation (ca. 450 to 1450 A.D.) by prehistoric Hohokam farmers, who built the most extensive canal irrigation systems in the pre-Hispanic Americas north of Peru.

Objective: To present data about an irragric soil, formed during a millennium of riverine canal irrigation in the Phoenix Basin, as an example of the valuable information about long-term anthropogenic soil change and processes available from research of ancient agricultural soils.



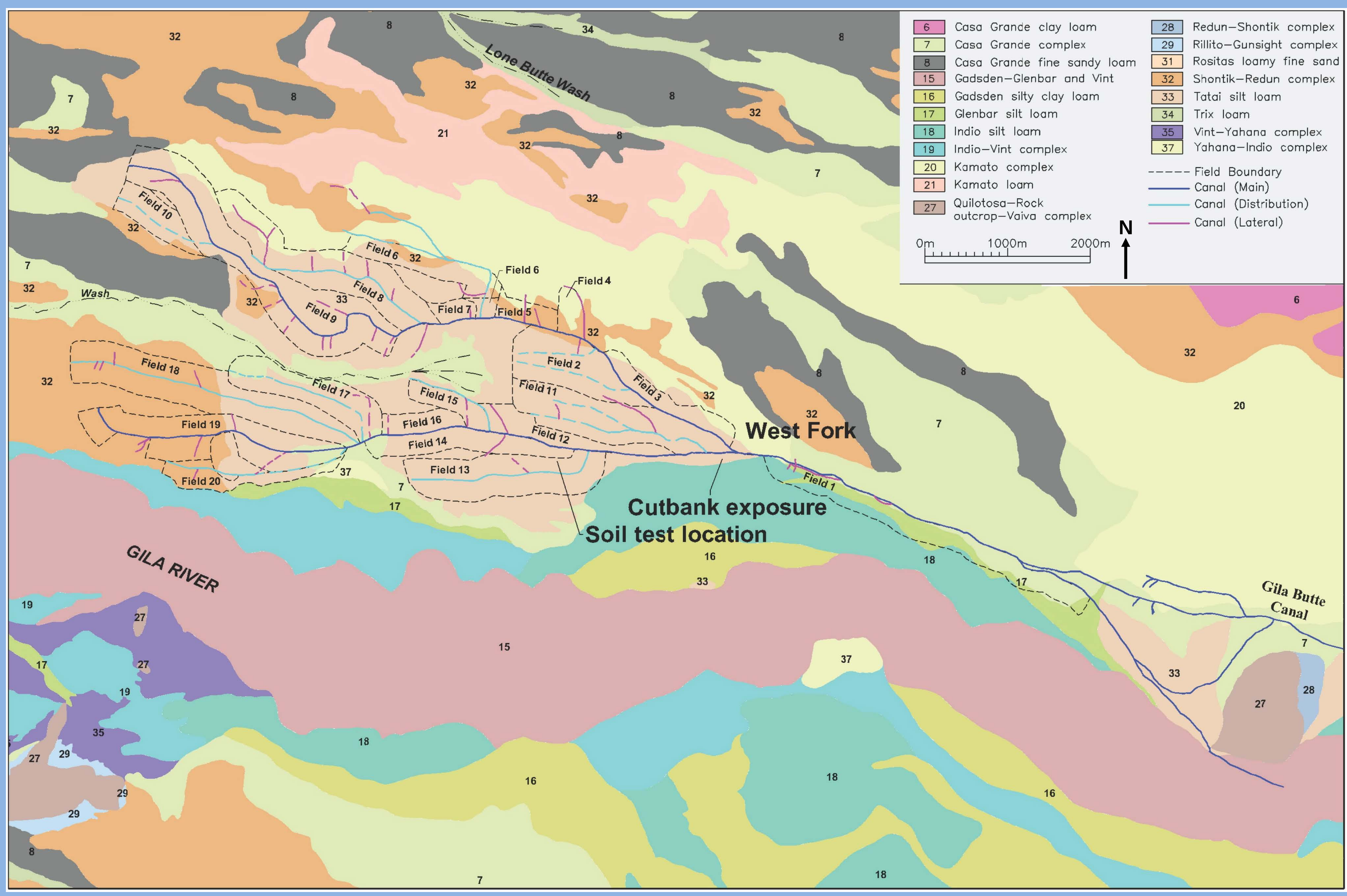
Prehistoric Hohokam irrigation canal excavated at Snaketown. Photo by Helga Teiwes.

Prehistoric Snaketown canal–field system, located on Pleistocene terrace of the Gila River (T-3 in generalized x-section below), mapped on to 1936 aerial photo. Sampling areas shown for comparison of soil properties within, adjacent to, and well–outside of the prehistoric irrigated fields (see table at lower right).



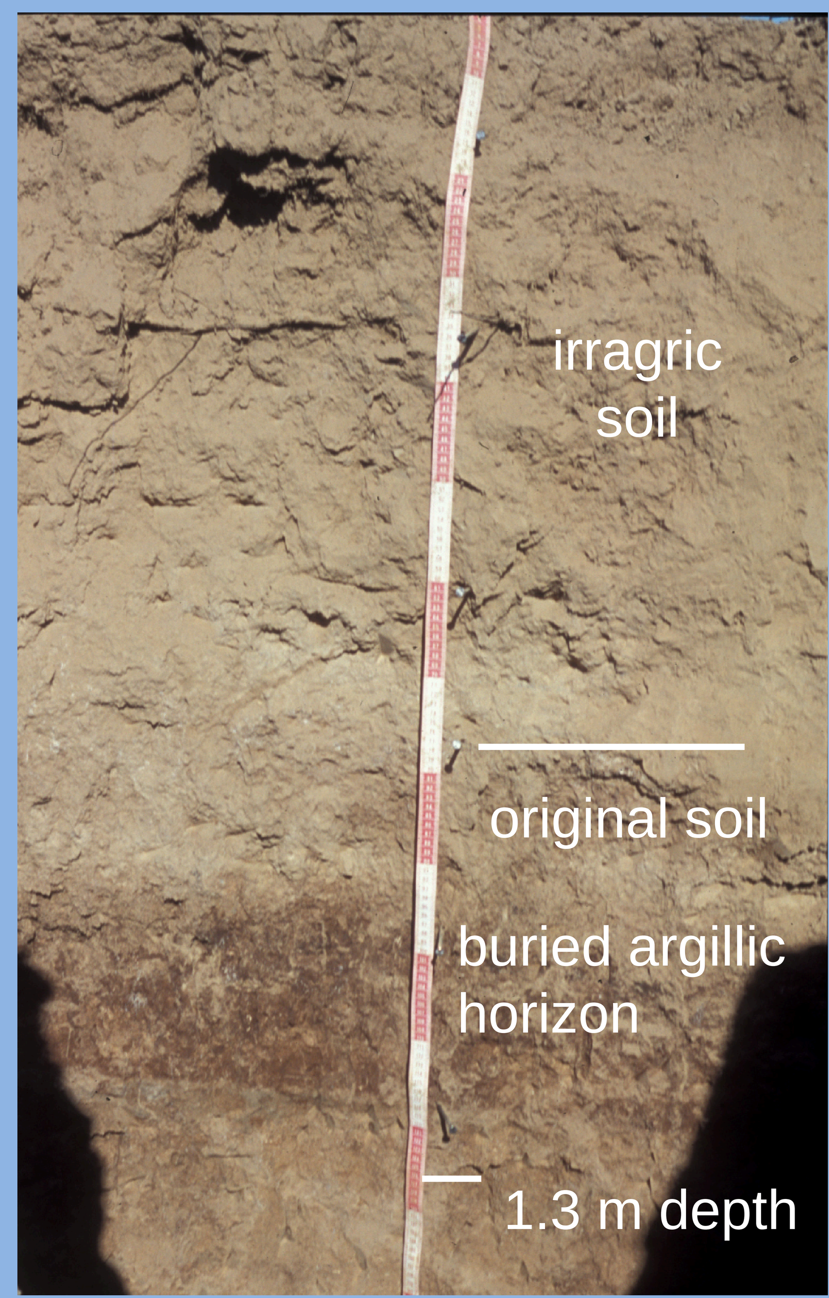
Irragric Soil Properties

The irragric soil consists of a mantle of silty-to-loamy textures with minimal pedogenic development overlying a natural soil with an argillic horizon on a Pleistocene stream terrace. Geologic studies indicate that this mantle is not natural loess or recent alluvium. A soil mapped independently by the USDA-Natural Resources Conservation Service with these horizons corresponds closely with the canal-field system. Sediment from prehistoric irrigation has been generally recognized in the region in the 1901 and 1998 soil surveys. Soil within the canal-field system tends to be lower in salt (EC), sodium (SAR), and pH compared with external soils. This suggests that irragric processes improved soil for crop production through long-term leaching and additions of fresh sediments with irrigation water. Indirect evidence for management of salt by the ancient farmers is 1) that the Snaketown irrigation system functioned for a long time (~ 1000 years), and 2) a record of careful salt management practices among historic Indian farmers in the area. See Woodson et al. (2015) for more information.



Map of the prehistoric Snaketown canal–field system overlaid on NRCS soil map, showing close correspondence between the Tatai soil (Map Unit 33 in table below) and the canal–field system. The soils and canal–field system were mapped independently.

NRCS soil map and information from Johnson et al. (1998) and NRCS web site (http://www.soils.usda.gov/). Soil texture class abbreviations: VFSL (very fine sandy loam), FSL (fine sandy loam), SCL (sandy clay loam), SIL (silt loam).



Light-colored mantle of silt loam is an anthropogenic irragric soil, about 77 cm thick, overlying the original soil that has an argillic horizon. Scale is divided into 10-cm bands.

Soil Series	Map Unit(s)	Classification (particle-size class and subgroup)	Summary of Key Properties
Casa Grande	6, 7, 8	Fine-loamy Typic Natrargid	natric horizon within 15 cm of surface overlain by FSL
Gadsden	15, 16	Fine Vertic Torrifluvent	undeveloped soil, mostly high clay throughout
Glenbar	15, 17	Fine-silty Typic Torrifluvent	undeveloped soil, loam - silt loam - to more clay throughout
Gunsight	29	Loamy-skeletal Typic Haplocalcid	high gravel content, sandy loam to loam
Indio	18, 19, 37	Coarse-silty Typic Torrifluvent	undeveloped soil, VFSL-SIL- to more clayey throughout
Kamato	20, 21	Fine Typic Natrargid	saline and sodic, natric horizon within 28 cm overlain by FSL
Quilotosa	27	Loamy-skeletal Lithic Torriorthent	undeveloped soil, high in gravel, shallow to bedrock
Redun	28, 32	Coarse-loamy Sodic Haplocambid	fine sandy loam to sandy loam throughout, some buried soil
Rillito	29	Coarse-loamy Typic Haplocalcid	average 15-35 % gravel, mostly sandy loam to loam
Rositas	31	Typic Torripsamment	undeveloped soil, mostly fine sand and loamy fine sand
Shontik	28, 32	Fine-loamy Sodic Haplocalcid	FSL to SCL over buried Bt-argillic horizon
Tatai	**33**	**Fine-loamy Sodic Haplocambid**	**silty to loamy over buried Bt-argillic horizon**
Trix	34	Fine-loamy Typic Torrifluvent	loamy (clay loam surface) over buried Bt-argillic horizon
Vaiva	27	Loamy-skeletal Lithic Haplargid	argillic horizon, high gravel content, shallow to bedrock
Vint	15, 19, 35	Sandy Typic Torrifluvent	undeveloped soil, mostly fine sand to loamy fine sand
Yahana	35, 37	Fine-silty Typic Haplosalid	highly saline & sodic, SIL, loam, silty clay loam, silty clay

Location Relative to Irrigated Agricultural Fields	Salinity - EC ($dS\ m^{-1}$)	Sodium - SAR	pH
Inside	14*	25***	8.1***
Adjacent	20	65	8.6
Well-Outside	21	57	8.5

Comparison of electrical conductivity (EC), sodium adsorption ratio (SAR), and pH (determined on saturated paste) between soils inside, adjacent to, and well-outside of the prehistoric Snaketown canal–field system. Data are means (weighted by layer thickness) for all depths sampled: surface soil (0-30 cm), mid-depth (30-91 cm), and deepest depth (> 91 cm). Asterisks indicate statistically significant differences among locations with the Kruskal–Wallis test at the following probability levels: *$P < 0.05$, ***$P < 0.001$. See Woodson et al. (2015) for more information. Data originally from ASC (2004).

Conclusions

- Anthropogenic sedimentation from a millennium of irrigation has had a long-lasting impact on the sedimentary record and soils in this arid environment.
- The Snaketown irrigated soil falls within the wide range of ancient irragric soils in other global regions for most characteristics such as age, duration, extent, sedimentation rate, thickness, texture, and salinity.
- Knowledge about ancient and traditional irrigation systems and soils can contribute to developing and maintaining viable and sustainable irrigation systems.

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