PART IV

DOCUMENTATION OF MONGOLIA'S DEER STONES – 2006 Field Season

Harriet F. (Rae) Beaubien
Senior Objects Conservator

Basiliki Vicky Karas
Contract Conservator, 3D scanning

Leslie G. Weber
Conservation Fellow, FY2006

OVERVIEW OF THE 2006 FIELD SEASON

The 2006 field season was the second year of conservators' involvement in the field activities of the Joint Mongolian-Smithsonian Deer Stone Project [DSP], directed by William W. Fitzhugh, of the National Museum of Natural History's Arctic Studies Center.[1] Led by senior conservator Harriet F. (Rae) Beaubien (primary author of this report), the conservation team consisted of conservation fellow Leslie G. Weber and contract conservator Basiliki Vicky Karas, who was also part of the 2005 field team. Our primary goal during the 2006 field season was to continue our deer stone documentation program, featuring 3D scanning. MCI's participation was supported by funds from the Smithsonian's Under Secretary for Science Endowment and the Samuel H. Kress Foundation.[2]

Beaubien and Weber arrived in Mongolia on 1 June 2006, along with most of the DSP team, with Karas following on 4 June. The 3rd Annual Symposium of the Joint Mongolian-Smithsonian Deer Stone Project was held in Ulaanbaatar, with conference presentations on 2 June and workshops on 3 June. Results from our previous season's scanning pilot test and plans for the 2006 season were outlined in Beaubien's presentation, entitled *3D laser scanning deer stones in Hovsgol aimag – 2005 field results*. Other contributions to the symposium included a presentation by Weber, sharing the results to date of her project at MCI, entitled *Analytical study and conservation of two extraordinary objects from the Xiongnu Cemetery, Gol Mod 2*. Excavated by the Khanuy Valley Project on Early Nomadic Pastoralism [KVP], under the direction of Drs. Francis Allard (Indiana University of Pennsylvania) and D. Erdenebaatar (University of Ulaanbaatar), the objects were conserved on site in 2005 and then later temporarily transferred to MCI for further study.[3]

After provisioning for the field, the DSP team left Ulaanbaatar on 6 June, along with KVP team members collaborating in the archaeological and ethnographic field work this year. The joint team spent several days (7-10 June) in the Khanuy Valley (Arkhangai aimag) en route to Hovsgol aimag. Once in the aimag capital of Muren, the scanning team, which now included an archaeological assistant, Songuulkhuu Namjil, and driver Narangil, remained to carry out deer stone scanning activities at the site of Ushkiin Uver (11-26 June) (**Fig.1**). Subsequently, we joined the DSP encampment at Ulaan Tolgoi for additional scanning (26-29 June). At the conclusion of the scanning phase, the conservation team returned to Ulaanbaatar, arriving 30 June. Karas and the equipment returned to the United States on 1 July, while Beaubien and Weber remained until 13 July in order to carry out archaeological conservation work on stored collections, including those of the KVP (this work is the subject of a separate report.[4]

All conservation activities were recorded in a hardbound notebook, supplemented with

worksheets for individual deer stones, digital photographs and digital scan files. The original documents and additional reports are archived at MCI, in Suitland, Maryland. The deer stone documentation activities are summarized below, with selected illustrations provided in the Illustrations section.

DEER STONE DOCUMENTATION

The documentation effort initiated by MCI in 2005 includes the following components: physical measurements and condition notes, photography, and 3D scanning, using systematic monument labels and side designations. Additional information, including context and previous documentation and conservation efforts, is expected to be incorporated into these records. Of these components, our focal activity has been 3D scanning, as a promising technology for serving both documentation and preservation needs.

3D Scanning – Background

For capturing deer stone information 3-dimensionally, the only method that had been tested previously by the DSP was direct molding, carried out on deer stone #14 at the Ushkiin Uver site by Smithsonian model-makers in 2002.[5] This method produces accurate documentation-to-scale of topographic and dimensional aspects, and is generally considered a relatively safe, simple and inexpensive procedure. There is, however, considerable risk of staining or damaging sensitive object surfaces during the application and removal of mold materials. In this particular case, all materials had to be imported, the molding stage took two days, and best results required experienced personnel at both molding and casting stages, making it an impractical choice for documenting deer stones on a bigger scale.

The scanning technique offers significant advantages: high-resolution dimensional and topographic information is gathered in a matter of hours and in digital format, without directly contacting the object surface. The digital files can be displayed graphically and exported, with further manipulation, for use in virtual exhibit and analysis applications, and to specialized milling and 3D printing machines to create high-resolution models. The digital files themselves have a better long-term preservation prognosis than any other 3D documentation method, with storage on CD and migration to other digital media as needed, and any number of reproductions can be made without data degradation, in contrast to a conventional mold's limited reusability.

For the 2005 pilot project, the 3-person MCI team used a Polhemus FastSCAN Cobra™ laser system for scanning.[6] Its portability and compactness were ideal for use in the field, but several features posed challenges in creating a suitable scanning environment for each deer stone: sensitivity to direct sunlight, which interferes with the data capture; poor performance in cold environments; and inability to be used in the vicinity of metal objects, given the system's use of magnetic field triangulation and resulting distortion in spatial data. To create adequate conditions for scanning, temporary tent-like shelters were built over the deer stones using wooden poles, including 5-meter lengths borrowed from nearby animal corrals, draped with medium-weight canvas and supplemented inside with light-weight black fabric.

Over a three-week period, scanning tests were conducted on twelve deer stones at six sites in the DSP's key research area – Ushkiin Uver (#1), Tsatstain Khoshun (#1), Evdt Valley (#1), Ulaan Tolgoi (#1-#5), Erkhel East 1 (#1-#2) and Erkhel North 1 (#1-#2). Complete raw data files were produced for ten of these (all but the first two) but one of them (Ulaan Tolgoi #2) was seriously flawed. Its great height exposed a shortcoming of the Polhemus system: its reliance

on a fixed datum point and functional range limits between the system components meant that objects over a certain size (approximately 2 m) could not be scanned as a single unit. In this case, files for upper and lower halves were generated, which would have to be unified during post-processing.

While the raw data files are generally good, they contain significant digital "noise" derived from an inherent weakness in the working properties of the hand-held laser scanner and system software. The post-processing steps, currently underway at MCI, have been time-consuming, in order to produce relatively clean exportable data files (.stl format). In the meantime, a second scanning system was acquired by MCI and this was selected for use in the 2006 project (described in the Materials and Methods section below).

Documentation Sites in 2006

The site of Ushkiin Uver was selected as a focus for the 2006 project because it contains one of the largest concentrations of deer stones, and includes the unusual "face" stone (#14), molded and cast by Smithsonian staff from the Office of Exhibits Central in 2002, as well as other exceptionally carved stones (**Fig.2**). It is considered a site at particularly high risk of vandalism because of the site's ready accessibility to visitor traffic via Muren. From published accounts within the last 20 years, the site originally contained 15 deer stones, one of which was subsequently lost to theft. Several pieces were recently recovered, and are now in storage at the Hovsgol Museum in Muren. Most of the stones at the site appear to have been cleaned of lichens; they display localized discoloration from animal rubbing, as the site is a thoroughfare for neighboring herds, and suffer from occasional graffiti. Since 1999, the site has been investigated by the Permanent Archaeological Joint Mongolian and Japanese Mission [PAJMJM], directed by Drs. D. Erdenebaatar and Dr. Takahama Shu (Kanazawa University).

Other deer stone sites were included in the documentation schedule as time permitted. Preference for additional scanning was given to Ulaan Tolgoi, the focus of our 2005 scanning effort as well as of the DSP's archaeological investigations (**Fig.3**). Another site of particular interest was KYR119, a ritual site in the Khanuy Valley (Arkhangai aimag), at which dozens of deer stones, re-used in later slab burial constructions, were excavated by Soviet-Mongolian projects in the mid-20th century (**Fig.4**). The site and neighboring *khirigsuur* sites have been a focus of investigation in recent years by the KVP.[7] Only photographic documentation was carried out at the latter, along with two other sites en route, Burdnii Ekh and Khushuutii Am (**Figs.5, 6**).

Methods and Materials

Deer Stone Labeling. The deer stone designations used for these records are described below. For upright stones, our convention for labeling the individual sides is to begin with the south face (side 1) and continue around the stone clockwise (west as side 2, etc.).

• Ushkiin Uver. The deer stone designations follow those used by Volkov[8] and by the PAJMJM[9] (**Figs.7, 8**). Deer stones 1-3 form the eastern row (from south to north) and continue with 4-14 in the western row (from north to south). Deer stone 15 is no longer extant on site, but two recently recovered fragments are now in the Hovsgol Museum, and designated as such.

• Ulaan Tolgoi. Following the system used in previous years by the DSP,[10] the stones at the site are numbered 1 through 5, from south to north (**Fig.9**).

• Burdnii Ekh. The deer stones, numbered by Beaubien on a sketch plan made at the site (**Fig.10**), were designated differently in Volkov's recording of the same site, named Khairkhan

Khundii.[11] His site plans are included for reference (**Figs.11, 12**).
• KYR119. Deer stone designations were assigned by Beaubien team in consultation with Allard. Deer stones 1-3 are located within the khirigsuur complex (**Fig.13**). The larger deer stone clusters were informally referred to as Group 1 (5-14), Group 2 (15-22), Group 3 (23-28), as shown on Allard's schematic plan map (**Fig.14**).
• Khushuutii Am. The 6 stones were designated 1 through 6 from south to north, following the system used by Volkov and also by PAJMJM[12] (**Fig.15**). The isolated stone to the north (mentioned also by PAJMJM but not recorded by Volkov) was assigned number 7.

General documentation. In addition to the scanning records, documentation included the following information. Digital photographs were taken of all accessible sides; these incorporated label, standard color and dimension scales where possible. Condition notes and measurements of the Ushkiin Uver deer stones were recorded using acetate overlays on photographs taken in 2005 (**Fig.16**). The color-coded condition features included deep cracks, spalling cracks, areas of exposed lamination layers, and losses; lichen, bird droppings and other biological accretions; stains from human applications and from animal rubbing; mineral crusts, concrete residues, and graffiti. For sides not previously photographed, drawings were made and coded as above. Site location and elevation were recorded with a Garmin GPS device**.** Tilt angle of sides and directional orientation of deer stone footprints were recorded with a Brunton pocket transit and compass. Any cleaning actions were also recorded, which included occasional removal of accretions using bamboo skewer and toothbrush, and clearance of loose stones and plant growth at the bases prior to scanning.

3D Scanning. MCI's Breuckmann triTos™ (GmbH) structured light scanning system was used during the 2006 field season, safely transported within a custom-made hard case. Its components include the sensor bar 30cm long), projector and camera, mounted together on a tripod, and the controller (**Figs.17, 18**). The camera lenses on the triTos™ are interchangeable to give varying fields of view; 325mm lenses were used, which allowed a 30cm field of view on the diagonal and a working distance of 1.38m. The triTos™ system software was run on a Hewlett-Packard Pentium IV laptop computer. The computer and scanner were powered in the field by a Honda EU1000i™ generator developed specifically for use with precision equipment (used in 2005 and stored in the interim in Ulaanbaatar).

Structured light scanning projects a sequence of organized patterns of structured light on a scan subject (seen in **Fig. 21**) as it is simultaneously photographed using a digital camera that is specially aligned with the projector. The photographic images show the distortion of the projected light pattern as it strikes the scan subject. Associated structured light software processes the projected light pattern distortion and color information disclosed by the digital photographs to generate point cloud data. Because the point cloud's (XYZ) range and (RGB) color values are recorded together, the color information is registered exactly with its corresponding 3D point.

The structured light scanning system is sensitive to light conditions, which diminish contrast in the light patterns projected onto the object. As in 2005, day-time scanning required that temporary shade shelters be built over the deer stones, but these also needed to accommodate the 1.38m working distance between the tripod-mounted camera and surfaces to be scanned. We modified our earlier shelter design by using traditional *ger* (yurt) walls to form a spacious rigid enclosure, in conjunction with a superstructure of wooden poles and large expanses of canvas to create a relatively light-tight tent-like structure (**Figs.19, 20**). The Breuckmann scanner did

not have the Polhemus' temperature sensitivity, so we were also able to scan at night, making a shelter unnecessary (**Figs.21, 22**). As a result, we selected deer stones that could be easily accommodated by shade shelters for scanning from mid-afternoon until dusk (approximately 11:00 pm) and more challenging deer stones for night-until-dawn scanning (**Figs.23, 24**).

Our procedure typically included mechanical removal of dimensional accretions (mostly bird droppings) and intrusive grass or stones around the base, prior to scanning. Because of its more cumbersome tripod mounting, scanning with the Breuckmann required at least 5 hours per stone (compared with 1-2 hours for the Polhemus). However, the data quality – much higher resolution (at micron levels, compared with ~0.5mm), as well as color information (not possible with the Polhemus) – and efficient post-processing software argued convincingly for the use of this system.

SUMMARY OF DOCUMENTATION ACTIVITIES

On-Site Documentation in 2006

The chart below summarizes the documentation activities carried out by the conservation team during the 2006 field season. Ushkiin Uver and Ulaan Tolgoi, the two sites at which 3D scanning was carried out, are listed first, followed chronologically by Burdnii Ekh, KYR119 and Khushuutii Am. Photographs of general views of the sites were taken in each location, in addition to the other documentation listed for each of the individual deer stones below.

DS Label	2006	General Documentation	Scanning Record
13-26 June 2006	**USHKIIN UVER** (Hovsgol aimag) [DSP]; **Uushigiin Övör** (Khövsgöl) [Volkov]; **Ulaan Uushig I** [PAJMJM] GPS location (for UU.01): UTM 47U0567007/5500721; Elevation 1314m [DSP-06]		
DS.01	Vertical	Log sheet with footprint measurements and compass orientation of sides, vertical tilt of sides [HFB]; condition record [SN]; Photos: 4 sides, top [LGW] – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05]	Complete raw data file of above-ground portion
UU.02	Vertical	Log sheet as above [HFB; LGW-SN; LGW]; sample taken; Photos: 4 sides, top – 13,14 June [2005 Photos: 4 sides, top – HFB, 2 July 05] [Volkov:188-Table 73]	Complete raw data file of above-ground portion
UU.03	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:188-Table 73]	Complete raw data file of above-ground portion
UU.04	Vertical	Log sheet as above [HFB; HFB; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:189-Table 74] [PAJMJM 1999 excavation]	Complete raw data file of above-ground portion
UU.05a	Loose (middle)	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, 2 breaks – 13,14,16,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:190-Table 75]	Complete raw data file
UU.05b	Vertical (base)	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, break – 13,14,16,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:190-Table 75]	Complete raw data file of above-ground portion
UU.05c	Loose (top)	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, break – 13,14,16,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:190-Table 75]	Complete raw data file
UU.06	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:190-Table 75]	Complete raw data file of above-ground portion
UU.07	Vertical (angled)	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides, top – HFB, 2 July 05] [Volkov:188-Table 73][PAJMJM 2005-06 excavation]	Complete raw data file of above-ground portion
UU.08	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:191-Table 76]	Complete raw data file of above-ground portion
UU.09	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:191-Table 76]	Complete raw data file of above-ground portion

UU.10	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:192-Table 77]	Complete raw data file of above-ground portion
UU.11	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:192-Table 77]	Complete raw data file of above-ground portion
UU.12	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides, top – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:189-Table 74]	Complete raw data file of above-ground portion
UU.13	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05]	Complete raw data file of above-ground portion
UU.14	Vertical	Log sheet as above [HFB; SN; LGW]; Photos: 4 sides – 13,14,25 June [2005 Photos: 4 sides – HFB, 2 July 05] [Volkov:194-Table 79]	Complete raw data file of above-ground portion
UU.x1	Horizontal, loose	Log sheet with condition record on drawings [HFB; HFB; LGW]; Photos: 4 sides, 2 breaks – 13,14,25 June [2005 Photos: (upright) 4 sides, top – HFB, 2 July 05]	Complete raw data file
UU.x2	Horizontal, loose	Log sheet with condition record on drawings [HFB; HFB; LGW]; Photos: 4 sides, 2 breaks – 13,14,25 June [2005 Photos: (angled) 4 sides, top – HFB, 2 July 05]	Complete raw data file
UU.x3	Loose	Log sheet with condition record on drawings [HFB; HFB; LGW]; Photos: 3 sides, 2 breaks – 13,14,25 June [2005 Photos: –]	Complete raw data file
		North khirigsuur complex	
xx	Vertical, burial	Photos: 4 sides (with top), plus context views– HFB, 25 June [PAJMJM 2003:28-Fig.4]	–
xx	Vertical, mound	Photos: 1 side, plus context views – HFB, 25 June [PAJMJM 2003:16-Fig.9]	–
26 June 2006	**HOVSGOL MUSEUM**, Muren (Hovsgol aimag)		
UU.15-1	Loose, upper	Photos: 4 sides, top, break – HFB, 26 June [Volkov:193-Table 78]	–
UU.15-2	Loose, lower	Photos: 4 sides, 2 breaks – HFB, 26 June [Volkov:193-Table 78]	–
27-28 June 2006	**ULAAN TOLGOI**, Lake Erkhel (Hovsgol aimag) [DSP] GPS location and elevation (for UT.02): N49° 55.907 / E99° 48.250; Elevation 1620m [DSP-05]		
UT.02	Vertical	– [2005 log sheet and Photos: 4 sides – HFB, 7 July 05**;** also see DSP reports]	Complete raw data file of above-ground portion [incomplete data in 2005]
7 June 2006	**BURDNII EKH** (Bulgan aimag, Saikhan sum) [DSP]; **Khairkhan Khundii** [Volkov] GPS location: N48° 34.639 / E102° 37.626; N48° 20.784 / E102° 22.581; Elevation 4402 ft. [DSP-06]		
DS.01 (Volkov #2)	Vertical	Photos: 4 sides – HFB, 7 June 06 [2005 Photos: 3 sides, in general views – HFB, 21 June 05] [Volkov:T.47]	–
DS.02 (Volkov #3)	Vertical	Photos: 4 sides – HFB, 7 June 06 [2005 Photos: 1 side – HFB, 21 June 05] [Volkov: not pictured]	–
DS.03 (Volkov #4)	Vertical	Photos: 4 sides – HFB, 7 June 06 [2005 Photos: 1 side, in general views – HFB, 21 June 05] [Volkov T.47]	–
DS.04 (Volkov #1)	Vertical	Photos: 4 sides – HFB, 7 June 06 [2005 Photos: 1 view, in general views – HFB, 21 June 05] [Volkov T.47]	–
DS.05 (Volkov #5)	Horizontal	Photos: 2 exposed (long) sides – HFB, 7 June 06 [2005 Photos: 2 views, in general views – HFB, 21 June 05] [Volkov T.47]	–
DS.06 (Volkov #6)	Angled, part buried	Photos: 2 exposed sides, 1 broken end – HFB, 7 June 06 [2005 Photos: as above – HFB, 21 June 05] [Volkov T. 48]	–
DS.07 (Volkov #7)	Angled, part buried	Photos: 2 overall – HFB, 7 June 06 [2005 Photos: as above – HFB, 21 June 05] [Volkov T.49]	–
DS.08 (Volkov #9)	Angled, part buried	Photos: 2 exposed sides, top – HFB, 7 June 06 [2005 Photos: as above – HFB, 21 June 05] [Volkov T.46]	–
DS.09 (Volkov#10)	Horizontal	Photos: 3 sides, broken base, top – HFB, 7 June 06 [2005 Photos: (inverted) 3 sides, base – HFB, 21 June 05] [Volkov T.46]	–
(Volkov #8)	–	Note that this deer stone was not visible in 2006[Volkov T.49]	
9 June 2006	**KYR119**, Khanuy Valley (Arkhangai aimag) [KVP]; Zhargalant / Öndör-Ulaan [PAJMJM] GPS location and elevation: N48° 10'10-30" / E101° 05' 34-35" [PAJMJM]		
DS.01	Vertical (tilted)	Photos: 4 sides, top – 9 June 06 [2005 Photos: as above – HFB, 12 June 05]	–

DS.02	Nearly horizontal part buried	Photos: 4 sides, top – 9 June 06 [2005 Photos: as above – HFB, 12 June 05]	–
DS.03	Nearly horizontal part buried	Photos: 4 sides, top – 9 June 06 [2005 Photos: as above – HFB, 12 June 05]	–
DS.04	Loose	Photos: 4 sides, top – 9 June 06 [2005 Photos: –]	–
DS.05	Horizontal	Photos: 3 sides, 2 ends – 9 June 06 [2005 Photos: 1 side – HFB, 12 June 05]	–
DS.06	Horizontal	Photos: 3 sides, top – 9 June 06 [2005 Photos: –]	–
DS.07	Horizontal	Photos: 3 sides, top – 9 June 06 [2005 Photos: 1 view – HFB, 12 June 05]	–
DS.08	Horizontal	Photos: 3 sides, base – 9 June 06 [2005 Photos: 1 side – HFB, 12 June 05]	–
DS.09	Horizontal	Photos: 2 sides + 1 edge, 2 ends – 9 June 06 [2005 Photos: –]	–
DS.10	Horizontal	Photos: 3 sides, 2 ends – 9 June 06 [2005 Photos: 1 view – HFB, 12 June 05]	–
DS.11	Vertical	Photos: 4 sides – 9 June 06 [2005 Photos: 2 side – HFB, 12 June 05]	–
DS.12	Vertical	Photos: 4 sides, top – 9 June 06 [2005 Photos: (horizontal) 2 sides – HFB, 12 June 05	–
DS.13	Horizontal	Photos: 3 sides + 1 edge, 2 ends – 9 June 06 [2005 Photos: 2 sides – HFB, 12 June 05]	–
DS.14	Horizontal	Photos: 3 sides, 2 ends – 9 June 06 [2005 Photos: –]	–
DS.15	Horizontal	Photos: 1 side + 2 edges, 2 ends – 9 June 06 [2005 Photos: –]	–
DS.16	Horizontal	Photos: 1 side + 2 edges, 2 ends – 9 June 06 [2005 Photos: –]	–
DS.17	Horizontal, part buried	Photos: 1 side + 1 edge, 1 end – 9 June 06 [2005 Photos: (exposed) 2 views – HFB, 12 June 05]	–
DS.18	Horizontal, part buried	Photos: 3 sides, 1 end – 9 June 06 [2005 Photos : (exposed) 2 views – HFB, 12 June 05]	–
DS.19	Horizontal	Photos: 2 sides – 9 June 06 [2005 Photos: 2 views – HFB, 12 June 05]	–
DS.20	Horizontal	Photos: 3 sides, 2 ends – 9 June 06 [2005 Photos: 3 views – HFB, 12 June 05]	–
DS.21	Horizontal	Photos: 3 sides, 2 ends – 9 June 06 [2005 Photos: (vertical) 1 view – HFB, 12 June 05]	–
DS.22	Horizontal	Photos: 3 sides, ends hidden – 9 June 06 [2005 Photos: 1 view – HFB, 12 June 05]	–
DS.23	Horizontal	Photos: 2 sides + 1 edge, 2 ends – 9 June 06 [2005 Photos: 1 view – HFB, 12 June 05]	–
DS.24	Horizontal	Photos: 2 sides + 1 edge, top – 9 June 06 [2005 Photos: –]	–
DS.25	Horizontal	Photos: 2 sides – 9 June 06 [2005 Photos: –]	–
DS.26	Horizontal	Photos: 2 sides + 1 edge, 2 ends – 9 June 06 [2005 Photos: 1 view – HFB, 12 June 05]	–
DS.27	Horizontal	Photos: 3 sides, 2 ends – 9 June 06 [2005 Photos: 1 view – HFB, 12 June 05]	–
DS.28	Horizontal	Photos: 2 sides + 1 edge, 2 ends – 9 June 06 [2005 Photos: 1 view – HFB, 12 June 05]	–
10-11 June 2006	**KHUSHUUTII AM** (Hovsgol aimag, Galt sum) [DSP]; **Khöshöötiyn am** (Khövsgöl) [Volkov, PAJMJM] GPS location and elevation: N48º 74.495 / E99º 91.994; Elevation 1557m [DSP-06]; N48º 42’ 41.6”-42’ 18.2” / E99º 53’ 54.5”-53’40.4” [PAJMJM]		
DS.01	Vertical	Photos: 3 sides (S,W,N) plus various views – HFB, 10 June [Volkov:201-T.86]	–
DS.02	Vertical	Photos: 2 sides (W, SE); plus various views – HFB, 10 June [Volkov:201-T.86]	–
DS.03	Vertical	Photos: 2 sides (NW, SE), plus various views – HFB, 10 June [Volkov:201-T.86]	–
DS.04	Vertical	Photos: 4 sides (N,S,E,W), plus various views – HFB, 10 June [Volkov:201-T.86][PAJMJM 2005:Fig.11 (inverted from Volkov)]	–
DS.05	Vertical	Photos: 3 sides (N,W,S); plus various views – HFB, 10 June	–
DS.06	Vertical	Photos: 2 sides (N,W); plus various views – HFB, 10 June	–
DS.07	Horizontal	Photos: 3 sides, broken end – HFB, 11 June [PAJMJM 2005:Fig.12]	–

On-going Data Processing and Dissemination of Results

Digital data generated from 3D scanning during the 2006 field season are currently being post-processed at MCI, for iconographic analysis of imagery, synthesis with archaeological information for publication and production of graphic and 3D models for exhibition. The raw data files are converted into .bre files using the triTos™ system software (Optocat) and exported to Rapid Form™ (XOS) 3D graphic software for all alignment, merging and subsequent processing steps. This includes filling holes, which is done by extrapolating information from the surrounding data mesh to close a void, i.e. if the data mesh surrounding a hole curves, then the hole fill function will continue the curve. Fills are recognizable as areas with a uniform mesh (in this viewing mode) or as smooth patches (in solid view). The final processed data files are exported in .stl format, and are archived at MCI.[13]

To date, OEC and other providers have contributed their expertise in the graphic modeling and model production stages of the project, which utilize the data in .stl format. Thus far, several techniques of model production have been tested, including computer numerical controlled (CNC) milling and rapid prototyping (also called 3D printing). Some of the graphic products and a partial digitally derived model of deer stone #14 from Ushkiin Uver, along with the 2002 cast, were included in the family festival entitled "Genghis Khan's Mongolia: 800 Years of Nationhood" held October 6-8, 2006 at the National Museum of Natural History. A number of recent talks and publications by members of the MCI scanning team have featured our work in Mongolia, including results from both 2005 and the 2006 seasons.[14]

Footnotes

[1]This collaboration began in June 2004, with Beaubien's participation as a workshop organizer/presenter in the DSP's first annual symposium, held in Ulaanbaatar; see Beaubien, in (W.W. Fitzhugh, J. Bayarsaikhan, and P.K. Marsh, eds.) (2005) *The Deer Stone Project: Anthropological Studies in Mongolia 2002-2004*, 163-184. Reports for the first year of participation in the field season (2005) is archived under *MCI 5974* and *MCI 5999* at MCI; see also Beaubien, in Arctic Studies Newsletter 13 (December 2005):26-28.

[2]The Archaeological Conservation Program, administered by Beaubien, promotes the partnership of conservation and field archaeology through a variety of activities, including provision of on-site conservation assistance to participating projects. On-site staffing is provided by Beaubien and conservation fellows and interns, with funding support for participant travel from the Samuel H. Kress Foundation, as well as the Smithsonian Institution and participating archaeological projects.

[3]Reports for the on-going conservation at MCI are archived under *MCI 6005*, in addition to *MCI 5999*.

[4]The report is archived under *MCI 6048* at MCI.

[5]A brief description of molding and casting procedures is provided in Beaubien, Karas, and Fitzhugh (in press), Documenting Mongolia's Deer Stones: application of digital imaging technology to preservation, *Third Forbes Symposium on Scientific Research in the Field of Asian Art* (Washington, DC: Freer Gallery of Art, Smithsonian Institution); Fitzhugh (2003), in *Mongolia's Arctic Connections: The Hovsgol Deer Stone Project, 2001-2002 field report* (Washington DC: Arctic Studies Center, NMNH), p.31.

[6]Procedures and results are described more fully in the report for *MCI 5945*, and in the following publications: Beaubien, Karas and Fitzhugh *op.cit*.; and Karas, Beaubien, and Fitzhugh (forthcoming), Documenting Mongolia's Deer Stones: application of 3D laser scanning technology to archaeological conservation, *Conservation of Archaeological Materials: current trends and future directions* (Williamsburg, VA: Colonial Williamsburg Foundation).

[7]Allard, Francis and Diimaajav Erdenebaatar (2005), Khirigsuurs, ritual and mobility in the Bronze Age of Mongolia, *Antiquity* 79#305:547-563. The site's excavation in 1990 is reported by Volkov (2002:100) and also in T. Sanjmiatov (1993), *Early History and Culture of Arkhangai* [in Russian] (Ulaanbaatar: D. Nabaan). Testing at part of the site was done by PAJMJM (2003:32).

[8]Volkov V.V. (2002), Stone Stelaes from Mongolia ("deer stones") [in Russian] (Moscow: Scientific World), pp.78-83, 187-194 (Tables 72-79).

[9]Shu, Takahama, Hayashi Tshio, Kawamata Masanor, Matshuhara Ryuji, D. Erdenebaatar (2006), Preliminary Report of the Archaeological Investigations in Ulaan Uushig (Uushigiin Övör) in Mongolia, *Bulletin of Archaeology, The University of Kanazawa* 28:61-102. Also see PAJMJM, Preliminary Report of the Archaeological Investigations in Mongolia, 2003:11-35; Preliminary Report of the Archaeological Investigations in Mongolia, 2004:57-62; Preliminary Report of the Archaeological

Investigations in Mongolia, 2005:63-92.
[10]Fitzhugh (2003) *op.cit*.; Fitzhugh (ed.) (2004), *The Hovsgol Deer Stone Project, 2003 Field Report*; Fitzhugh et.al. (2005) *op.cit*.
[11]Volkov 2002:57-59, 161-164 (Tables 46-49).
[12]PAJMJM 2005:87-88, Figs.10-12.
[13]Data files are archived at MCI, under *MCI 6084* through *MCI 6089*.
[14]In addition to previous citations: Karas and Beaubien, 3D scanning Mongolia's ancient deer stones *Arctic Studies Center Newsletter* 14 (February 2007):43-44; Karas and Steve Hand, Polyworks and the Mongolian Deer Stone Project, *International PolyWorks Users Meeting* (October 2006), Quebec City; Beaubien (for Beaubien, Karas and Weber), 3D scanning deer stones on the Mongolian steppe, *American Institution for Conservation annual meeting* (April 2007), Richmond, VA; Beaubien (for Beaubien, Karas and Fitzhugh), 3D scanning for field documentation of Mongolia's deer stone monuments, *Society for American Archaeology, 72nd annual meeting* (April 2007), Austin, TX; Beaubien, 3-D Scanning of Mongolian Deer Stones: tools for preservation and access, *UCLA/Getty Program in Ethnographic and Archaeological Conservation* (May 2007), Los Angeles.

ILLUSTRATIONS

Fig.1 Weber, Songo, Beaubien, Narangil and Karas [29 June 2006]

Fig. 2 Ushkiin Uver-western row, looking south (15 June 2006)

Fig.3 Ulaan Tolgoi, near Erkhel Lake (2 July 2005)

Fig. 4 KYR119, Khanuy Valley-one of several clusters of deer stones (9 June 2006)

Fig. 5 Burdnii Ekh, looking north (21 June 2005)

Fig. 6 Khushuutii Am, looking southeaset (10 June 2006)

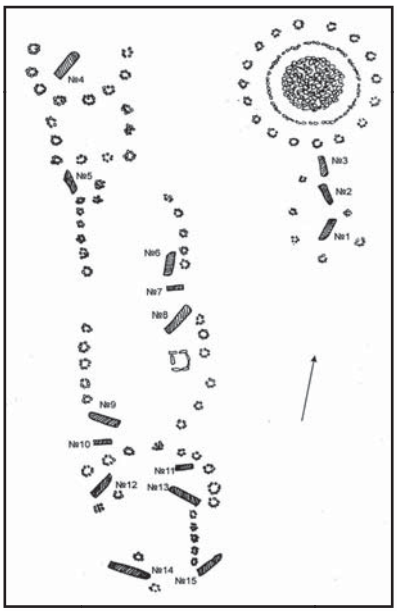

Fig. 7 Ushkiin Uver plan map, as shown in Volkov (2002: 187-Table 72)

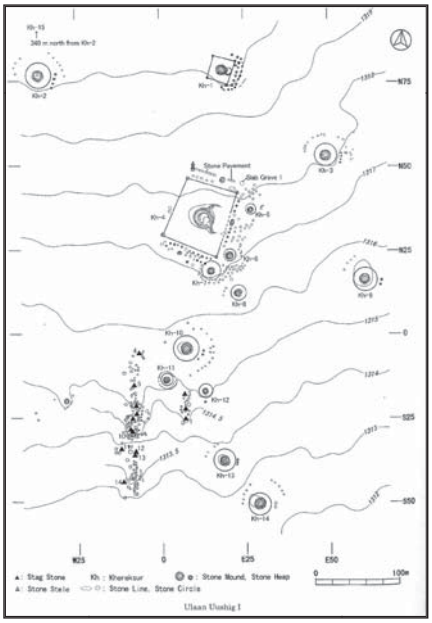

Fig. 8 Ushkiin Uver plan map, as shown in PAJMJM (2006:84-Pl.2)

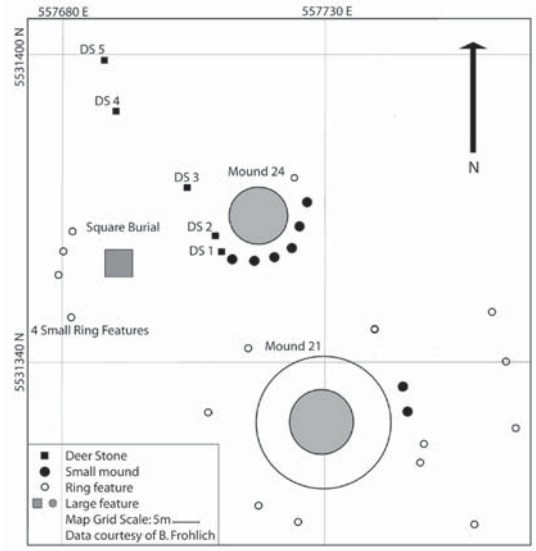

Fig. 9 Ulaan Tolgoi plan map (DSP-06)

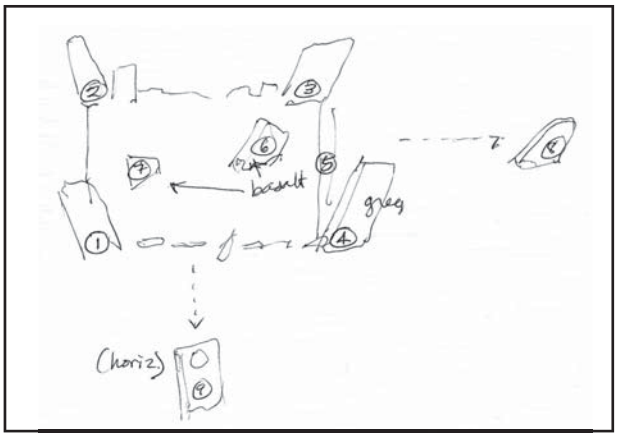

Fig. 10 Burdnii Ekh sketch plan (Beaubien, 7 June 2006)

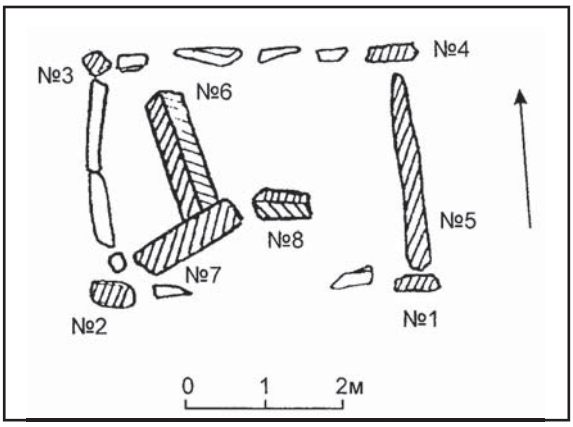

Fig. 11 Burdnii Ekh plan map of main group in Volkov (2002: 162-Table 47)

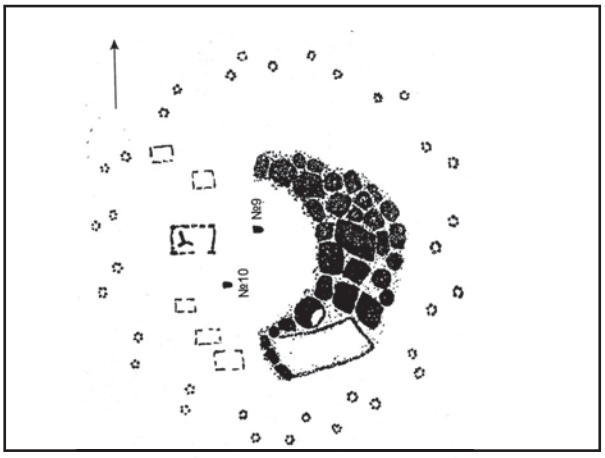

Fig. 12 Burdnii Ekh plan map of periphery in Volkov (2002:161-Table 46)

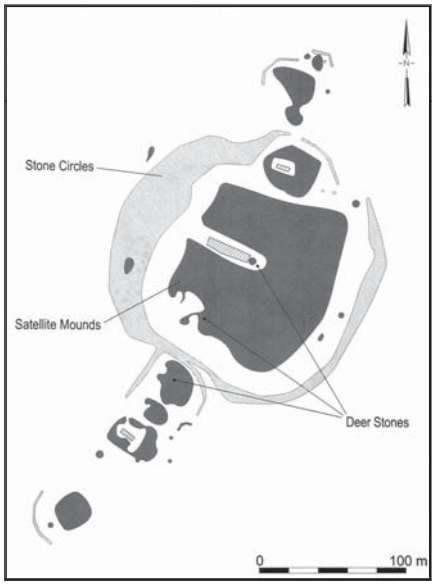

Fig. 13 KYR119 plan map of area with deer stones 1-4, from Allard (2005)

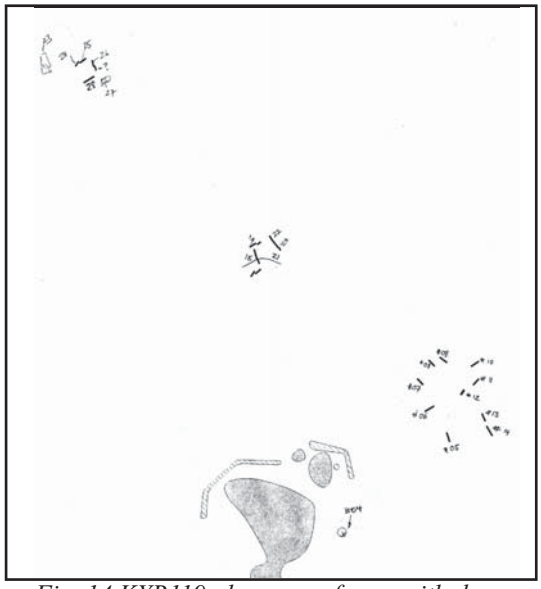

Fig. 14 KYR119 plan map of area with deer stones 5-28, from Allard (2005), annotated (9 June 2006)

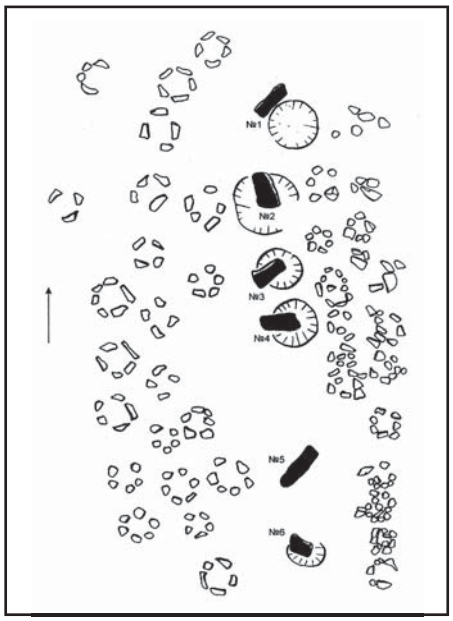

Fig. 15 Khushuutii Am plan map from Volkov (2002:200-Table 85)

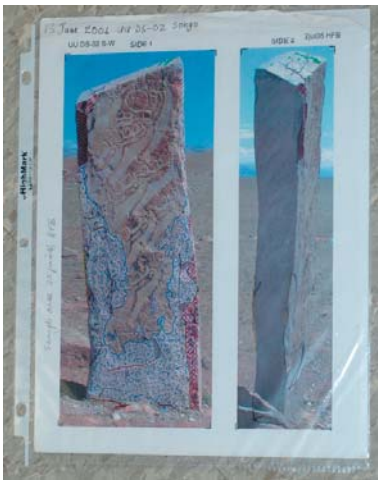

Fig. 16 Part of the condition record for deer stone #2 at Ushkiin Uver (June 2006)

Fig. 17 Weber and Karas scanning deer stone #12 at Ushkiin Uver, with the computer and controller components (June 2006)

Fig. 18 Beaubien scanning deer stone #12 at Ushkiin Uver, with projector-camera component (June 2006)

Fig. 19 Constructing the ger shade shelter in preparation for scanning deer stone #3 at Ushkiin Uver (June 2006)

Fig. 20 The completed ger shade shelter for deer stone #3 at Ushkiin Uver (June 2006)

Fig. 21 Scanning deer stone #2 at Ushkiin Uver (June 2006)

Fig. 22 Scanning deer stone #14 at Ushkiin Uver (June 2006)

Fig. 23 Scanning the lower portions of deer stone #2 at Ulaan Tolgoi (June 2006)

Fig. 24 Scanning the upper portions of deer stoe #2 at Ulaan Tolgoi (June 2006)