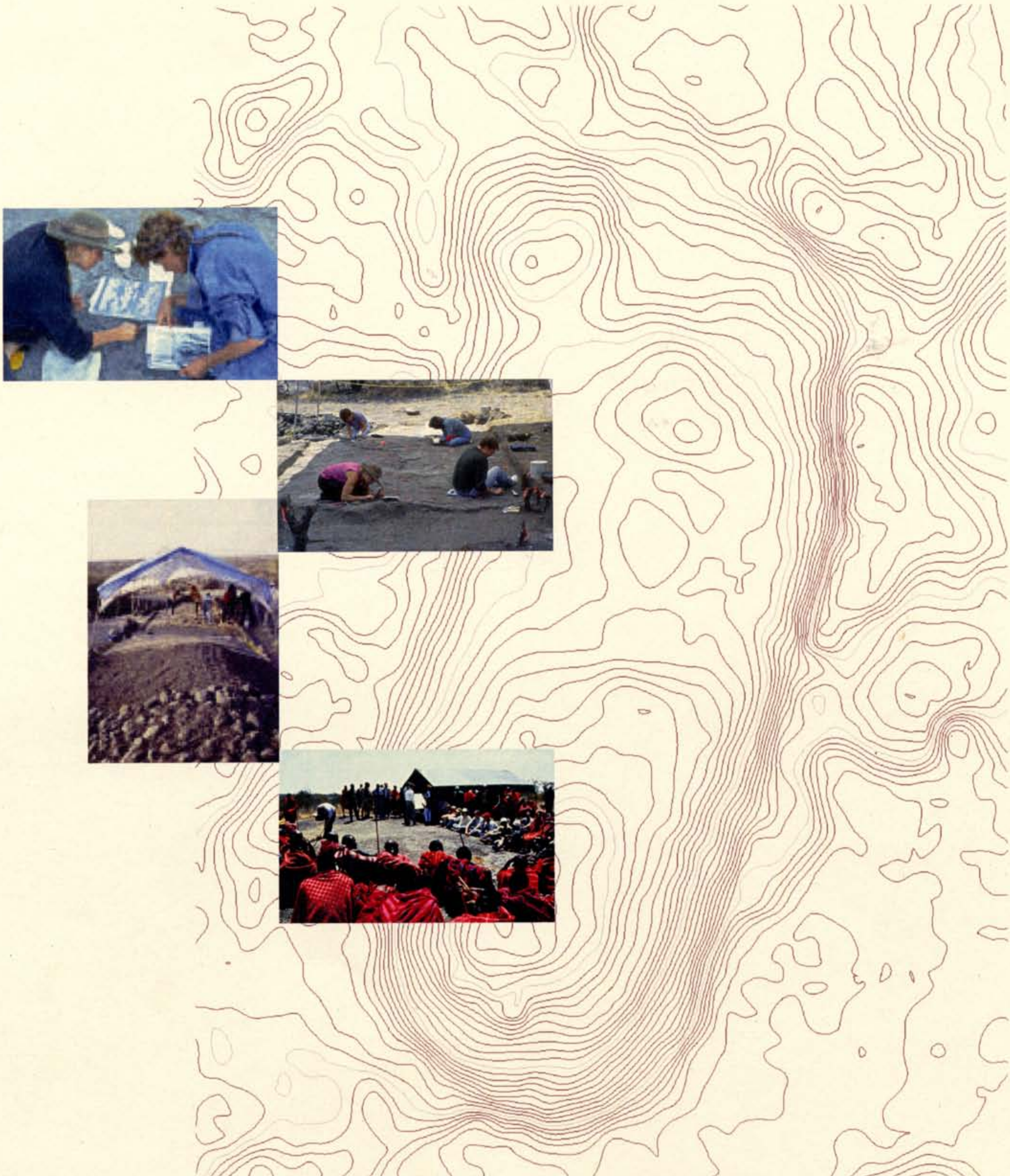
LAETOLI PROJECT

Conservation of the hominid trackway at Laetoli, Tanzania



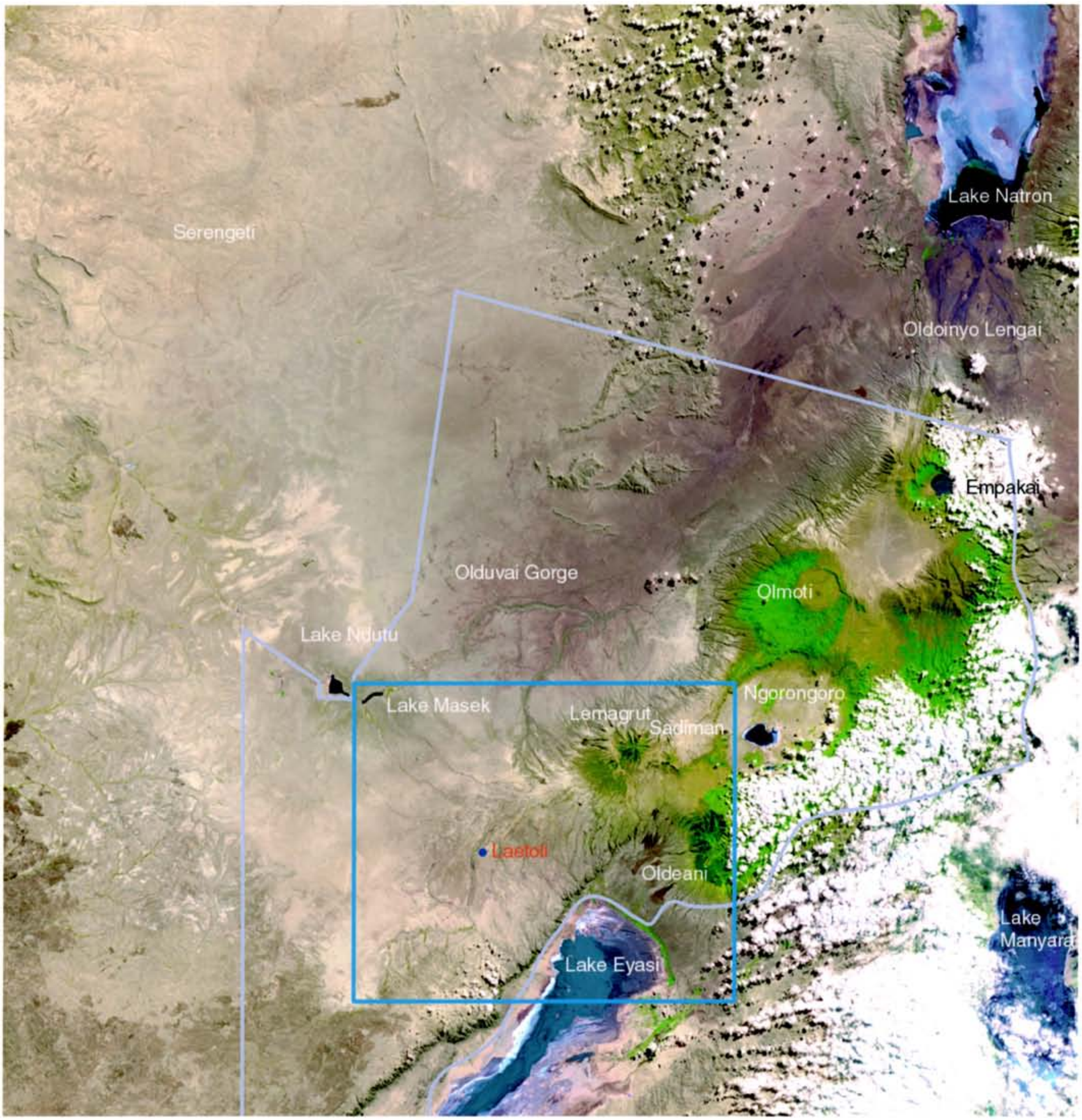
1996–1998 REPORT

The Getty Conservation Institute

LAETOLI PROJECT

REPORT ON THE 1996-1997 FIELD SEASONS AND THE OLDUVAI MUSEUM EXHIBITION

February 2000



Satellite photograph showing the Laetoli area (in box) and Olduvai Gorge within the boundaries of the Ngorongoro Conservation Area. "Laetoli" marks the location of Site G.

LAETOLI PROJECT

REPORT ON THE 1996-1997 FIELD SEASONS AND THE 1998 OLDUVAI MUSEUM EXHIBITION

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LAETOLI PROJECT

Report on the 1996-1997 Field Seasons and the 1998 Olduvai Museum Exhibition

EXECUTIVE SUMMARY

- The 1996-1998 field campaigns and activities completed the final phases of the joint Getty Conservation Institute (GCI)—Government of Tanzania project to conserve the hominid footprint trails at Laetoli. Activities completed during this period included the conservation, documentation and reburial of the northern 20m of the trackway, development of a long-term monitoring and maintenance plan for the site, evaluation of part of the reburial monitoring trench, and design and installation of an exhibition at the Olduvai Museum.

- The objective of the 3-month long 1996 field season (July 9-Oct 1) was to re-excavate, conserve, document, study and rebury the remaining 20 meters of the trackway. A joint GCI-Tanzanian team, consisting of 25 persons, participated in the project. The team was based in a tented camp near the village of Endulen. Additionally, a separate three-member team, operating under a permit from the Tanzanian Department of Antiquities, undertook a palaeoanthropological restudy of the trackway. As in previous years, field interventions were reviewed prior to the campaign by the Consultative Committee, comprising eminent specialists, both local and international.

- Re-excavation of the northern 20m of the trackway revealed the presence of all the tuff features recorded as hominid footprints in 1978, with the exception of prints G1-1 and G2/3-1, which had been destroyed by erosion; the total number of prints recorded in 1996 was 39. In addition to the hominid prints, 18 hipparion prints from Trackway A, 145 lagomorph prints, and 7 guinea fowl prints were re-excavated and recorded in 1996. Geological features such as Fault 3, where the trackway drops 0.50m, and the graben formed by Faults 1 and 2, were also revealed in the course of excavation.

- The 1978 reburial fill over the northern 20m was shallower than that which covered the southern 10m reburied in 1979 and there was more variation in the type of fill and boulder covering. Coarse sand from the Garusi River bed was used as reburial fill except over the major part of the middle sector of the trackway, where no prints are preserved, which was covered with a clayey soil. The northernmost 4m of the 1978 reburial was found to have been capped with tuff blocks rather than the volcanic boulders used throughout the rest of the mound.

- The northernmost 10m of the trackway where most of the prints are preserved was in poor condition from weathering when first excavated in 1978. Re-excavation in 1996 revealed further weathering of the tuff, insect activity on the trackway, and widespread root penetration by small roots of weeds and grasses. The fragile and damp tuff was subject to cracking and powdering of the surface on drying; the irregular surface of the trackway was susceptible to detachment of tuff fragments from foot traffic.

- The poor condition of the northern 20m of trackway as found in 1996 required more intensive and widespread interventions than on the southern trackway sector in 1995. 1996 conservation treatments focused on documenting and monitoring the condition during the period of exposure, root removal or reduction where removal was not possible, and mitigating damage to the tuff through stabilization and readhesion treatments.

- Within the area excavated in 1996 there were 32 acacia trees recorded (38 were recorded in the 10m southern part of the trackway in 1995). Distribution of the trees over the entire trackway showed that *Acacia seyal* was the predominant species occurring mainly in the southern and northern sectors where the reburial fill was Garusi River sand; *Acacia mellifera* dominated the middle sector, where clayey soil had been used to rebury the trackway. All acacia trees (which had been killed in 1994) were treated as in 1995: stumps and roots were removed whenever possible, voids resulting from removal were filled, and remnant stumps were treated with preservative to deter decay.

- Documentation of the trackway followed methodologies established in 1995. Photogrammetry of the trackway and individual footprints was conducted with digital and conventional cameras by consultants from the Department of Geomatics, University of Cape Town. The results are contour maps of the northern 20 meters of the trackway with a precision of less than 0.5 mm and contour distances of 5 mm for the trackway and 1 mm for the individual footprints. Documentation for condition recording was conducted with an 8 x 10 Polaroid camera and conditions were recorded on clear acetate sheets in the field. All aspects of the campaign were documented by conventional photography and informal video recording. Formal photography in 35 mm and medium format (2.25 x 2.25 in) was undertaken of individual footprints prior to reburial.

- Replication of all original 1978-79 molds and casts was completed in 1996. The long section "A" cast of the southern sector was patinated for display at the Olduvai Museum, and prototypes were developed for potential use by the National Museums of Tanzania in future production of casts. All 1995-1996 molds and casts are now in storage in the National Museum in Dar es Salaam; the original 1978-1979 molds and casts are stored at Olduvai.

- The ancient drainage patterns at Site G were one of the greatest threats to the trackway prior to its discovery in 1978 - resulting in erosion of the hominid trail north of prints G1-1 and G2/3-1 - and continued to affect the site adversely after the placement of the reburial mound in 1978 - with loss of prints G1-1 and G2/3-1. Site stabilization measures were undertaken beginning in 1994 and continued in 1996 and 1997. These addressed drainage run-off to the NW gully and pooling of water in the vicinity of the northern half of the trackway.

- The three palaeoanthropological re-study projects (morphological description, microstratigraphy, and gait) that began in 1995 under separate permit from the Department of Antiquities were continued in 1996 on the northern and middle trackway sectors. At the time of completing this report, only the microstratigraphy report had been received and is included here.

- After conservation, documentation and scientific study, the 20 meters of trackway was reburied under a composite layering of sieved sands (some 53 cubic meters) and geosynthetic materials (geotextile, Biobarrier and Enkamat) to a height of 0.85-1.00m and capped with lava boulders. The 1996 reburial covered twice the area of the 1995 reburial; the irregular topography of the northern 20m of trackway required specialized layering and stabilization of the mound.

- A long-term monitoring and maintenance plan for Site G was developed in 1997 and approved for implementation by the Department of Antiquities in 1998. The plan recognizes and addresses major threats to the site, the roles of the local communities in protecting the site, reporting and communication lines between the Department of Antiquities and the Ngorongoro Conservation Area Authority, and duties and responsibilities for site guards, Olduvai Station staff and the DoA Head of Conservation. Implementation of the plan by the Tanzanian authorities is the means by which the site will be preserved over the long term.

- In 1997 - two years after its establishment - the SE quadrant of the reburial monitoring trench was excavated to assess preliminary results before the end of the project. Although the lower layers of the trench were very wet, causing organic materials (the cotton cloth and wood samples) to decay, the results were deemed satisfactory since tuff features were well preserved, notwithstanding the more aggressive environment vis-à-vis the trackway reburial. Based on analysis of Biobarrier in the trench, the predicted effectiveness of the material as a root inhibitor is estimated to be another 20 years.

- The design, production and installation of an exhibit at the Olduvai Museum marked the final phase of activity for the Laetoli project. The museum was repaired and expanded by the Department of Antiquities with the construction of an Orientation room. New displays were designed for the Orientation room, the Olduvai room and the Laetoli room. The Laetoli room includes a cast of the southern sector footprints and panels highlighting the significance of the hominid footprints, their discovery and excavation, and their conservation.

- With the completion of the 1996 campaign and exhibition on Laetoli, the project has achieved its objectives to conserve the trackway, document it for future study and interpretation, and educate the public about the importance of the hominid trackway and the need for its protection. What remains to be done is to complete formal publication and make accessible to the conservation and scientific communities the data for further study and interpretation.

PART I. INTRODUCTION

by Martha Demas and Neville Agnew

BACKGROUND

The Pliocene site of Laetoli, which preserves both hominid and faunal tracks, as well as hominid, animal and plant fossils, has immense scientific value, particularly for understanding human evolution. The trackway at Site G, fortuitously preserved within layers of aeolian and airfall volcanic tuff, not only records the diversity of life in the Pliocene savannas of East Africa, but more significantly, offers unique evidence of bipedalism in hominids from 3.6 million years ago. Site G, excavated by Mary Leakey and her team in 1978-79, was documented and then reburied under a mantle of soil and lava boulders (Figs 5, 6). After the trackway's reburial in 1979, acacia and other vegetation took root in the burial fill. A preliminary assessment of the trackway's condition undertaken by a joint Tanzanian-Getty Conservation Institute team in July 1992 revealed that acacia roots had penetrated the footprint surface, and had damaged individual hominid prints.

The 1996-1998 Laetoli field campaigns completed the third and fourth phases of activity in the collaborative project of the Getty Conservation Institute (GCI) and the Government of Tanzania to preserve the hominid footprint trails at Laetoli. With the completion of these phases, the goals established in an Agreement signed by the GCI and the Government of Tanzania in June 1994 have been achieved. These were:

- to implement a conservation program for the hominid trackway at Site G, which included reburial of the hominid trackway for the long term;
- to develop a monitoring and maintenance program for the long-term preservation of the site; and
- to create museum exhibitions in Tanzania for public education and to raise public awareness about the importance of the Laetoli site.

The four phases of the Laetoli project were:

Phase 1 (1993)

Phase 1 involved assessment of condition and conservation needs through partial re-excavation of a 3 x 3m trench over the trackway. This was undertaken in July-August 1993 by a joint Tanzanian-GCI team, operating under a Letter of Intent signed by both parties. The results and recommendations from the assessment campaign are recorded in the **Report on the 1993 Field Season**. The recommendations from the 1993 report (Part XI. Conclusions and Recommendations) formed the basis for planning the conservation work at Laetoli for Phases 2-4.

Phase 2 (1994)

Phase 2 involved mapping the site, treatment of the trees growing on the trackway with herbicides, initial stabilization measures to control erosion of the site, making a new master mold from the 1979 cast of part of the southern trackway sector stored at Olduvai, and informing the local Maasai elders of the project and enlisting their support for the future protection of the site. This phase was undertaken in two field campaigns during the 1994 calendar year (May and July-August). Results of the field campaigns are detailed in the **Report on the 1994 Field Season.**

Phase 3 (1995-96)

Phase 3 consisted of two conservation field campaigns over a two-year period; the southern third of the trackway was the focus of the 1995 campaign, with the middle and the northern sectors completed in July-September 1996. The field campaigns entailed re-excavation of the trackway, conservation treatment, documentation of the hominid prints by photogrammetry, scientific re-study, and reburial of the trackway in a manner that will ensure its future protection. Replication of the 1978-1979 molds and casts stored at Olduvai was completed in 1996. The 1995 campaign is covered in the **Report on the 1995 Field Season**; the 1996 campaign is included in this report.

Phase 4 (1996-98)

Phase 4 involved development of a maintenance and monitoring program for Laetoli, re-excavation of a portion of the reburial monitoring trench for evaluation purposes, and creation of a museum exhibition in Tanzania at the Olduvai Museum.[1] Phase 4 activities are covered in this report. Publication of the conservation of the trackway is in progress, to be completed by early 2001. Publication of the scientific restudy of the hominid prints and the trackway will be undertaken by the palaeoscientists who conducted the study.

OVERVIEW OF THE 1996 FIELD SEASON

The 1996 field campaign took place over a twelve week period, from July 9 to October 1. The objective of the 1996 season was to excavate, conserve, document, study, and rebury the remaining 20 meters of the trackway, following the methodology established in 1995, and to implement measures for its long-term protection. Photos 2-13 show the trackway in 1978, and in 1996 at significant stages during the campaign.

Planning for the 1996 campaign included a meeting with the Laetoli Consultative Committee (LCC) in February 1996 to review the results of the 1995 campaign and plan for the 1996 season (see Appendix A for list of LCC members).
Participating in the 1996 campaign were the following team members (titles reflect 1996 status):

<u>*Getty Conservation Institute Team*</u>
Michael Airy, hydrologist, Cook and Airy Consulting Engineers, Kenya
Neville Agnew, Associate Director, Programs, GCI
Francesca Alhaique, PhD candidate, Anthropology Dept., Washington University, St. Louis
Angelyn Bass, Research Fellow, GCI
Ulrike Bruessler, PhD candidate, Dept of Geomatics, University of Cape Town
Pedro Pablo Celedon, Barefoot Productions, Los Angeles, consultant videographer
Chester Cain, PhD candidate, Anthropology Dept., Washington University, St. Louis
Martha Demas, Project Manager, Special Projects, GCI
Pia Dominguez, Barefoot Productions, Los Angeles, consultant videographer

[1] An exhibition cast was made for the National Museum in Dar es Salaam in 1995.

Elizabeth Hildebrand, PhD candidate, Anthropology Dept., Washington University, St Louis
Po-Ming Lin, Los Angeles, geotechnical and logistics consultant
John Lewis, Los Angeles, consultant photographer
Frank Long, Los Angeles, consultant photographer
Fiona Marshall, Anthropology Dept., Washington University, St. Louis, consultant archaeologist
Tom Moon, Kansas City, consultant scientific photographer
Francesca Piqué, Conservation Specialist, Special Projects, GCI
Leslie Rainer, Senior Research Fellow, Special Projects, GCI
Heinz Rüther, Head, Dept. of Surveying and Geodetic Engineering, University of Cape Town, consultant photogrammetrist
Eduardo Sanchez, Assistant Conservator, Dept. of Antiquities Conservation, The J. Paul Getty Museum
Ron Street, Manager, Molding Studio, Metropolitan Museum of Art, New York, consultant preparator

Tanzanian Team

Joel Bujulu, former Senior Principal Research Officer, Plant Protection Division, Tropical Pesticide Research Institute, Arusha; consultant to the Department of Antiquities
Donatius Kamamba, Conservation Architect, Department of Antiquities
Ferdinand Mizambwa, Technician and Mason, Department of Antiquities
Godfrey Olle Moita, Conservation Assistant, Olduvai Gorge
Jesuit Temba, Conservator and Preparator, National Museum of Tanzania

Palaeoanthropological Study Team

Craig Feibel, Visiting Assistant Professor, Dept. of Anthropology, Rutgers University
Bruce Latimer, Curator, Dept. of Physical Anthropology, Cleveland Museum of Natural History
Peter Schmid, Professor, Anthropological Institute and Museum, University of Zurich-Irchel

Field work took place at the site of Laetoli; molding and casting was undertaken at the project camp at Endulen. The base camp for the project team was set up by Hoopoe safari company, Arusha, under contract to the GCI, near Endulen village for the duration of the twelve week campaign. As during previous campaigns, the Ngorongoro Conservation Area Authority (NCAA), in particular Mr. Lazaro Mariki (Western Zone Coordinator), assisted the project team in many ways. The official representatives of the village of Endulen (Mr. Augustine Pakaay Ollonyokye and Mr. Saitabau Ole Kereto) and Ward Officer, M. Osokoni, facilitated establishment of the camp, hiring of workmen and guards for the site, and construction of a permanent house for the site guards at Laetoli.

Summary of project activities and responsibilities

Direction and overall supervision of the 1996 field campaign was provided by Donatius Kamamba of the Department of Antiquities and Martha Demas and Neville Agnew of the Getty Conservation Institute. The field campaign schedule and major areas of responsibilities are presented in Appendices B and C.

Photographic documentation was conducted for all project activities for the duration of the campaign. The primary responsibility was Tom Moon's, with additional coverage provided by Neville Agnew, Angelyn Bass, Martha Demas and Francesca Piqué. During the 1996 campaign, Moon was assisted by Frank Long who undertook all video recording and took over photography after Moon's departure in week 8. Additional photography and professional video coverage was provided by John Lewis and Pedro Pablo Celedon during the week of August 12.

The re-excavation of the southern third of the trackway was supervised by Fiona Marshall, assisted by Donatius Kamamba and Martha Demas. The archaeological team comprised Francesca Alhaique, Chester Cain, and Lisa Hildebrand, with Angelyn Bass, Francesca Piqué, and Leslie Rainer from the conservation team. Re-excavation of the trackway surface by the archaeological team took place largely between July 18 – September 5. Cain undertook conventional surveying and mapping of the excavated trench and its features; survey data was supplied by Heinz Rüther.

The conservation team in the field consisted of Angelyn Bass, Donatius Kamamba, Francesca Piqué, Leslie Rainer, Eduardo Sanchez, and Jesuit Temba. Angelyn Bass coordinated the conservation work, which followed the methodology established in 1995 by Jerry Podany (Head of Antiquities Conservation, J. Paul Getty Museum). The work of the conservation team (July 29 – September 8) included final excavation of the footprints, recording the condition of the trackway, removal of tree stumps and extraction of roots, and treatment of the tuff where required.

Photogrammetric recording of the trackway was undertaken from August 19 – September 8 by Heinz Rüther, assisted by Ulrike Bruessler and Tom Moon. The photogrammetric team also surveyed trench and datum points, and all trackway features. Tom Moon undertook the stereo Hasselblad photography. Frank Long developed the 5x7-inch photogrammetric glass plates in the field.

Po-Ming Lin and Joel Bujulu undertook the assessment of the 1995 treatment of acacia trees with herbicide and additional treatment of acacia trees in 1996. The use of a preservative on stumps and roots left *in situ* in the trackway was done by Neville Agnew and Joel Bujulu.

Site stabilization efforts were extensive in 1996 and were supervised by Neville Agnew and Donatius Kamamba, assisted by Po-Ming Lin and Ferdinand Mizambwa. Michael Airy provided advice on the hydrology and control of surface drainage of the site. On-site sampling and sub-surface moisture and temperature monitoring were conducted by Neville Agnew and Po-Ming Lin.

The scientific study of the trackway was again conducted under a separate permit from the Department of Antiquities by Craig Feibel, Rutgers University and Bruce Latimer, Cleveland Museum of Natural History from August 4-10; and Peter Schmid, Zurich University, from August 19-25.

Reburial of the excavated portion of the trackway took place from September 9-30. The reburial of the trackway was supervised by Martha Demas and Neville Agnew, with Angelyn Bass, Po-Ming Lin, Chester Cain, and Donatius Kamamba. Po-Ming Lin and Ferdinand Mizambwa supervised the extraction, sieving and transportation of all reburial materials.

Molding and casting work was undertaken at Endulen camp from July 15-28. The work was supervised by Ron Street, assisted by Jesuit Temba.

Community relations and arrangements for the Maasai consecration ceremony were handled by Donatius Kamamba and Godfrey Olle Moita.

Three workmen from the village of Endulen--Josefat Nachan, Rotiken Ole John, Oretete Ole Njolio--and Sanin'go Ole Mtengere from Esere--assisted the team throughout the campaign. Sangali Keriko and Peter Koromo assisted with collection and seiving of sand for two weeks beginning August 23.

Logistics of the field campaign, including shipments and customs clearance, were orchestrated from Los Angeles by Kathleen Louw and in Tanzania by Nassra Czunyi and Oliver Davidson.

Visitors to the site

There were several visitors to the site over the course of the three month campaign. Mary Leakey visited for a week on her own from August 12-17. Her visit was timed to coincide with the presence of the video crew, international press and the Maasai consecration ceremony. She returned for a more peaceful three-day visit with her daughter-in-law, Meave Leakey (Head of Palaeontology, Kenya National Museums) and Meave's two daughters on Sept. 9-12. Daniel Ndagala (Commissioner of Culture) and Mam Biram Joof (Unesco representative), both members of the Laetoli Consultative Committee, visited the site on August 17, also for the press weekend and Maasai ceremony. Mark Stanley Price, Director of the African Wildlife Fund, visited on August 8. On September 8 Timothy Tear (Frankfurt Zoological Society) came to the site to discuss plans and exhibitions for the new Serengeti Visitors Center at Seronera, which is to include a segment on early man. Rob Blumenschine (Rutgers University) who is conducting fieldwork at Olduvai and O. Kileo, Head of Olduvai Station, visited the site on August 26. From the local community, school children and their teachers, families of the workmen and site guards, and staff of the Endulen Hospital also visited the site on different occasions throughout the campaign. Village and regional representatives and NCA officials visited the site at various times during the three months.

From August 16-18, during Mary Leakey's visit and the Maasai consecration ceremony, members of the international press were on site. CNN, the BBC and AP were represented: Gary and Christine Striker from CNN; Martin Dawes, David Munds, and Alina Gracheva from BBC and WTN; and Susan Linnee from the Associated Press. The news crews recorded parts of the blessing ceremony and conducted formal interviews with Mary Leakey, Martha Demas, Neville Agnew, Fiona Marshall, Dr. Ndagala, Commissioner of Culture, and with the traditional religious leader (*Oloiboni*) of the Maasai community, Mr. Birikaa Ole Kereto.

Site set-up

Two tents were set up along the eastern escarpment of Site G for use by the site guards and for storage of tools, equipment and materials used during the campaign. During the second week of excavation, prior to exposure of the footprint tuff surface, temporary shelters were erected over the excavated portion of the trackway. The shelters remained over the trackway until reburial, except for periodic removal for unimpeded photography.

OVERVIEW OF THE 1997 FIELD SEASON AND THE OLDUVAI MUSEUM EXHIBITION

In June 1997, Donatius Kamamba visited the GCI, where he helped with preparations for the 1997 campaign, and traveled to the southwest United States to review management practices in US National Parks.

Final field work at the site took place in July 1997. The main purpose was to evaluate the reburial monitoring trench that had been implemented in 1995 at Test Site 3 as a method of long-term monitoring of the condition of the trackway. Additional stabilization measures were undertaken at this time to further protect the reburial mound from erosion at its northern end.

Design, production and installation of a new exhibit for the Olduvai Museum occupied most of 1998. The official opening of the Museum took place in October 1998, attended by the Vice President of Tanzania, Dr. Omar Ali Juma, and officials from the Ministry of Education and Culture, the Department of Antiquities, the Ngorongoro

Conservation Area Authority, and the local communities. Martha Demas and Neville Agnew attended the opening as representatives of the GCI.

TERMINOLOGY USED IN THIS REPORT

The following descriptive terms for tuffs, soils and excavated horizons were defined for the 1995 report and are here repeated with revisions to reflect corrections or conditions in 1996; new terms have been added to clarify the geological faults and the use of terms such as "southern, middle and northern sectors of the trackway." Where applicable, these follow the definitions originally established by R. Hay, adapted specifically to Site G and the hominid trackway by C. Feibel in his more recent work.

- Southern, Middle, and Northern Sectors of the Trackway: The terms southern, middle and northern sectors refer to three discrete sections of the trackway defined by prominent features. The southern sector encompasses approximately the southern 10.25-10.50m of the trackway, from the unexcavated Augite-Biotite ledge at the south to Fault 3 at its northern end. The middle sector encompasses approximately an 8.5m length of trackway from Fault 3 to the southern edge of Fault 2 (or the graben); the northern sector comprises the final approximate 10.0m stretch of trackway from the graben to the 1996 excavated northern end at N123 (Fig. 10).

- Faults 1, 2, 3 and 4: Faults 1 and 2 define the north and south boundaries respectively of the graben (Photo 11). Fault 3 is the largest break in the trackway surface, marking the northern end of the southern sector and a 0.50m drop in the trackway surface (Photo 17). Fault 4 is marked by a shallow, but abrupt, rise in the tuff near the southern end of the trackway.

- Graben: The graben is the down-faulted block of tuff created by Faults 1 and 2 (Photos 11, 38b).

- Footprint Tuff: The approximately 15 cm thick layer of volcanic tuff, comprising an Upper Unit (4-6 cm thick), subdivided into 4 units or layers; and a Lower Unit

(7-10 cm thick), subdivided into 14 units or layers (Fig. 1). Each sub-unit or layer represents an ashfall from a single eruption. The hominid tracks at Site G were formed in the uppermost layer (layer 14) of the Lower Unit, which marks the transition between the Lower and Upper Units. The term Footprint Tuff is always capitalized when referring to this geological unit or part thereof.

• Horizon B: This marks the surface of layer 14 of the Lower Unit of the Footprint Tuff (Fig. 1), in which the hominid tracks were formed (also referred to in the report as the "footprint surface"). Horizon B was well preserved over most of the southern sector. In practice, excavation of the southern sector in 1979 to a single microlevel of the Footprint Tuff was not consistently achieved. Thus, the footprint surface or Horizon B as excavated in 1979 and re-excavated in 1995-96 shows evidence of remnants of Footprint Tuff layers other than layer 14, particularly of the lowest lamina of the Upper Unit Footprint Tuff. In the northern and middle sectors, Horizon B had been largely eroded out, exposing various levels of Lower Unit tuff (Photo 27).

• Calcite layer: A secondary deposit of calcite (approximately 1 mm maximum thickness) lines many of the footprints in the well preserved southern trackway sector. It is discontinuous and does not extend uniformly over Horizon B. The calcite precipitated from ground water after the footprints were buried by subsequent ashfalls. A calcite layer was also well preserved in large patches in the graben, but was rarely preserved in the northern sector.

• Well preserved tuff: In the southern sector, this comprises the largest area with the greatest number of hominid prints, extending from the unexcavated Augite Biotite in the south to the "weathered tuff" (see below) in the north (Fig. 12). The tuff here is at Horizon B and is well consolidated with calcite and in part covered with a secondary calcite skin; it was sufficiently covered by a mantle of original overburden to protect it from weathering. In the northern trackway sector only remnants of well preserved tuff are found. Unweathered tuff below Horizon B is found at the northern end of the southern sector and throughout much of the middle sector.

• Weathered tuff: Weathering occurs where the tuff was insufficiently covered by a mantle of overburden to protect it from the normal processes of weathering and soil formation (Photo 30). In appearance, it is darker than the well-preserved tuff with distinctive polygonal cracking (Photo 37); physically it is weaker and softer than the well preserved tuff. In the northern and middle trackway sectors weathered tuff occurs as localized patches, particularly widespread north of Fault 1 and southeast of Fault 2. In the southern sector there is a heavily weathered strip of tuff at Horizon B, from approximately N99 to N100.70. Six poorly preserved hominid prints were excavated in this section in 1979.

• Lower Unit tuff: Since the uppermost layer of the Lower Unit tuff—layer 14—has its own distinct designation (Horizon B), the term Lower Unit tuff is in practice used to refer collectively to the layers of tuff below Horizon B (layers 1-13; Fig 1). The Lower Unit Tuff is exposed in the northernmost area of the southern sector trackway, immediately north of the weathered tuff. The exposed tuff in this area represents a well consolidated, but fractured, tuff layer below Horizon B (Photo 28). One shallow, amorphous depression in the surface of this tuff has been interpreted as representing a hominid footprint (identified as G2/3-23). The middle sector of the trackway is composed entirely of Lower Unit tuff, with the exception of the island of tuff containing prints G1-24 and G2/3-17, which preserves Horizon B. Lower Unit tuff, eroded to various levels, comprises most of the northern sector.

• Clayey stratum: This refers to the unstratified deposit of clay-rich aeolian tuff underlying the Footprint Tuff. It is visible below the Footprint Tuff in the NW gully and at Fault 3. This is also the stratum in which the reburial monitoring trench at Test Site 3 was believed to be excavated in 1995; however the stratigraphy is now uncertain (see Part V, Appendix A; and Part XII).

• Black Cotton Soil: This is the name given to the ubiquitous, heavy, clay-rich, black soil in the Laetoli area. At Site G it occurs principally on the eastern side where it forms an erosional escarpment. Presumably, it derives, as a weathering product, from a younger volcanic deposit.

• Augite Biotite Tuff: This represents the "culmination of the eruptive sequence recorded by the Footprint Tuff" (Hay in Leakey and Harris 1987, p. 36), deposited above the Upper Unit of the Footprint Tuff. The Augite Biotite tuff was not excavated in 1979 at the extreme southern end of the trench and remains as an irregularly-shaped area approximately 2 m x 0.60 - 1.30 m (Fig. 12). In the 1995 report, the term is used descriptively in the archaeological and conservation reports to refer to the unexcavated matrix above Horizon B of the Footprint Tuff. In such usage, the term Augite Biotite may include the Upper Unit of the Footprint Tuff, which however, was not always clearly distinguishable in the weathered profiles (it is provisionally identified as the tuff layer that was left unexcavated in 1979 in the west trench (see 1995 Report, Photo 6). According to the Laetoli monograph, the edge of the Augite Biotite defines a small fault, which truncates print G2/3-31 (Leakey and Harris 1987, p. 490).

• Ngarusi/Garusi: The seasonal Garusi river defines the northern end of Site G, where it removed the Footprint Tuff (Fig. 5). Most of the fossils from the Laetoli area came from the eroded gullies of the Garusi river and its tributaries. In all the Laetoli literature, the term Garusi is used for this river. In the 1995 General Management Plan for the Ngorongoro Conservation Area, the spelling was changed to "Ngarusi" at the request of the local inhabitants. We have retained the use of the traditional spelling (Garusi) in this report, but have included the new spelling on the site maps (Figs 5-7).

NUMBERING OF HOMINID AND ANIMAL PRINTS

Hominid Prints

The numbering sequence used by the original excavators was explained in the 1995 report and has been retained in the 1995-96 documentation for consistency of recording. In the original recording, 39 prints were inventoried for the G1 trail; 31 for the G2/3 trail. With the exception of prints G1-1 and G2/3-1, which have been removed by erosion, it was possible to re-locate all the tuff features recorded as footprints in 1978-79. In the northern and middle sectors, inventory numbers were sometimes assigned by Louise Robbins in 1978 to the tuff surface based solely on predicted stride length of the hominids. In those cases where no hominid morphology could be detected, as determined by Bruce Latimer, documentation in the form of condition recording and mapping was limited; these are referred to as having "limited documentation" in the list of prints in Appendix D.

There remain two areas of uncertainty with regard to numbering of the prints. In the northern sector, at approximately N119, the prints become muddled where the hominids appear to have broken stride and erosion and weathering has made identification of prints difficult (prints G1-6, 7, 8, 9 and G2/3-5). With respect to two of these prints, the numbering system used on the plan published in Day 1986 does not correspond to the numbering established by Louise Robbins in the field. Print G2/3-5 in the Robbins photos and 1978 inventory is labeled G1-7 on the Day 1986 plan; print G1-7 in the Robbins documentation is labeled G2/3-5 on the Day plan (Fig. 2). We have retained the original 1978 numbering for these prints in order to maintain consistency with the 1978 photographic documentation of the trackway, but no interpretation is implied. They are shown on the trackway plans as "attribution uncertain."

The descriptions of G2/3-23 and G2/3-22 in the Laetoli monograph remain somewhat problematic (Leakey and Harris 1987, p. 494). Print G2/3-23 is described as lying "immediately north of the main transverse fault"; on the plan published in Day 1986, print G2/3-23 is shown immediately north of the weathered tuff (Fig. 2), where we located it in 1995 (Fig. 12). Print G2/3-22 is described as a shallow depression in the lower part of the Footprint Tuff and as the "most northerly of the G2/3 footprints in the southern sector"—a description that corresponds more closely with print G2/3-23 as located on the Day 1986 plan. We have retained the numbering of the prints on the Day 1986 plan, which is also consistent with the 1978 field documentation. The list of prints in Appendix D notes the inconsistencies.

Animal Prints

The two hipparion trails in the southern sector re-excavated in 1995 were designated Trackways B and C in Leakey and Harris 1987, 471ff, and numbered from 1-13 and 1-12 respectively. The 1996 re-excavation of the northern sector revealed the third hipparion trail, designated Trackway A in Leakey and Harris 1987, 471ff (Photo 2; Fig. 4). Due to inconsistencies in the original numbering and mapping of Trackway A, we assigned numbers based on identification of prints *in situ*; eighteen hipparion prints were identified and numbered A1-18 (Fig. 14), from north to south (see Part II for further discussion of the hipparion trails).

Seven guinea fowl prints, drawn on the plan published in Day 1986, were re-located and numbered GF1-7. In 1996, the many lagomorph prints (some of which may be a small antelope such as dik dik) on the northern trackway sector were surveyed and numbered L1-145 (Fig 14).

A NOTE ON THE PLANS AND SECTIONS

The general map of the site (Figs 5-7) is based on the map drawn by MMG Surveyors, Arusha, in 1994, and amended by Chet Cain in 1995 and 1996, based on survey by Heinz Rüther. The plan of the northern and middle sectors was drawn by Cain, based on survey of the trackway by Heinz Rüther. The final site maps and trackway plans were completed on AutoCAD by Rand Eppich. Final sections (A, B, C, D, E) were drawn using Freehand software, with final editing by Cynthia Godlewski (Figs 18-21). The photogrammetric plan (Figs 15-17) was produced by Heinz Rüther from the digital terrain models using a variety of software and transported into AutoCAD for final output by Gaetano Palumbo and Rand Eppich.

Acknowledgments

The contributions of Cynthia Godlewski in the preparation of this report are gratefully acknowledged.

Members of the Laetoli Consultative Committee (1995-1996)

The Consultative Committee for the Preservation of the Laetoli Footprints was composed of the following members:

- Dr Mary Leakey, excavator of Laetoli, Nairobi, Kenya
- Professor Desmond Clark, Professor Emeritus, University of California, Berkeley
- Professor David Pilbeam, Department of Anthropology, Harvard University
- Mr Webber Ndoro, University of Zimbabwe
- Dr Daniel Ndagala, Commissioner of Culture, Ministry of Education and Culture, Tanzania
- Dr Mam Biram Joof, Regional Representative, Unesco
- Dr Cassian Magori, Dept. of Anatomy, University of Dar es Salaam (1995 only)
- Mr Victor Runyoro, Senior Ecologist, Ngorongoro Conservation Area Authority (1996 only)
- Mr F. Mkunyi, Acting Chief Manager, Management of Natural Resources Dept., Ngorongoro Conservation Area Authority (1996 only)
- Dr Simon Waane, Director, Department of Antiquities
- Mr Donatius Kamamba, Architectural Conservator, Department of Antiquities
- Dr Neville Agnew, Associate Director for Programs, Getty Conservation Institute
- Dr Martha Demas, Project Manager, Getty Conservation Institute

1996 LAETOLI PROJECT CAMPAIGN PARTICIPANTS

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Cleveland Museum of Natural History

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Godfrey Olle Moita,
Conservation Assistant,
Dept. of Antiquities

1996 LAETOLI CAMPAIGN SCHEDULE

prep week	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	weeks 9	weeks 10-11
July 11-14	July 15-21	July 22-28	July 29-Aug 4	Aug 5-11	Aug. 12-18	Aug. 19-25	Aug 26-Sept 1	Sept 2-8	Sept. 9-15	Sept. 16-30
DIRECTION	DIRECTION	DIRECTION	DIRECTION	DIRECTION	DIRECTION	DIRECTION	DIRECTION	DIRECTION	DIRECTION	DIRECTION
M. Demas	M. Demas	M. Demas	M. Demas	M. Demas	M. Demas	M. Demas	M. Demas	M. Demas	M. Demas	M. Demas
D. Kamamba	D. Kamamba	D. Kamamba	D. Kamamba	D. Kamamba	D. Kamamba	D. Kamamba	D. Kamamba	D. Kamamba	D. Kamamba	D. Kamamba
				N.Agnew	N.Agnew			N. Agnew	N. Agnew	
ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY	ARCHAEOLOGY
C. Cain	F. Marshall	F. Marshall	F. Marshall	F. Marshall	F. Marshall	F. Marshall	C. Cain	C. Cain	C. Cain	C. Cain
L. Hildebrand	C. Cain	C. Cain	C. Cain	C. Cain	C. Cain	C. Cain				
	L. Hildebrand	L. Hildebrand	F. Alhaique	F. Alhaique						
	F. Alhaique	F. Alhaique								
CONSERVATION	CONSERVATION	CONSERVATION	CONSERVATION	CONSERVATION	CONSERVATION	CONSERVATION	CONSERVATION	CONSERVATION	CONSERVATION	CONSERVATION
A. Bass	A. Bass	A. Bass	A. Bass	A. Bass	A. Bass	A. Bass	A. Bass	A. Bass	A. Bass	A. Bass
			F. Piqué	F. Piqué	F. Piqué	E.Sanchez	L. Rainer			
			J. Temba	E.Sanchez	E. Sanchez	L. Rainer	J. Temba			
				J. Temba	J. Temba	J. Temba				
					L. Rainer					
DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST	DOC/MLD&CST
T. Moon	T. Moon	T. Moon	T. Moon	T. Moon	T. Moon	T. Moon	T. Moon	T. Moon	Frank Long	Frank Long
	R. Street	R. Street		F. Long	F. Long	F. Long	F. Long	F. Long		
	J. Temba	J. Temba				H. Rüther	H. Rüther	H. Rüther		
						U. Bruessler	U. Bruessler	U. Bruessler		
SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY	SCIENTIFIC STUDY
			B. Latimer	C. Feibel	M. Leakey	P. Schmid			M. Leakey	
				B. Latimer						
OTHER	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER	OTHER
G. Ollemoita	G. Ollemoita	G. Ollemoita	G. Ollemoita	G. Ollemoita	G. Ollemoita *	G. Ollemoita	G. Ollemoita			G. Ollemoita
			P.M. Lin	P.M. Lin	P.M. Lin	P.M. Lin	P.M. Lin	P.M. Lin	P.M. Lin	P.M. Lin
F. Mizambwa	F. Mizambwa	F. Mizambwa	F. Mizambwa	F. Mizambwa	F. Mizambwa	F. Mizambwa	F. Mizambwa	F. Mizambwa	F. Mizambwa	F. Mizambwa
	F. Mizambwa	F. Mizambwa			GCI video crew @ 4					
pax 8	pax 12	pax 12	pax 13	pax 18	pax 20	pax 16	pax 13	pax 11	pax 14	pax 8

G1 and G2/3 Footprint List

G1 Footprints

PRINT	TRACKWAY SECTOR	CAST	COMMENTS
G1-1	North	Yes	Lost to erosion
G1-2	North	Yes	
G1-3	North	Yes	
G1-4	North	No	Limited documentation
G1-5	North	No	Limited documentation
G1-6	North	No	
G1-7	North	No	Labeled G2/3-5 on Day 1986 plan
G1-8	North	No	
G1-9	North	No	
G1-10	North	No	
G1-11	North	No	
G1-12	North	No	
G1-13	North	No	
G1-14	North	No	
G1-15	North	No	Limited documentation
G1-16	North	No	Limited documentation
G1-17	North	No	Limited documentation
G1-18	North	No	Limited documentation
G1-19	North	Yes	

G1-20	North	No	Limited documentation
G1-21	North	No	Never excavated
G1-22	North	Yes	
G1-23	North	No	Never excavated
G1-24	Middle	Yes	
G1-25	South	Yes	
G1-26	South	Yes	
G1-27	South	Yes	
G1-28	South	Yes	
G1-29	South	Yes	
G1-30	South	Yes	
G1-31	South	Yes	
G1-32	South	No	
G1-33	South	Yes	
G1-34	South	Yes	
G1-35	South	Yes	
G1-36	South	Yes	
G1-37	South	Yes	
G1-38	South	Yes	
G1-39	South	Yes	

G2/3 Footprints

PRINT	TRACKWAY SECTOR	CAST	COMMENTS
G2/3-1	North	Yes	Lost to erosion
G2/3-2	North	Yes	
G2/3-3	North	Yes	Limited documentation
G2/3-4	North	No	Limited documentation
G2/3-5	North	No	Labeled G1-7 on Day 1986 plan
G2/3-6	North	No	
G2/3-7	North	Yes	
G2/3-8	North	No	
G2/3-9	North	Yes	
G2/3-10	North	No	
G2/3-11	North	No	Limited documentation
G2/3-12	North	No	Limited documentation
G2/3-13	North	No	Limited documentation
G2/3-14	North	No	Limited documentation
G2/3-15	North	No	Limited documentation
G2/3-16	North	No	
G2/3-17	Middle	No	

G2/3-18	South	Yes	
G2/3-19	South	Yes	
G2/3-20	South	Yes	
G2/3-21	South	Yes	
G2/3-22	South	Yes	Leakey and Harris 1987 description not consistent with in situ location
G2/3-23	South	No	Limited documentation; Leakey and Harris 1987 description not consistent with in situ location
G2/3-24	South	Yes	
G2/3-25	South	Yes	
G2/3-26	South	Yes	
G2/3-27	South	Yes	
G2/3-28	South	Yes	
G2/3-29	South	Yes	
G2/3-30	South	Yes	
G2/3-31	South	Yes	

PART II. RE-EXCAVATION OF THE NORTHERN 20 METERS OF THE TRACKWAY

by Fiona Marshall

INTRODUCTION

The aim of the archaeological team during the 1996 field season was to re-excavate the northern 20 meters of the hominid trackway of Site G, originally excavated by Mary Leakey and her team in 1978, in order for conservation, documentation and scientific re-study of the trackway to be undertaken prior to reburial. Subsidiary aims were to map the excavated trenches and features and the position of the 1996 re-excavation relative to the site as a whole, and to assist in the final reburial of the site.

The re-excavation was directed by Fiona Marshall, with Donatius Kamamba, from the Tanzanian Department of Antiquities, and Martha Demas of the GCI. The archaeological team comprised Francesca Alhaique, Chester Cain, and Elizabeth Hildebrand with Angelyn Bass, Francesca Piqué and Leslie Rainer of the GCI conservation team, and assistance from Ferdinand Mizambwa and Godfrey Olle Moita of the Antiquities Department, and Jesuit Temba, conservator from the National Museum of Tanzania. Archaeological survey was done by Chester Cain. The archaeological team was supported by four workmen: Josefat Nachan, and Rotiken Ole John and Oretete Ole Njolio from Endulen and Sanin'go Ole Mtengere from Esere.

SCHEDULE OF ACTIVITIES

Re-excavation began at the site on July 15, 1996, following inventory of equipment and photographic documentation of the site (July 12-13). The 1978 reburial mound and adjacent areas were cleared of grasses, and Angelyn Bass and Lisa Hildebrand made a collection of all plant taxa growing on the mound; fauna near or in the mound was also recorded. Concrete marker bollards were cast in preparation for survey and gridding. On July 16, the mantle of boulders from the 1978 mound was removed (Photos 7, 8), after photography by Tom Moon and mapping by Chester Cain, and tracing the tuff surface and stratigraphy, revealed by erosion at the gully edge, began.

Discussions took place between Demas, Marshall and Kamamba regarding the strategy for defining the area to be excavated, and the siting of boulder piles, backdirt piles and sieving areas for reburial. Major sieving piles were located as in 1995 just south of Test Site 3. Boulders to be reused for capping the reburial were sited just west of the trackway. Archaeological survey commenced July 16 with re-establishing the northern corners of the 1995 excavation trench. The profile of the 1978 reburial mound was also drawn. July 17, the trench outlines and grid positions for the northern portion of the site to be excavated were established and marked with bollards (Photo 8). July 18, surveying continued with mapping of the plan of the 1978 reburial mound. The 1978 mound, with mantling boulders removed, was photographed by Tom Moon, and excavation of upper levels began.

Re-excavation of the 1978 reburial fill and exposure of the trackway surface, unexcavated hominid prints, and small mammal, bird and hipparion prints took place between July 18 and September 5. Final excavation of hominid prints took place by conservators between July 29 and August 11. Verification of trench boundaries and detailed surveying of features by archaeologists and photogrammetrists, and transcription of these points took place between August 28-September 7. General surveying and mapping by Chester Cain of the trench, plans, profiles, reburial profiles, and the site in general occurred at intervals between July 16-September 24.

SURVEY OF THE 1996 TRENCHES

As in 1995, siting of the 1996 trench was hampered by lack of maps of the area excavated in 1978 tied in to a site datum. As a result, the general configuration of the 1978 reburial mound and 1978 photographs were relied upon in positioning the 1996 trenches. Field notes from the 1978 season provided by Tim White (University of California, Berkeley) were also very useful to the team. Trench boundaries were modified once re-excavation allowed their precise location on the palaeo-landsurface to be identified through features visible in 1978 photographs (Photos 9-11).

The northern portion of the site had a very shallow overburden at the time that it was first found in 1978, and large areas were exposed during the original excavation (Photos 2, 5). Since there were no 1978 trench walls to re-locate[1], as in 1995, the aim was to establish an approximately 3 m wide trench on the reburied surface that preserved the hominid and hipparion trackways. The assumption was that the hominid tracks were centered under the 1978 reburial mound. The tuff surface in the north was expected to be relatively flat, but the definition of the boundaries of the graben, the eroded area without prints south of the graben, and the configuration of Fault 3, including the island of tuff preserving a pair of prints at the base of the fault, were uncertain since none of these features are shown in published maps from the 1978 field season.

The grid system used was that established in 1995, increasing to the north and east (Fig. 10). The northern corners of the 1995 excavation trench (E100/N103, E104.5/N103) were relocated by triangulation from datum points external to the 1995 reburial mound: points S, E-2, and W-2.

Four trenches were established in 1996, covering 20 meters (N103-N123). From the south proceeding northward the trenches were designated Trench 4, 5, 6, and 7 respectively (Fig. 11).

Trench 4.

Trench 4 is rectangular, 4.5x4m, from N103 to N107, and lies to the north of Trench 3, the northernmost trench excavated in 1995. It encompasses the poorly preserved tuff surface, without prints, completing the southern sector of the trackway. It also includes Fault 3, and the well preserved hominid prints G1-24 and G2/3-17 that lie at the base of the fault to the north (Fig. 11). Co-ordinates of the corners of Trench 4 are southwest E100/N103, northwest E100/N107, northeast E104.5/N107, and southeast E104.5/N103.

[1] Only in trench 4 was there a trench wall to re-locate. This was the continuation of the 1979 trench on the southern sector.

Trench 5

Trench 5, is L shaped, running from N107-N112. It is 2-3 m wide and 5 m long (Fig. 11). This trench encompasses much of the eroded tuff surface, without prints, to the north of Fault 3 (and is referred to as the middle sector of the trackway). Co-ordinates of the corners of Trench 5 are southwest E100/N107, west E100/N110, and E99/N110, northwest E99/N112, northeast E102/N112, east E102/N110, and southeast E102/N107.

Trench 6

Trench 6 is L-shaped, 3-3.5 wide and 5m long, running from N112-117 (Fig. 11). It was enlarged to 3.5m at the northern end to encompass the hipparion trail. This trench covered the graben and a short stretch of trackway to the north of Fault 1. Both of these areas preserve hominid prints. Co-ordinates of the corners of Trench 6 are southwest E99/N112, west E99/N115.50, and E98.50/N115.50, northwest E98.50/N117, northeast E102/N117, southeast E102/N112.

Trench 7

Trench 7 is rectangular, 3.5 x 6m (Fig. 11). Originally 3m wide, it was extended half a meter to the west to include the hipparion trail lying outside the 1979 reburial mound. It runs from N117-123, and covers an area of tuff surface preserving the majority of prints in the northern sector. Corners of Trench 6 are southwest E98.50/N117, northwest E98.50/N123; northeast E102/N123, and southeast E102/N117.

Before excavation, the profile of the 1978 reburial mound was drawn (Fig. 19). Elevations were measured each meter from N103 to the northern end of the 1978 reburial mound following the center of the mound. The plan of the irregular northern end of the 1978 reburial mound was also drawn.

Since little top soil was preserved above the tuff in the vicinity of Trenches 4 -7, pegs or nails could not be used to mark trench boundaries. Instead, concrete bollards were cast with hooks in the center at the top. These were placed on fill material, and were heavy enough to ensure that they could not be moved inadvertently (their basal diameter was 20 cm). Trench boundaries were marked with twine attached to the central hook of the bollard, and bollards were labeled with grid numbers (Photos 8, 9). Corners E100/N103 and E104.5/N103 lay in the 1995 reburial mound, but were marked for the duration of the excavations with bollards inserted into the mantling boulders.

1996 GENERAL EXCAVATION STRATEGIES AND METHODS

Identification of key areas of the trackway, such as stretches preserving hominid prints, and major features such as the graben and the faults was assisted by the exposed tuff surface at the northernmost end of Trench 7, topographic features and variation in the 1978 reburial fill. Most of the reburial mound consisted of a relatively consolidated coarse granular fill. However, a much less consolidated area of fill was obvious between c. N112-114, and a clay rather than granular fill was present in the area between N108-N112; a second area of softer granular fill could be defined at approx. N107.5. It seemed likely that the areas of soft fill corresponded to areas of deeper fill over footprints at the base of the third fault and the graben, and the clay overlay the section without footprints. These assumptions proved to be correct on re-excavation.

Because Trenches 6 and 7 preserved the majority of the hominid prints to be prepared for conservation work, excavation focused first on these areas. Once the graben was defined, early work in Trench 6 was concentrated on the portion of Trench 6 from the graben northward (Photo 15). Trench 4 was excavated during the later stages of work on Trenches 6 and 7, and Trench 5 was the last to be completed.

Excavation of the first several spits below the surface of the 1978 reburial mound was conducted by shovel-shaving for one or two spits of approximately 10 cm each. Excavation of lower units of the fill generally took place in arbitrary 5-10 cm levels. The strategy in excavation of the lower reburial fill was to stay just above the tuff surface, so that it could be revealed through delicate work in the final spit. Since there was no detailed information on the contours of the tuff surface, this was not always possible, but excavators became alert to specific clues that they were approaching the tuff surface, particularly the presence of dampness, small rootlets, and fine black sand.

Excavation in proximity to the trackway surface was conducted using trowels and brushes or "Olduvai" tools (5" nails hammered out to form a chisel end, and mounted in a wooden handle). Shaped wooden tongue depressors were mainly used in exposure of the well preserved tuff surface, but when the fill was very compacted the Olduvai tools were most effective. Where the tuff surface was wet and very fragile it was left to dry as long as possible and wooden tools were used including tongue depressors and applicator sticks. Short brushes and wooden tools were used for fine cleaning.

Hand-held air bulbs were helpful for blowing away loose fill material and defining the tuff surface in fragile areas (Photo 22a); jewelers' loops provided magnification when necessary. In a few areas, where overburden was especially consolidated, as in the washed out areas at the very north of Trench 7, or where overburden was especially deep, as in the eastern side of the graben, archaeological picks were used to remove fill. These were used by experienced crew members, until reaching within a few cm above the tuff surface.

Small mammal, bird and hipparion prints were excavated by archaeologists and conservators. Hominid prints were defined by the archaeological crew but the final excavation and fine cleaning was done by conservators (see Part III). There were 1978 casts only for the northernmost portion of the trackway and for selected individual prints, but those that existed were an invaluable guide to definition and excavation of prints (Photos 16, 21). Where casts did not exist photographs were relied on for location and definition of footprints. Archaeologists worked closely at all times with conservators and with scientific photographers. Preventive conservation in the form of consolidation of fragile surfaces took place where necessary during excavation.

The shelter used in 1995 (described in the 1995 Report) was erected over Trench 7 and the northern portion of Trench 6, in order to mitigate rapid drying out of the mound and tuff surface during re-excavation. Additional shelters covered with tarps were used over Trenches 4 and 5 as needed.

To further reduce the effect of rapid drying of hominid prints and protect them from windblown dust and accidental damage, small cotton bags cut to the shape of the G1 and G2/3 prints and filled with finely sieved sand were laid on the hominid prints (Photo 3). Towards the end of the season it became necessary to protect the site from early intermittent rains. This was accomplished by covering existing shelters with water-proof tarps. Sandbags were also used parallel to both the western and eastern boundaries of trenches in areas where the re-excavation was vulnerable to run-off from the surrounding area. Prints at the base of the third fault were additionally protected by a tarpaulin since they lay close to the western edge of the shelter. At night the sides of the shelter were rolled down to protect against intrusion of animals.

CHARACTERISTICS OF THE 1978 REBURIAL FILL AND BOULDER COVERING

There was far more variation in the kind and condition of fill and boulder covering in the northern 20m than was encountered in the southern 10m in 1995. In all areas, except in Trench 5 and the southernmost portion of Trench 6, between N108-N112/113, coarse sandy fill from the Garusi River bed predominated. The uppermost layer (circa 10-20 cm) of the reburial fill was consolidated and bound together with grass roots. Depth of fill was variable. In the northern section of Trench 7 the fill was shallow, ~15cm deep, and very consolidated, probably due to calcification during the 18 years since reburial. Fill deepened to the south, to ~25cm at N118. In the graben, fill was up to 50cm deep (Fig. 19), unconsolidated and wet.

Between N108-N112/113, the area between the graben and the base of Fault 3, where there are no footprints, the reburial was very shallow, 5-10 cm deep, and predominantly clay rather than sandy fill; the clay was always extremely consolidated and the boulder capping left deep impressions in it (Photos 8, 9).

The shallow 1979 west trench wall as defined in Trench 4 was composed of clayey soil with distinct lenses of sandy fill. This suggests a deliberate construction of the trench wall, perhaps to retain the reburial fill, or the remains of the covering laid down in 1978 and re-excavated in 1979 following the trench lines established at that time. A similar phenomenon of a constructed trench wall was also noted in 1995 for parts of the west trench of the southern trackway sector (see 1995 Report).

The 1978 Garusi sand fill ranged in size from cobbles as large as 10 cm in maximum dimension (including in one case, a large stone tool overlying one of the hominid prints) to fine sands usually present in a thin layer approximately 3 mm above the tuff. Pebbles of 1 cm maximum dimension were common (Photo 22b). The fill also contained a number of fossils, including Artiodactyl teeth.

The boulder covering of the northern 20 meters also varied. The northernmost 4m of the reburial (from N117) was covered with tuff blocks rather than the volcanic boulders that were used throughout the rest of the reburial mound in 1978 and 1979 (Photo 20b).

Fauna was abundant in the fill, especially in the upper levels of the reburial fill and included: mice, skinks, lizards, centipedes, scorpions, and beetles. Termites were commonly associated with stumps that had been killed in 1994. None of these appeared to be doing harm to the tuff, but minor damage to the tuff surface was caused by pupating larvae of cut-worms and trails of an unidentified insect (see below and Part III for insect damage to the tuff surface).

As in 1995, ungerminated acacia seeds were found in the reburial fill, particularly in the lower levels; more than 20 were recovered. These were seeds of *Acacia seyal*, the tree predominantly associated with the 1978-79 reburial mound, and common in riverine environments.

EXCAVATION OF TRENCHES 4 –7

Trenches 4 and 5

Trenches 4 and 5 can be subdivided into four distinct areas, each of which required its own re-excavation strategies, and revealed different tuff surfaces. These are described below.

1. *The continuation of the southern sector of the trackway to Fault 3 (N103-N104/106).* In this area the overlying reburial fill was relatively deep, circa 25 cm, but unconsolidated (Fig. 18). Between N103-N104/106 it was possible to brush away the dry fill revealing the tuff surface. The tuff surface in this area was low in the sequence, and did not preserve prints. It was relatively flat, quite consolidated, but very fractured with parallel jointing running NE –SW (Photo 28). The tuff is 7-8cm thick overlying a clay layer, as seen in section at Fault 3 (Photo 17). Two excavation nails were found; one close to the 1978 western boundary of the tuff surface at the south edge of Fault 3 (Fig. 12) and presumably used to mark 1979 excavation boundaries, and the other coincidentally on line with the 1995-96 west trench line and probably used to mark the 1978 excavation boundaries, as seen in Photo 5.[2]

2. *The slope of Fault 3 (N104.50-N105.50/107), where no tuff is preserved.* The definition of the slope of Fault 3 (N104.50-N105.50/107) involved brushing off overlying unconsolidated burial fill, and light work with trowels. This area was apparently not fully revealed in 1978. The paleolandsurface was most closely followed immediately south of G 1-24 and G 2/3-17, where a one meter wide area was excavated in 1978 on the slope of the fault. Reburial fill was removed from both the excavated and unexcavated areas, without excavating further than in 1978 (Photo 17).

3. *The small island of tuff at the base of Fault 3 (N105.30-N107.10).* This is a narrow (30-80 cm wide), raised area of tuff oriented NE-SW on which prints G 1-24 and G 2/3-17 lie (Photos 17, 18). It was covered by ~25cm of relatively unconsolidated reburial fill. The upper surface of the footprint tuff surface as revealed was in good condition in this region, without root or insect damage, or marked weathering, and appears to have been well preserved by the 1978 reburial. Just north of this ridge, two shallow depressions low in the tuff sequence may represent undertracks, designated G2/3-15 and G 2/3-16 in 1978.

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[2] The 1978 excavation continued approximately 5 m south of Fault 3 to try to find the continuation of the hominid trail. The 1978 western excavation boundary was shifted further east in 1979, to align with the hominid trail, which lies further to the east south of Fault 3.

4. The stretch of tuff low in sequence between the island of tuff and the graben (N106.20/107.10-N112). This area does not preserve prints and was reburied in 1978 with clay rather than sandy fill. It was difficult to excavate because the clay was very compacted. It was underlain by only a very thin layer of sandy fill, which tended to adhere to the tuff surface. Olduvai tools were used and in some cases small picks to remove upper layers of clay. The tuff surface in this region is low in the sequence, very consolidated and preserves only possible undertracks of animal prints and two hominid prints just north of the island (G2/3-15,16). It is fractured but generally level, with a deep fissure at N107-108.50, oriented NE-SW, parallel to the jointing pattern of the tuff to the north (Fig. 13). This consolidated tuff surface transitions abruptly in Trench 6 to a clayey weathered tuff that forms the southern edge of the graben. The southern edge of this weathered tuff defines an irregular line running NW-SE. Isolated tuff blocks were found in situ at the apex of the V-shaped southern boundary of the graben (Fig. 13).

Trenches 6 and 7 (N112-123)

Trenches 6 and 7 cover the northern 11m of the trackway, from just south of the graben to the NW gully in the north. The tuff surface was first exposed by Marshall and Demas in a narrow E-W transect at approximately N119 (Photo 14), the area preserving hominid prints G1-10, G 2/3-5, and G2/3-6. It was only once this was completed, and when the northern edge of the graben was fully exposed, that it was possible to use features on the 1978 photographs to relocate with any precision the hominid footprints relative to trench boundaries. The excavated transect revealed that Trench 7 sampled much more of the area east of the hominid prints, than west, and would probably exclude, or at least crowd, some of the hipparion prints, which had not been covered by the 1978 reburial mound. As a result the trench was extended 50 cm to the west, from E 99 to E 98.50 (Fig. 14).

As noted by the original excavators, the tuff surface in Trenches 6 and 7 was very broken up, with considerable topographic relief (Photos 27, 40), as a result of extensive weathering and fracturing due to its proximity to the surface (White and Suwa 1987, 487, 490; Leakey and Harris, 1987, 490f). Unlike the prints in the southern trackway, those in the north are mainly not in upper levels of tuff; underprinting is common. A comparison of the photogrammetric contour plans of the northern and southern sectors (Figs 15, 17) shows clearly the differences in preservation of the tuff surface and prints.

Despite the poor condition of the northern sector of the trackway, the tuff level was relatively easy to follow since only the coarse sandy fill was being removed, which ranged from small pebbles to fine black sand. This fill matrix was generally quite distinct by size, color and texture from the tuff surface. In a few cases where tuffaceous or clay pellets were incorporated into the fill, and mimicked particles of footprint tuff, ambiguous particles were left unexcavated until it was clear where the tuff surface was in adjacent areas. In addition, small rootlets were typically distinguishable just above the tuff surface and following it laterally, and formed a marker surface. In most cases the fill released fairly readily from the tuff surface. However, embedding of fine particles from the overburden in the weathered tuff was common, particularly at the wetter southern end of the Trench 6. In these cases the fill was left to dry completely, at which point it was possible to brush further material out of the tuff surface.

Insect activity on the trackway surface was found in Trench 7 and the northern part of Trench 6 (that is, north of the graben). Twenty nine lunette-shaped pupal casings, some containing larvae, were recorded in this area (Photo 31). Several of these larvae were preserved in alcohol and identified by John Mwangi, Technical Supervisor, Department of Invertebrate Zoology, Kenya National Museums, as chafers (Order *Coleoptera*, Family *Scarabaeidae*, Sub family *Melolonthinae)*. These are mainly nocturnal leaf-eating beetles as adults, and root-feeding white grubs as larvae, commonly known as cut-worms. Fortunately none of these casings co-incided with hominid prints. Insect trails on the tuff surface were however present in a few of the hominid prints.

The graben surface was extremely irregular and undulating, with a depth of up to 30 cm below the tuff level north of Fault 1 (Photo 38b); the western half of the graben shows far more topographic relief than the east. Consequently, the reburial fill was deepest in the graben, and was wet. Under these circumstances, the tuff was soft, and very vulnerable to damage; in the vicinity of prints G1-22, 23, the tuff has a distinct calcite skin. The graben was the only area in which a large pebble, 4 cm in diameter, was found substantially embedded into the surface. This is an indication of how sensible to deformation wet tuff is. In these areas it was necessary to allow the tuff to dry before proceeding. Once the tuff dried it hardened considerably, and became more amenable to careful exposure. In some areas however the tuff surface when dry was extremely powdery and fragile. The decision was made for conservators to consolidate such areas when necessary during the excavation process, in order to prevent damage.

In a few areas, small pieces of transparent plastic were found. These were usually 1 cm square or less, and usually close to tree stumps, or on the west edge of the 1978 reburial mound. However, in the graben a few large pieces (up to 15 cm maximum diameter) were found, directly overlaying and adhered to the tuff surface at the northwest edge of the graben floor. Since a layer of plastic has never been found it is not clear what happened to the plastic that reportedly was placed in the 1978-79 reburial. On the basis of the condition of the plastic fragments as examined in the field, it seems probable that the plastic had degraded chemically.

Area of erosion near the NW gully

Excavation of the northernmost section of tuff in Trench 7, at approximately N121.50, revealed an erosional channel where water flow had cut through the exposed tuff layers (Photo 19, Fig. 14). For the most part, the channel deposits could be easily followed out since they were comprised of clayey alluvial wash, rather than sandy fill, often highly compacted, and including pieces of grass, thorn and stick. At the margins of the erosional channel, many microlevels of the tuff surface were exposed. Some of these levels had broken down, and weathered in a way that made them difficult to distinguish from each other, and from the channel fill. The narrow erosional channel (approximately 35-40cm wide where it cuts through higher tuff to the north and south) opens up to the west toward the NW gully.

As described in Part V (Site Stabilization), the erosional channel was created by the ancient drainage patterns at Site G, which were only partially and temporarily deterred by the 1978 reburial mound. The entire northern end of the 1996 Trench 7 was found to have been affected by water run-off to the NW gully. Unfortunately this included the northwesternmost end of the hominid trails, where the first two footprints (G1-1 and G1-2) were excavated in 1978. When re-excavated in 1996, this area (referred to as the "area of erosion" on the plans, Fig 14) was composed of gray, fine-grained clayey material in which fragments of tuff (probably L10) were floating (Photo 21). Exposure and water flow over this area had resulted in chemical change followed by disruption of the tuff, which removed all traces of prints G1-1 and G2/3-1 (except the probable posterior margin of G1-1).

The 1996 mapping of the 1978 reburial mound prior to re-excavation clearly revealed that the northwestern area of the hominid trackway was only partly covered by the reburial mound (Fig. 9). The area of erosion lay just beyond the northernmost line of the remaining reburial mound. The original configuration of the 1978 reburial mound is not known, but it must certainly have covered prints G1-1 and G2/3-1. Absence of the boulder covering and underlying fill in this area cannot be entirely accounted for by water run-off since the area of erosion was still buffered by the remaining mound (Photo 20b). It therefore seems likely that some disturbance to the mound occurred subsequent to reburial in 1978, exposing the tuff to rain and run-off for many years. Photographs of the trackway taken in 1993 at the start of the project showed that the reburial mound was in this condition at that time (Photo 20a).

DEFINITION AND NUMBERNG OF HOMINID AND FAUNAL PRINTS

Since the tuff surface in Trenches 6 & 7 is highly irregular, and the upper portion of the footprint tuff not well preserved, the hominid prints were often preserved only as undertracks or dents in the tuff (Photo 40). In 1978, prints were numbered from north to south, following the initial discovery of the first print G1-1. The numbering system was established by Louise Robbins. In cases where there was no discernible print, numbers were assigned to the tuff surface based on the predicted stride length of the hominids. For the sake of consistency in record keeping, the 1978 numbering system for hominid and faunal prints was used, identifying ambiguous depressions that had been given an inventory number from the 1978 photographs (see also Part I for discussion of the numbering of the hominid prints).

The numbering of hipparion trackway A in the northern sector of the trackway posed problems during re-excavation. The plan of this trail published in Leakey and Harris 1987 (Fig 12.16, p. 476) shows only eight prints (numbered 1-8); the text on page 456 records 16 prints in this trail. The plan published by Day (1986) also shows 16 prints, but without numbers (Fig. 2). For purposes of recording we assigned numbers to hipparion prints (A1-18), using Day's plan to confirm the prints assigned to trail A, and adding two (A1 or A2 and A3) that were not recorded on the Day plan; these additional two prints were identified in situ as probable hipparion prints. From A4 through A18, the correspondence between the 1996 plan and the Day plan is clear, but it was not clear whether A1 or A2 corresponded to the northernmost hipparion print recorded on the Day plan (Figs 2, 14). Nor is it possible to be certain about the correspondence between the Leakey and Harris 1987 plan (Fig. 12.16) and the 1996 plan; as noted for the southern hipparion trails in 1995, the 1987 plan of the northern trail is published with the north arrow reversed.

Lagamorph prints (some of which may be dik dik prints) were recorded for the northern sector of the trackway, and numbered L1-145; seven guinea fowl prints were also re-located and numbered GF1-7 (Fig. 14).

MAPPING

The N-S profile of the 1978-9 mound was mapped before excavation, and features in the 1996 trench were mapped after excavation. The 1996 reburial mound was mapped and profiled on completion. Verification of trench boundaries, detailed surveying of features, and transcription of these points took places between August 28-September 7.

Additional features mapped for the overall site plan included the final stabilization and drainage control work, 1996 survey points, and the thorn fence around the perimeter of Site G. In conjunction with photogrammetrists, major features of the excavated surface were surveyed and mapped for the trench plan. Features included the location of faults, major cracks, boundaries of the eroded areas in the northern section of the excavated area, locations of animal footprint trails, recent insect activity noted on the tuff, and inventoried stumps. Elevations of the tuff surface in the trench were also taken.

CONCLUDING REMARKS

The northern 20 meters of the hominid trackway, Site G, preserved 41 hominid prints, as recorded in 1978. All the prints or features identified as prints were re-located in 1996, with the exception of G1-1 and G2/3-1, both of which were lost to erosion. The character of this section of the trackway was highly variable, being dissected by 3 major faults, and preserving the surface of Horizon B in only a few areas. The northern 20 meters of the trackway excavated in 1996 is divided into three trackway sectors, as follows:

1) The northern sector of the trackway, approximately 10.0m in length (N113-123): this includes the graben and Faults 1 and 2, preserving one excavated and two unexcavated hominid prints; and the area north of the graben, which preserves the majority of the footprints.

2) The middle sector of the trackway, approximately 8.5m in length (N104.5-113): this includes the ~6 m section south of the graben (circa N107-113), where only 2 shallow depressions identified as G2/3-15 and G2/3-16 in 1978 are preserved; the small island of well preserved footprint tuff with two hominid prints (G1-24 and G2/3-17); and the slope of Fault 3.

3) The continuation of the southern sector of the trackway, approximately 1.5m in length (N103-104.5): this is an extension of the area excavated in 1995; the southern trackway sector is defined as ending at Fault 3 in the north. In this section excavated in 1996, the upper unit of the Footprint Tuff was eroded, and no hominid prints are preserved.

The 1996 re-excavation of the northern 20 m of the hominid trackway at Site G, accomplished over an eight week period, was challenging but successful. Difficulties resulted from the lack of published survey information on the location of the footprints and other features within the mound, and of the irregular conformation of the tuff surface. Other concerns during excavation were the high level of consolidation of the 1978 fill, the degree of weathering and fragility of the tuff surface north of the graben, the amount of moisture in the fill of the graben, and the extensive growth of lateral acacia roots in the graben and areas immediately to the north.

Re-excavation and subsequent mapping and photogrammetry have provided for the first time detailed plans of the hominid footprints in relation to the tuff surface and present day topography of the site. Re-excavation also showed that ungerminated acacia seeds were common throughout the reburial fill. As in 1995 we concluded that these were accidentally introduced with the 1978 river sand. Living fauna was found in the trench, mostly insects. Unlike 1995, re-excavation also revealed minor damage to the tuff surface as a result of insect activity (cut-worms in particular) associated with the presence of roots.

The northern sector of the trackway was in 1978 already extensively weathered and dislocated as a result of its proximity to the surface and gully edges. Excavation in 1996 documented some continued subsurface weathering under the 1978 reburial mound and suggested that the northernmost tuff surface had not been preserved as well under reburial as the southernmost end of the trackway. The 1996 re-excavation also documented the unfortunate loss of the original two hominid prints G1-1 and G2/3-1, as a result of erosion. Print G1-2 was endangered by erosion, since it lay on the very edge of the area still found covered by boulders in 1996, but was fortunately undamaged. It seems certain that prints G1-1, G2/3-1 and G1-2 were originally carefully buried. Mary Leakey, on examining the area during the first of her 1996 visits, assured us that this was the case. It therefore seems likely that the end of the mound was disturbed at some point since 1978, and the exposed tuff subjected to the impact of rain and water run-off.

Thirty-two trees were found in the 20m excavated during 1996, about half the density of trees found in the southernmost section of the site excavated in 1995.

Although the density of trees and therefore roots was far less in the northern 20m, the weathered nature of the tuff surface in Trenches 4-7 made it more vulnerable to damage by roots. This was especially clear during excavation in the area to the north of the graben where lateral roots had threaded their way in and out of the tuff surface, not necessarily following fissures as in 1995. Elsewhere, however, the large fissures and cracks in the northern trackway provided a convenient path for roots (Photo 29). Four hominid footprints (G1-2, 19 and G2/3-10, 17), though none of the hipparion footprints, were pierced by larger, disruptive roots (1-5mm diam.).

In conclusion, given that the northern sector of the trackway was never well preserved, excavation showed that it had survived the 18 years of shallow reburial relatively well. Despite this fact, the cumulative effect of the 32 trees growing in the area, weathering and erosion of the tuff, and the activity of insects had a more significant impact on the trackway than was evident in the south. Six prints were damaged and two were completely lost to erosion (see Part III for more details on damage to prints). The re-excavation and subsequent conservation work at Laetoli was timely as by 1996 root growth and erosion were serious threats to the trackway.

PART III. CONSERVATION OF THE NORTHERN 20 METERS OF THE TRACKWAY

by Angelyn Bass, Leslie Rainer, Francesca Piqué, Eduardo Sanchez, and Donatius Kamamba

INTRODUCTION

Due to the severely weathered and eroded condition of the tuff on the northern and middle sectors of the trackway, conservation work during the 1996 campaign focused on recording the condition of the trackway, stabilizing fragile tuff, and cutting and removing where possible, acacia stumps and roots and grass roots that had penetrated the tuff. The conservation team worked with the archaeologists to re-excavate the trackway and undertook the final excavation and cleaning of the hominid prints.

The conservation team comprised Angelyn Bass, Francesca Piqué, and Leslie Rainer from the GCI, Eduardo Sanchez from the J. Paul Getty Museum, Donatius Kamamba from the Tanzanian Department of Antiquities, and Jesuit Temba from the National Museum in Dar es Salaam. Of the six team members, five had participated in the 1995 campaign to conserve the southern sector of the trackway. Conservation procedures were discussed with Jerry Podany, head conservator on the project, prior to the field campaign. Martha Demas and Donatius Kamamba reviewed all decisions in the field, prior to implementation. Bass and Kamamba supervised the day-to-day conservation activities on site.

RE-EXCAVATION OF THE FOOTPRINTS

The first task of the conservators was to work with the archaeologists to re-excavate the trackway surface and to remove fill from the hominid prints. Since the condition of the tuff was fragile in areas, it was necessary that conservators work side by side with archaeologists during re-excavation to treat these areas as they were uncovered.

As detailed in Part II, re-excavation of the trackway was carried out in stages, until the tuff surface was located. After areas with hominid footprints and geological features such as Faults 1 and 2 were exposed, the tuff surface was fine-cleaned with shaped wooden tools, hand-held air bulbs, and fine, short bristle brushes. When possible, a thin layer of fill was temporarily left on the surface of the hominid prints to slow drying and reduce cracking of the surface. Complete removal and fine cleaning of fill from prints took place after the fill was thoroughly dry. Areas of the northern and middle sectors with footprints-- the north central portion, the center of the graben, and the base of Fault 3-- were excavated and fine-cleaned first to allow for conservation and palaeoscientific study.

The conservators undertook final re-excavation of individual hominid prints. Infill was removed with a variety of shaped, soft wooden or rubber-tipped tools, porcupine quills, soft to medium-hard bristle brushes, and hand-held air bulbs (Photo 22). Acetone was used on and around unexcavated print G1-21 to help distinguish and remove the overburden while preserving the matrix of unexcavated tuff. This technique resulted from the difference in permeability between the tuff and the overburden, which caused the acetone to penetrate and evaporate at different rates, making it easy to visually distinguish between the layers.

The fill in the prints was generally well-compacted, damp and cohesive, and released in discrete clumps. Particle size of the fill ranged from 0.5cm to clay particle size, with fines tending to concentrate in the lower levels of the print (Photo 22). For the most part, re-excavation of the prints was straightforward and the fill easily removed, though some of the heavily weathered and embedded prints such as G2/3-6 and G2/3-8 posed a certain degree of difficulty. As in 1995, deeply embedded particles were not removed and areas of fragile tuff were immediately documented and treated.

Replicas of casts and photographs from 1978 were used to guide the hominid footprint re-excavation and fine cleaning (Photo 16). Only 11 of the 41 prints on the northern and middle sector--G1-1,2,3, 19, 22 24 and G2/3-1,2,3,7, and 9--had original casts or molds in storage at Olduvai. (N.B. 27 of the 29 prints on the southern sector had original casts or molds). Ron Street prepared replicas of the 11 prints for use in the field (see Part IX). For the remaining prints, 1978 photographs served as the principal reference. A log was kept which recorded the condition of each footprint excavated and characteristics of the infill material.

CONDITION AND TREATMENT RECORDING

After excavation, the northern sector, and portions of the middle sector were photographed with an 8x10 Polaroid camera (Photo 50) and the condition of the tuff was assessed and graphically recorded. In addition to conditions observed in 1995 on the southern sector, which included extent and degree of loss, cracks, previous interventions, root growth, and adherent overburden (see 1995 Report), conditions pertaining to weathered tuff and insect activity were also recorded (Appendix B lists all the conditions recorded in 1995 and 1996). Each condition was assigned a graphic symbol, and the symbol was annotated on transparent sheets overlaid on 8x10 color Polaroid photographs. This procedure also served to record conservation treatments.

Photodocumentation with an 8x10 Polaroid camera was the same as that done in 1995, where areas of the tuff surface (approximately 1m^2) were recorded in a series of "flyover" shots, and footprints were photographed individually (see Part VI for further discussion and schematic map of Polaroid flyover photography). Twenty-five of the 41 northern and middle sector hominid footprints were photographed individually and received a detailed condition assessment; condition recording of the remaining 16 prints, which were not individually photographed because they had little or no morphology, or in the case of G1-1 and G2/3-1, were lost to erosion, was conducted on the flyovers. A 15m^2 area of the middle sector (from N107-N112) that did not preserve footprints and was covered with a hard, clayey overburden was not fully fine-cleaned and was not formally recorded. Appendix A lists all the prints for the entire trackway covered by individual Polaroids.

CONDITION OF THE TRACKWAY AND HOMINID PRINTS

In contrast to the smooth, well-preserved southern sector of the trackway, the northern and middle sectors were considerably more weathered and fragile. The tuff was found to be damp upon excavation (even wet in the graben) and was cracked and heavily embedded with particles of overburden. It contracted upon drying, and weathered cracks increased in size. During the 1978 excavation of the northern sector, Peter Jones also observed that wetness of the tuff, along with rapid drying, was one of the principal agents of deterioration (Leakey and Harris 1987; p. 553). Physical disruption by penetration by acacia roots >1mm diameter occurred in four prints (G1-2, G1-19, G2/3-10, G2/3-17) in the middle and northern sectors of the trackway. In addition, the northern and middle sectors with irregular surfaces and prominent tuff edges were extremely susceptible to incidental damage. For this reason, protocols were established to minimize foot traffic on the trackway.

Many of the prints had been moderately or significantly (e.g. Photos 36-37) altered from weathering; others were unchanged (e.g. Photos 32-33). Comparison of the prints with 1978 photographs and casts indicated that weathered tuff was a pre-existing surface condition prior to excavation in 1978, but also that additional weathering had since occurred, especially in the area of the graben and the northern sector. Print G1-19, located just north of Fault 1, had weathered considerably since 1978. What appeared from a cast and photographs as a relatively smooth and complete surface in the original excavation was extensively cracked in a polygonal pattern, rough from particle embedding, and a 4-5mm diameter acacia root had penetrated the heel (Photos 36, 37).

The most significant change that occurred since 1978 was the loss of G1-1 and G2/3-1 (Photo 21). As explained in greater detail in Part II (Archaeology), their loss was probably the result of disturbance to the northern end of the 1978 reburial mound, which exposed parts of the tuff and allowed rain and water run-off to erode the prints over a period of many years.

It was observed that some of the best preserved prints had a layer of calcite on the surface. Because of their calcite skin, the interior surfaces of prints G2/3-7 and 9 and G1-2, 22 and 24, were hard, had little damage from surface embedding, and generally exhibited greater physical stability and resistance to cracking throughout the period of their exposure (e.g. Photos 32-33; 34-35). Also, roots tended to be deflected along the surface of the print rather than grow through the tuff. The unweathered tuff with its calcite skin in the southern sector is also a reason for the good preservation of that section of the trackway.

Weathering phenomena

Tuff that had started to decompose into clays, referred to as 'weathered tuff,' was a common phenomenon on the northern sector already in 1978. Weathered tuff was also observed on the southern sector, but only in a discrete 1.40x1.90m wide strip at the northern end (see 1995 Report, p. 22, and Fig. 12 in this report).

The degree and location of weathered tuff varied considerably. Often, localized patches of weathered tuff would suddenly transition into areas of stable, competent tuff (Photo 40). Reasons for this patchy weathering phenomenon are unknown. Weathering may have resulted from a number of factors: changing hydrological conditions; wetting and drying cycles, especially under conditions of shallow reburial; differences in depth of the original overburden prior to excavation, which varied considerably from south to north; differences in jointing; and extraneous influences such as roots and insects that could alter the environment. The most severe weathering was at Faults 1 and 2 where the large fractures with displacement were conduits for water entering the tuff.

Weathered tuff was distinct from unweathered tuff in its physical appearance (such as texture and color) and composition. The weathered tuff was darker than unweathered tuff, with a coarser texture, and cracked in a network pattern through the surface (Photo 30). Quantitative mineralogical analysis of weathered and unweathered tuff conducted at the GCI showed that the percentage of clay in the weathered tuff was nearly two to three times greater by weight (10-15% versus <5%), while the percentage of zeolite was up to five times less (<3% versus 10-15%). Calcite percentages were relatively similar at 65% by weight.

The pattern-cracking was principally due to swelling clays in the tuff that expand and contract with moisture content. It is likely that the extent of cracking is roughly proportional to the clay content of the tuff. As excavation proceeded, the tuff was exposed to low ambient RH conditions, and dried, causing it to contract. Although the overall trend was drying, cycles of wetting also occurred which caused the clays to swell. Condensation occurred typically in the early morning when the tuff surface reached the dew point temperature.

The extent and degree of particle embedding was also proportional to clay content. Experiments at the GCI (see 1995 Report, Part XII) showed that the type of tuff (weathered vs. unweathered) and wetness, which softens clay-rich weathered tuff, were critical variables in the degree of sand embedding.

Weathered tuff was commonly invaded by acacia roots (>1mm in diameter), and also rather extensively by small acacia, grass, and asparagus rootlets (<1mm in diameter). The soft, weathered, clay-rich tuff provided an attractive environment for root penetration due to its cracked structure and moisture retained in the clay. Damage to weathered tuff from roots was clearly seen throughout the northern sector, and in the southern sector, in the weathered strip, where acacia root penetration was concentrated (fourteen of sixteen penetrating tap roots in the southern sector were located there). In addition to acacia trees, grasses, weeds and shrubs flourished in the shallow burial of the northern and middle sectors, creating extensive networks of rootlets that infiltrated the weathered tuff and grew along and into cracks (Photos 24, 28, 29). Extensive networks of rootlets were also observed in photographs from 1978-79. Though rootlets caused little apparent physical disruption at the macroscopic scale, their impact may be significant on the microscopic (Photo 25) and biochemical levels, though the extent has not been determined. Due to the pervasiveness of these rootlets, many were not recorded or counted in the 1996 condition documentation. This may misleadingly imply that root growth and penetration was not as widespread in the northern as in the southern sector; in reality, damage from roots and rootlets was more extensive in the north.

Numerous prints were penetrated by rootlets, which were easily cut with a scalpel and removed with tweezers. Four prints, G1-2, G1-19, G2/3-10, and G2/3-17 were disrupted by penetration from roots greater than 1mm diameter; elsewhere large roots penetrated the tuff in close proximity to prints (e.g. G2/3-3). Treatment of damaged tuff and removal or reduction of large penetrating roots is presented later in this section.

It was apparent that the condition of the tuff in the weathered areas became increasingly unstable during exposure. Over the seven weeks the trackway was open, the weathered tuff had dried and contracted and some cracks had grown in size, making the surface susceptible to damage. Monitoring of hominid print G1-19 (with a 10x scale loop fit with a linear graticule) showed a widening of cracks up to 0.8mm from the time it was excavated to the time it was reburied (Photo 36; Appendix C). To protect the trackway from direct sunlight, and to reduce fluctuations in surface temperature, which ranged from 8° in the early morning to 62°C by about 2pm, protective shelters were placed over the exposed trackway. This reduced the surface temperature range from 8-33°C. To protect and slow drying of the hominid tracks, small cotton sand bags sewn into the shape of a foot were placed over individual prints. The sand bags protected the tuff from accidental impact and stabilized the microclimate at the tuff level (Photo 3).

Bedacryl and cellulose nitrate

Two synthetic materials were detected on the surface of several hominid prints. They were later identified by IR spectroscopic analysis as an acrylic resin, Bedacryl (also identified in 1995), and cellulose nitrate, which contained a phthalate type plasticizer (probably di-isooctyl phthalate) (see Appendix D for cellulose nitrate spectra).

From correspondence with Tim White, a member of the 1978 field team, it was learned that Bedacryl had been used extensively where the edges of eroding prints needed stabilization. The resin was found in seven prints: G1-3, 14, 19, and 22, and in G2/3-6, 8 and 9. Unlike the southern sector, where the resin, which had been used to stabilize prints before molding, was found on all of the prints and left a distinct stain, Bedacryl was far less obvious on the northern sector, and was apparent only under close examination of the tuff surface as clear stringers that bridged across cracks in the tuff. The Bedacryl *in situ* retained considerable flexibility after 18 years.

White also reported the use of an acetone soluble "glue" to readhere detached tuff fragments. This is certainly cellulose nitrate, which appeared as a brittle, yellow material, in prints G1-14 and G2/3-6. The extent of the adhesive's use on the trackway in 1978 is not known. It was recorded that a fragment of broken tuff on the lateral side of G2/3-9 had been readhered with glue, though no traces of the adhesive were visible in that area. The reattached fragment was in stable condition: the joint was hairline in size, well adhered, and no yellow staining was apparent.

Cellulose nitrate, also known as nitrocellulose, is commercially available in many forms (one form commonly used in the United States is Duco cement). It was customarily used in the past as an adhesive for joining pottery and other porous objects found in excavations. Despite its former widespread use and acceptance as a quick drying, reversible adhesive, it is no longer considered a stable material, and has been proven to degrade in external environments (particularly susceptible to UV light), and to yellow upon aging[1]. Though the traces of resin found on the trackway tended to be brittle and yellow, the buried environment no doubt protected the material from significant degradation, allowing reattached fragments to remain well adhered.

Insect activity

Insect activity was observed in prints G1-13 and G1-6 and on numerous areas of the northern sector of the trackway. Two types were observed: one, a sinuous, trail-like formation on the tuff surface; and the other, small lunette-shaped cradles or craters found both in the fill and attached to the tuff. This seems to have occurred since the trackway was reburied in 1978.

Trail-like formations were found in three places of the northern sector, including the heel of G1-6 and the arch portion of G1-13. These surficial features, as though an

[1] Koob, S.P. 1982. Instability of Cellulose Nitrate Adhesives. *The Conservator*, no. 6. ICCROM.

Selwitz, Charles. 1988. *Cellulose Nitrate in Conservation.* Research in Conservation, no 2. J. Paul Getty Trust.

insect or a larva had been tracking the surface of the tuff excreting a solid trail of particles, were well cemented together and firmly attached to the tuff surface. The trails varied in length up to 3cm and in diameter up to 4mm. These features did not appear in the 1978 photographs, indicating that they formed after the trackway was reburied. There was no evidence of this type of activity on the southern sector.

Sections of the trails were removed only from the heel of G1-6 and from two areas in G1-13 at the request of the palaeoscientists who felt the forms obscured the morphology of the prints and consequently their interpretation. They were removed with a scalpel and a dental pick, after which the area was consolidated with a 25% dispersion of Acrysol WS-24 in water. Traces of the trails remained on the surface of both prints. The third trail outside the prints was not treated.

The second type of insect activity was small lunette-shaped pupal casings found in the fill and also attached to, and sometimes slightly excavated into, the surface of the tuff, several of which contained a larva, and some which retained the chitinous residue of a pupal cast (Photo 31). The insects found in the casings were identified by John Mwangi of the Kenya National Museum as chafers (Order *Coleoptera*, Family *Scarabaeidae*, Sub family, *Melolonthinae*), commonly known as cut-worms. There were 29 of these small casings found in the tuff, averaging 1cm in diameter and 0.5cm deep. There was a concentration of the casings just east of G2/3-9. It is not understood why the larvae chewed a shallow depression in the tuff (possibly to attach the casing to the tuff), or what made that particular location favorable or why such insect activity was more abundant in the northern sector of the trackway. It may have been related to the depth and compactness of the overburden and the susceptibility of the wet, soft tuff to boring. The shallow overburden in the northern sector, with abundance of grass and weed roots in proximity to the trackway surface, may have provided a suitable environment for a larger population of cut-worms. Alternatively, in the southern sector it is possible that they were not noticed in the upper levels of the burial mound where re-excavation began with shovel shaving. Though a casing was found in the fill of G1-11, none of the prints were damaged by the insect activity.

Overall condition of the graben

Excavation and conservation of the graben posed challenges. The graben, formed by Faults 1 and 2, was wet during excavation. Not only was excavation more difficult because the surface was soft, but the wet tuff also exhibited numerous conservation problems upon drying. After exposure much of the graben surface tended to crack and delaminate in thin layers from the underlying stratum, requiring immediate stabilization to prevent detachment of tiny tuff fragments. Also, portions of the tuff surface, especially the area around unexcavated print G1-21, were powdery after drying. Powdering tuff could be easily brushed away with light abrasion. This powdering phenomenon was also observed in 1995 on the southern sector at the small southern fault and near prints G1-38, 39 and G2/3-30 and 31 (also where moisture tended to accumulate), but to a lesser extent. Powdering areas were consolidated with a single application of a dilute acrylic dispersion.

Three hominid prints were located in the graben: G1-21, 22, and 23. G1-21 and 23 had been defined but never excavated in 1978 (Photo 38); their tuffaceous matrix was intact in 1996. G1-22, which was fully excavated in 1978, was in good condition, composed of firm, competent, calcite-cemented tuff.

Condition of middle sector of the trackway and Trench 4 (southern sector)

The 8.5 m long section, called the middle sector of the trackway, which included the tuff south of Fault 2 to Fault 3, was eroded when first excavated in 1978 and preserved only four hominid prints: G1-24, and G2/3-15, 16, and 17. G1-24 and G2/3-17, located on an island of tuff that preserved Horizon B, were in good-to-fair condition, though a large acacia root had penetrated the heel of G2/3-17. G2/3-15 and G2/3-16 were preserved as poor undertracks, and their condition was essentially unchanged from 1978 photographs. Most of the tuff on the middle sector was fractured and had an irregular, rough surface. Jointing was extensive, and most of the tuff surface was covered in 1978 with a hard, clayey layer. Conservation treatments in the middle sector were primarily limited to reattaching dislodged fragments and filling voids left from removed stumps of the large, woody *Acacia mellifera*, which predominated in this area.

Trench 4, which included the continuation of the southern trackway sector just south of Fault 3, does not preserve any prints, and is characterized by jointing in roughly NE-SW dominant trends. The jointing left the tuff heavily fractured (Photo 28). Tuff fragments were often disrupted and displaced by acacia and grass roots. Dislodged tuff fragments were reattached.

CONSERVATION TREATMENTS

Over the approximately seven weeks that the footprints were exposed, it became apparent that areas of weathered tuff became progressively weaker: cracks widened, due to drying and contracting of the tuff, and segments became loose. These changes in condition were of great concern, and in an effort to minimize damage, a program of regular inspection and treatment of the northern sector and graben was undertaken.

Every three to four days the trackway was inspected for damage and change, focusing especially on a 2m wide strip in the center of the northern sector where the majority of the hominid prints are located. Unstable areas were marked with colored tape (Photo 23), recorded on the graphic condition survey and then treated. Following is a description of the principal deterioration conditions and the general treatments applied. Since the degree and extent of instability or damage varied along the trackway, treatment method and concentration of the solutions also varied depending on the need. Modifications of standard treatment procedures were documented on the individual condition survey notes.

Stabilization of loose tuff

In areas of weathered tuff, where pattern cracking was extensive, polygons of tuff were often loose and in danger of becoming dislodged. This condition became more severe as the tuff dried and contracted, and the cracks became wider. In some cases the cracking varied between a few millimeters in width, as seen in the graben, to 5-6mm at Fault 1. It was necessary to consolidate these areas to protect the tuff from damage during the work.

In 1993 and again in 1996, an aqueous acrylic dispersion, Acrysol WS-24 (manufactured by Rohm and Haas), was field-tested on an outlying area of naturally exposed tuff prior to its use on the trackway. Percentages of up to 25% were found to be satisfactory and effective at stabilizing loose tuff, without changing its appearance.

Loose areas of tuff were consolidated with a dispersion of WS-24 in water, ranging between 15-25% depending on the severity of the situation. The dispersion was applied with a syringe and allowed to slowly enter the base of the cracks. Care was taken not to flood the tuff surface. If overflow did occur, the area was dabbed on the surface with a cotton swab and water to remove the excess.

Treating the loose areas was an important preventive conservation measure to avoid complete detachment and dislodgment of tuff. However, in a few cases, complete detachment did occur, and the fragment was readhered.

Readhesion of detached fragments

The problem of detached tuff fragments and detached segments of calcite veins was encountered during excavation, but became more extensive as the trackway dried out and became weaker, compounded by unavoidable foot traffic over the surface.

Readhesion of detached fragments followed the procedure developed in 1995 (see 1995 Report) with a slight modification in the concentration of the acrylic. Large fragments were generally readhered with commercially prepared acrylic resin (Acryloid B-72 resin in organic solvent supplied by HMG). The detached fragment was removed and the adherent surfaces were preconsolidated with a 10% solution of B-72 in acetone. Then a 50% solution of B-72 was used to bond the two surfaces. Initially the B-72 was used at 100% as an adhesive, but this proved to be too viscous to penetrate into the porous surface and would not always bond the tuff surfaces efficiently. It was decided to dilute the solution so that the material would penetrate the surface deeply and bond to the contact faces.

A slightly different procedure was used in Trench 4, where larger fragments (>5cm^2) of tuff were detached and large voids were present. Detached fragments were laid in a mortar bed composed of 4 parts fine sieved sand: 1 part WS-24 full strength: 1 part water. Once the mortar set, a 25% dispersion of WS-24 in water was injected into the weak area. The fragment was held in place until it had bonded, and then the surface was dabbed with water to prevent any staining.

Infilling of voids

Voids occurred primarily in the areas where roots and stumps were removed, and occasionally, under the tuff surface, such as along the lateral margin of print G2/3-7. Although the origin and cause of some of the voids was unclear, it was felt that it was important to fill these areas to prevent deformation and collapse under load of the reburial.

Voids were filled as follows: if the exposed edges and walls of the voids were noticeably weak, or unstable enough to accept the infilling material, they were pre-consolidated with one application of 2.5% B-72 in acetone and allowed to dry. With some of the larger voids left by disintegrated or routed stumps, Polywrap film was placed in the void to act as an interface. The space was filled with a mortar composed of 4 parts sieved reburial fill and 1 part 25-50% aqueous solution of Acrysol WS-24, which was gently but firmly pushed into the void. To create a homogeneous appearance, the void was filled flush or slightly recessed below the tuff level, and the surface of the fill was covered with loose sieved tuff. The fill remains discernible under close observation. The filling technique was satisfactory, did not shrink on setting, and ensured stability of the void.

Consolidation of powdery surfaces

Localized areas of the tuff surface, primarily in the northeast portion of the trackway and the graben, were found to be powdery and would disintegrate upon touching. Reasons for the powdering are two-fold: the mineralogical composition of certain individual Footprint Tuff layers results in a naturally weak tuff with poor cohesion, as suggested by Craig Feibel. In other cases, advanced weathering together with drying upon exposure of wet areas, such as the graben, resulted in a clayey, friable tuff surface that was easily abraded by tools or foot traffic.

In 1996, comparative off-site field tests using Acrysol WS-24 and B-72 in varying dilutions were done to evaluate their suitability for consolidation of powdering tuff. Acrysol WS-24 was tested at 25%, 33%, and 50% dilutions of the manufactured product in water. Paraloid B-72 was diluted with acetone and tested at 2.5% and 5% of the product as supplied. Results were recorded and assessed in terms of effectiveness and color change. In general, the WS-24 at all concentrations penetrated the surface easily and had a deep consolidating effect. B-72 in acetone was less penetrating and harder to use as the acetone evaporated quickly, increasing the concentration of the solution on the surface and limiting its penetration. No change of gloss was observed on any of the test areas.

Following evaluation of the tests, WS-24 at 50% was selected. Powdery surfaces were treated with this dispersion applied by brush. Normally, one application was sufficient, but in a few cases where the powdery surface persisted, a second application was necessary. This method worked well without causing color change or gloss to the surface. Following treatment, the surfaces showed no further powdering for the duration of exposure.

ROOT TREATMENT

Thirty-two trees were located in the 20m excavated area in 1996 (Figs 12-14; Photo 41). Ten of these were stumps from trees cut in 1978-79, most of which had rotted and disintegrated, leaving a detritus-filled void. Thirty-seven lateral roots associated with the inventoried stumps penetrated the tuff surface in the 1996 excavated area (these numbers do not reflect the myriad of rootlets that penetrated the trackway surface, but only roots that could be clearly associated with an inventoried stump).

The largest and most damaging acacia trees were found on the middle sector south of the graben. The trees in this area--mainly *Acacia mellifera*--had large trunks with tap and lateral roots that severely disrupted and damaged the tuff. Prior to treatment, the roots were numbered, photographed, measured and plotted on a map of the trackway. Photographs were taken and included the stump or root number, a centimeter scale and a centimeter arrow pointing north. Measurements of the stump's base diameter, height at the time of removal, and number and length of lateral roots were taken and recorded on a root data sheet and photographed with a Polaroid camera.

Prior to cutting and removal of stumps and roots, surrounding disrupted tuff was consolidated. Aqueous solutions of Acrysol WS-24, ranging from 15-50% were applied by syringe to the disrupted area. Application was repeated after the cutting procedure in cases where the tuff was severely disrupted and likely to be affected by vibrations caused by the cutting procedure. As already mentioned, when root reduction left a void in the tuff, the area was filled with an acrylic amended soil mixture to prevent collapse under load of the reburial.

Root treatment procedures were similar to 1995 and were as follows: large stumps were first cut with a standard hand-held saw or a fine-tooth flexible hand saw (Photo 26). Each stump was cut as close to the tuff surface as possible. A high speed Dremel motor fitted with a small fine-tooth circular saw blade was used to cut lateral roots at the point where they entered the tuff's surface. The remaining lateral roots and smaller roots that did not penetrate the tuff, were cut with standard pruning shears or with a surgical scalpel and removed with tweezers. If final reduction of the lateral roots was possible, the Dremel motor was fitted with a 1/8" diameter router bit and the root was routed out, leaving as little of the wood as possible. In cases where much of the wood was remaining, especially in the stumps, 1/4-1/8" holes were drilled and preservative was applied to inhibit decay and insect attack (see Part IV).

CONCLUDING REMARKS

The 20m of the trackway conserved in 1996 posed very different problems and conservation issues from those encountered on the southern sector in 1995. Advanced and extensive weathering, insect activity, and greater root penetration, all of which interrelate, made for more intensive and widespread conservation interventions than in

1995. 1996 conservation treatments focused on documenting and monitoring the condition of the trackway, root removal or reduction, and mitigating damage to the tuff through stabilization and readhesion treatments.

When the trackway was reburied in 1996, it was in a generally stable condition: loose or dislodged fragments had been stabilized and reattached with an adhesive, and all prominent roots and stumps removed or cut below the trackway surface and treated with a wood preservative to deter insect attack. To prevent the erosion and damage that had occurred previously from inadequate surface protection, the trackway was reburied under a multi-layered mound of geofabrics and sieved soils that will provide a stable, well-protected environment for its long-term preservation. In addition, the site was modified with surface berms and drain pipes to divert and channel surface water away from the trackway.

Embedding: *Fine particles of sand and other fines from the 1978-79 overburden which were impressed in the tuff or in the Bedacryl layer; deeply embedded particles were not removed.*

Silicone: *Fragments or residue of white silicone rubber from molding the trackway in 1978/79.*

Excavation tool marks: *Visible traces of score marks or incisions in the tuff as a result of excavation with chisel, dental pick or other implements in 1978-79.*

Inventory number on tuff: *Inventory number of print marked on tuff surface with permanent ink in 1979.*

Other:
Plastic fragments: remnants of plastic, possibly from the 1978-79 reburial.

Yellow staining: localized discoloration of the tuff, presumably from cellulose nitrate, an adhesive detected in prints excavated in 1978.

Root damage:

- surface roots: root (>1mm diameter) or rootlet (<1mm diameter) remaining on the tuff surface after initial excavation and cleaning of print. Surface roots were recorded since they are visible at the time of recording. Some left impressions in the tuff and were recorded accordingly. All surface roots were removed.

- root mat: area of interwoven rootlets, usually from grasses and shrubs, found on the tuff surface.

- inventoried stump: a stump left in situ *in 1978/79 or 1995/96. The 1978-79 stumps were rotten and left only a void.*

- root impression: imprint in the tuff resulting from the pressure of a surface root.

- subterranean root: a root or portion thereof that had penetrated below the tuff but was not removed (subterranean roots that were removed are defined as treatments);

Insect activity:

-Non-specific insect activity: areas of surface tuff marred by small ant holes, or insect trails (a combination of tuff fragments and particles from the overburden that have bonded together). This condition does not refer to fossil termite burrows.

-Cut-worm pupal cases: small lunette-shaped craters (average 1cm diameter x 0.5cm deep) found on the tuff surface; some of the casings contained larvae, which were identified as Coleoptera, commonly known as cut-worms. The craters are natural casts formed around the pupal cases.

1995-1996 Interventions

Consolidation/stabilization:

A treatment applied to stabilize powdery and loose tuff by injecting an aqueous consolidant, Acrysol WS-24 (a methyl and ethyl methacrylate copolymer), into the disrupted area; dispersions ranged from 10% to 50% in water (v/v)

Fills:

A treatment to replace lost material or fill voids in the tuff from root removal or decay in order to prevent collapse of the void under the weight of reburial overburden and discourage insect activity. Composition of mixtures varied depending on localized conditions, but all were based on a mixture of Acrysol WS-24 and a filler such as sieved soil and tuff or fume silica.

Reattachment:

Detached tuff was re-adhered with solutions of varying concentration of Paraloid B-72 in organic solvent.

Root treatment:

- Cut root or stump: exposed, cut, and sometimes routed, end of a root left in the tuff because it could not be removed without damage to the tuff.

- Removed root: subterranean root that was removed by hand with a scalpel and tweezers.

Other:

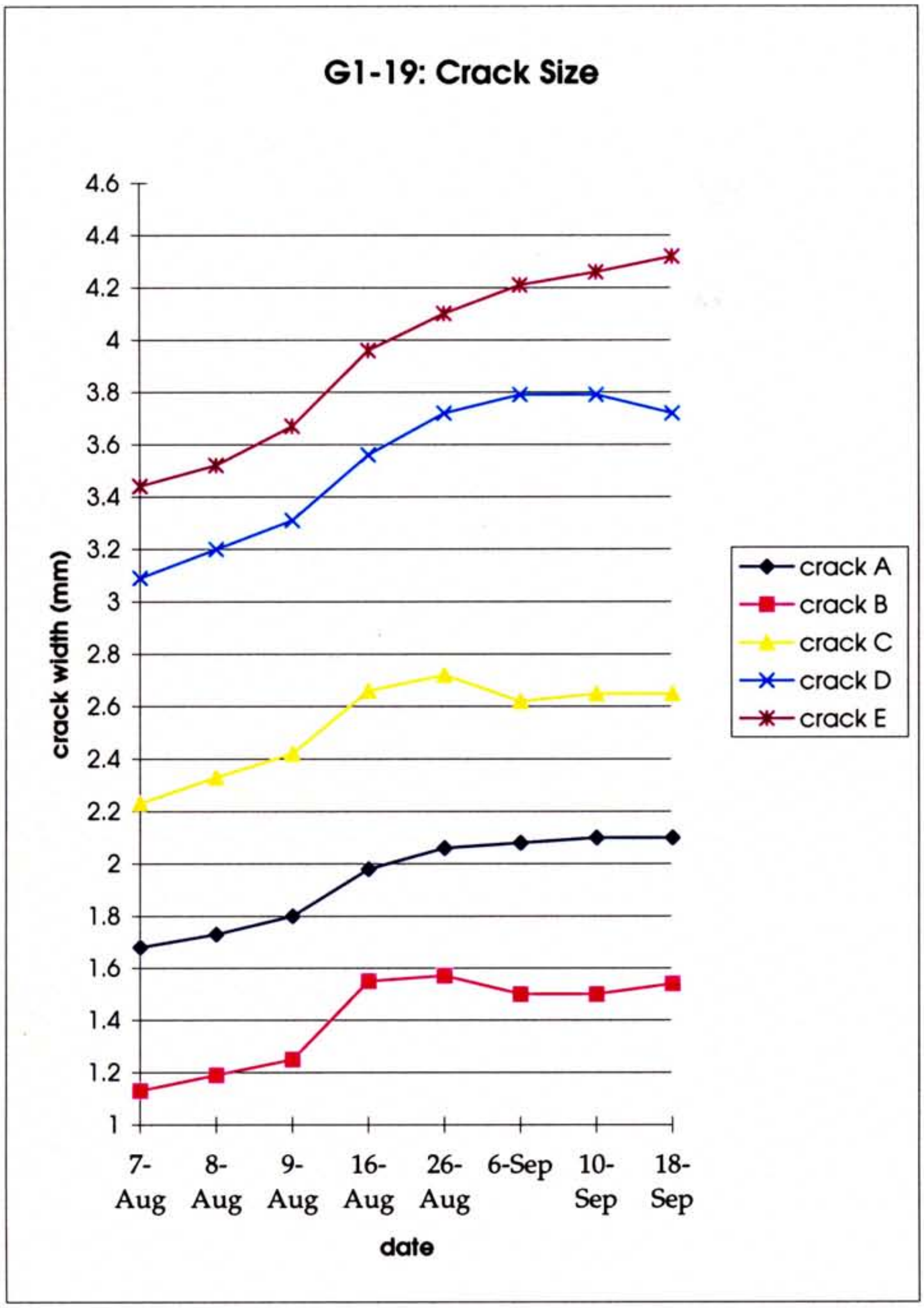
PCP: Remnants of stumps and large roots were treated with PCP wood preservative to prevent rapid decay of the wood and collapse of adjacent tuff into the hole. PCP was applied to roots and stumps on the trackway, but was not required in footprints.

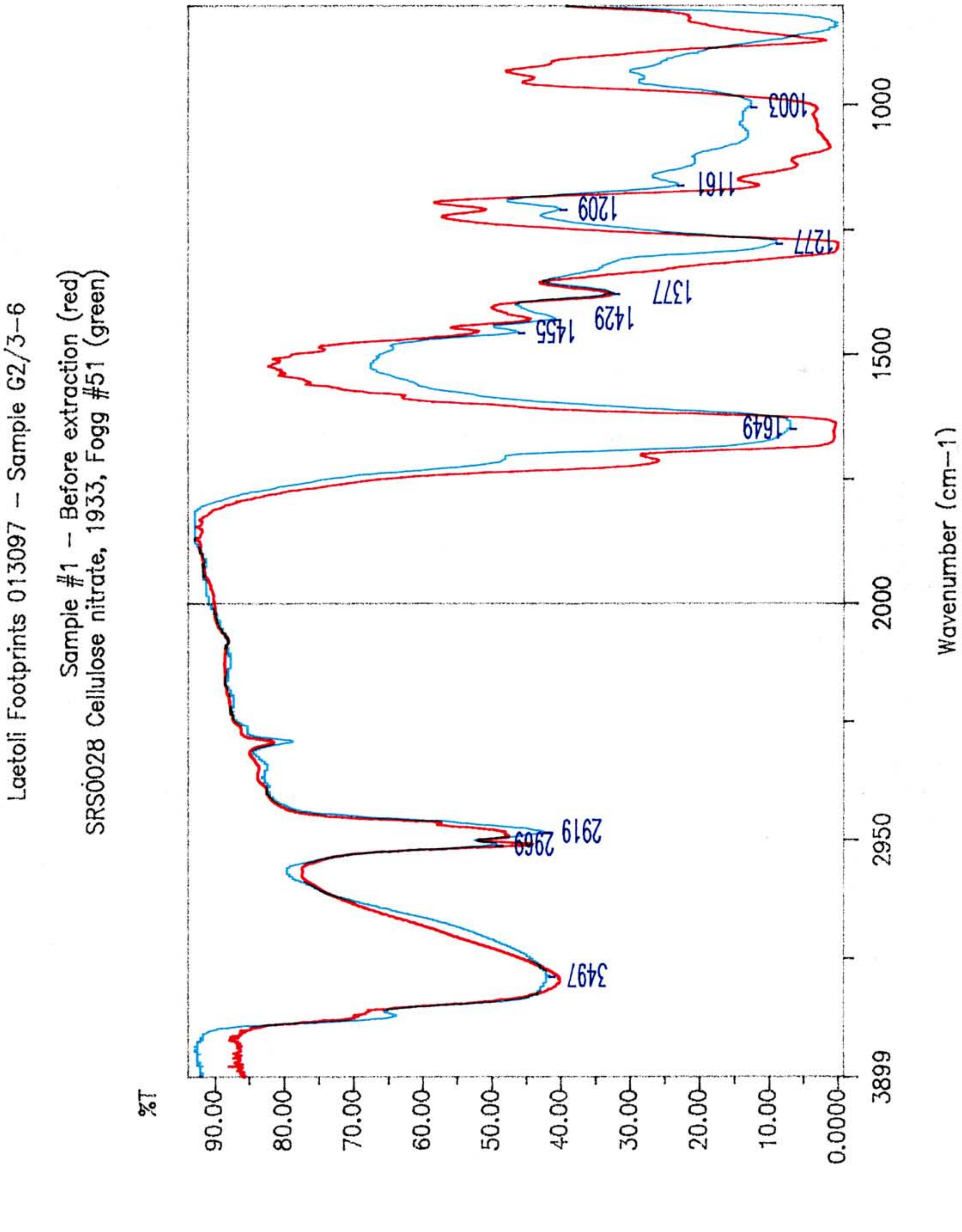
Bedacryl removal: Bedacryl was removed from the surface of hominid prints G1-26 and G2/3-25 and hipparion prints B8 and C2 with acetone applied with brushes or in a cotton poultice

Insect trail removal: Modern insect trails attached to the tuff surface were removed from the heel of G1-6 and from two areas in G1-13. This was done at the request of the palaeoscientists who felt the forms obscured the morphology of the prints and consequently their interpretation. They were removed with a scalpel and a dental pick, after which the area was consolidated with a 25% dispersion of Acrysol WS-24 in water.

G1-19 CRACK SIZE MEASUREMENTS

DATE	crack A	crack B	crack C	crack D	crack E
7-Aug	1.68	1.13	2.23	3.09	3.44
8-Aug	1.73	1.19	2.33	3.20	3.52
9-Aug	1.8	1.25	2.42	3.31	3.67
16-Aug	1.98	1.55	2.66	3.56	3.96
26-Aug	2.06	1.57	2.72	3.72	4.1
6-Sep	2.08	1.5	2.62	3.79	4.21
10-Sep	2.1	1.5	2.65	3.79	4.26
18-Sep	2.10	1.54	2.65	3.72	4.32




Laetoli Footprints 013097 – Sample G2/3–6
Sample #1 – Before extraction (red)
SRS0028 Cellulose nitrate, 1933, Fogg #51 (green)
%T
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.0000
3899
2950
2000
1500
1000
Wavenumber (cm–1)
3497
2969
2919
1649
1455
1429
1377
1277
1209
1161
1003

PART IV. ACACIA TREES AND OTHER VEGETATION

by Neville Agnew, Joel Bujulu and Po-Ming Lin

DISTRIBUTION AND GROWTH PATTERNS OF ACACIA TREES ON THE TRACKWAY

Excavation of the northern 20m of the trackway in 1996 revealed the presence of 32 inventoried acacia trees within the 1996 established trench lines between N103-N123 (Figs 12-14). Of these 32 trees, 13 were growing in the middle sector of the trackway, 12 in the northern sector, and 7 in the short stretch of the southern sector excavated in 1996. This compares with 38 inventoried trees in the 10m of excavated trench in 1995. Although far less dense than the 1995 area, the species and distribution of trees found in 1996 differed from that encountered in 1995.

The breakdown according to species of tree in 1995 and 1996 is as follows:

1995	1996	Totals
seyal: 25	*seyal*: 11	*seyal*: 36
mellifera: 0	*mellifera*: 8	*mellifera*: 8
drepanolobium: 3	*drepanolobium*: 2	*drepanolobium*: 5
Not identifiable: 10	Not identifiable: 11	Not identifiable: 21
Total: 38	**Total: 32**	**Total: 70**

The breakdown according to trackway sector is as follows:

Southern sector	Middle sector	Northern sector
seyal: 26	*seyal*: 1	*seyal*: 9
mellifera: 0	*mellifera*: 8	*mellifera*: 0
drepanolobium: 3	*drepanolobium*: 2	*drepanolobium*: 0
Not identifiable: 16	Not identifiable: 2	Not identifiable: 3
Total: 45	**Total: 13**	**Total: 12**

Looking at the distribution of tree species over the whole trackway, certain patterns can be distinguished. *Acacia seyal* was the predominant species in the southern and northern sectors of the trackway[1] (e.g. Photo 41), whereas *Acacia mellifera* dominated in the middle sector. This pattern coincides with the differences in overburden used to rebury the trackway in 1978-79: *Acacia seyal* predominated where the trackway was reburied with fill from the Garusi River (and especially where deeply buried in the southern sector); *Acacia mellifera* predominated where the trackway was reburied with clay in the middle sector. *Acacia mellifera* was not common around the trackway. Two large specimens, present when the site was excavated in 1978-79, as may be seen from photographs taken at the time, existed at the southern and northern ends of the trackway. (Both were killed, at different times, during the course of the present project.) It is certain that seeds from these two trees were plentiful on and around the trackway when Leakey excavated. Probably it is no coincidence that *A. mellifera* predominated in the middle sector, because in this area the backfill used was clearly from the excavation, whereas Garusi sand was brought in for the southern and northern sectors where most of the hominid tracks occur. The *Acacia mellifera* were substantial stumps and were the most difficult to remove because they were hard and fibrous; they also caused the most disruption to the trackway surface, but fortunately this was confined to portions of the middle trackway where no footprints were preserved.

Eleven of the 1996 inventoried stumps could not be identified with certainty, bringing the total of unidentified stumps to 21 for the entire trackway. All but two of these 21 unidentified stumps are believed to be trees that were *in situ* in 1978-79. They were found in a very decayed condition—many leaving only a void in the tuff with decayed bark but identifiable as cut stumps in photos from 1978. *Acacia drepanolobium* that were identified on the trackway were also found to have decayed quickly. It is therefore probable that most, if not all, of the unidentified stumps found in 1995 and 1996 were *Acacia drepanolobium* (with the exception of nos 82-84, 155, which were probably *Acacia seyal*; see note 1 below), which is the dominant species known to be growing at the site when it was excavated in 1978-79.

[1] The total count for *A. seyal* on the southern sector is more likely 30 since four of the unidentifiable stumps were those of trees that were cut down and killed in 1992 without having been identified, or photographed, and were probably *seyal*.

Unidentified stumps on the trackway:

Trackway sector	After 78-79 reburial	In situ 78-79
Southern sector	Nos 27-1, 173 Nos 82, 83, 84, 155 (all killed in 1992, probably *A. seyal*)	Nos 151, 152, 153, 156, 157, 168, 169, 170, 171, 172
Middle sector		Nos 174, 175
Northern sector		Nos 159, 160, 161

The number of stumps and roots that penetrated the tuff was difficult to calculate with any precision. Where a root could be associated (with certainty or probability) with a particular inventoried stump, it was recorded with the information about that stump on the data collection forms for each inventoried stump, but these do not reflect the myriad of small roots and rootlets that had penetrated the tuff and which were encountered throughout the trackway surface. Damage to the tuff from penetration of roots is discussed in Part III.

BIOLOGICAL ACTIVITY ASSOCIATED WITH TREE STUMPS ON THE TRACKWAY

Thirty five of the inventoried trees on the trackway were affected by insects (Photo 42), primarily termites (identified in the 1995 Report as *Procryptotermes sp.*) and borer beetles (not identified), which were often present together. Insects were found in all three species of acacia. Fungi were also noted on 12 trees. These were both hyphal species (as noted in the 1995 Report) and bracket fungi, possibly (*Trametes*) or a similar genus, but were not positively identified.

ACACIA TREES OUTSIDE THE TRACKWAY

Po-Ming Lin and Joel Bujulu undertook inventory and treatment of trees growing outside the trackway. A total of 162 trees (or tree clusters) were treated in 1996. Of these, 122 trees, as well as 10 *Asparagus africanus*, were treated with herbicide (Roundup®) around the trackway, in what is defined as the 3m wide vegetation-free (other than grasses and herbs) buffer zone. The majority of trees were seedlings (1mm-2cm diameter) and required only frilling treatment. Only nine trees were sufficiently large to treat by application of herbicide into drilled holes. Many of the trees were new sprouts from trees cut in 1995 during cleaning but not seen or treated at the time. An additional 40 trees, mainly seedlings, were treated around the berms, and nine trees in the NW gully.

The majority of identifiable trees outside the trackway were *Acacia drepanolobium* (about 70%); there were only a few *Acacia seyal* and one *Acacia mellifera* recorded.

In 1997 the large landmark *Acacia mellifera* (seen in Photos 8 and 9 at the top of photo, and Photo 49) at the northern end of the site was cut and killed with Roundup®. This decision was reluctantly taken when it was found, while doing further drainage work at the northern end of the reburial mound (see Part V), that large (approximately 1.5 cm diameter) roots extended as far as the northern end of the excavated trackway. The roots, up to 5m long, were mainly lying on the surface of the Footprint Tuff in a few cm of soil that covers the tuff in this area, but some penetrated the tuff and were clearly a threat to the trackway. It is probable that root growth towards the trackway had, over the years, occurred because of the moisture available from drainage across the trackway into the NW gully.

TREATMENT OF REMNANT ACACIA STUMPS AND ROOTS ON THE TRACKWAY

Preservation of remnant stumps and roots in the trackway was deemed necessary to prevent collapse of adjacent tuff into the void resulting from decay under load of reburial. Off-site testing of preservatives was done in a limited way in 1995, as described in the field report of that year (p. 45). Stump #75, to the east of the northern sector was partly re-excavated in 1996 to a depth of 15 cm. This had been killed with herbicide and treated with pentachlorophenol (PCP) solution. The wood was found to be in sound condition, though split at the cut surface because of desiccation; bark was peeling from the wood. The stump was still firmly anchored in the ground (Photo 43). There was no evidence of insect, termite or fungal deterioration. It was backfilled as a future witness. By contrast, an untreated stump (killed in 1994 using Roundup®) was badly deteriorated.

Reasons for the choice of PCP over other potential wood preservatives, including the water-soluble sodium salt of PCP, were given in the 1995 Report. It was thus of value to have corroborating evidence of the effectiveness of this preservative. It was judged unnecessary to evaluate the other three off-site stumps tested (with the PCP sodium salt and two metal naphthenates).

For the present campaign pentachlorophenol (PCP) was imported under license from the Tanzanian government (Ref. No. UTV/AR/K.20/11/89, June 30, 1995). Aldrich Chemical Co. supplied the PCP: Lot # 08329 KG, 99% + purity; 200 g was dissolved in 5 liters of 1:1 acetone and iso-propyl alcohol to make a 4% w/v solution.

The procedure established in 1995 for the treatment of remnant stumps and roots was followed. Solution was applied by dropping-pipette and a small brush and volumes were recorded (Photo 44). Two applications were made. It was found that an efflorescence of PCP developed, due to rapid evaporation of the solvents, on the surfaces of stumps that were more heavily treated. Subsequently these were treated with 70% iso-propyl alcohol to redissolve the PCP and effect absorption into the wood.

A total of 66.7g of PCP was used in the treatment on the trackway. Quantities applied and root/stump numbers are provided in the report of Joel Bujulu submitted to the GCI (but not included here). Unused PCP solution was placed in the charge of Bujulu for safe disposal in Arusha.

IDENTIFICATION OF VEGETATION AT SITE G

Specimens of vegetation growing on the trackway in 1996 were collected for identification by staff of the herbarium of the NCAA, courtesy of Asantael Melita. Only grasses and shrubs were collected; acacia trees were not sampled since they had been previously identified. These are listed in Appendix A, along with inventories of vegetation undertaken in 1995 on the buried trackway and in 1994 from site transects.

VEGETATION RECORDED AT SITE G IN 1996, 1995 AND 1994

	TRACKWAY 1996 (Identified by NCAA herbarium staff)	**TRACKWAY 1995** (Identified by J. Bujulu)	**SITE G 1994** (Identified by L.B. Mwasumbi)
TREES			
Acacia mellifera		X	X
A. drepanolobium		X	X
A. kirkii			X
A. seyal			X
A. sp		X	
A. tortilis			X
Boscia angustifolia			X
Commiphora africana			X
Rhus natalensis			X
SHRUBS, HERBS & WEEDS			
Abutilon angulatum			X
A. hirtum	X	X	
Asparagus africanus	X	X	X
Aspilia mossambicensis	X	X	
A. sp			X
Barleria sp.			X
Bidens pilosa	X	X	
Capparis fascicularis			X
C. sp.			X
Cissus quadrangularis			X
Conyza pyrhopappa			X
Crotalaria laburnifolia L	X	X	
Duosperma crenatum			X
Hirpicium beguinotii			X
Hypoestes forskalii			X
H. verticillaris	X	X	

	TRACKWAY 1996 (Identified by NCAA herbarium staff)	TRACKWAY 1995 (Identified by J. Bujulu)	SITE G 1994 (Identified by L.B. Mwasumbi)
Leonotis sp.	X	X	
Maytenus heterophylla			X
Plectranthus caninus			X
Solanum incanum	X	X	
S. sp.			X
Tagetes minuta	X	X	X
Vernonia sp.			X
Zanthoxylum chalybeum			X
GRASSES			
Aristida adscensionis			X
A. kenyensis		X	
Chloris gayana	X	X	X
C. sp.			X
Cynodon dactylon	X	X	X
Hyparrhenia cymbaria	X	X	X
Panicum maximum	X	X	
Polypogon plebeium			X
Setaria sphacelata			X
Sporobolus africanus			X
S. spicatus			X

PART V. DRAINAGE CONTROL AND SITE STABILIZATION

by Neville Agnew

INTRODUCTION

As in campaigns of previous years the earlier site work of surface drainage and stabilization was assessed for effectiveness in 1996 and 1997. It was found necessary to undertake additional interventions, as was forewarned in the 1995 Report. During a visit to the site in the wet season it was possible to witness first hand the effectiveness and deficiencies of the drainage control measures, and to decide upon additional measures.

The 1996 stabilization measures were supervised by Neville Agnew and Donatius Kamamba, with assistance throughout by Po-Ming Lin and Ferdinand Mizambwa.

EVOLUTION OF THE DRAINAGE PATTERNS AT SITE G

Previously it has been pointed out that Site G may receive, on average, around 540 mm (21.5 in) of rain in the period from November to April. Prior to the construction of the reburial mound over the northern sector of the trackway in 1978, all the surface runoff, perhaps as much as 0.75 million liters of water per annum, was focused at the northern part of the trackway where it drained into the NW and West gullies, and via them to the Garusi drainage system. These ancient drainage patterns slowly eroded the thick accumulation of volcanic overburden that originally covered the trackway, exposing the Footprint Tuff at the northern end of the trackway, where the first print (G1-1) was discovered in 1977, and removing traces of prints that continued the trail to the north.

The placement of the reburial mound in 1978 partially interrupted these drainage patterns by blocking run-off to the West gully, focusing it at the northern end of the reburial mound, which created an erosional channel and led to accelerated growth of the NW gully (Fig. 6; Photos 19, 20), and resulted in pooling of water in a low-lying area east of the northern part of the reburial mound. Photo 45, taken in 1994, shows the intensive growth of vegetation in this low-lying area. In fact, subsurface moisture from auger samples (holes 4-6, Appendix A) was high (12-15% at depths of around 20 cm) to saturated (20% at variable depths, from 20-50 cm). These high values likely correlate with pooling in this area.

Although the drainage problem was recognized at the outset of the project and addressed by stabilization measures beginning in 1994, the discovery during the 1996 field campaign that the two most northerly hominid prints had been lost to erosion emphasized the critical need to effectively deal with drainage of the site as a whole, with particular attention to the northern end of the trackway and the aggressive growth of the NW gully.

CONSTRUCTION OF BERM 4, DRAINAGE CHANNEL AND OUTLET SUMP

The construction of an additional berm (Berm 4) at Site G was implemented for several reasons. In February 1996 the site was visited by members of the Laetoli Consultative Committee who were meeting at Ngorongoro. Rain had fallen over the preceding days which allowed assessment of the effectiveness and condition of the berms constructed in 1993 and 1994. Berm 3 was of particular interest because it had been made to intercept Drainage No. 1, thus preventing run-off to the NW gully (compare Figs 6 and 7). As had been anticipated, and discussed in the field report of 1995, ponding of water had occurred in a low point behind the berm (to the east) to a depth of 20 cm. While Berms 1 and 2 relieve surface flow from the largest catchment area of the site, Berm 3 is intended to deal with the remainder of the site, in particular to prevent erosional flow over the northernmost section of the trackway, which it effectively does.

A decision was taken to construct Berm 4 after it was found that this could be done without having to cut a drainage channel through Footprint Tuff. That a drainage channel would be required was evident because of the higher elevation at the outfall of Berm 4. Specifically, there were several reasons for deciding in favor of the additional berm, despite the unavoidable need to dig a drainage channel – a consideration that had prevented an outfall channel being cut for Berm 3. The berm would:

- Prevent significant ponding at Berm 3. Buffalo were reported by the site guards as having watered at the ponded water, and their fresh tracks were evident during the visit of the Consultative Committee. The likelihood of cattle being drawn to the water, despite the protective thorn fence around the site and instructions having been given by community elders to local herd boys to keep cattle off the site, was also a consideration.
- Standing water at Berm 3 would seep into the soil and tuff and contribute to the overall subsurface moisture in the low-lying area on the eastern side of the northern half of the reburial mound.

On balance, therefore, it was deemed important to further intervene to drain the site as efficiently as possible.

The line of Berm 4 with its associated open channel intercepts run-off from Drainage No. 3 near the southern end of the trackway and diverts it to the confluence of flow from Berms 1 and 2 (Fig. 7). The position of the berm was determined with several constraints in mind. First, its drainage channel should not cut through Footprint Tuff; and second it should lie close to Berm 3 in order to minimize the catchment between the two berms and ponding at the low point of Berm 3.

A line of auger holes (numbers 11-18, see map in Appendix A) was established in order to check that Footprint Tuff was absent in this area, as was shown to be the case. The auger holes also served to allow subsurface moisture measurements from the samples that were withdrawn.

Berm 4 was constructed in the same way as the other berms on the site, that is from lava boulders set on the surface and cemented together with weak soil cement. The drainage channel for the berm was dug approximately between auger holes #15 (the low point) and #18; closer to the trackway reburial mound the natural fall of the ground was adequate for surface drainage, which required only surface cleaning and removal or treatment with Roundup® of a number of small acacias to about 30 cm east of the berm. No Footprint Tuff was destroyed in cutting the channel for the berm. The channel is approximately 30 cm deep at the outfall by 25 cm wide and extends some 14 m. It is cement and cobble-lined (Photo 46).

A sump was constructed at the outfall of Berm 4 because of concern that with essentially all the site surface drainage being focused at this point, that is, from Berms 1, 2, 4, rapid erosion would occur (Fig. 7). In discussion with hydrologist Michael Airy, the sump was designed with a subsurface PVC delivery pipe (15 cm diameter, length 15.7 m) to the Garusi drainage system. The pipe has a fall of approximately 0.75 m over its length (1:20). Internal dimensions of the sump are 1.2 x 1.1 x 0.6 m deep, constructed of lava boulders with a 1:2 cement mix. A steel grill was fabricated by the welder at the Endulen hospital from 4x4 cm angle steel (1.0 x 0.85 m) with eight cross-bars of 12 mm diameter steel. The grill is padlocked to the sump and set into it at a 45° angle (Photo 46). It functions to prevent clogging of the outfall pipe by debris. The pipe outlet is armored all around with cemented cobbles, and delivers run-off from the sump to a cobble and cement apron (approximately 0.5 x 0.7 m) before entering the existing natural drainage to the Garusi River bed. Site guards hold the key to the padlock for the grill and will, as needed, clear accumulated debris and sediment from the sump.

A small new channel to the sump was built to deliver drainage from the eastern slope of the site which is comprised of black cotton soil. Additionally, the inlet channel to the sump from Berms 1 and 2 was widened and reinforced on the western side with boulders to prevent erosion at the inlet which would lead eventually to the sump being circumvented.

During the short field campaign of 1997 repairs and modifications to the drainage channel for Berm 4 were done. The inlet edge of the channel was cut back from vertical to 45° to allow easier inflow along its length. The apron at the outflow of the sump pipe was also repaired and extended.

The drainage channel for Berm 4, the sump, and the auger holes are the only significant intrusions on the site over the course of the project. Fig. 7 and Photo 47 show the configuration of the site drainage system at completion.

STABILIZATION OF THE WEST GULLY

The West gully was stabilized in 1996 using the same methods developed for the NW gully (see 1995 Report). This gully, while not actively growing as a result of run-off, lies close to the reburial mound, and it was felt important to stabilize it lest it become active at some future time as a result of topographic changes on site.

Two horizontal holes were augered from within the gully, below the Footprint Tuff, in a southeasterly direction for temperature and moisture determinations. These were not backfilled as they may serve to a small degree to aid subsurface drainage of the site. Photo 48 shows the completed work.

STABILIZATION AND DRAINAGE CONTROL ADJACENT TO THE REBURIAL MOUND

In 1997 pooling was observed to have occurred in a low-lying area adjacent to the eastern side of the northern half of the reburial mound, and as mentioned already, subsurface moisture was high here at relatively shallow depths (see Appendix A). The ground level was raised in this area to facilitate drainage around the northern end of the mound and into the NW gully. Fill material of eroded tuff collected from the Garusi drainage system was laid on the surface which was then built up with soil gleaned from the eastern end of the site. The fill was sloped from the perimeter wall of the reburial mound to ground level and compacted by hand. The edge was lined with small boulders to create a low retaining wall to reduce erosion. A surface capping of fine sandy soil, from the south-east area of the site, which naturally forms a hard and compact layer, was used to promote run-off. Photo 49 shows the stabilization at significant stages.

A new, very shallow, drainage channel was scraped into the soil alongside the retaining wall and led around the northern end of the mound and into the NW gully (Figs 7, 8).

Where the low retaining wall connected with the end of the trackway mound Footprint Tuff was exposed and here the small boulders were laid on red plastic sheet on the tuff before being cemented in place. The purpose of the plastic is to act as an isolating barrier and prevent any adverse effects on the tuff of soluble salts from the cement. Exposed edges of the plastic were trimmed so that it would not be visible.

Where water falls into the NW gully a cemented lip and channel was created by incorporating existing boulders from the 1994 stabilization of the gully (Fig. 8). In this way the gully may be used for water disposal to the Garusi drainage system without the danger of further erosion.

The drainage channel was tested using buckets of water and worked well; however, the sloped fill, retaining wall, and shallow channel will undoubtedly require maintenance from time to time, and the fill itself will probably need additional material as it settles.

In passing it should be noted that it was during this work that extensive lateral roots were found from the large landmark *Acacia mellifera* at the northern end of the site (see Photo 49). The roots, surface and subsurface, were up to 5 m long and extended to the edge of the mound. Some of the roots penetrated the Footprint Tuff. As discussed (Part IV) the tree was cut and killed during the 1997 fieldwork.

CONCLUDING REMARKS

The drainage control and site stabilization work of the 1994-1997 seasons constitutes one of the important interventions undertaken at the site to protect it for the future. The ancient drainage patterns were clearly one of the greatest threats to the trackway prior to its discovery in 1978 and continued to affect the site adversely after the placement of the reburial mound in 1978. In conjunction with the design of the 1996 reburial mound, the stabilization measures were, therefore, aimed primarily at controlling surface run-off to the northern end of the trackway into the NW gully.

All of the site interventions were sensitive to the need to impact the site as little as possible and not to destroy, through excavation of drainage channels, extant

Footprint Tuff. Although the problems of site drainage have now all been addressed, regular maintenance of the drainage system on the site and repairs to the gully stabilizations will be needed, as described in Part XI, Appendix B. Without maintenance the system will rapidly degrade and in the event of heavy rains damage may occur to the site.

SUBSURFACE SAMPLING: STRATIGRAPHY AND MOISTURE AND TEMPERATURE MEASUREMENTS

Subsurface Moisture Measurements

Soil moisture was determined at a number of positions around the trackway site. The purpose was to obtain quantitative information on the moisture content and the moisture retaining capacity of the soil at the peak of the dry season, in order to determine the relationship between soil type, including partially to heavily weathered tuffs, and moisture retention, and additionally to obtain an understanding of the variation in moisture around the site. It was noted in the 1995 campaign that the extreme southern end of the trackway was distinctly damp upon excavation, and at Test Site 3 the clayey tuff contained moisture, whereas other parts of the trackway were dry.

Moisture was determined by the calcium carbide method in which carbide reacts quantitatively with moisture in soil to liberate acetylene gas. Pressure of the gas generated in the reaction vessel registers on a pressure gauge which is calibrated to read percentage moisture by weight of soil. Accuracy of the method depends upon complete mixing of soil and carbide. In the case of heavy, clayey soils, such as occur at Laetoli, there may not occur adequate break-up of clayey lumps, and the results may thus be lower than the actual values. The carbide meter is capable of measuring up to 20% water. Results, given below, were undoubtedly affected in some instances by the high clay content of the soil; however, overall it is felt that moisture content and variation with depth is sufficiently accurate and representative for the purposes for which measurements were done. The carbide meter was calibrated in the laboratory by gravimetry of soil samples heated to constant weight at 105° C.

Sampling was done with a 5cm diameter shell auger, with extension arm capable of coring to a depth of 2m. Samples were withdrawn, weighed quickly to prevent loss of moisture, and shaken with an excess of calcium carbide in the reaction vessel until the maximum pressure was registered. A total of 23 holes was made to varying depths, usually to the point at which hard, or relatively unweathered tuff was encountered. Holes were spaced at 5m intervals, except hole 18 where the interval was 3.15m. The corings were related insofar as possible to the tuff stratigraphy, and checked in the field from time to time by geologist Craig Feibel. Identifications given below should be regarded as tentative. See Auger Map in this appendix for location of the auger holes. It should be noted that auger sites 11 - 18 were chosen with the additional purpose of ascertaining whether Footprint Tuff occurred along this line since construction of a new berm (Berm 4), which required excavation of an accompanying drainage ditch, was being considered.

Results are summarized below:

Auger holes 1 - 10 extend parallel to the trackway on the eastern side, from the southernmost point of the reburial into the erosional gully of the Garusi.

- Holes 1 - 3 were shallow; not deeper than 10cm before hard Footprint Tuff was encountered, underlying gray soil; with minimal (3 - 4%) moisture. These holes overlay the extension to the east of the fractured plate that forms the southern trackway sector.

- Hole 4, is at the base of Fault 3; possible Footprint Tuff was encountered at about 80cm. The overlying gray, clayey soil was saturated (+20%) at a depth of 50 cm, but decreased to 16% at 75cm in proximity to the Footprint Tuff.

- Hole 5, probably corresponding with the continuation east of the downfaulted block of tuff (the graben), encountered Augite Biotite at 40 cm with 14% moisture.

- Holes 6 - 8 were progressively shallower before harder rock, with the appearance of variably weathered Footprint Tuff, was encountered. Hole 6 was situated at the eastern limit of the low-lying area east of the northern part of the trackway; its saturated conditions at 27 cm reflect perching of subsurface water in this area, probably related to partial damming of run-off by the 1978 reburial mound. Hole 7 encountered hard tuff at 16cm with 10% moisture. Hole 8 is close to the edge of the northernmost extension of the trackway's fractured plate of Footprint Tuff, where the small escarpment occurs leading down to the Garusi drainage system.

- Hole 9 was the deepest of all 23 auger holes at a depth of 160 cm. Soft, variably colored (gray, brownish, white) layers of powdery and clayey material graded into each other. At 100cm calcitic fossil termitaria nodules were encountered. Hard, unweathered tuff was encountered at 148cm. Moisture in excess of 20% occurred at 53cm depth, though it became dryer (13.6%) at 160cm.

- Hole 10 was similar, though cored only to a maximum depth of some 53cm, where 19.6% water was measured. This hole showed a layer of organic, fibrous material, with the appearance of a fine root mat somewhat deteriorated, in a dark clay layer at 25cm where the moisture content was 14%.

Holes 11 - 18 extend from the southeast corner of the trackway reburial mound towards the sump of Drainage Channel no. 2. Here the overburden tends to be black cotton soil, grading via variable clayey and powdery material at depths ranging from 15-75 cm into weathered Augite Biotite Tuff overlying harder Footprint Tuff. In this clayey layer saturated moisture conditions pertained. This is the layer into which the reburial monitoring trench at Test Site 3 was dug.

Holes 19 -23 extend the line of holes 1 - 10 to the south. Possible Footprint Tuff was found at 20, 32, 35, 75, and 50cm depth in these holes respectively. Overlying material was variably dark soil initially, grading into clayey, crumbly, moist weathered tuff, changing abruptly into hard to very hard Footprint Tuff in some holes (20, 21). Moisture increased steadily with depth through clay materials to saturation around 40cm, though closer to unweathered tuff it decreased again to around 17%.

In summary, the overlying soil to a depth of 5-10 cm was very dry with about 5–7 % water, while lower clay-rich layers derived from weathered, presumably aeolian, tuffs, and black cotton soil types, along holes 11-18, held moisture tenaciously and were effectively saturated (20%). Depth of weathering was very variable; the Footprint Tuff, where encountered, was generally much less weathered than either the overlying Augite Biotite Tuff and clay-rich layers, or the underlying, undifferentiated aeolian tuffs, which were heavily weathered to a depth of more than a meter, as in Hole 9. Weathered Footprint Tuff also tended to be dryer, as in Holes 19-23. Saturated dark clay soils showed little evidence of moisture-seeking root growth, except in a few instances, e.g., Holes 10, 11 where, however, the fine root mats were dead though preserved to some degree, presumably because of the anaerobic conditions pertaining under near saturation.

At the time of the selection of Test Site 3 for the reburial monitoring trench in 1995 it was believed, and stated in the 1995 report, that the Footprint Tuff, which dips to the southwest, had eroded away in the location of the test site, and indeed throughout most of the area that lies to the east of the southern sector of the trackway. This may be true, but it is less certain than previously believed because of the results from the auger holes along the line of Berm 4. On the basis of the tentative identification of tuff stratigraphy from auger samples, we cannot be certain that the clayey tuff (presumably aeolian) encountered in the monitoring trench does not lie above Footprint Tuff. Auger holes 11-18 yielded material that was tentatively identified as Footprint Tuff by Craig Feibel at depths of about 15-75cm below the surface. Given the erosional and tectonic history of the site, it seems possible that the Footprint Tuff may underlie much of the sediment in the area to the east of the southern trackway. For the present, it is not possible to make a categorical statement about the tuff sequence here, but the augering suggests a more complex stratigraphy than previously thought.

Subsurface Thermal Profiles:

Temperature measurements were made at the surface and in auger holes (previously used to sample for moisture content, as described above) to varying depths of over a meter and a half at a number of points on the eastern side of the trackway. The purpose was to determine the diurnal thermal flux with depth below the surface so that an estimate could be made of the effective life of Biobarrier in the buried environment at Laetoli. The rate of release of the herbicide from the nodules adhered to Biobarrier geotextile is temperature dependent.

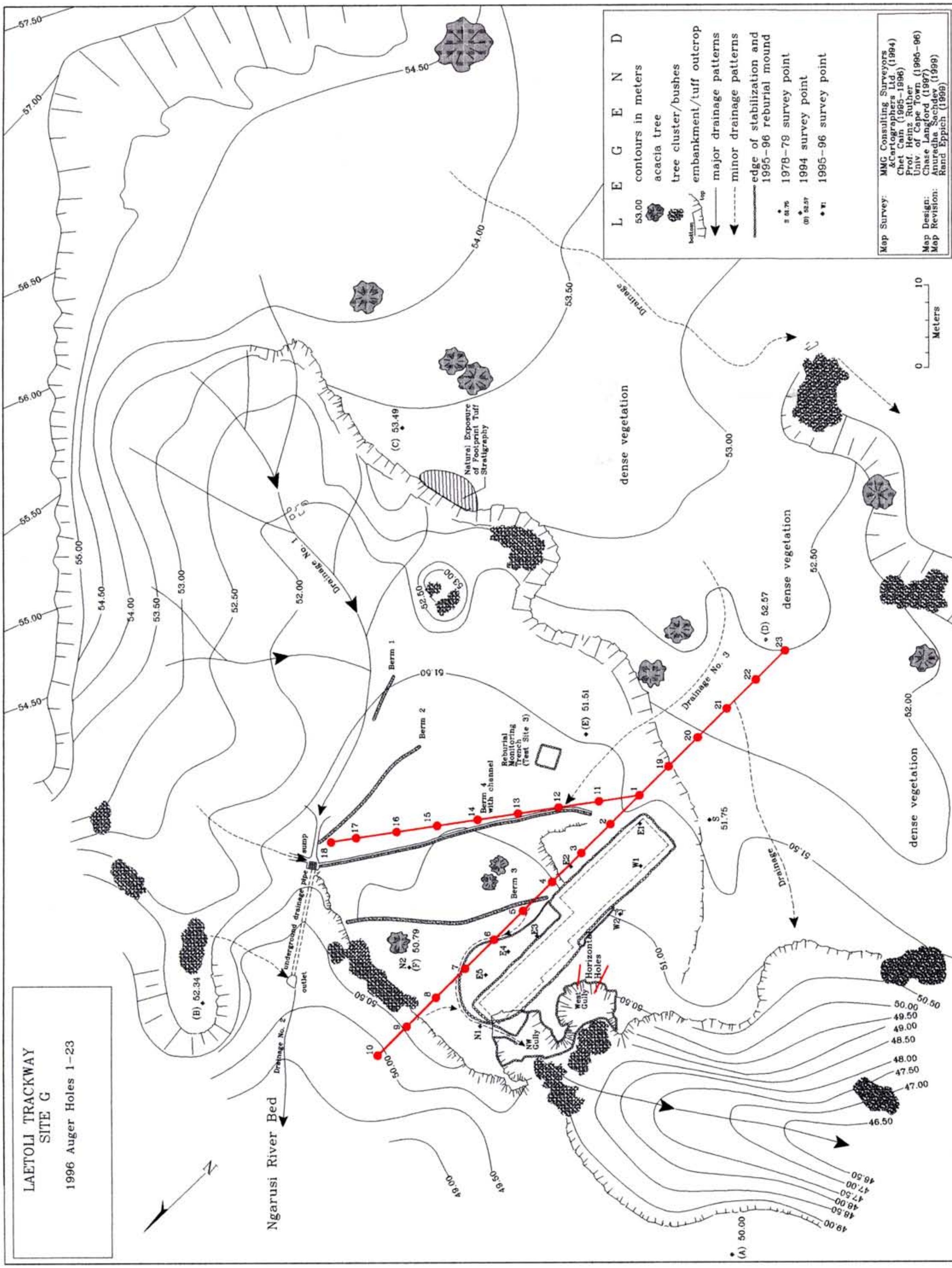
Temperatures as determined in auger holes extending through overlying soil and into weathered clayey tuff may not, strictly speaking, be representative of temperatures in the reburial mound because the former is undisturbed and the latter was not compacted. However, over time, as the mound settles it will naturally compact and more closely replicate undisturbed conditions.

Surface temperature was measured by a hand-held radiant infra-red thermometer; subsurface temperature was determined by a custom-built stainless steel probe 132cm in length, with four thermistors epoxy-embedded into milled recesses in the tubing of the probe such that they were flush with the surface. Thermistors were spaced at 33cm with the bottom-most thermistor at 13cm from the conical tip. Wires from the thermistors connected to a hand-held digital read-out were housed within the tube for protection, emerging at the cross-bar handle. The instrument was designed and tested by Shin Maekawa of the GCI Scientific Program and constructed by Jim Davies of the J. Paul Getty Museum machine shop. In the field the probe was checked against an accurate alcohol thermometer. All three methods gave consistent readings with an accuracy of 0.1 - 0.2 degree C.

Graphs 1 and 2 show typical temperature variation with depth during the course of a day in mid-August. As may be expected, horizontal surfaces exposed to the sun increased very rapidly in temperature and peaked in the early to mid-afternoon. The highest surface temperature recorded was 62°C (at auger hole 22 to the south of the trackway (see Auger Map for location) at noon on August 8; at the same time the full-shade temperature was 34°C. The lowest surface temperature found (at the same location) was 8°C, at 7:30 a.m. Below a depth of about 20cm the soil temperature was very stable at 22 -25°C. At 3cm depth the temperature was markedly reduced by comparison with the fully exposed ground surface (Graph 2).

Biobarrier manufacturers have supplied data on effectiveness over time versus temperature (Graph 3). In the Laetoli reburial mound the average depth of the two Biobarrier layers is 0.25 and 0.5m, excluding the boulder capping. Assuming a mean annual soil temperature of between 20 -25 °C at these depths the anticipated life of the fabric as an effective root inhibitor is expected to be 20 years.

Map 1


LAETOLI TRACKWAY
SITE G
1996 Auger Holes 1–23
N
Ngarusi River Bed
L E G E N D
53.00 contours in meters
acacia tree
tree cluster/bushes
embankment/tuff outcrop
bottom
top
major drainage patterns
minor drainage patterns
edge of stabilization and 1995–96 reburial mound
1978–79 survey point
1994 survey point
1995–96 survey point
Map Survey: MMG Consulting Surveyors &Cartographers Ltd. (1994)
Chet Cain (1995–1996)
Prof. Heinz Ruther
Univ. of Cape Town (1995–96)
Map Design: Chase Langford (1997)
Map Revision: Anuradha Sachdev (1999)
Rand Eppich (1999)
Meters
0
10
dense vegetation
Drainage
Drainage No. 1
Drainage No. 2
Drainage No. 3
Berm 1
Berm 2
Berm 3
Berm 4 with channel
Reburial Monitoring Trench (Test Site 3)
Natural Exposure of Footprint Tuff Stratigraphy
sump
underground drainage pipe
outlet
West Gully
NW Gully
Horizontal Holes
(A) 50.00
(B) 52.34
(C) 53.49
(D) 52.57
(E) 51.51
(F) 50.79
51.75
N1
N2
E1
E2
E3
E4
E5
W1
W2
57.50
57.00
56.50
56.00
55.50
55.00
54.50
54.00
53.50
53.00
52.50
52.00
51.50
51.00
50.50
50.00
49.50
49.00
48.50
48.00
47.50
47.00
46.50
1
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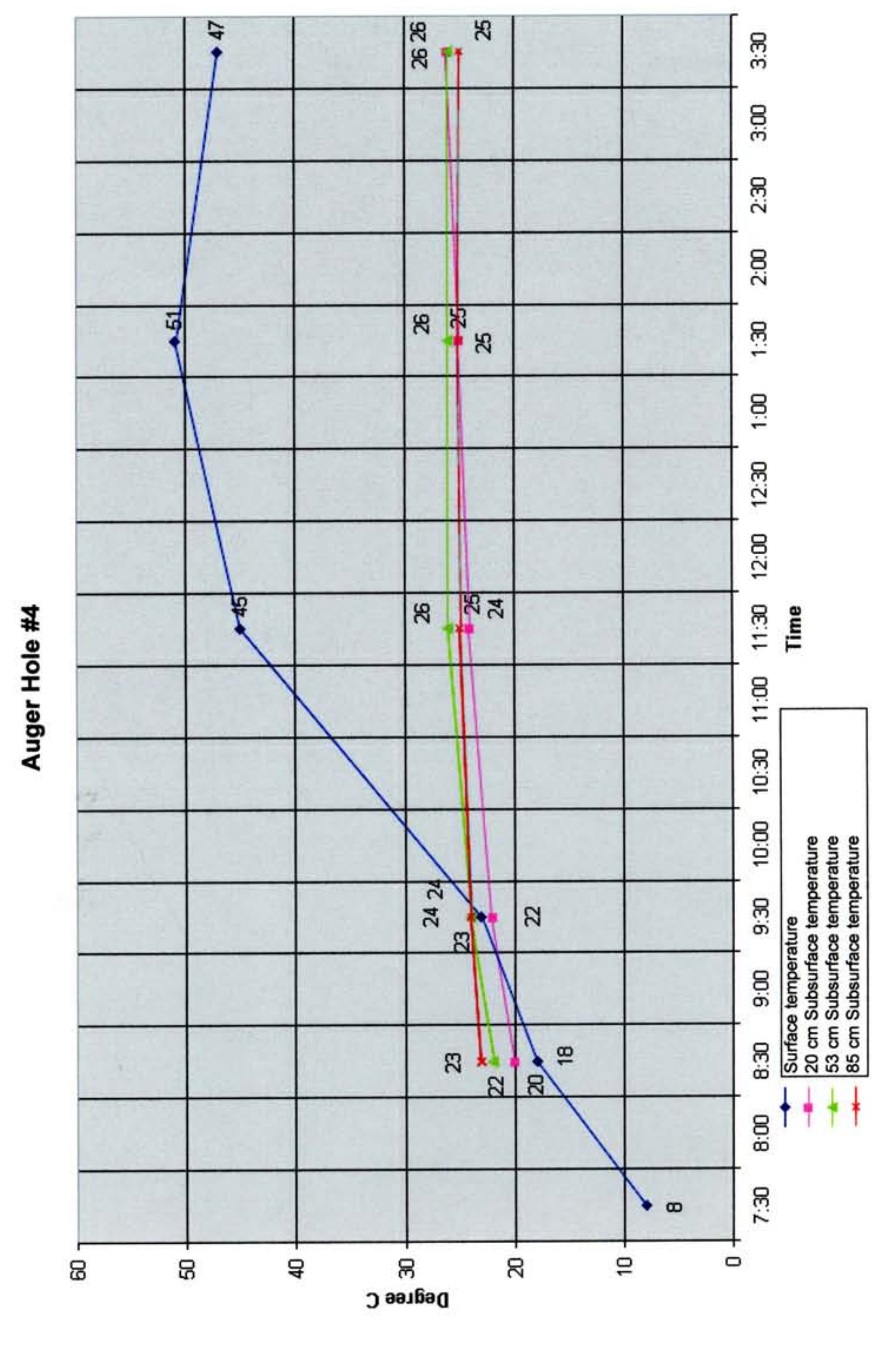
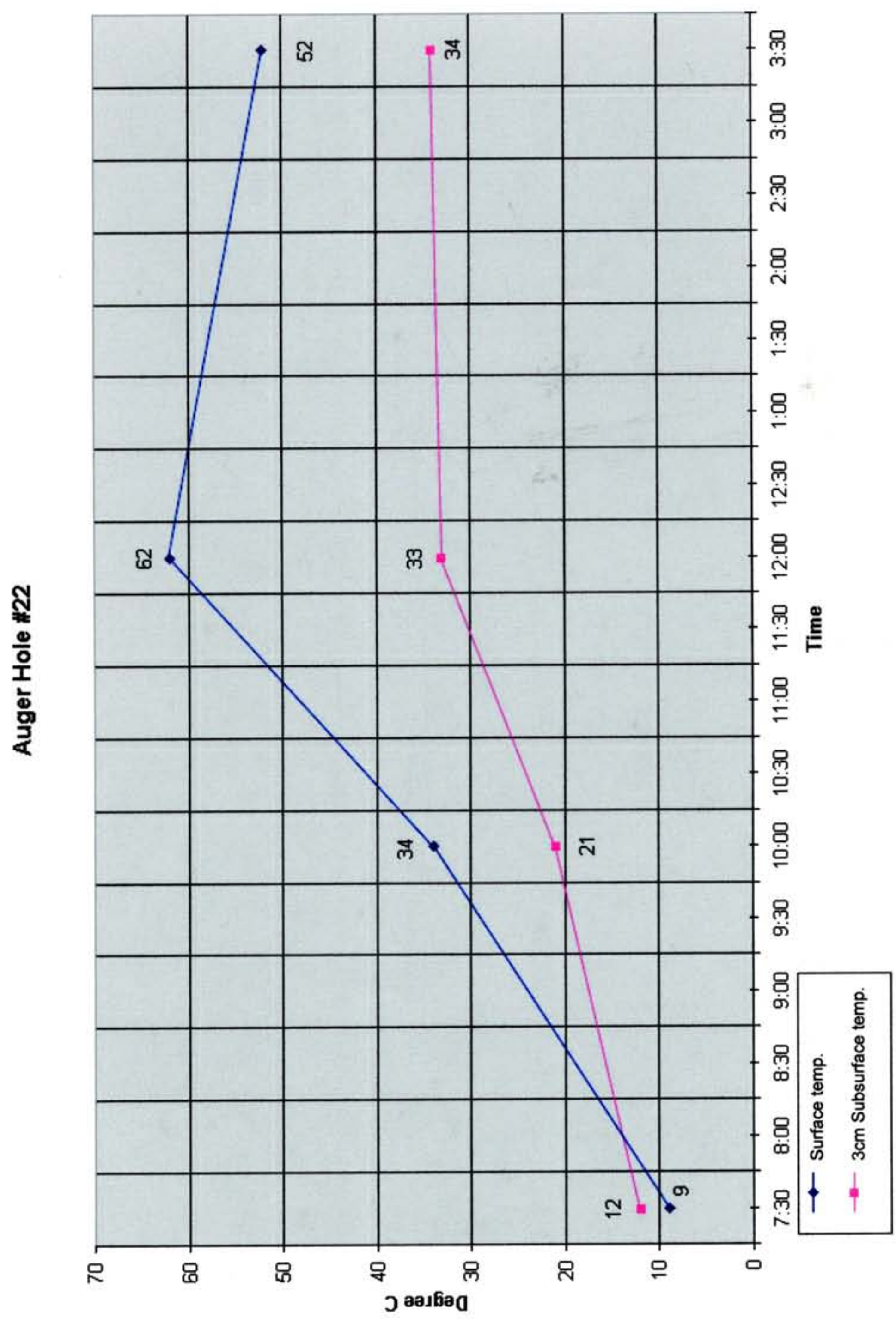
22
23

Graph 1


Auger Hole #4
Degree C
Time
Surface temperature
20 cm Subsurface temperature
53 cm Subsurface temperature
85 cm Subsurface temperature

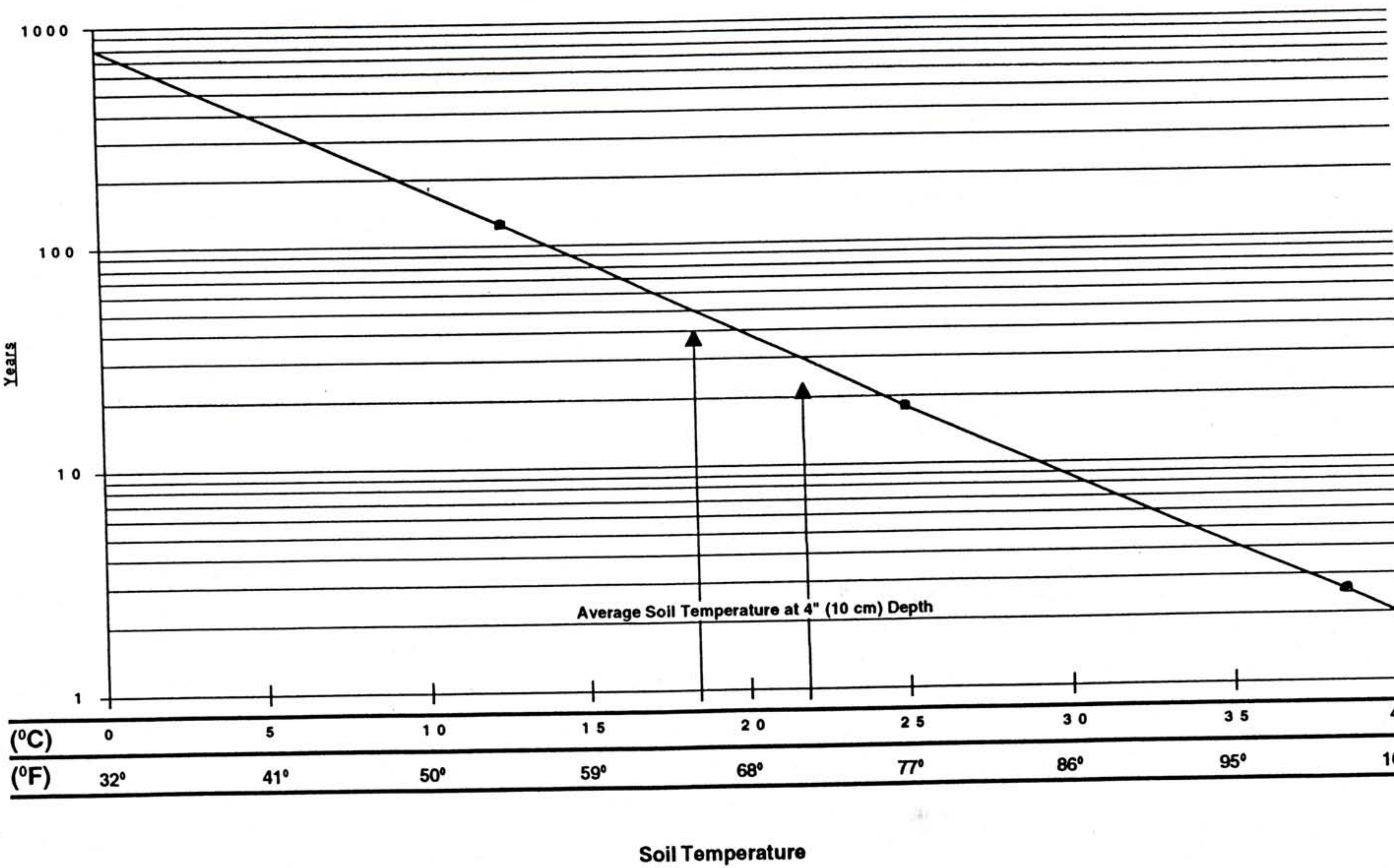
Graph 2



Auger Hole #22
Degree C
70
60
50
40
30
20
10
0
7:30
8:00
8:30
9:00
9:30
10:00
10:30
11:00
11:30
12:00
12:30
1:00
1:30
2:00
2:30
3:00
3:30
Time
9
34
62
52
12
21
33
34
Surface temp.
3cm Subsurface temp.

Graph 3

Biobarrier® Effective Life



PART VI. PHOTOGRAPHY

by Tom Moon

INTRODUCTION

This report outlines the photodocumentation undertaken in the 1996 Laetoli field campaign. Activities include: comprehensive photography of the trackway and campaign activities; detailed 35mm and medium format color and black-and-white photography of the trackway and hominid footprints before and after conservation treatment; extensive 8x10 Polaroid photography of the trackway and hominid prints for conservation documentation; exposure and processing of 5x7 photogrammetric glass plates; and assistance in all aspects of the photogrammetric recording. Procedures and protocols for photo-documentation generally followed those established in 1995 (see 1995 Report for detailed description of technical procedures).

In 1996 Frank Long served as photography and documentation assistant and also conducted video recording of field activities. Following my departure on Sept. 7, Long completed the 8x10 Polaroid photography, general photography of site stabilization, reburial and other activites, and final site photography, as well as a black-and-white photomosaic of the northern sector prints (Photo 40). Long's report on the videography is included at the end of this chapter.

PHOTOGRAPHIC EQUIPMENT AND FILM

The following photographic equipment was used:

General photography

- Canon F-1N cameras with 24mm, 35mm, 50mm and 100mm prime lenses, and a 35-105mm zoom lens.
- Frank Long used a Canon AT-1 camera with 28mm and 50mm prime lenses and a 28-70mm zoom lens for general photography and a Nikon P6006 camera with a 28-70mm zoom lens or a 50mm macro lens to do specific documentation work on the trackway.

Photogrammetry

- Hasselblad 500C/M cameras. One Hasselblad, used for the photogrammetry flyovers, had a prefocused and taped down 80mm lens mounted on it for the duration of the task, while another one, used for stereo-pair photography of the individual footprints enclosed by the calibration frame, used a prefocused and taped down 40mm lens. Multiple exchangeable film backs were used with the Hasselblads.

Individual footprint photography

- Canon F-1N using a 100mm macro lens
- Hasselblad 500 C/M using the 135mm macro lens with a helical focusing mount.
- Norman 200B flash unit for lighting the individual footprints.
- Minolta Flashmeter III and a Minolta Spotmeter for setting light levels with the flash, and determining exposure settings.
- Minolta Color Temperature Meter II with its corresponding flash receptor was used to set color temperature for the flash pictures.

Polaroid photography

- Cambo SCX 8x10 camera with two lenses, a 305mm f/9 Schneider G-Claron and a 240mm Caltar f/5.6.
- Calumet manual Polaroid processor, and 8x10 Polaroid film holders.

Film

- Kodak Lumiere 100 Professional color transparency film, an E-6 process film, was used in both 120 format, LPP 120, as well as 35mm format, LPP 135-36. The LPP emulsion was used because of its neutral color balance. Both film stocks were tested for color balance and effective speed prior to the campaign.
- Kodak T-Max 100 black-and-white negative film. This was used only in the 120 format, TMX 100-120.
- 5x7 T-Max 100 glass plates were used in the photogrammetry.
- Polaroid Polacolor ER 8x10 Instant Film Type 809 for the conservation documentation.

GENERAL PHOTOGRAPHY

As in 1995, general photography included recording field activities and team members working, recording of specific procedures, site flora and fauna, and detailed photography of stumps and roots found on the trackway. Also, thorough recording of the condition of the reburied southern sector and of the northern and middle sectors before re-excavation was conducted during the first few days of the campaign. As different teams worked on the trackway, their activities were recorded and their photographic needs were met. Set camera positions were established and recorded in the logs for ease in duplicating positions and camera/lens combinations were used in sequential photography. A 12-foot tripod was used again to record the work from an elevated viewpoint. This year a Bogen extension plate was attached to the top of the tripod to facilitate attaching and removing a Gitzo tripod head. The tripod was usually placed off the trackway surface for photography, except when a centered shot was required when it was placed on the middle sector where there were no prints. The tripod legs rested on sandbags that evenly distributed the load over a fairly large area and prevented damage to the tuff surface.

8X10 POLAROID PHOTOGRAPHY

8x10 color Polaroid photographs of the trackway and the individual hominid footprints were taken for use in recording the trackway's condition. Apart from the camera (Photo 50), Polaroid photography equipment included the crossbar and camera bracket assembly (described in the 1995 Report) which supported the large camera over the trackway, and two lenses, a 305mm and a 240mm lens. The 240 mm lens was used primarily in the overview shots because it allowed a greater area to be photographed from a standard height, and a wide aperture of f/5.6 that provided bright image focusing.

The flyover shots, which recorded most of the exposed trackway surface, were made at either a magnification of M=0.17 or M=0.185, the former covered an approximate area of 43.25x55 inches (110x140 cm), the latter covered an approximate area of 40.5x51.25 inches (103x130 cm). The map in Appendix A shows the distribution of shots over the trackway with magnification indicated. Only a small portion of the middle sector of the trackway without prints, from approximately N107 -N110.75, was not photographed with Polaroids to conserve time. Forty-three overview Polaroids were taken of the northern and middle trackway sectors, making a total of 79 Polaroid's taken in 1995 and 1996, covering the 30 m length of re-excavated trackway.

Individual hominid footprints were also photographed for purposes of condition recording. As in 1995, prints were delineated by a stainless steel wire frame scored at 5mm intervals (Photo 51). Four different magnifications were used: M = 0.75 for the majority of the G1 footprints; M = 0.54 for the majority of the G2/3 footprints; and two others that were used in the area of Trench 7 where the footprints are spaced closely together (prints G1-6,7,8 and G2/3-5) and were photographed together, M=0.42 and M=0.51. Twenty-five prints were recorded in the northern and middle trackway sectors, making a total of 54 prints covered by Polaroids for the entire 30m excavated area.

The Polaroid photography was successful. Polaroid Type 809 film is designed for use with electronic flash or at relatively short exposures. The slow shutter speeds of 1/8, 1/4, and 1 second, necessary for adequate depth of field in our use, caused excessive reciprocity law failure. The effective film speed was reduced from ISO 80 to ISO 50 for the 1/8 second exposure, to ISO 40 for the 1/4 second exposure, and ISO 20 for the 1 second exposure. Massive color correcting filtration was needed to achieve an adequate color balance: CC30R and CC05M at ISO 50; CC30R, CC05M, and CC 10Y at ISO 40; and CC40R, CC05M, and CC10Y at ISO 20. I started with the manufacturer's suggested settings and filtration, and made additional corrections to achieve a good compromise.[1] The results were adequate for their use in condition recording.

PHOTOGRAMMETRY

I collaborated with the photogrammetry team in two ways: assisting in the photogrammetric procedures that used the Zeiss UMK camera where I was responsible for the exposure measurement and processing of the glass plates; and providing

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1 Since we weren't using the film in a manner consistent with its design, the results were necessarily a compromise. Polaroid color film is intended for viewing using a tungsten light source, so the color rendition always improves when viewing the prints under a desk lamp rather than in the field under the ambient daylight.

Hasselblad cameras and lenses for making various exposures to supplement the main Zeiss UMK and Kodak DCS420 ones.

Additional images were made for photogrammetry using Hasselblad cameras with taped down lenses preset for focus. The flyovers and the calibration frame pictures were both made using Kodak Lumiere 100 film. The flyover pictures used a Hasselblad 500C/M with an 80mm lens. The individual footprint pictures used a Hasselblad 500C/M camera with a 40mm lens. All exposures were determined using a gray card in the tuff plane read with the Minolta Spotmeter F set to ISO 80. No bracketting of exposures were made since these photographs were for color information only, and were not needed to be exact renditions of the footprints.

The exposure and processing of the 5x7 T-Max plates followed the procedures outlined in the 1995 report. That procedure was followed for all the processing runs[2] (a total of 88 plates were processed) and produced negatives of excellent gradation and tonal range. The plates were repacked into their original boxes using the spacers and cushioning materials for transport to South Africa by Heinz Rüther.

PHOTOGRAPHY OF INDIVIDUAL FOOTPRINTS

The photography of the trackway footprints was undertaken after the completion of the conservation portion of the campaign. Photography of each of the individual footprints was made at the same scale. That is, the largest footprint was accommodated within the camera frame, and then all the others were photographed at the same magnification. The tripod was taped securely at this camera height, and only the lens barrel was adjusted to accommodate focusing. A leg would be adjusted to accommodate very uneven tuff surfaces. At all other times the tripod was left at its established height. The 35mm magnification is M=0.07, and the 6x6cm is M=0.11.

The same lens and body combination was used throughout the photography. For the 6x6cm (2.25 x 2.25 in.) photography, a Hasselblad 500C/M body was used in

[2] The runs were: August 30, 8 plates with Long; September 1, 22 plates with Long; September 2, 22 plates by Long; September 3, 16 plates by Long; and September 5, 20 plates with Long.

conjunction with a helical focusing mount and the Hasselblad-Zeiss 135mm Makro Planar lens with a lens shade. For the 35mm photography, a Canon F-1N camera body with a motor drive and a Canon 100mm macro lens was used.

The color transparency film used for both formats was Kodak Lumiere 100 LPP film. This film has a neutral color balance, moderate speed, and high resolution. Additionally, Kodak T-Max 100 film was used in the Hasselblad format (6x6 cm) for making black-and-white negatives of each footprint. In all the color footprint photography, bracketed exposures were made to insure the best possible rendition.[3]

The protective canopy provided an even source of fill-light at an optimum color temperature. The color temperature of the light was 5200°K±150° during the hours when the canopy illumination completely covered the trackway, that is, between 10 AM-2:30 PM.[4] The base exposure for this fill-light was 1/60 sec at f/8.5 to 1/60 sec at f/11.3. The base exposure "peak" occurred when the sun was directly over the canopy. I used a Norman 200B flash unit with a Norman LH2 lamphead with a 2D reflector as the main light. This flash was adjusted to 5200°K in combination with the fill light, at a 3:1 lighting ratio, with strips of Rosco filters. The 3:1 light ratio was used to ensure that the shadows were all "open" and that the highlights and shadows would all be in an exposure range compatible with the transparency film. The flash was placed on a small light stand approximately half-way between the longitudinal and transverse axes of the footprint aiming approximately 45° downward to the plane of the tuff. This gave an "architectural" lighting which would accommodate the varying depths, ridges, and textures of the tuff. In other words, a standard lighting geometry was established so that each of the footprints was lighted in a consistent manner, and from the same angle, so

[3] The brackets were ± 1 stop from the nominal (metered) exposure. The 35mm shots included a metric arrow scale and the footprint number in each shot; 6x6 cm photography had only the arrow scale included.

[4] The canopy illumination was dependent on the sun's ascension. It provided complete coverage between 10:00 AM and 2:30 PM, but coverage was adequate on the west in the AM and on the east in the PM to extend shooting hours when only an individual footprint was being photographed. The side panels that protected the trackway from morning and afternoon sunlight were not used during photography because they cast a pattern on the trackway.

that all could be viewed similarly. Each one would have the same visual characteristics as all the others.

Additionally, for the 35mm photography, a second lighting protocol was also used. In this, the main light was aligned in the same diagonal axis as in the former lighting, but its height to the tuff surface was decreased. To adjust for the increased brightness, the light stand was moved away from the footprint. For example, if the standard lighting of the footprint placed the lamphead 55 inches above the surface of the tuff, the lamphead's vertical axis touched the tuff surface also 55 inches away from the footprint giving a lighting angle of 45°. In the "raking light" rendition the lamphead was placed 35 inches above the tuff surface, 70 inches away, giving a lighting angle of 29°. This additional set of photographs gave a higher visual relief to the tuff surface, while still holding detail.

LOG SHEETS

The photography log sheets were redesigned for 1996 by the GCI and were provided for field use in bound volumes. They contain spaces for dates, subject matter, and technical notations. A schedule of abbreviations was followed in the field to record subjects, people, tripod and camera position. The logs and abbreviations were also submitted to the GCI with the photos.

REPORT ON THE VIDEOGRAPHY

by Frank Long

Video documentation and photographic work at Laetoli in 1996 was undertaken to complement the work of the three previous campaigns. Pre-campaign planning centered on the acquiring of adequate sound recording equipment to enhance the quality of the video tape documentation and the ultimate flexibility of its use. Campaign videography included general documentation of the site and surrounding areas, the trackway and personnel, various details of the trackway and the excavation and conservation work, impressions and comments from the scientific personnel, visits and special events at the site as well as coverage of the work in progress.

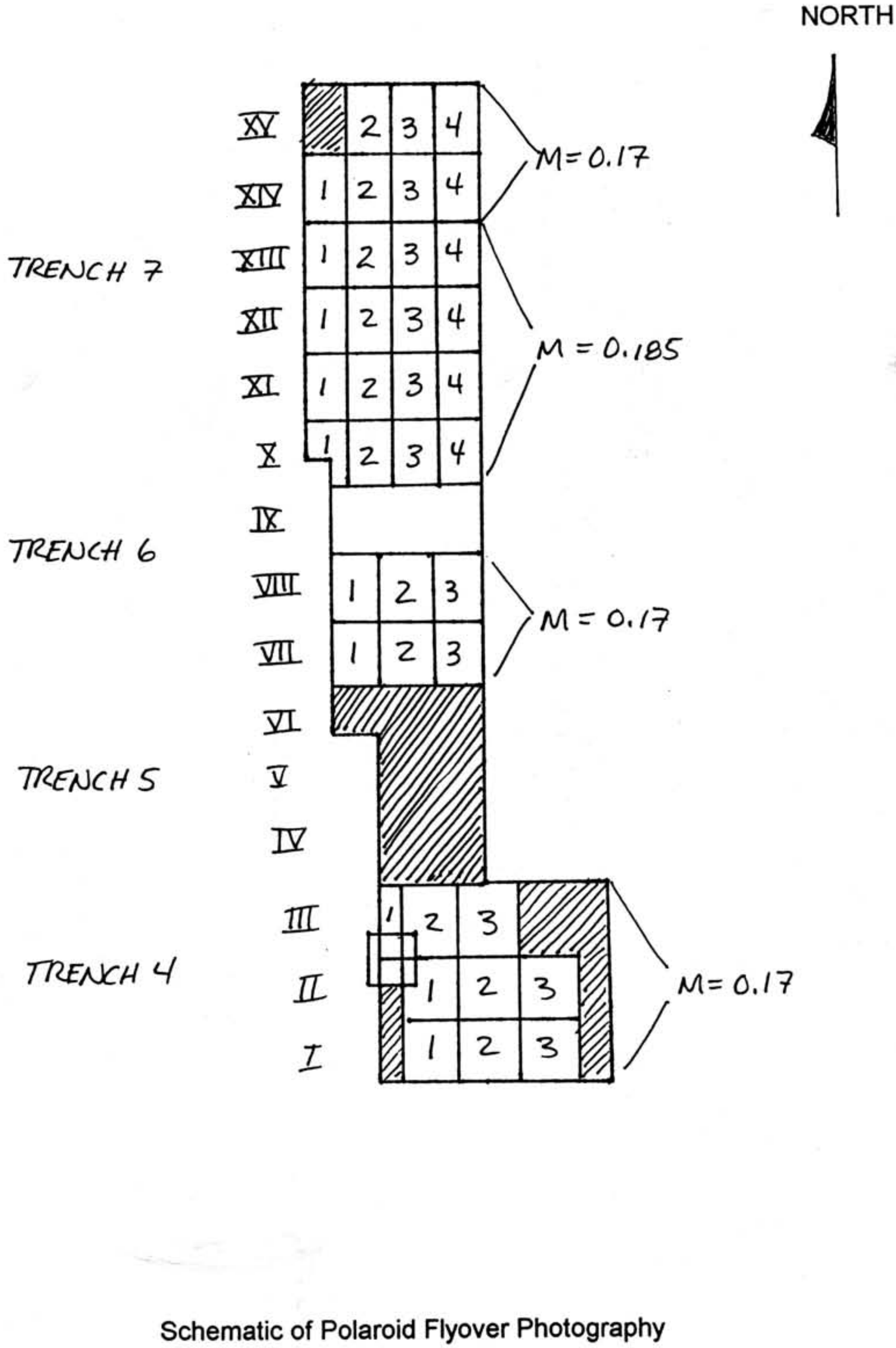
EQUIPMENT

A Sony TR700 HI-8 video camcorder was used for the video documentation. This is a consumer grade video camera and recorder with a variety of features to aid in simplifying video productions, and a number of limitations which come with consumer cameras. For the purposes of sound recording, an Audio Technica AT 825 Stereo Microphone with a special Hi8 mic input adaptor was used. To combat the wind conditions at the site, a Rycote mini windjammer wind sock was acquired. Tape stock used was the Maxell Hi-8 Metal particle tape in 120 minute loads.

At times during the campaign, various tools were employed to support cameras and sound equipment as necessary. A Gitzo reporter tripod with a Bogen friction head #3047 was used alternatively for either still camera or the video camera. A shoulder pod was also used as needed when documenting work at the site with the camcorder. A boom was created from Tom Moon's light stand extension arm for use with the AT825 microphone.

General site videography

Videography followed the general procedures established in the previous campaign. The primary concern was to get usable material with good sound and a sense of the work being done at the site. The video camcorder is not a scientific documentation tool, but it can provide an accurate record of the site conditions and the work environment. Care was taken to record day-to-day work, as well as to document the visits of various groups and individuals to the site. All aspects of the campaign work, from excavation and conservation to sieving of sand and reburial were recorded. In a much more limited way, camp life and procedure was documented.



Schematic of Polaroid Flyover Photography

PART VII. PHOTOGRAMMETRIC RECORDING OF THE TRACKWAY

by Heinz Rüther

INTRODUCTION

For the photogrammetric survey of the northern part of the hominid trackway site at Laetoli, the Getty Conservation Institute contracted a team from the Department of Geomatics at the University of Cape Town (UCT).

UCT Field Team		
Heinz Rüther		project leader
Ulrike Brüssler	Ph.D. student	scientific field assistant

The following report gives details of the field work, describes the data processing strategy and reports on the results to date. All relevant co-ordinates of survey points, photogrammetric control points and calibration frame points are provided in the report.

The photogrammetric field work was carried out at Laetoli from the 18th of August to the 7th of September 1996. The data processing stage began immediately after the return from Tanzania and a set of results was completed in February 1997 (see Figs 22-24 for resulting contour maps of individual hominid footprints and Figs 15-17 for photogrammetry of trackway sectors).

OBJECTIVE OF THE FIELD WORK

It was the objective of the field work to acquire complete photogrammetric coverage of the hominid footprints in the northern trackway and extensive coverage of the surrounding tuff surface. The photography was done with digital and conventional cameras.

PREPARATIONS

Form sheets, spreadsheets and computer programs

The following was prepared for the field campaign

- Spreadsheet to record and compute the survey control point observations
- Spreadsheet to record and compute the observations for the photogrammetric control points
- Spreadsheet to record and compute the positions of the foot frame
- Spreadsheet to record and compute the observation of the height survey
- Least squares network adjustment program for the evaluation of the point positions of all control points
- Form sheets for recording of the photography

Separate sheets were prepared for the UMK 10, the DCS 420 and the Hasselblad photography.

Mechanical devices

The footprint frame with 71 retro-reflective targets was rebuild in aluminium to make the frame easier to transport and more manageable than the original steel frame used in the first campaign.

ENGINEERING SURVEY AND PHOTOGRAMMETRIC SURVEY PROCEDURES

The field survey of the Laetoli trackway can be divided into three fieldwork components:

- The establishment of a datum by means of the survey control points
- A conventional high precision survey of photogrammetric control points on the trackway
- The acquisition of the photogrammetric images

Establishment of the Laetoli Control System

The co-ordinate systems are explained in detail in the 1995 report

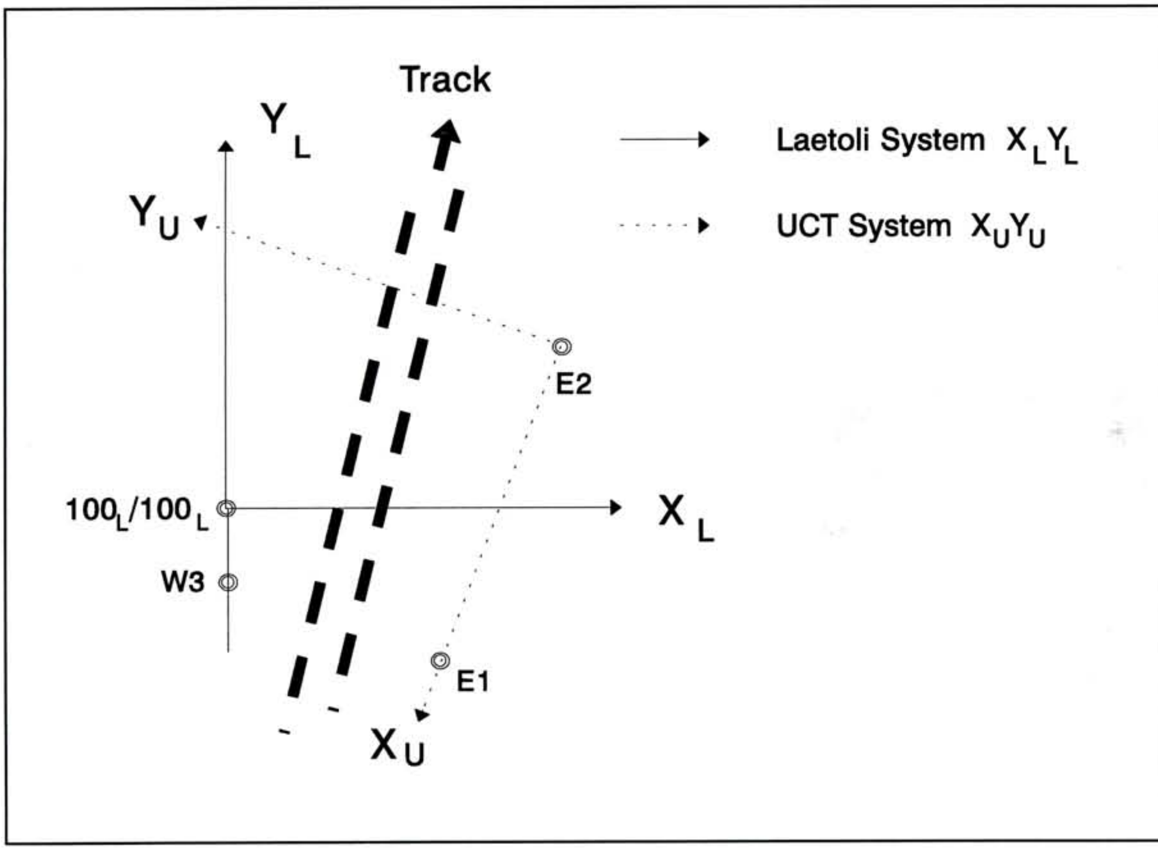


Figure 1 Co-ordinate systems at Laetoli

Method and procedure for the engineering survey of the photogrammetric control points

Placing of the photogrammetric control points

Fifty-seven control point markers - metal disks with a diameter of 14mm and a thickness of 1 mm- were temporarily attached to the tuff surface using a removable adhesive. The markers were painted black and a self-adhesive retro-reflective disk with a diameter of 6mm was attached to the approximate center of each disk.

In the northern part of the track the points were aligned in three rows of 15 points each for the center-, east- and west-row approximately parallel to the hominid track. In the graben area two rows with 4 points each were laid out, and in the southern part two rows of 3 points each. The separation between the rows was approximately 0.9 m and the distance between the points in along-track direction approximately 0.45m.

Targets were placed by inspection, as the tolerances for the target positions were not critical as long as the points would be visible in the photography. Nevertheless, an attempt was made to place the targets in the approximate positions as predetermined in the original control point design. The following table shows how the control points were labelled for each of the rows.

Row	**Control points**	**Number of Points**
North - West row	TW1, TW2 ... TW13	13
North - East row	TE1, TE2 ... TE15	15
North - Center row	TC1, TC2 ... TC15	15
Graben row- West	GW1, GW2, ... GW4	4
Graben row – East	GE1, GE2 ... GE4	4
South -West row	SW1, SW2,SW3	3
South - East row	SE1, SE2,SE3	3
		Total: 57

Table 1 Control point layout

The co-ordinate lists 4.3.1 and 4.3.2 give the surveyed positions of the 57 control points, together with the 6 survey reference points.

Triangulation of survey control points and data processing

To determine the photogrammetric control point position with sub-millimeter precision, six external survey control points were chosen from which horizontal and vertical angle observations were carried out using a Leica TC1000 single second theodolite.

The six external points were:

- E2: an existing point (1995 survey) was reused, the control re-measurement proved that its position compared to last year was unchanged.
- W2: an existing point (1995 survey) was reused after control measurement confirmed that it was unchanged.
- N1: a center- punched brass stud in cement was established at the northern end outside the exposed trackway as an extension of the center line of control points.
- E3: a new point was placed at the east side of the graben and marked with a center-punched brass stud in cement.
- E4: new point was placed at the East side of the trackway between graben and northern end of the trackway.
- E5: new point was placed at the North-east corner of the trackway.

The triangulation observation included all horizontal and vertical angles as well as all distances between the points. A PSION Workabout Data logger with the BOOKER 6.0 software was used to record the data. The observations were reduced in the camp using the prepared spreadsheets in accordance with standard survey methods. The reduced observations were entered into a least squares survey network adjustment. The adjustment results are excellent with point position precision better than 0.5mm.

Triangulation of the photogrammetric control points

The 57 control points were triangulated from the six control points W2, N1, E3, E4, E5 using a Leica TC 1000 theodolite. Distance measurements were done in the northern part of the trackway for checking purposes. In the graben and the southern part of the track this was not possible due to the delicate surface which did not allow a survey prism to be placed over the control points. The control point disks were measured by pointing at the targets in the following sequence:

1. Bottom left - horizontal and vertical angle
2. Top right - horizontal and vertical angle

The mean of observation 1 and 2 provided angle readings to the disk center in horizontal and vertical direction. Observation to the control points in the northern part where done from the station N1, E3, E5, E4. The control points in the graben as well as the ones in the southern part were observed from E3, E5, and N1. Every control point was provided with at least 3 redundancies.

The observations were reduced in a second pre-designed and tested spreadsheet. The same spreadsheet served to provide provisional co-ordinates as required for the least square adjustment. The results were excellent and the precision in the order of or better than 0.5mm were achieved.

Height datum and height determination

The method of establishing a height reference system and the determination of heights was the same as employed in the field campaign 1995. The heights were linked to the 1995 system.

Point co-ordinates in the L/S co-ordinate/ height system

The following tables provide a list of co-ordinates of the survey control points, the photogrammetric control points and the survey points from the previous site survey in the new Laetoli system with S-system (L/S – system).

Survey reference points

Name	X [m]	Y [m]	Height [m]
N1	100.1066	124.8469	50.4305
E2	105.9803	103.2516	51.4006
E3	102.9377	111.8407	50.5711
E4	104.2031	116.0161	50.5191
E5	104.1419	119.9689	50.4441

Table 2 Reference points

Photogrammetric control points

Name	X [m]	Y [m]	Height [m]
TE1	100.8316	115.6230	50.3019
TE2	100.7815	116.0670	50.2676
TE3	100.7303	116.5199	50.2930
TE4	100.6449	116.9628	50.2803
TE5	100.5807	117.4113	50.2747
TE6	100.5014	117.8494	50.2738
TE7	100.4462	118.2948	50.2640
TE8	100.3700	118.7428	50.2839
TE9	100.3125	119.1842	50.2531
TE10	100.1988	119.6206	50.2239
TE11	100.1661	120.0637	50.2535

Name	X [m]	Y [m]	Height [m]
TE12	100.1107	120.5153	50.2721
TE13	100.0461	120.9597	50.2630
TE14	99.9559	121.3962	50.2193
TE15	99.8884	121.8481	50.2129
TC1	99.8790	115.4673	50.3446
TC2	99.8730	115.9322	50.3095
TC3	99.8333	116.3760	50.2544
TC4	99.7647	116.8311	50.2902
TC5	99.7098	117.2764	50.2929
TC6	99.6332	117.7094	50.2745
TC7	99.5612	118.1500	50.2642
TC8	99.4922	118.5888	50.2583
TC9	99.4191	119.0227	50.2608
TC10	99.3448	119.4793	50.2562
TC11	99.2606	119.9286	50.2432
TC12	99.2386	120.3744	50.2706
TC13	99.1341	120.8251	50.2381
TC14	99.0664	121.2647	50.2172
TC15	99.0883	121.7705	50.1952
TW1	99.0575	115.4313	50.3187
TW2	98.9735	115.8750	50.2791
TW3	98.9304	116.3230	50.2750
TW4	98.8653	116.7537	50.2572
TW5	98.8117	117.1814	50.2593
TW6	98.7396	117.6122	50.2737
TW7	98.6820	118.0506	50.2751
TW8	98.6123	118.4954	50.2647
TW9	98.5630	118.9301	50.2755
TW10	98.5447	119.3866	50.2885

Name	X [m]	Y [m]	Height [m]
TW11	98.4648	119.8142	50.3859
TW12	98.3790	120.2830	50.3282
TW13	98.3265	120.7144	50.2453
SE1	101.1060	105.7825	50.7764
SE2	101.0530	106.1704	50.7505
SE3	100.9819	106.6822	50.6898
SW1	100.1929	105.6536	50.7070
SW2	100.1940	106.1166	50.6971
SW3	100.1165	106.5401	50.6539
GE1	100.6337	113.7442	50.2054
GE2	100.5684	114.2530	50.1844
GE3	100.4897	114.6404	50.2077
GE4	100.484	115.0915	50.1966
GW1	99.6428	113.6378	50.3123
GW2	99.6287	114.1306	50.2408
GW3	99.5418	114.5102	50.2234
GW4	99.3492	115.1185	50.2118

Table 3 Control points

Photogrammetry Field Procedures

Photogrammetric data acquisition for the trackway

Contr. point	Contr. point	Image	Image	Image	Contr. point	Contr. point	Image	Image	Image
North Section of the Trackway									
GW4					GE4				
TW1	TC1	AL1	A1	AR1	TC1	TE1	BL1	B1	BR1
TW2	TC2	AL2	A2	AR2	TC2	TE2	BL2	B2	BR2
TW3	TC3	AL3	A3	AR3	TC3	TE3	BL3	B3	BR3
TW4	TC4	AL4	A4	AR4	TC4	TE4	BL4	B4	BR4
TW5	TC5	AL5	A5	AR5	TC5	TE5	BL5	B5	BR5
TW6	TC6	AL6	A6	AR6	TC6	TE6	BL6	B6	BR6
TW7	TC7	AL7	A7	AR7	TC7	TE7	BL7	B7	BR7
TW8	TC8	AL8	A8	AR8	TC8	TE8	BL8	B8	BR8
TW9	TC9	AL9	A9	AR9	TC9	TE9	BL9	B9	BR9
TW10	TC10	AL10	A10	AR10	TC10	TE10	BL10	B10	BR10
TW11	TC11	AL11	A11	AR11	TC11	TE11	BL11	B11	BR11
TW12	TC12	AL12	A12	AR12	TC12	TE12	BL12	B12	BR12
TW13	TC13				TC13	TE13			

Contr. point	Contr. point	Image	Image	Image	Contr. point	Contr. point	Image	Image	Image
Graben									
GW1	GE1								
GW2 GW3	GE2 GE3	AL22 AL23	A22 A23	AR22 AR23	SW2	SE2	AL26	A26	AR26
GW4	GE4	AL24	A24	AR24	SW3	SE3			
Single overlap in the southern part of the north section of the Trackway									
SW1	SE2								
SW2	SE2	AL26	A26	AR26					
SW3	SE3								

Table 4 UMK and DCS images with associated control points

Table 4 shows the layout of the UMK and DCS images, which were taken to cover the trackway. The table is designed according to which control points are visible on each of the images. As an example the shaded area indicates that images AL6, A6 and AR6 contain control points TW5, TW6, TW7, TC5, TC6 and TC7. The total number of UMK images is given in table 5 below.

UMK images	North	6 * 12	72
	Graben	3 * 3	9
	South	3 * 2	6
	Total		87

Table 5 Number of UMK images

The following diagram shows the design of a single overlap indicating the three camera positions (one on the center line of the strip and one each on the left and right of the center line at a distance of half the base line length). The numerical values of the various design parameters (a to h, cc and A to E) vary with the elevation of the cameras above the surface, 'flying height', and with the interval between control point lines. Values for the parameters are listed in the following tables (overlap area highlighted with gray shading). Different flying heights had to be implemented on site due to the sloping ground. Three different elevations, representing typical flying heights, are given in the tables, with a fixed separation of 0.3 m in height between the DCS and UMK. The lateral interval between control point was 1.0 m for the southern sector (1995) and 0.9 m for the northern sector (1996).

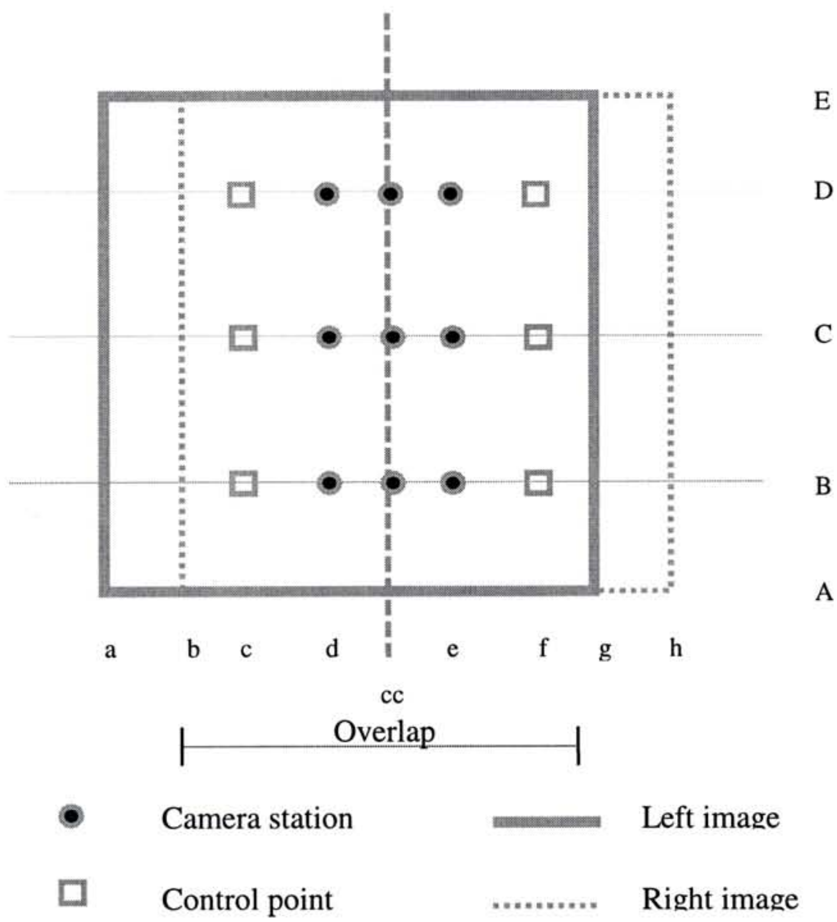


Figure 2 Overlap design for DCS and UMK cameras

The survey was designed to provide complete dual stereo cover for the conventional and digital cameras. Overlap designs are shown in the following tables.

FLIGHT PLAN		**DCS**	**DCS**	**DCS**	**UMK**	**UMK**	**UMK**
Camera height above surface		1.50	1.60	1.70	1.20	1.30	1.40
Length of base line (m)		0.30	0.30	0.30	0.30	0.30	0.30
Nominal focal length (mm)		14.5	14.50	14.50	100.0	100.0	100.0
Image format : width (mm)		13.5	13.50	13.50	155.0	155.0	155.0
Image format : height (mm)		9.0	9.0	9.0	110	110	110
Image scale (1 in..)		103	110	117	12	13	14
Width of ground cover (m)		1.4	1.5	1.6	1.9	2.0	2.2
Length of ground cover (m)		0.9	1.0	1.1	1.3	1.4	1.5
Lateral overlap (m)		1.1	1.2	1.3	1.6	1.7	1.9
Interval between strip centers (m)		0.90	0.90	0.90	0.90	0.90	0.90
Adopted value for center line of left strip		1.15	1.15	1.15	1.15	1.15	1.15
Lateral interval betw. Contr. Pnts (m)		1.00	1.00	1.00	1.00	1.00	1.00
LEFT STRIP							
LELI Left edge of left image	a	0.30	0.26	0.21	0.07	-0.00	-0.08
LERI Left edge of right image	b	0.60	0.56	0.51	0.37	0.29	0.22
LCP Left Control Point	c	0.65	0.65	0.65	0.65	0.65	0.65
LC Left Camera	d	1.00	1.00	1.00	1.00	1.00	1.00
C Center	Cc	1.15	1.15	1.15	1.15	1.15	1.15
RC Right Camera	e	1.30	1.30	1.30	1.30	1.30	1.30
RCP Right Control Point	f	1.65	1.65	1.65	1.65	1.65	1.65
RELI Right edge of left image	g	1.70	1.74	1.79	1.93	2.01	2.09
RERI Right edge of right image	h	2.00	2.04	2.09	2.23	2.31	2.39

RIGHT STRIP							
LELI Left edge of left image	a	1.20	1.16	1.11	0.97	0.89	0.82
LERI Left edge of right image	b	1.50	1.46	1.41	1.27	1.19	1.12
LCP Left Control Point	c	1.55	1.55	1.55	1.55	1.55	1.55
LC Left Camera	d	1.90	1.90	1.90	1.90	1.90	1.90
C Center	Cc	2.05	2.05	2.05	2.05	2.05	2.05
RC Right Camera	e	2.20	2.20	2.20	2.20	2.20	2.20
RCP Right Control Point	f	2.55	2.55	2.55	2.55	2.55	2.55
RELI Right edge of left image	g	2.60	2.64	2.69	2.83	2.91	2.99
RERI Right edge of right image	h	2.90	2.94	2.99	3.13	3.21	3.29
Along track geometry							
along track distance between control		0.45	0.45	0.45	0.45	0.45	0.45
	A	0.23	0.20	0.17	0.04	-0.02	-0.07
	B	0.25	0.25	0.25	0.25	0.25	0.25
	C	0.70	0.70	0.70	0.70	0.70	0.70
	D	1.15	1.15	1.15	1.15	1.15	1.15
	E	1.17	1.20	1.23	1.36	1.42	1.47

Table 6 Photogrammetric design of the trackway photography

Along track positions of control point rows

Row	1	0.25	Row	9	5.19
Row	2	0.70	Row	10	5.64
Row	3	1.15	Row	11	6.09
Row	4	1.60	Row	12	6.54
Row	5	3.39	Row	13	6.99
Row	6	3.84	Row	14	7.44
Row	7	4.29	Row	15	7.89
Row	8	4.74	Row	16	8.34

Table 7 position of control point rows

Photogrammetric data acquisition for the individual footprints

A total of 25 imprints were recorded photogrammetrically:

16 imprints in track G1: G1-2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 19, 21, 22, 23, 24

9 imprints in track G2/3: G2/3-2, 3, 5, 6, 7, 8, 9, 10, and 17

The recording dates and sequence were

2-9-96	**3-9-96**	**4-9-96**	**5-9-96**
1 G1 – 2	6 G1-7	21 G1-24	23 G1-21
2 G1 - 3	7 G1-9	22 G2/3-17	24 G1-22
3 G1 – 6	8 G1-11		25 G1-23
4 G1 - 8	9 G1-12		
5 G1 - 10	10 G1-13		
	11 G1-14		
	12 G1-19		
	13 G2/3-2		
	14 G2/3-3		
	15 G2/3-5		
	16 G2/3-6		
	17 G2/3-7		
	18 G2/3-8		
	19 G2/3-9		
	20 G2/3-10		

Table 8 Table with recording dates and sequences

Survey of the control frame

The portable control point frame with 71 retro reflective targets was surveyed prior to the fieldwork under laboratory conditions using 18 images in a bundle adjustment calculation. The following table lists the co-ordinates of the frame control points in the local frame system in units of millimeters.

CONTROL FRAME COORDINATES

	x [mm]	y [mm]	z [mm]
1	1049.92	942.52	1222.78
2	1052.21	996.42	1198.08
3	1053.91	1048.6	1174.46
4	1055.61	1105.39	1148.36
5	1057.94	1161.78	1122.78
6	1058.12	1217.44	1097.43
7	1063.32	1359.97	1033.26
8	1065.25	1410.65	1010.43
9	1069.07	1454.79	990.91
10	1097.18	1456.08	991.98
11	1148.59	1457.36	993.99
12	1195.56	1457.85	995.98
13	1240.44	1457.96	998.21
14	1295.95	1457.53	1001.1
15	1345.24	1456.45	1004.08
16	1396.03	1455.49	1006.83
17	1396.17	1408.36	1027.87
18	1393.14	1355.94	1051.28
19	1391.33	1310.66	1071.7
20	1390.00	1234.49	1106.22

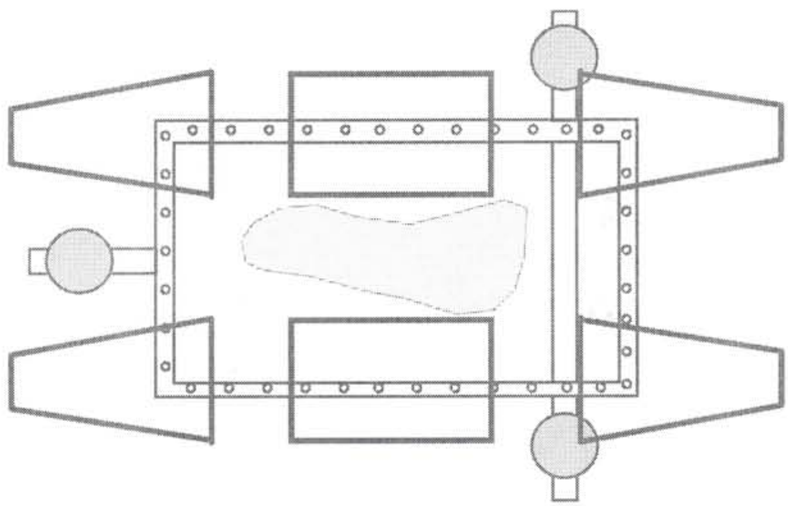
	x [mm]	y [mm]	z [mm]
21	1386.77	1186.59	1127.93
22	1387.37	1139.58	1149.25
23	1384.26	1084.24	1174.41
24	1384.27	1037.00	1195.93
25	1383.18	988.12	1218.15
26	1380.88	935.26	1242.2
27	1320.96	937.85	1238.63
28	1266.72	939.76	1235.10
29	1200.88	939.19	1232.02
30	1143.95	938.76	1229.54
31	1086.42	939.67	1226.23
32	1375.62	1280.75	1092.34
33	1332.70	1279.98	1090.52
34	1288.45	1281.57	1087.68
35	1249.65	1281.71	1085.59
36	1205.33	1281.01	1083.75
37	1161.52	1281.79	1081.44
38	1121.08	1281.45	1079.36
39	1061.25	1264.36	1084.14
40	1062.14	1295.99	1069.87
41	1089.70	923.70	1063.83
42	1090.58	977.68	1039.24
43	1091.70	1028.95	1016.5
44	1092.73	1078.48	993.7
45	1094.69	1129.89	970.52
46	1096.48	1183.32	946.37
47	1097.96	1231.89	924.45
48	1100.10	1278.26	903.89
49	1102.14	1319.60	884.9
50	1103.73	1364.42	864.58

	x [mm]	y [mm]	z [mm]
51	1137.98	1365.36	862.91
52	1183.14	1367.44	863.96
53	1231.07	1367.68	866.29
54	1276.83	1366.28	869.32
55	1350.05	1366.6	872.52
56	1371.46	1363.76	878.46
57	1370.8	1320.87	897.67
58	1371.35	1276.76	917.83
59	1368.28	1223.03	941.87
60	1366.04	1174.98	963.75
61	1363.65	1127.11	985.21
62	1362.15	1078.99	1006.88
63	1361.59	1031.77	1028.32
64	1361.93	985.24	1049.65
65	1359.19	938.36	1070.98
66	1358.83	903.46	1086.93
67	1300.52	902.2	1080.99
68	1250.00	899.73	1079.5
69	1194.48	899.63	1076.58
70	1155.57	899.44	1074.67
71	1114.91	900.88	1071.85

Table 9 Control frame coordinates

DCS 420 digital camera photography

Six digital RGB images of the footprint were captured with the control frame placed over each of the 25 footprints in turn. Image capture was done with the camera handheld at an elevation of approximately 0.9m. Aperture and exposure values were typically in order of f8 and 1/125. A 14mm lens was used and the camera was calibrated three times at site at a fixed (taped down) focal length. The DCS images were downloaded onto the hard disk of the notebook computer and backed up onto ZIP drives. All the images were changed into grayscale format and inspected to ensure best quality. Due to changes in the exposure times compared to the 1995 campaign (the chip proved to be less light-sensitive than expected and light-meter readings had to be adapted) better histograms were achieved, resulting in improved appearance and thus better prospects for the planned visualization .



Six camera positions for the photography of individual footprints

Figure 3 Figure of image geometry DCS 420 – individual footprints

In order to map the individual footprints it was necessary to surround each imprint with a framework of control points. The position of the control points had to be determined in the Laetoli system. For this purpose the surveyed control points were transformed from their arbitrary co-ordinate system into the trackway system.

The centers of the control points were then determined by photogrammetric software and used in a bundle adjustment to provide the exterior orientation parameters of the exposure stations. The table below shows the accuracies achieved in the bundle adjustment.

	v_x [mm]	v_y [mm]	σ [mm]
G1-2	0.0011	0.0009	0.0010
G1-3	0.0009	0.0009	0.0009
G1-6	0.0010	0.0010	0.0010
G1-7	0.0010	0.0010	0.0010
G1-8	0.0011	0.0010	0.0011
G1-9	0.0010	0.0009	0.0010
G1-10	0.0011	0.0011	0.0012
G1-11	0.0010	0.0009	0.0010
G1-12	0.0008	0.0008	0.0009
G1-13	0.0009	0.0010	0.0010
G1-14	0.0011	0.0011	0.0012
G1-19	0.0010	0.0009	0.0010
G1-21	0.0012	0.0012	0.0012
G1-22	0.0011	0.0011	0.0011
G1-23	0.0010	0.0009	0.0010
G1-24	0.0012	0.0012	0.0012
G23-2	0.0012	0.0011	0.0012
G23-3	0.0011	0.0010	0.0011
G23-5	0.0010	0.0010	0.0010
G23-6	0.0011	0.0011	0.0011
G23-7	0.0009	0.0009	0.0009
G23-8	0.0010	0.0010	0.0010
G23-9	0.0012	0.0011	0.0012
G23-10	0.0012	0.0012	0.0012
G23-17	0.0012	0.0012	0.0013

Table 10 Bundle adjustment accuracies

Hasselblad photography

Color images of each imprint were captured with the control frame placed over the imprint, using a 40mm lens taped down at a fixed focal length. The camera was supported on a tripod for improved stability during exposures with typical values of f11 and 1/60s.

The total number of all images taken are listed in Table 11 below.

	Track	Footprint	Cast
UMK 10	87	-	12
DCS 420	151	144	-
Hasselblad	96	96	36

Table 11 Total number of images

Throughout the image capturing stage for each of the imprints, utmost care had to be taken not to disturb the control frame in its position and orientation. The frame had to remain *in situ* for the UMK, DCS and Hasselblad photography once its position was determined with the total station in order to provide co-ordinates within the overall site co-ordinate system.

Photographic Processing

The UMK10 glass plates were developed by Tom Moon and his assistant Frank Long in the specially erected 'dark tent'. Processing proved very time consuming and the glass plates were developed in three separate sessions of 24, 36, 38 plates on September 1, 3 and 5 respectively. The quality of the photographic plates proved exceptional with excellent definition on clear high resolution.

PHOTOGRAMMETRIC DATA PROCESSING

The photogrammetric process

The table below attempts to explain the photogrammetric process in a systematic fashion.

Flowchart of the photogrammetric procedures for the determination of digital surface or terrain models (DTM) for digital and scanned analog images

Procedure for digital camera images	Procedure for scanned analog images
Procedure for digital camera images **DCS-camera**	**Procedure for scanned analog images** **UMK-camera**
Control point measurement Identification of control points on each of the images covering the area to be mapped and automated measurement of the image co-ordinates of the control points in pixel co-ordinates.	
Image orientation Restitution of the orientation of all images in object space. Automated determination of the elements of interior and exterior orientation.	**Image orientation** Setting up of a stereo image pair in the stereo plotter. Establishment of relative and absolute orientation (i.e. the restitution of the position of the two cameras in object space) to enable stereo viewing.
Interest point extraction Automated extraction of interest points by means of interest operators	

Surface reconstruction	**Surface reconstruction**
Multi-Photo-Geometrically-Constrained Matching (MPGC). Identification of identical points an all images based on the parameters determined in the calibration stage. Generation of xyz co-ordinates of all matched points (point cloud).	Manual plotting of contours and spot heights of points

Generation of a grid-DTM

from random interest points	from points along the contours and from spot heights

Final Products

Contour map Generated using contouring software	Visualization/CAD formats 3D models, solid models, wire grids	**Ortho images**

Table 12 Flowchart of photogrammetric procedures

DIGITAL ORTHO-IMAGE GENERATION

Image from DCS-camera

Conventional Image

Scanning

The image (positive or negative) is scanned. During or subsequent to this process the fiducial mark co-ordinates are measured to allow for misalignment of the image in the scanner

Input Data

- original image
- DTM
- interior and exterior orientation parameters
- pixel size
- required output format (ortho-image size and output-pixel size < image pixel)

- **Input Data**
- original image
- DTM
- interior and exterior orientation parameters
- affine transformation parameters from scan
- required output format (ortho-image size and output-pixel size < image pixel)

Densification of DTM

Interpolation of additional height points to create a DTM with a height for each pixel (typically done as part of resampling)

Resampling
Calculation of gray values for transformed pixel centers of the rectified image by interpolation from surrounding pixel centers.

↓

Line features and annotation
Separate generation of contours, roads, waterways etc as well as grid lines and general annotation.

Table 13 Digital Ortho-Image Generation

Control point measurement

The digital image as obtained with the video-still-camera is displayed on a computer screen and control points are identified on each of the images covering the area to be mapped. This can be done by an automated search routine if the control points are well defined and a suitable search routine is available. The search routine would typically be based on a template matching routine, full automation is seldom possible. A best scenario for automated matching is given in close-range-photogrammetric applications where the environment can be controlled and targets can be clearly (visually) separated from the background. In cases of aerial photogrammetry full automation is only possible if the photographed area is of a relatively homogeneous appearance and targets are well marked.

A semi-automated approach is the second choice. Here the operator finds the point by inspection on the screen and selects the point using the computer's pointing device. A window is then allocated around the target and an automated process extracts the target center. Both approaches result in image co-ordinates of the control points in pixel co-ordinates with sub-pixel accuracy.

In case of the Laetoli images automatic extraction was possible as the targets were designed to clearly stand out against the tuff surface of the trackway.

If scanned conventional photographs are used (in the case discussed here the UMK images) then the photographs must undergo an affine transformation via the fiducial marks to allow for misalignment of the photograph in the scanner.

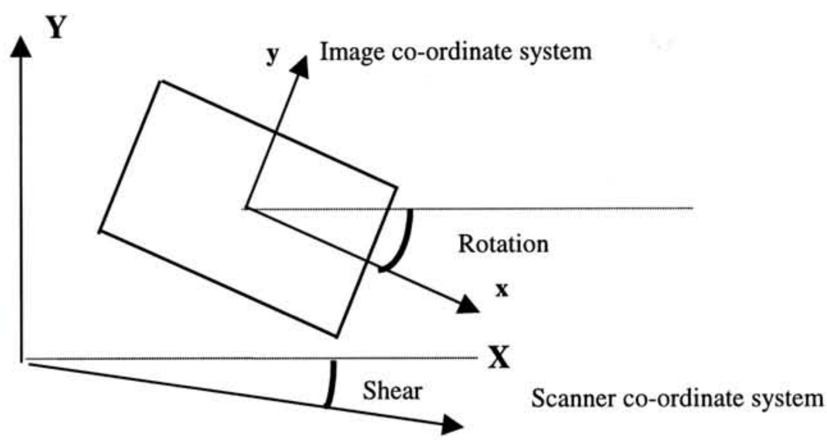


Figure 4 Affine transformation from scanner to image co-ordinate system (x-shift, y-shift, x-scale, y-scale, rotation and shear)

Pixel size (in x and y) is defined by settings in the scanner, the x and y values should be compatible with the scales derived from the affine transformation. The UMK images were scaled at pixel sizes of either 7.5 or 15 micron.

Generally fiducial marks are not available if a digital camera is used (typical for close-range application or low-level small-format photography for rapid low accuracy mapping). Then the image corners have to serve to define the co-ordinate reference system. Affine transformation parameters are typically known a priori. The shear deformation of the chip as well as the pixel size is generally accepted as being constant and can be determined in an *a priori* calibration process. There is no rotation as the pixel array on the chip is used as reference system and thus the axes' directions automatically coincide with the pixel lines. However it is necessary to allow for the difference between the image co-ordinate system and the chip/pixel co-ordinate system. The former has its origin in the image center with axes increasing to the left and the top, the latter has its origin in the top left corner of the image and increases to the right and the bottom.

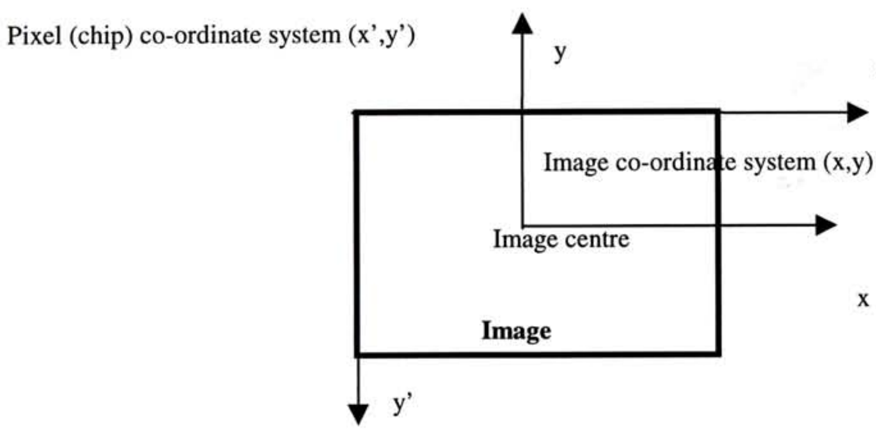


Figure 5 Image co-ordinate systems

Image orientation

The elements of the interior orientation of the camera (principal distance, principal point position in x and y, as well as lens distortion parameters and other systematic error parameters) can be determined either in a separate camera calibration or established together with the exterior orientation elements in one mathematical process provided sufficient control points in a suitable geometric configuration are visible on the image(s). For the UMK photography separate interior orientation was carried out. The interior orientation elements for the individual foot print images taken with the DCS camera were determined together with the exterior orientation element using the 80 control points of the calibration/ control frame visible in each image.

The orientation of the images (cameras) in space (three rotations and the XYZ position of the perspective center of the lens system) are determined in a bundle adjustment or a space resection algorithm (with or without calibration parameters).

This procedure requires the following input values:

- the elements of the interior orientation (unless they are to be determined as part of the solution, in which case good provisional values must be provided)

- image co-ordinates of the control points in units of pixels or millimeters. If the data are in pixel units, then the pixel dimensions and the affine shear of the pixel array must be provided (assuming that the software can correct for affine distortion)

- object space (XYZ) co-ordinates of the control points

provisional values for the exterior orientation parameters (the DLT -Direct Linear Transformation-algorithm was employed to determine these provisional values provided the control points are not in a plane).

The results of this step are:

- the adjusted orientation parameters (ϕ, ω, κ, $X_{0,}$ $Y_{0,}$ Z_0) and interior orientation elements if included into the model as unknowns.

- standard deviations (variance co-variance matrix) of the adjusted parameters

Interest point extraction

In order to obtain surface points, an interest points operator is convolved with one of the images, this is an algorithm which automatically finds image points which differ radiometrically (i.e. in appearance) from their immediate neighborhood. Such points are typically edges, lines, corners, points etc, they are in this context referred to as 'interest points', they are representative of the surface to be surveyed and form the basis for the next step.

Automated Surface Reconstruction (by image matching)

Point position determination by photogrammetric methods is based on the identification and measurement of image points of the same object points on two or more images and subsequent intersection of the rays formed by the these 'conjugate' image points and their respective perspective centers (a point in the camera's lens system). The photogrammetric model used for the intersection of conjugate rays in object space is that of the collinearity condition.

A very effective method for the automatic detection of conjugate or matching points is the Multi-Photo-Geometrically-Constrained-Matching (MPGC) technique. This method forms a window around the interest point on the reference image and searches the other (or search-) images for an area of minimum difference (in appearance) allowing for possible differences in the rotation, scaling and shape of the search patch due to differences in perspective. A global difference in the radiometry of the various images is also allowed for. The need for this correction arises for example if light conditions between images change. The search space on the search images is geometrically constrained by restricting the search to a narrow band around the so-called epipolar line. The epipolar line is a theoretical line (or more in practical terms, a narrow band) on which a conjugate point can be expected. The fact that the locus for the conjugate point is a line and not a point derives from the fact that the object point height is not known. Minimizing the difference between the reference and search patch is achieved by means of a least squares adjustment which minimizes the sum of the squares of the gray value differences between the search and reference patches in an iterative process. The position with the minimum (in a least squares sense) difference in gray values is then accepted as the conjugate point provided a number of quality criteria are met.

Implementation of the epipolar line constraint requires knowledge of the orientation of the images in object space and the orientation parameters determined in the calibration stage above are used as a basis for the geometric constraint.

In a final stage xyz co-ordinates of the conjugate points are evaluated by 3D-intersection using again the orientation parameters. The matching and intersection operation can be combined into a single operation. The result of the intersection is a cloud of points (XYZ co-ordinates) describing the surface.

Linked bundle adjustment /MPGC software was employed for the trackway photogrammetry. The software was developed at the Department of Surveying and Geodetic Engineering at the University of Cape Town.

The table below lists the number of points found on each imprint, the type of computer used and the processing time. Processing time depends on the type of system used, the load on the system and the RAM available. Times given here can therefore merely be a rough guide. The number of matched points was largely a function of the size selected area, which had to be chosen larger for a bigger footprint or for one not clearly defined. The ratio of successful matches in relation to the points of interest entered into each matching routine was between 95-99%, an indication of excellent matching results.

Foot print	Number of Points	Processing Time
G1-2	9997	120min
G1-3	10229	120min
G1-6	11469	180min
G1-7	9423	160min
G1-8	11096	180min
G1-9	13361	190min
G1-10	12267	180min
G1-11	12960	200min
G1-12	10888	105min
G1-13	10505	180min
G1-14	11873	210min
G1-19	10595	165min
G1-21	9893	128min
G1-22	11852	140min
G1-23	10222	129min
G1-24	11072	150min
G23-2	12032	150min
G23-3	11236	180min
G23-5	9423	160min
G23-6	9767	160min
G23-7	9616	140min
G23-8	12633	300min
G23-9	11906	250min
G23-10	14447	225min
G23-17	10856	150min

Table 14 Matching results and processing time for Pentium Processor

The computer used for the matching routines was a Pentium, 166 MHz, 96 RAM

Generation of a grid-DTM

The next stage of the surface reconstruction is the generation of a regular grid from the random point cloud. This is done by interpolation of point heights for the grid points at the pre-selected grid interval. The height of each of the grid points is interpolated from the points of the point cloud in its immediate neighborhood. Typically the user of DTM software is given a choice of different interpolation techniques, such as nearest neighbor, bilinear interpolation or cubic convolution. The DTM generation for the individual footprints from the random point cloud was executed with the 'HIFI' software made available by Photogrammetrie GmbH Munich. The DTM from the UMK photogrammetry was produced from contour lines in their digital form using ARCInfo TIN (Triangulation by Irregular Networks) software. The generation of the DTM grid from the contour lines is in principle identical to the DTM generation from the point cloud. The difference between the two methods lies in the distribution of the source points. In the contour model, the points are aligned in linear form along contour lines, in the point cloud points are distributed in a random pattern.

Rectification of the perspective image

Due to the properties of the perspective projection, point positions on a photographic image differ from those on a map, which is an orthogonal. The quantity and the direction of the displacement depends on the elevation of the terrain (or in close range photogrammetry, the elevation of the object points above the chosen reference surface), the elements of interior orientation of the camera, the position and orientation of the camera, any systematic image distortions (e.g. lens distortion). If all these quantities are known, then each point, or pixel, can be moved into its orthogonal projection position.

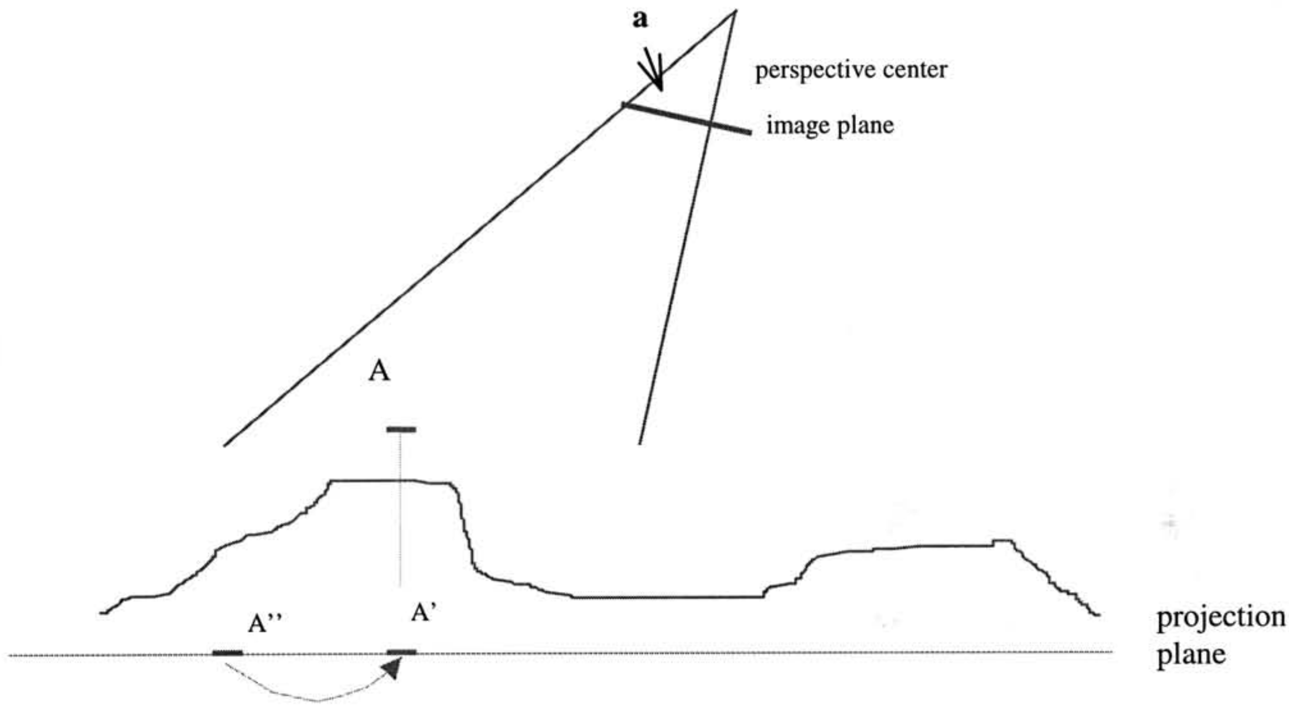


Figure 6 Rectification of an image

A	Object point
A′	desired position of A on the mapping plane (orthogonal projection)
A″	apparent position of A due to height displacement
a	image point corresponding to A

Given the

- orientation parameters and APs (additional parameters) for the camera,
- the original image and the
- DTM

each point (pixel) of the image can be moved into its correct position in the orthogonal projection of a mapping surface (i.e. the ortho-image).

Digital rectification (resampling)

There are two methods to move pixels into the correct position on the ortho image:

- the direct method
- the indirect method

In the **direct** method each pixel on the original image is moved to its position on the ortho image. In this approach the ortho image pixels are distributed in an irregular formation on the ortho image and have to be resample to produce a regular grid.

In the **indirect** method, the position of each of the regular grid pixels on the ortho image is calculated on the original image and the original gray value corresponding to this point is adopted for the ortho image.

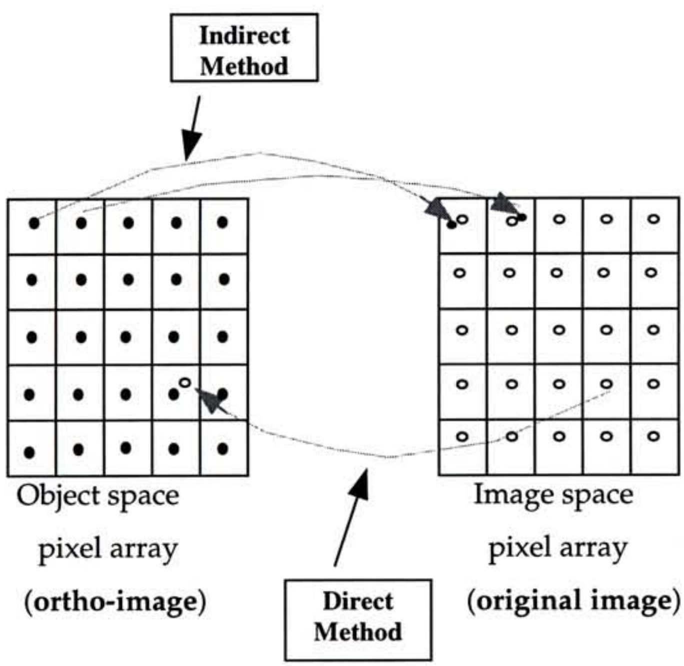


Figure 7 Resampling techniques for ortho-image generation

In both techniques the calculated position of a pixel will generally not coincide with a pixel center of the array into which the pixel is transformed. It is therefore necessary to interpolate or 'resample' the gray value of the transformed location.

In the direct method a regular grid is introduced into the array of irregular transformed points. The original gray values of the points surrounding each grid point are then used to interpolate gray values for the grid points.

In the indirect method each of the regular grid points of the ortho-image is transformed into the original image pixel array. The gray values in the neighborhood of each grid-point are then used to interpolate a gray value for the grid points.

As in the case of the DTM generation, the simple method of interpolation for the resampling process is the nearest neighbor method, which adopts the gray value of the pixel nearest to the calculated position. More advanced approaches makes use of more than one neighboring gray value. Among these are bilinear interpolation and cubic splines or cubic convolution.

For the trackway photogrammetry a combination of ortho-image software written in the department and commercial software written at the University of Zürich was used. Indirect resampling with bilinear interpolation was used for the ortho-images of the trackway.

DTM densification

For the process of resampling it is not only necessary to interpolate the gray values, but also heights must be interpolated once more to produce a densified DTM matching the grid interval of the ortho image array. This interpolation is typically done individually for each pixel position as part of the rectification procedure and not, as would be theoretically possible, in one operation for the entire image.

Line features and annotation

In order to turn the ortho-image into a readable map, separate coverages need be created showing contours, gridlines and grid intersection, original roads, waterways, boundaries and other natural or man-made features typically shown on a map. In addition to these coverages for names, text, etc. are created. GIS or CAD software can be used for this process. For the trackway ARC Info and AutoCAD were used to produce the required coverages. The coverages can be displayed in any required combination. Linking the ortho-image to a GIS will provide a powerful management and visualization environment.

CONCLUDING REMARKS

The digital photogrammetric recording of Laetoli was one of the first projects of its nature with respect to the accuracy and completeness of the recording process. The achieved accuracy of better than half a millimeter, together with a point density of typically more than 10 000 points for the point clouds representing each imprint, offers a new approach to archaeological documentation and visualization. Similar results can be achieved with laser scanning devices and these should be considered for similar projects in the future, however, such devices are, at least at present, not suited for use under difficult field conditions and photogrammetry, especially digital photogrammetry, is still the principal and ideal tool for the accurate recording of archaeological and heritage sites.

The UCT team wishes to express its appreciation for the invaluable assistance received from GCI personnel, especially from Martha Demas, Neville Agnew and Gaetano Palumbo.

Appendix VII-A

1. Ortho-Image Information for Individual Footprints and Trackway

1.1 Individual Footprints

This information is for the ortho-images with the scale 1:1.
For the ortho-images with the scale 2:1, the number of pixels in width and height will be doubled, and the other information will remain unchanged.

G1-2:

DEM INFO:
The centre of dem is: 99645.00 120367.00
The bottom left corner of dem is: 99565.00 120217.00
The top right corner of dem is: 99725.00 120517.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99565.00 120217.00
The object width and height of ortho-image are: 160.00 300.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 160 300

CAMERA INFO:
Camera pos XcYcZc: 99598.86 120536.44 1231.77
Pixel size x, y: 0.009090 0.009090
Rotation o, k, p: 0.099551 -0.092028 -1.368964
xp yp pd: -0.0064 -0.0269 14.6400

G1-3:

DEM INFO:
The centre of dem is: 99550.00 120020.00
The bottom left corner of dem is: 99410.00 119890.00
The top right corner of dem is: 99690.00 120150.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99410.00 119890.00
The object width and height of ortho-image are: 280.00 260.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 280 260

CAMERA INFO:
Camera pos XcYcZc: 99555.94 120049.77 1204.69
Pixel size x, y: 0.009090 0.009090
Rotation o, k, p: -0.037776 0.057821 -2.228290
xp yp pd: -0.022700 -0.022800 14.6337

G1-6:

DEM INFO:
The centre of dem is: 99700.00 119298.00
The bottom left corner of dem is: 99600.00 119208.00
The top right corner of dem is: 99800.00 119388.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99600.00 119208.00
The object width and height of ortho-image are: 200.00 180.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 200 180

CAMERA INFO:
Camera pos XcYcZc: 99621.07 119296.01 1173.21
Pixel size x, y: 0.009090 0.009090
Rotation o, k, p: 0.093248 -0.044249 -2.405800
xp yp pd: -0.023800 -0.039200 14.633

G1-8:

DEM INFO:
The centre of dem is: 99850.00 119074.00
The bottom left corner of dem is: 99760.00 118954.00
The top right corner of dem is: 99940.00 119194.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99760.00 118954.00
The object width and height of ortho-image are: 180.00 240.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 180 240

CAMERA INFO:
Camera pos XcYcZc: 99776.21 119087.41 1177.04
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.070273 -0.019732 -1.984858
xp yp pd: -0.008600 -0.034800 14.643100

G1-9:

DEM INFO:
The centre of dem is: 99680.00 118970.00
The bottom left corner of dem is: 99550.00 118840.00
The top right corner of dem is: 99810.00 119100.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99550.00 118840.00
The object width and height of ortho-image are: 260.00 260.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 260 260

CAMERA INFO:
Camera pos XcYcZc: 99575.99 118914.78 1262.44
Pixel size x,y: 0.009090 0.009090
Rotation o, k,p: 0.183209 -0.021078 -2.284400
xp yp pd: 0.009400 -0.028 14.636

G1-10:

DEM INFO:
The centre of dem is: 99845.00 118675.00
The bottom left corner of dem is: 99735.00 118545.00
The top right corner of dem is: 99955.00 118805.00

The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99735.00 118545.00
The object width and height of ortho-image are: 220.00 260.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 220 260

CAMERA INFO:
Camera pos XcYcZc: 99907.30 118823.25 1143.20
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: -0.045495 -0.041342 -1.252469
xp yp pd: -0.032200 -0.0171 14.641

G1-11:

DEM INFO:
The centre of dem is: 99780.00 118315.00
The bottom left corner of dem is: 99670.00 118185.00
The top right corner of dem is: 99890.00 118445.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99670.00 118185.00
The object width and height of ortho-image are: 220.00 260.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 220 260

CAMERA INFO:
Camera pos XcYcZc: 99640.54 118298.72 1319.33
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.130544 -0.012952 -2.015742
xp yp pd: -0.0275 -0.0437 14.643600

G1-12:

DEM INFO:
The centre of dem is: 99875.00 117894.00
The bottom left corner of dem is: 99775.00 117764.00
The top right corner of dem is: 99975.00 118024.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99775.00 117764.00
The object width and height of ortho-image are: 200.00 260.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 200 260

CAMERA INFO:
Camera pos XcYcZc: 99847.45 117957.42 1316.34
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.058824 0.013650 -1.178606
xp yp pd: -0.024800 -0.033900 14.631800

G1-13:

DEM INFO:
The centre of dem is: 99798.00 117503.00

The bottom left corner of dem is: 99708.00 117363.00
The top right corner of dem is: 99888.00 117643.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99708.00 117363.00
The object width and height of ortho-image are: 180.00 280.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 180 280

CAMERA INFO:
Camera pos XcYcZc: 99744.68 117449.95 1223.53
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.057914 0.004635 -2.109499
xp yp pd: -0.010500 -0.026600 14.642500

<u>G1-14:</u>

DEM INFO:
The centre of dem is: 99914.00 117218.00
The bottom left corner of dem is: 99724.00 116998.00
The top right corner of dem is: 100104.00 117438.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99724.00 116998.00
The object width and height of ortho-image are: 380.00 440.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 380 440

CAMERA INFO:
Camera pos XcYcZc: 99869.55 117280.75 1247.15
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.112677 -0.014036 -1.042909
xp yp pd: -0.012100 -0.016600 14.634600

<u>G1-19:</u>

DEM INFO:
The centre of dem is: 99995.00 115451.00
The bottom left corner of dem is: 99905.00 115301.00
The top right corner of dem is: 100085.00 115601.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99905.00 115301.00
The object width and height of ortho-image are: 180.00 300.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 180 300

CAMERA INFO:
Camera pos XcYcZc: 99782.88 115513.65 1363.20
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.147212 -0.143517 -1.879572
xp yp pd: 0.001300 -0.034200 14.636700

<u>G1-21:</u>

DEM INFO:
The centre of dem is: 100170.00 114870.00
The bottom left corner of dem is: 100100.00 114730.00
The top right corner of dem is: 100240.00 115010.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 100100.00 114730.00
The object width and height of ortho-image are: 140.00 280.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 140 280

CAMERA INFO:
Camera pos XcYcZc: 100151.13 114718.14 1205.75
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.096296 0.029771 -2.081585
xp yp pd: 0.031500 -0.094700 14.606500

G1-22:

DEM INFO:
The centre of dem is: 100261.00 114472.00
The bottom left corner of dem is: 100161.00 114362.00
The top right corner of dem is: 100361.00 114582.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 100161.00 114362.00
The object width and height of ortho-image are: 200.00 220.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 200 220

CAMERA INFO:
Camera pos XcYcZc: 100185.39 114576.27 1230.28
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.163561 0.033008 -1.061246

G1-23:

DEM INFO:
The centre of dem is: 100115.00 114115.00
The bottom left corner of dem is: 100035.00 113975.00
The top right corner of dem is: 100195.00 114255.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 100035.00 113975.00
The object width and height of ortho-image are: 160.00 280.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 160 280

CAMERA INFO:
Camera pos XcYcZc: 100055.01 114260.36 1323.05
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: -0.028702 -0.191403 -1.819767
xp yp pd: -0.026800 -0.062700 14.613600

G1-24:

DEM INFO:
The centre of dem is: 100370.00 106050.00
The bottom left corner of dem is: 100300.00 105930.00
The top right corner of dem is: 100440.00 106170.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 100300.00 105930.00
The object width and height of ortho-image are: 140.00 240.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 140 240

CAMERA INFO:
Camera pos XcYcZc: 100258.50 106112.73 1704.13
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.174854 0.045528 -1.407834
xp yp pd: 0.002 -0.024800 14.613600

G23-2:

DEM INFO:
The centre of dem is: 99935.00 120350.00
The bottom left corner of dem is: 99815.00 120150.00
The top right corner of dem is: 100055.00 120550.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99815.00 120150.00
The object width and height of ortho-image are: 240.00 400.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 240 400

CAMERA INFO:
Camera pos XcYcZc: 99835.72 120375.81 1216.94
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.163589 -0.005252 -1.551403
xp yp pd: 0.012200 -0.043400 14.635800

G23-3:

DEM INFO:
The centre of dem is: 99800.00 120075.00
The bottom left corner of dem is: 99690.00 119885.00
The top right corner of dem is: 99910.00 120265.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99690.00 119885.00
The object width and height of ortho-image are: 220.00 380.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 220 380

CAMERA INFO:
Camera pos XcYcZc: 99680.56 120136.26 1242.81
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.134210 -0.069115 -1.589744
xp yp pd: -0.035900 -0.041800 14.634500

G23-5 + G1-7:

DEM INFO:
The centre of dem is: 99900.00 119175.00
The bottom left corner of dem is: 99800.00 119005.00
The top right corner of dem is: 10.00 119345.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99800.00 119005.00
The object width and height of ortho-image are: 200.00 340.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 200 340

CAMERA INFO:
Camera pos XcYcZc: 99815.55 119196.25 1318.44
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.141408 -0.058321 -1.981310
xp yp pd: -0.004300 -0.046900 14.642500

G23-6:

DEM INFO:
The centre of dem is: 100090.00 118875.00
The bottom left corner of dem is: 99980.00 118645.00
The top right corner of dem is: 100200.00 119105.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99980.00 118645.00
The object width and height of ortho-image are: 220.00 460.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 220 460

CAMERA INFO:
Camera pos XcYcZc: 100032.70 118884.44 1306.89
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.099040 -0.028159 -1.675045
xp yp pd: -0.023400 -0.021700 14.638200

G23-7:

DEM INFO:
The centre of dem is: 100035.00 118405.00
The bottom left corner of dem is: 99935.00 118195.00
The top right corner of dem is: 100135.00 118615.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99935.00 118195.00
The object width and height of ortho-image are: 200.00 420.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 200 420

CAMERA INFO:
Camera pos XcYcZc: 99893.29 118425.68 1325.46
Pixel size x,y: 0.009090 0.009090

Rotation o,k,p: 0.159501 -0.032305 -1.743168
xp yp pd: -0.016100 -0.051200 14.637700

G23-8:

DEM INFO:
The centre of dem is: 100194.00 117985.00
The bottom left corner of dem is: 100114.00 117775.00
The top right corner of dem is: 100274.00 118195.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 100114.00 117775.00
The object width and height of ortho-image are: 160.00 420.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 160 420

CAMERA INFO:
Camera pos XcYcZc: 100082.69 117978.25 1223.48
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.107232 -0.009203 -1.768415
xp yp pd: -0.030900 -0.049600 14.642700

G23-9:

DEM INFO:
The centre of dem is: 100080.00 117500.00
The bottom left corner of dem is: 99970.00 117250.00
The top right corner of dem is: 100190.00 117750.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 99970.00 117250.00
The object width and height of ortho-image are: 220.00 500.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 220 500

CAMERA INFO:
Camera pos XcYcZc: 99878.63 117572.18 1261.16
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.206073 -0.060121 -1.674147
xp yp pd: -0.013800 -0.033200 14.642900

G23-10:

DEM INFO:
The centre of dem is: 100265.00 117105.00
The bottom left corner of dem is: 100175.00 116905.00
The top right corner of dem is: 100355.00 117305.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 100175.00 116905.00
The object width and height of ortho-image are: 180.00 400.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 180 400

CAMERA INFO:

Camera pos XcYcZc: 100166.82 117143.82 1221.13
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.123286 -0.079719 -1.684909
xp yp pd: -0.000200 -0.040800 14.642300

<u>**G23-17:**</u>

DEM INFO:
The centre of dem is: 100570.00 106190.00
The bottom left corner of dem is: 100480.00 106010.00
The top right corner of dem is: 100660.00 106370.00
The DEM grid interval is: 2.5

ORTHO-IMAGE INFO:
The bottom left corner of ortho-image is: 100480.00 106010.00
The object width and height of ortho-image are: 180.00 360.00
The ortho-image scale is 1
The width and height of ortho-image in pixels: 180 360

CAMERA INFO:
Camera pos XcYcZc: 100432.26 106200.93 1683.86
Pixel size x,y: 0.009090 0.009090
Rotation o,k,p: 0.098584 -0.059300 -1.860888
xp yp pd: 0.004200 -0.052200 14.613400

1.2 Trackway

DIGITAL ORTHOPHOTO GENERATION Version 1.2

NORTH TRACK

<u>**A2**</u>

Original digital image name = a2.tif
Orthophoto file name (character data) = a2-ortho.kon

X, Y Object co-ordinates:
Upper left corner: 101578.578 95297.398
Lower right corner: 102908.578 94317.398

x,y number of grid cells and grid spacing : 1331 981 1.0000 -1.0000

Min, max x, y grid cells of saved orthophoto with respect to the input DTM grid 1 1331 1 981

Interpolation method: Bilinear

<u>**A4**</u>

Original digital image name = a4.tif
Orthophoto file name (character data) = a4-ortho.kon

X,Y Object coordinates:
upper left corner: 101410.109 96213.875
lower right corner: 103010.109 95023.875

x,y number of grid cells and grid spacing : 1601 1191 1.0000 -1.0000

Min,max x, y grid cells of saved orthophoto with respect to the input DTM grid 1 1601 1 1191

Interpolation method : Bilinear

A6

Original digital image name = a6.tif
Orthophoto file name (character data) = a6-ortho.kon

X,Y Object coordinates:
upper left corner: 101586.203 96983.000
lower right corner: 102926.203 95883.000

x,y number of grid cells and grid spacing : 1341 1101 1.0000 -1.0000

Min,max x, y grid cells of saved orthophoto with respect to the input DTM grid 1 1341 1 1101

Interpolation method : Bilinear

A8

Original digital image name = a8.tif
Orthophoto file name (character data) = a8-ortho.kon

X,Y Object coordinates:
upper left corner: 101671.375 97879.968
lower right corner: 103011.375 96769.968

x,y number of grid cells and grid spacing : 1341 1111 1.0000 -1.0000

Min,max x, y grid cells of saved orthophoto with respect to the input DTM grid 1 1341 1 1111

Interpolation method : Bilinear

A10

Original digital image name = a10.tif
Orthophoto file name (character data) = a10-ortho.kon

X,Y Object coordinates
upper left corner: 101723.281 98846.976
lower right corner: 103053.281 97696.976

x,y number of grid cells and grid spacing : 1331 1151 1.0000 -1.0000

Min,max x, y grid cells of saved orthophoto with respect to the input DTM grid 1 1331 1 1151

Interpolation method : Bilinear

A12

Original digital image name = a12.tif
Orthophoto file name (character data) = a12-ortho.kon

X,Y Object coordinates
upper left corner: 101856.515625 99697.765625
lower right corner: 103156.515625 98557.765625

x,y number of grid cells and grid spacing : 1301 1141 1.0000 -1.0000

Min,max x, y grid cells of saved orthophoto with respect to the input DTM grid 1 1301 1 1141

Interpolation method : Bilinear

A14

Original digital image name = a14.tif
Orthophoto file name (character data) = a14-ortho.kon

X,Y Object coordinates:
upper left corner: 101830.828 100682.781
lower right corner: 103190.828 99452.781

x,y number of grid cells and grid spacing : 1361 1231 1.0000 -1.0000

Min,max x, y grid cells of saved orthophoto with respect to the input DTM grid 1 1361 1 1231

Interpolation method : Bilinear

A16

Original digital image name = a16.tif
Orthophoto file name (character data) = a16-ortho.kon

X,Y Object coordinates
upper left corner: 101988.585 101466.757
lower right corner: 103298.585 100386.757

x,y number of grid cells and grid spacing : 1311 1081 1.0000 -1.0000

Min,max x, y grid cells of saved orthophoto with respect to the input DTM grid 1 1311 1 1081

Interpolation method: Bilinear

Appendix VII-B

DIARY OF SITE WORK - LAETOLI 1996

Sunday, 18th August:

- Transfer of staff without equipment from Arusha to the camp at Endulen

Monday, 19th August:

- Site reconnaissance.
- Test images with DCS 420 camera.

Tuesday, 20th August:

- Day spent in the camp, preparing of spreadsheets, backing up DCS images from Monday.

Wednesday, 21st August:

- Day spent in the camp

Thursday, 22nd August:

- Placing of the new survey points E3, E4, E5, N1.
- Positioning of a temporary height datum point in the form of a survey tape mounted on a vertical staff close to the site.

Friday, 23rd August:

- Day spent in the camp

Monday, 26th August:

- Transfer of equipment from Arusha to the camp at Endulen

Tuesday, 27th August:

- Change of work plan through loss of the T1010, which got broken on the transport
- Triangulation / Trilateration survey of the control points E2, N1, W2, E5, E4, E3. Data booked on the Psion Data Logger
- Downloading of the data using in-house program 'workabout'.
- Begin of the processing of the triangulation survey, data inspection and reduction of observations.

Wednesday, 28th August:

- Calibration of the total station T 1000 for use in the control point survey.
- Placement of the first 45 control points in the northern part of the trackway.
- Tacheometry survey of the site with 396 points.
- Processing of the triangulation survey, processing of the tacheometric survey data.

Thursday, 29th August:

- Triangulation and trigonometrical height survey of the target points from 4 control stations.
- Processing of the data.
- Loading glass plates for UMK camera

Friday, 30th August:

- Calibration of the DCS camera using the foot-frame
- Begin of the photogrammetric survey of the trackway.
- UMK 10, DCS 420, Hasselblad images on trackway 12 and 11.

  Notation used:
  AR for right image on the western track section
  AC for center image
  AL for left image

  BR for right image on the east track section
  BC fir center image
  BL for left image

Names starting with T are control points visible on the images. TW stands for the West row of control points and they are numbered from 1- 15 increasing in the northerly direction. G stands for the graben area and S for the southern section of the trackway

Track Line 12:

UMK	AL12/A12/AR12 BL12/B12/BR12			
DCS	AL12/A12/AR12 BL12/B12/BR12			
Hasselblad	AL12	AR12	BL12	BR12
Control	TW13, TW12, TW11, TC13, TC12, TC11, TE13, TE12, TE11			

Track Line 11:

UMK	AL11/A11/AR11 BL11/B11/BR11			
DCS	AL11/A11/AR11 BL11/B11/BR11			
Hasselblad	AL11	AR11	BL11	BR11
Control	TW13, TW12, TW11, TC13, TC12, TC11, TE13, TE12, TE11			

- Downloading and Acquisition of the DCS images.
- Quality of the images is excellent.
- Processing of the triangulation survey
- Processing of the control point survey

Saturday, 31st August:

- Continuation of the photogrammetric survey of the trackway.
  Trackways: 6, 7, 8, 9, 10

Track Line 6:

UMK	AL6/A6/AR6 BL6/B6/BR6
DCS	AL6/A6/AR6 BL6/B6/BR6
Hasselblad	AL6 AR6 BL6 BR6
Control	TW5, TW6, TW7, TC5, TC6, TC7, TE5, TE6, TE7

Track Line 7:

UMK	AL7/A7/AR7 BL7/B7/BR7
DCS	AL7/A7/AR7 BL7/B7/BR7
Hasselblad	AL7 AR7 BL7 BR7
Control	TW6, TW7, TW8, TC6, TC7, TC8, TE6, TE7, TE8

Track Line 8:

UMK	AL8/A8/AR8 BL8/B8/BR8
DCS	AL8/A8/AR8 BL8/B8/BR8
Hasselblad	AL8 AR8 BL8 BR8
Control	TW7, TW8, TW9, TC7, TC8, TC9, TE7, TE8, TE9

Track Line 9:

UMK	AL9/A9/AR9 BL9/B9/BR9
DCS	AL9/A9/AR9 BL9/B9/BR9
Hasselblad	AL9 AR9 BL9 BR9
Control	TW8, TW9, TW10, TC8, TC9, TC10, TE8, TE9, TE10

Track Line 10:

UMK	AL10/A10/AR10 BL10/B10/BR10
DCS	AL10/A10/AR10 BL10/B10/BR10
Hasselblad	AL10 AR10 BL10 BR10
Control	TW9, TW10, TW11, TC9, TC10, TC11, TE9, TE10, TE11

- Placement of the 14 control targets in the southern section of the trackway
- Downloading and Acquisition of the DCS images
- processing of the network data
- processing of the control point data

Sunday, 1st September:

- Continuation of the photogrammetric survey of the trackway.

Trackways: 2,3,4,5

Track Line 2:

UMK	AL2/A2/AR2 BL2/B2/BR2
DCS	AL2/A2/AR2 BL2/B2/BR2
Hasselblad	AL2 AR2 BL2 BR2
Control	TW3, TW2, TW1, TC3, TC2, TC1, TE3, TE2, TE1

Track Line 3:

UMK	AL3/A3/AR3 BL3/B3/BR3
DCS	AL3/A3/AR3 BL3/B3/BR3
Hasselblad	AL3 AR3 BL3 BR3
Control	TW4, TW3, TW2, TC4, TC3, TC2, TE4, TE3, TE2

Track Line 4:

UMK	AL4/A4/AR4 BL4/B4/BR4
DCS	AL4/A4/AR4 BL4/B4/BR4
Hasselblad	AL4 AR4 BL4 BR4
Control	TW5, TW4, TW3, TC5, TC4, TC3, TE5, TE4, TE3

Track Line 5:

UMK	AL5/A5/AR5 BL5/B5/BR5
DCS	AL5/A5/AR5 BL5/B5/BR5
Hasselblad	AL5 AR5 BL5 BR5
Control	TW6, TW5, TW4, TC6, TC5, TC4, TE6, TE5, TE4

- Consolidation, backing up, sorting, cleaning and pre-processing of all data acquired up to this stage
- Downloading and backing up of DCS images captured on Friday and Saturday.
- Processing of the 24 glass plates

Monday, 2nd September:

- Calibration of the DCS 420 for individual footprints
- Begin of the photography of the individual footprints (DCS and Hasselblad):
  G1 - 2/3/6/8/10
- Survey of the control points in the southern section
- downloading of the images captured during the day
- downloading of survey data
- processing of control point survey

Tuesday, 3rd September:

- Continuation of the photography of the individual footprints
  G1 - 7/9/11/12/13/14/19
  G2/3 - 2/3/5/6/7/8/9/10
- Processing of glass plates
- processing of control point survey

Wednesday, 4th September:

- Continuation of the photography of the individual footprints
  G1 - 24
  G2/3 - 17

- Continuation of the photogrammetric survey of the trackway.

Trackways: 1,G2,G3,G4,S1

Track Line 1:	
UMK	AL1/A1/AR1 BL1/B1/BR1
DCS	AL1/A1/AR1 BL1/B1/BR1
Hasselblad	AL1 AR1 BL1 BR1
Control	TW2 TW1, GW4, TC2, TC1, GE4, TE2, TE1,
Track Line G2:	
UMK	ALG2/AG2/ARG2 BLG2/BG2/BRG2
DCS	ALG2/AG2/ARG2 BLG2/BG2/BRG2
Hasselblad	ALG2 ARG2 BLG2 BRG2
Control	GW4, GW3, GW2, GE4, GE3, GE2
Track Line G3:	
UMK	ALG3/AG3/ARG3 BLG3/BG3/BRG3
DCS	ALG3/AG3/ARG3 BLG3/BG3/BRG3
Hasselblad	ALG3 ARG3 BLG3 BRG3
Control	GW1, GW2, GW3, GE1, GE2, GE3
Track Line G4:	
UMK	ALG4/AG4/ARG4 BLG4/BG4/BRG4
DCS	ALG4/AG4/ARG4 BLG4/BG4/BRG4
Hasselblad	ALG4 ARG4 BLG4 BRG4
Control	GW1, GW2, GW3, GE1, GE2, GE3
Track Line S1:	
UMK	ALS1/AS1/ARS1 BLS1/BS1/BRS1
DCS	ALS1/AS1/ARS1 BLS1/BS1/BRS1
Hasselblad	ALS1 ARS1 BLS1 BRS1
Control	SW1, SW2, SW3, SE1, SE2, SE3

Thursday, 5th September:

- Continuation of the photography of the individual footprints
  G1 - 21/22/23
- Rest of glass plates processed
- Tacheometric Survey for the roots and edges of the site
- Survey of the control points in the graben
- downloading of the images and the survey data

Friday, 7th September:

- Calculation of the control points
- processing of 4 individual footprint data
- packing of the equipment

Saturday, 8th September:

- leaving the site at 7 o'clock am

PART VIII. OVERVIEW AND INVENTORY OF MOLDS AND CASTS

by Martha Demas

INTRODUCTION

The importance of the existing 1978-79 molds and casts of sections of the hominid trackway was recognized at the outset of the project and therefore made an essential part of the conservation program established for Laetoli. The 1996 field season marked the end of a three-year program to replicate the molds and casts and to train Tanzanian personnel from the National Museum in the care and production of molds and casts. What follows is a review of these efforts and a status report on the molds and casts of Laetoli.

REPLICATION

At the beginning of the project, all the molds and casts made in 1978 and 1979 were located in the storage room at the Olduvai camp. The aim of the replication effort was to make molds and archival casts of all the hominid print casts to ensure that these important documents would be available in the future. All of the molds and casts were evaluated for their ability to yield additional replicas; every effort was made to use the original mold, but where these were no longer viable, molds were taken from existing casts. All of the molds were made of silicone rubber; all the casts of polyester resin-glass fiber, with the exception of the section "A" master cast (see below).

The long section "A" cast that covers most of the prints in the well preserved southern sector of the trackway is the largest and in many respects the most important of the 1978-79 casts (see Part IX, Appendix A). In 1994, a new mold was made from the original cast (the original mold was never located) and from this, an archival epoxy resin cast was made. The section "A" cast was made in epoxy, which is a more expensive, but very durable material, for two reasons:

1. it documents the best preserved section of the hominid trackway;
2. it would be the most desirable cast to replicate in the future for educational and exhibition purposes. Given the limited life of any mold and the fragility of the

original cast, it was felt essential to provide a long-lasting cast from which future molds could be taken without risk to the original cast.

Although it was recognized that the 1994 silicone mold would have a limited life, the brevity of its existence in good condition could not have been anticipated. The mold was transported without incident from Olduvai, where it was made, to Dar es Salaam in 1994, but due to improper handling in the museum, the mold was torn in 12 places. These tears were repaired by Ron Street in 1995 in order to make the field and museum casts, but the mold is now effectively no longer useable for purposes of making study casts or for high quality museum casts.

TRAINING

Training of staff from the National Museum took place during the three field seasons (1994-1996). Moses Lilombero participated in 1994-95 seasons; Jesuit Temba participated in all three seasons. Field training, conducted by Ron Street of the Metropolitan Museum of Art in New York, involved preparation, replication of molds and casts, patination of casts, development of prototypes for further replication, and handling and transportation.

In order to further build the capacity of the National Museum to care for their existing molds and casts and produce additional casts for educational and exhibition purposes, the GCI sponsored a visit to the United States for Jesuit Temba in March-April 1996. The visit included a three-week stay in Los Angeles, where he worked with Jerry Podany (Head, Antiquities Conservation, J. Paul Getty Museum) on conservation and care of artifacts. This was followed by three weeks in Cleveland, where Temba was sponsored by the Cleveland Natural History Museum, courtesy of Bruce Latimer. There Temba worked in the preparation department under preparator Jenny Smith on molding and casting techniques.

The making of the section "A" mold in 1994 was videotaped and the tape provided to the National Museum as a reference for future efforts to make a new mold from the master epoxy cast.

INVENTORY AND STORAGE

Inventory and assessment of condition of the original molds and casts at Olduvai was an on-going activity beginning in 1993. The 1996 inventory, which follows this report (Appendix A), records all the molds and casts of the Laetoli hominid prints—both the original 1978-79 molds and casts and the 1994-96 molds and casts—their condition as assessed in 1996, and their location as of October 1996.

In September 1996, all the molds and casts made during the 1996 season and all remaining molding and casting raw materials were transported to Dar es Salaam; they were received in good condition on September 5, 1996. Wooden storage shelves were built in the National Museum storerooms by Jesuit Temba to hold the Section "A" molds and casts (Photo 55). The National Museum now holds all the molds and casts made from 1994-1996; all the original 1978-1979 molds and casts remain in storage at Olduvai (Photo 54).

CONCLUDING REMARKS

With the conclusion of the 1996 field season, all the original casts of the Laetoli footprints have been replicated, inventoried and stored, which meets the objectives of the Laetoli Project to ensure the existence of these critically important records. Access to the casts for study by researchers is a prerogative of the Tanzanian government. The GCI does not hold any molds or casts of the trackway. Replication of casts to sell for study purposes or museum exhibitions outside Tanzania is a longer term proposition that will require commitment by the Tanzanian government to carry through by establishing a casting unit at the National Museum capable of making high quality replicas. The training received by National Museum staff, particularly Jesuit Temba, is adequate to the task, assuming requisite assistance and materials are provided. The demand for replicas by scholars and museums is well known. It is hoped that with the foundation laid, the National Museum will find the means to fulfill this need while it exists and replicas remain pertinent to the study of human evolution.

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
Not identified	LP-15 (C)	1978 polyester cast; (28x116.5cm)	good		Olduvai
Not identified	LP-19 (C)	polyester cast; (27.5x23cm)	fair: brittle		Olduvai
G1-01	LP-07 (M)	1978 latex and burlap mold w/plaster support; (37x25cm)	poor		Olduvai
G1-01	LP-10 (C)	1978 polyester cast w/plaster support (37x25cm)	good	"LAET.G1/[1]/78" inscribed on cast plaster support	Olduvai
G1-01	Section E				
G1-01	LP-10.96 (C)	1996 polyester cast	good	made from 1996 mold	National Museum (Dar)
G1-01	LP-10.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1978 cast LP-10	National Museum (Dar)
G1-02	LP-18 (C)	1978 plaster cast; (33x23cm)	good		Olduvai
G1-02	Section E				
G1-02	LP-05.96 (C)	1996 polyester cast	good	made from 1996 mold	National Museum (Dar)
G1-02	LP-05.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1978 cast LP-05	National Museum (Dar)
G1-03	Section E				
G1-19	LP-30 (M)	1978 silicone rubber and cloth mold with plaster support	fair, tuff inclusions indicating made directly from trackway	G1/19/78 inscribed on mold plaster support	Olduvai
G1-19	LP-30 (C)	1978 polyester cast w/plaster support; also	good		Olduvai
G1-19	LP-30.96 (C)	1996 polyester cast	good	made from 1978 mold LP-30	National Museum (Dar)
G1-19	LP-30.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1996 cast	National Museum (Dar)
G1-22	LP-29 (M)	1978 silicone rubber and cloth mold w/plaster support	fair, tuff inclusions indicating made directly from trackway	G1/22/78 inscribed on mold plaster support;	Olduvai
G1-22	LP-29	1978 polyester cast w/plaster support (28x20cm)	good	"LAET. G1/22/78" inscribed on cast plaster support	Olduvai
G1-22	LP-29.96 (C)	1996 polyester cast	good	made from 1978 mold LP-29	National Museum (Dar)
G1-22	LP-29.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1996 cast	National Museum (Dar)
G1-24	LP-16 (C)	1978 polyester cast; (27x17cm)	poor: brittle, fractured, and delaminated		Olduvai

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
G1-24	LP-25 (M)	1978 silicone rubber and cloth mold w/plaster support	fair, tuff inclusions indicating made directly form trackway	"G1/24/78" inscribed on mold plaster support	Olduvai
G1-24	LP-25 (C)	polyester cast w/ plaster support (27x19cm)	good	"LAET. G1/24/78" inscribed on cast plaster support	Olduvai
G1-24	LP-25.96 (C)	1996 polyester cast	good	made from 1978 mold LP-25	National Museum (Dar)
G1-24	LP-25.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1996 cast	National Museum (Dar)
G1-25	LP-08 (C)	1978 or '79 polyester and fiberglass cast w/plaster support (39x30cm)	good		Olduvai
G1-25	LP-13 (C)	1978 or '79 polyester cast w/plaster support (39x27cm)	poor: broken cast		Olduvai
G1-25	Sections A, B & C				
G1-26	LP-14 (C)	1978 or '79 plaster cas; (22x12.5cm)	good		Olduvai
G1-26	LP-26 (M)	1978 silicone rubber and cloth mold w/plaster support	fair: silicone torn in spots; remnants of tuff on the surface	"G1/26/78" inscribed on mold plaster support	Olduvai
G1-26	LP-26 (C)	1978 polyester cast w/ plaster support (35x23cm)	good	"LAET. G1/26/78" inscribed on cast plaster support	Olduvai
G1-26	Sections A & B				
G1-27	Section A				
G1-28	Sections A, B & C				
G1-29	Sections A, B & C				
G1-30	Sections B & C				
G1-31	Sections B & C				
G1-33	LP-09 (C)	1979 polyester cast w/plaster support; (38x30cm)	good	"G1-33" written on cast	Olduvai
G1-33	Section A				
G1-34	LP-04 (C)	1979 polyester and fiberglass cast w/plaster support; (42x32cm)	good	"G1-34" written on cast	Olduvai
G1-34	LP-23 (C)	1979 polyester and fiberglass cast; (44.5x29cm)	good		Olduvai
G1-34	Section A				
G1-35	Sections A & D				
G1-36	Sections A & D				
G1-37	Sections A & D				

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
G1-38	Section A				
G1-39	Section A				
G2/3-01	LP-12 (M)	1978 latex and burlap mold w/plaster support (40x29cm)	poor: cannot cast		Olduvai
G2/3-01	LP-40 (C)	1978 polyester cast w/plaster support; (41x30cm)	good (based on 1995 inventory only)		Olduvai
G2/3-01	LP-12.96 (C)	1996 polyester cast	good	made from 1996 mold	National Museum (Dar)
G2/3-01	LP-12.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1978 cast LP-12	National Museum (Dar)
G2/3-02	LP-03 (M)	1978 latex and burlap mold w/plaster support; (52x33cm)	poor: latex and plaster support adhered together		Olduvai
G2/3-02	LP-17 (C)	1978 plaster cast; (39.5x25cm)	poor: broken during transport from Olduvai to Endulen, not usable	"G2-2-'78" written on plaster support	Olduvai
G2/3-02	Section E				
G2/3-02	LP-03.96 (C)	1996 polyester cast	good	made from 1996 mold	National Museum (Dar)
G2/3-02	LP-03.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1978 cast LP-03	National Museum (Dar)
G2/3-03	Section E				
G2/3-07	LP-28 (M)	1978 silicone rubber and cloth mold w/plaster support	fair, tuff inclusions indicating made directly form trackway	"G2/7/78" inscribed on mold plaster support	Olduvai
G2/3-07	LP-28 (C)	1978 polyester cast with plaster support (44x22cm)	good	"LAET. G2/7/78" inscribed on cast plaster support	Olduvai
G2/3-07	LP-28-96 (C)	1996 polyester cast	good	made from 1978 mold LP-28	National Museum (Dar)
G2/3-07	LP-28.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1996 cast	National Museum (Dar)
G2/3-09	LP-27 (M)	1978 silicone rubber and cloth mold w/plaster support	fair: silicone torn in spots, tuff inclusions indicating made directly from trackway	"G2/9/78" inscribed on mold plaster support	Olduvai
G2/3-09	LP-27 (C)	1978 polyester cast with plaster support (36x18cm)	cast plaster support fractured and delaminating	"LAET. G2/9/78" inscribed on cast plaster support	Olduvai
G2/3-09	LP-27.96 (C)	1996 polyester cast	good	made from 1978 mold LP-27	National Museum (Dar)
G2/3-09	LP-27.96 (M)	1996 silicone rubber mold w/polyester support	good	made from 1996 cast	National Museum (Dar)

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
G2/3-18	LP-24 (C)	1978 or 1979 polyester and fiberglass cast	good	no mold found	Olduvai
G2/3-18	Sections A, B, & C				
G2/3-19	LP-22 (C)	1978 or 1979 polyester and fiberglass cast (49x38cm)	good		Olduvai
G2/3-19	Section A				
G2/3-19	Section B				Olduvai
G2/3-20	Section A				
G2/3-21	LP-06 (C)	1979 polyester and fiberglass cast; (53x26.5cm)	good	Dark brown color (possibly from excess of catalyst in polyester).	Olduvai
G2/3-21	Sections A, B & C				
G2/3-22	LP-21 (C)	1979 polyester and fiberglass cast (46x25cm)	good	Dark brown color (possibly from excess of catalyst in polyester).	Olduvai
G2/3-22	Sections B & C				
G2/3-24	Section A				
G2/3-25	Section A				
G2/3-26	Sections A & D				
G2/3-27	Sections A & D				
G2/3-28	Sections A & D				
G2/3-29	Section A				
G2/3-30	Section A				
G2/3-31	Section A				

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
G1-25, G1-26, G1-27, G1-33, G1-34, G1-35, G1-36, G1-37, G1-38, G1-39, G2/3-18, G2/3-19, G2/3-20, G2/3-24, G2/3-25, G2/3-26, G2/3-27, G2/3-28, G2/3-29, G2/3-30, G2/3-31	Section A 79 (C)	1979 polyester and fiberglass cast (4.70m x 0.75m)	fair: numerous areas cracked and delaminated; blisters on the surface (from preparation); large areas of unsupported gel coat on the surface; minor gel coat detachment during 1994 re-molding. This cast cannot be re-molded without risking more damage.	used to make silicone mold in 1994; no original mold found	Olduvai
G1-25, G1-26, G1-27, G1-33, G1-34, G1-35, G1-36, G1-37, G1-38, G1-39, G2/3-18, G2/3-19, G2/3-20, G2/3-24, G2/3-25, G2/3-26, G2/3-27, G2/3-28, G2/3-29, G2/3-30, G2/3-31	Section A 94 (C)	1994 epoxy master cast	good	made from 1994 mold as the archival master cast for Section A	National Museum (Dar)

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
G1-25, G1-26, G1-27, G1-33, G1-34, G1-35, G1-36, G1-37, G1-38, G1-39, G2/3-18, G2/3-19, G2/3-20, G2/3-24, G2/3-25, G2/3-26, G2/3-27, G2/3-28, G2/3-29, G2/3-30, G2/3-31	Section A 94 (M)	1994 silicone rubber mold w/ polyester support	fair; 12 areas were torn during transport in museum in Dar in 1994 and were repaired in 1995. Any new casting will reflect the repairs.	made from 1979 cast	National Museum (Dar)
G1-25, G1-26, G1-27, G1-33, G1-34, G1-35, G1-36, G1-37, G1-38, G1-39, G2/3-18, G2/3-19, G2/3-20, G2/3-24, G2/3-25, G2/3-26, G2/3-27, G2/3-28, G2/3-29, G2/3-30, G2/3-31	Section A 94 (C)	1994 polyester cast	good	made from 1994 mold before damage and patinated in 1995	on exhibition at National Museum (Dar)

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
G1-25, G1-26, G1-27, G1-33, G1-34, G1-35, G1-36, G1-37, G1-38, G1-39, G2/3-18, G2/3-19, G2/3-20, G2/3-24, G2/3-25, G2/3-26, G2/3-27, G2/3-28, G2/3-29, G2/3-30, G2/3-31	Section A 95 (C)	1995 polyester cast	good	made from 1994 mold after damage and patinated in 1996; shows repairs made to mold in 1995.	on exhibition at Olduvai Museum
G1-25, G1-26, G1-27, G1-33, G1-34, G1-35, G1-36, G1-37, G1-38, G1-39, G2/3-18, G2/3-19, G2/3-20, G2/3-24, G2/3-25, G2/3-26, G2/3-27, G2/3-28, G2/3-29, G2/3-30, G2/3-31	Section A 95 (C)	1995 polyester cast	good	made from 1994 mold after damage as a field cast; cut into four pieces; shows repairs made to mold in 1995.	National Museum (Dar)

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
G1-25, G1-26, G1-28, G1-29, G1-30, G1-31, G2/3-18, G2/3-19, G2/3-21, G2/3-22	Section B, LP-32 (M)	1979 latex and silicone rubber mold (silicone in footprints and latex between footprints) w/plaster support on pipe support; (2.25mx77cm)	poor: latex and silicone rubber portions separating from each other; latex is brittle and unevenly layered; silicone areas are cracked and deformed (from poor quality silicone); remnants of tuff embedded in surface.	made in 1979, but earlier in excavation than Section A.	Olduvai
G1-25, G1-28, G1-29, G1-30, G1-31, G2/3-18, G2/3-21, G2/3-22	Section C, LP-32 (C)	1979 polyester cast; (1.85m x 0.77m); cast from Section B.	good: tuff particles from mold embedded in surface; silicone from a second molding also on surface; white surface gel coat w/slight pigmentation.	partial cast from Section B mold; cast does not include prints G1-26 and G2/3-19, which are on the mold (Section B) and for this reason was designated Section C.	Olduvai
G1-25, G1-28, G1-29, G1-30, G1-31, G2/3-18, G2/3-21, G2/3-22	Section C, LP-32.95 (C)	1995 polyester cast (2)	good	made from 1995 mold; one made for archive and one for field use	National Museum (Dar)
G1-25, G1-28, G1-29, G1-30, G1-31, G2/3-18, G2/3-21, G2/3-22	Section C, LP-32.95 (M)	1995 silicone rubber mold w/ polyester support	good	made from 1979 cast LP-32	National Museum (Dar)
G1-35, G1-36, G1-37, G2/3-26, G2/3-27, G2/3-28	Section D, LP-31 (M)	1979 (or later) silicone rubber mold w/plaster support and pipe support; (1.63m x 0.70m)	Fair. Edges and cloth in rubber deteriorated/	may be a second generation mold (made from Section A cast) since there are no signs of tuff or rootlets remaining on the surface.	Olduvai
G1-35, G1-36, G1-37, G2/3-26, G2/3-27, G2/3-28	Section D, LP-31.96 (C)	1996 polyester cast (2)	good	made from 1979 mold LP-31; patinated	given to Esere and Endulen village schools
G1-1, G1-2, G1-3, G2/3-1, G2/3-2, G2/3-3	Section E, LP-41 (M)	1978 latex and burlap mold w/ plaster support and wood (stick) support frame (1.25m x 0.70m)	poor: cannot cast		Olduvai

1996 INVENTORY OF LAETOLI, SITE G HOMINID FOOTPRINT MOLDS AND CASTS

PRINT #	INVEN-TORY #	DESCRIPTION	CONDITION (1996)	COMMENTS	STORAGE LOCATION
G1-1, G1-2, G1-3, G2/3-1, G2/3-2, G2/3-3	Section E, LP-41 (C)	1978 polyester cast (1.32m x 0.70m)	good: small holes and tears; tuff and rootlets (lifted from molding) embedded on surface; white gel coat	may have been remolded (traces of silicone on the surface). Dark color may indicate too much catalyst in preparation.	Olduvai
G1-1, G1-2, G1-3, G2/3-1, G2/3-2, G2/3-3	Section E, LP-41.95 (C)	1995 polyester cast (2)	good	made from 1995 mold; one made for archive and one for field use	National Museum (Dar)
G1-1, G1-2, G1-3, G2/3-1, G2/3-2, G2/3-3	Section E, LP-41.95 (M)	1995 silicone rubber mold w/ polyester support	good	made from 1978 cast LP-41	National Museum (Dar)

PART IX. MOLDING AND CASTING ACTIVITIES

by Ron Street

INTRODUCTION

Molding and casting work for the 1996 Laetoli field season took place at the Endulen field camp and at Olduvai from July 15-27. The molding and casting operations were undertaken by Ron Street, GCI consultant, and Jesuit Temba from the National Museum of Tanzania. The 1996 work focused on preparing cast replicas of nine individual 1978 molds and casts from the northern portion of the trackway and on preparing cast sections of hominid prints for use by local schools. Work was also undertaken to patinate various casts and develop prototype molds, models and casts for exhibition and educational purposes by the Tanzanian authorities.

MOLDING AND CASTING

The molds and casts in storage at Olduvai, made directly from the Laetoli trackway, remain the best documentation of the actual prints as excavated in 1978 and 1979. Because of their extraordinary value for study and exhibition, and for field use during re-excavation, remolding and recasting of the 1978 originals continued during the 1996 field campaign. Nine individual footprint molds and casts were replicated by remolding and recasting.

Individual molds and casts of prints

The condition of the individual footprint molds and casts from the northern and middle trackway was assessed in 1996. Prints G1-1, G1-2, G2/3-1, and G2/3-2 were molded in 1978-9 directly from the trackway using a natural latex rubber molding compound. These latex molds had deteriorated beyond any practical use. Prints G1-19, G1-22, G1-24, G2/3-7, and G2/3-9 were molded from the trackway in 1978 using a silicone rubber molding compound (most likely Silastic E). These silicone molds also showed signs of deterioration: the edges of the silicone had become frayed, holes and abrasions showed in some areas, and the cloth impregnated in the silicone was decomposing. The central image of the print was however still very good. The corresponding casts from the latex and the silicone molds are very detailed and accurate. Unfortunately they were made from either a hard plaster (G1-2 and G2/3-2) or polyester resin backed with plaster (G1-1, G1-19, G1-22, G1-24, G2/3-7, G2/3-9, G2/3-1). Both these techniques produce a very fragile cast. The unsupported plaster casts are extremely brittle and easily broken. The casts made with polyester resin supported with plaster were beginning to de-laminate. Separation of the thin layer of approximately 3mm of resin from the plaster support was of great concern. Once the thin polyester laminate is separated from the plaster it is subject to breakage and loss. Pieces of the edges had been lost, and cracks were beginning to develop where the resin had separated from the plaster. The G1-1 cast was completely unattached from the plaster support and was extremely frail in that state. To create a stable, permanent record of these molds and cast before any further deterioration could occur, master silicone molds and master polyester casts were made of the nine prints.

Because the latex molds had deteriorated, master silicone rubber molds were made of four casts originally produced from the now unusable latex molds. From the new 1996 master silicone molds, polyester casts were made. The casts will be used for scientific and educational study, field use during re-excavation, and as master casts. The 1996 master silicone molds and casts of prints G1-1, G1-2, G2/3-1, G2/3-2 were labeled, "1996 mold from 1978 cast", and "1996 cast from 1996 mold of 1978 cast."

The five 1978 silicone molds (G1-19, G1-22, G1-24, G2/3-7, G2/3-9), although deteriorated, still provided excellent impressions of the original prints. The molds had some tuff inclusions and other indications that they were made directly from the trackway. Unlike the latex molds, it was determined that casts could be produced from the silicone molds made in 1978. This was preferable to remolding the casts because working directly from the silicone molds ensured a more faithful reproduction. This also prevented any possible damage to the fragile casts made from them in 1978. The 1996 casts from these 1978 molds were made with polyester resin. The master molds of these 1996 casts were half finished when I departed camp. Jesuit Temba completed the molding process. See the 1994 and 1995 Laetoli reports for technique, processes and materials used for molding and casting.

1979 Section "D" Mold

The 1979 section "D" mold was also evaluated during the 1996 field season. This mold is most likely made from the 1978 section "A" polyester cast and contains prints G1-37, G1-36, G1-35, G2/3-28, G2/3-27, and G2/3-26 (see Appendix A). It had no tuff inclusions or other indications that it was made directly from the trackway. The mold was in fair condition. Edges of the mold were ragged, torn, and abraded. Some small holes had developed sporadically around the surface of the mold due to the poor quality of construction, inferior materials, and poor storage. Decay of the cloth impregnated inside the rubber was also advanced. The rubber, probably "Silastic E," has retained good detail despite these problems. It was determined that a cast could be made from the mold without endangering it. Subsequently two casts were made of this mold. A third cast was made from the corresponding part of the 1994 master silicone mold of section "A." In comparison, the casts from "D" mold and "A" mold showed no noticeable differences. Only the outline of the casts differs due to the extent of the molds themselves. The two section "D" casts were made for use at schools in Endulen and Esere.

A poor quality cast of Section "D," which had been confiscated by the NCA police some years previous, was given to Jesuit Temba for return to the National Museum. No details of how the cast came to be confiscated were forthcoming. The cast was taken to Dar es Salaam with the other molds and casts (see below).

Prototype Models

Four models and two molds were developed as prototypes. The purpose of the prototype is to explore ways for developing segments of the trackway impressions into various configurations for use as educational tools. Because the section "A" mold is difficult and expensive to produce, alternative ideas for the display of cast trackway sections were explored with Jesuit Temba. Individual prints G1-34 and G1-35 and a single four-print section containing prints G1-33, G1-27, G1-26, and G1-25 were cast from the 1994 mold of section "A". Print G1-35 was cast twice. The individual prints

G1-34 and G1-35, were cut into rectangular shapes. The edges of the cast projected approximately 2.5 inches beyond the actual print. Side walls were added to two of the cast prints G1-34 and G1-35 to configure the prototypes into a rectangle measuring approximately 6" wide by 12" long by 2.5" deep. These configurations were then molded to produce prototype molds that could then be cast in different ways with different materials. The prototype mold of print G1-35 was cast in plaster; the second cast of print G1-35 was framed in wood. The molds and models will allow the Antiquities Department to experiment with ideas for presentation, costs, production feasibility, and feedback about marketability.

PATINATION

Patination of the following casts was completed:

- one complete polyester cast made in 1995 from the 1994 section "A" master mold (Photo 53),
- two 1996 polyester casts of the 1978-9 section "D" mold,
- one 1996 cast of the corresponding "D" section made from the 1994 "A" master mold,
- a single cast of a four print section from the 1994 "A" master mold containing prints G1-33, G1-27, G1-26, and G1-25,
- two prototype casts of G1-35 and one G1-35 also cast from the 1994 section "A" master mold.

The patina of the casts is made to resemble the exposed tuff at Site G. See the 1995 Laetoli report for a description and materials used for patination of the trackway casts.

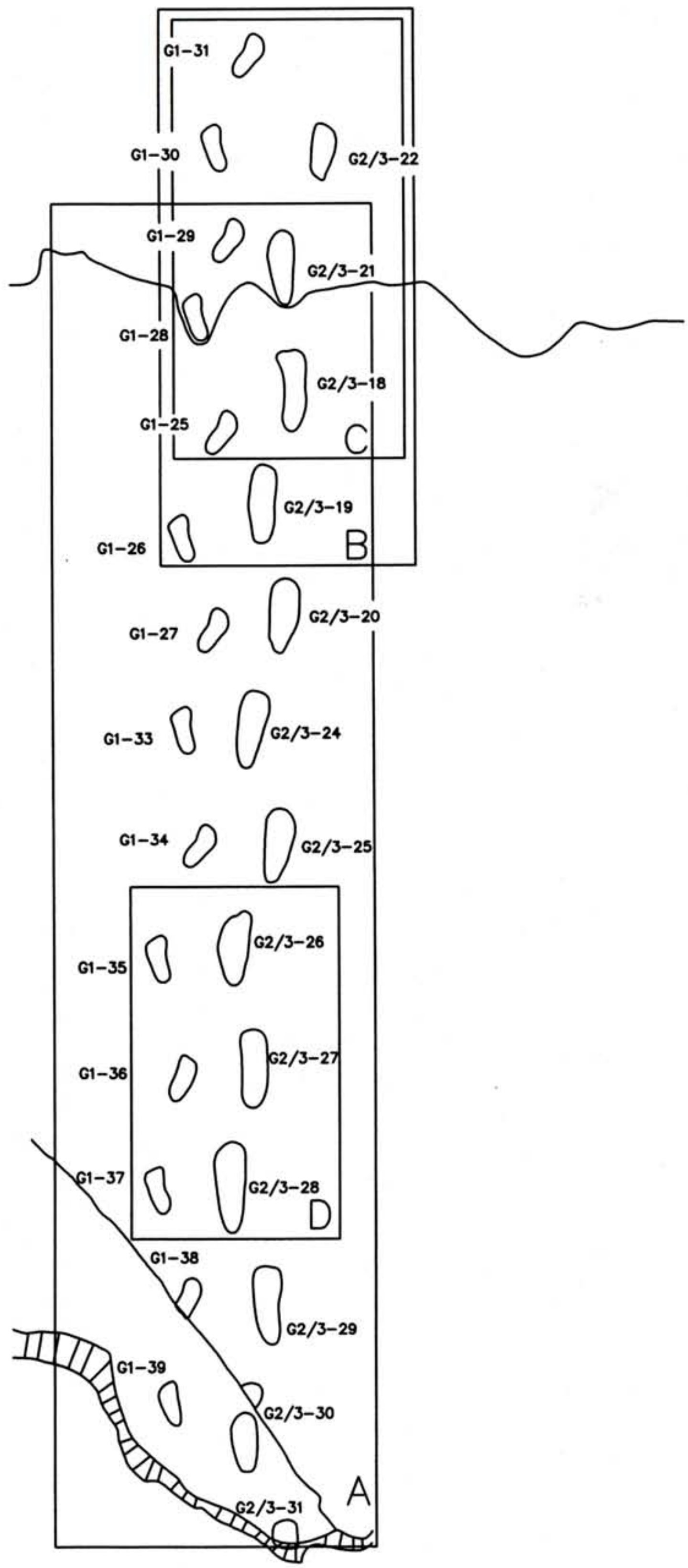
STORAGE OF MOLDS AND CASTS

At the end of the 1996 season, the 1994 Section "A" mold and the molds and casts made in 1996 were taken to Dar es Salaam for permanent storage. Preparation of the molds and casts for transport were handled by Jesuit Temba. All the original 1978-79 molds and casts were left at Olduvai. Along with other Laetoli-related materials stored in the "Laetoli Room" at the Olduvai camp, the 1978-79 molds and casts were placed on the storage racks constructed in 1995 (see Appendix B; Photo 54).

A NOTE ON THE TRANSPORTATION OF THE SECTION A MOLD

Two methods have been used to transport the 1994 section "A" master mold. One method was to secure the polyester support on top of a Land Rover, and store the rubber mold inside the vehicle. The other was to place the polyester support, with the rubber inside the support, in the back of a truck with a bed long enough for it to lay flat. The disadvantage of the first method is that the rubber needs to be rolled. This places stress on the rubber and can cause damage. However, this method was used for six different transports of the mold without any damage to the rubber. By rolling the rubber around a canvas tarp and plastic sheeting, the degree and tightness of the rolls can be reduced, providing a more cushioned package. A Land Rover with a full-length roof rack to support the weight of both the polyester and rubber would allow transport of both together on the rack. Land Rovers are preferable to other vehicles because of their superior suspension.

The mold was once transported flat in the back of a truck from Endulen to Olduvai. This method should be used only with a substantial amount of padding under the mold. With this method, the mold needs to be tied down against the padding so that it does not jump over the rough roads. Both methods of transporting the mold have drawbacks. The safe handling and transport of the mold depends on an understanding of the mold materials and their susceptibility to damage.



Southern sector of the trackway showing locations of mold and cast sections A-D

Location of 1978-79 Molds and Casts in Storage at Olduvai

SHELF 1

Empty

					G1-24	G1-25	G1-26		G1-34	
G1-1	G1-2	G1-17	G1-19	G1-22	G1-24	G1-25	G1-26	G1-33	G1-34	G1-37

G2/3-1 G2/3-2 G2/3-7 G2/3-9 G2/3-18 G1-19 G2/3-21 G2/3-22 LAET / 78 Site G Matrix samples

1979 Section B Mold
1979 Section C Cast

Box:
LAET / 78
Site G Matrix Samples

1979 Section D Mold

Boxes:
Misc unlabeled
LAET Site G Matrix from hominid prints
LAET Site G Footprints in-filling
LAET Site G Footprint Matrix (4 boxes)

1978 Section E Mold
1978 Section E Cast

SHELF 2

Empty

1979 Section A Cast

1995 Section A Cast
(patinated for museum exhibition)
moved to Olduvai Museum 9/98

PART X. REBURIAL OF THE NORTHERN 20 METERS OF THE TRACKWAY

by Martha Demas and Neville Agnew

INTRODUCTION

Reburial of the southern 10m of the trackway took place in 1995 and is fully described in the 1995 Report. The northern 20m of the trackway (which includes the northern end of the southern trackway sector, and the middle and northern trackway sectors) was reburied in 1996 from September 11 to 26. The work was supervised by Martha Demas and Neville Agnew, assisted by Angelyn Bass, Po-Ming Lin, Chet Cain, Donatius Kamamba, Ferdinand Mizambwa, and Godfrey Olle Moita.

The reburial overburden was identical to that used in 1995 to rebury the southern sector and the methodology established in 1995 was followed in 1996. The overburden is a composite of multiple layers of geotextile, Biobarrier, fine and coarse sand fills, and local soil fill, mounded to a maximum height of approximately 1m and capped with lava boulders (Figs 20, 21). The function of this composite overburden is to isolate and protect the footprints from vegetation and erosion, and to maintain a stable environment at the footprint tuff surface, while allowing free passage of water. The mounded shape has a sufficient gradient to ensure surface runoff. As with the southern sector, re-vegetation by grasses will be allowed to stabilize the mound.

SELECTION, DESCRIPTION AND PREPARATION OF REBURIAL MATERIALS

The 1995 Report describes the laboratory testing conducted at the GCI to determine the appropriate granular materials to be used in reburial (chemically stable, and consisting of rounded, medium to fine grained, moderately sorted sand with significant carbonate content and low soluble salts). As described in the 1995 Report, the following materials were selected for use in the 1995 and 1996 reburial.

Granular Fills

Two local sands were used in the reburial: one, a light colored sand from the Kakesio River; and the other, a dark colored sand from the Garusi River. The Garusi sand is mineralogically similar to the trackway tuff, having been derived by erosion of the Laetolil Beds. It has a high carbonate content (~40%), which will serve as a buffer against carbonic acid (from atmospheric CO_2 in rainwater). Such water percolating down through the reburial mound will become saturated with calcium carbonate and therefore be less likely to cause calcite dissolution at the footprint tuff surface. Though capillary rise of groundwater will also occur, it too will be saturated with calcium carbonate from the underlying tuff.

As in 1995, both the Garusi and Kakesio sands were sieved through wire screens to remove large particles and organic matter, particularly acacia seeds (see 1995 Report for screen sizes). The sands were sieved dry at their source (approximately 3 km from Site G) and were then transported by hired lorry and mixed on site at Laetoli. In addition to the newly quarried sand, surplus sieved Kakesio and Garusi sand from the 1995 season was used and the 1978 burial fill excavated from the trackway, also Garusi River sand, was sieved for re-use. The reburial area was approximately $90m^2$, requiring over $53m^3$ of sieved sand for its completion.

Geosynthetic Materials

Three types of geosynthetic material were used in the reburial: <u>Biobarrier</u>®, a geotextile (<u>Typar 3401</u>®), and <u>Enkamat</u>®. <u>Biobarrier</u> is a polypropylene geotextile studded with herbicide nodules that slowly release the root inhibitor *trifluralin*. *Trifluralin* is a low toxicity herbicide that is bio-degradable, is essentially water insoluble and therefore non-leaching and non-migrating in soil, and is non-systemic, that is, it will not be absorbed by plant roots, nor kill plants whose roots contact the nodules. <u>Biobarrier</u> functions only to inhibit root growth in the vicinity of the fabric; the plant will not be killed, but the growth of its roots close to the fabric will be stopped. Results of an off-site test in 1993 (Test Site 3) using a layer of the <u>Biobarrier</u> confirmed that it blocks root growth, but does not kill vegetation, and that the released herbicide does not migrate more than a few millimeters within the soil. <u>Biobarrier</u> is being used in the reburial overburden as a second line of defense against root penetration by acacias into the Footprint Tuff; the primary defense must be active and regular site monitoring and maintenance (see Part XI).

Typar 3401® geotextile is a non-woven, polypropylene fabric, light grey in color, whose tight matrix of fibers allows permeation of moisture, while acting also as a deterrent to root penetration. The permeable nature of a geotextile is essential to preventing the entrapment of moisture below, which results when using an impermeable material such as plastic. Another advantage of geotextiles is their durability in a buried environment. Testing and use of geotextiles at Laetoli in 1992, 1993 and 1994 confirmed that they caused roots, mainly weeds and grasses, to be deflected laterally where these grew into contact with the geotextile, rather than permitting them to grow vertically. There was also no evidence of insect attack or fabric deterioration. Like Biobarrier, however, geotextile is not intended as a long-term deterrent to root growth into the trackway. Roots will find their way through and around the geotextile eventually; hence the absolute need for regular monitoring and maintenance.

Enkamat is a 3-dimensional, lightweight, flexible nylon matting used to stabilize soil and control erosion.

PLACEMENT OF THE REBURIAL MATERIALS

All fill materials were stockpiled as needed on a tarpaulin east of the trackway trench; they were placed on the trackway by hand, using *korais* (shallow metal pans), until sufficient depth was achieved to allow wheelbarrows to be brought onto the accumulated fill and dumped. Reburial began at the southern end (Trench 4) where a vertical separator was placed in 1995 against the then unexcavated portion of the 1978/9 mound (Photo 17). The separator was removed prior to beginning reburial in 1996. The shape of the mound was controlled by brushing; the center line of the mound followed that established in 1995 at E102.25 in Trench 4, but was gradually shifted to the west to approximately E101 at Fault 3 and then to E100.50 at approximately N110, following the westward shift of Trenches 5 - 7.

As reburial proceeded, the perimeter wall of large lava boulders for the reburial mound was established in advance around the 1996 trench, at a distance of approximately 0.50-1m from the edge of the trench (Fig. 8; Photos 58, 59). Boulders were laid on the ground surface and a sand-cement mortar (2:1) was used between the boulders; in the area of Fault 3 two courses of stone were needed in order to retain fill on the slope of the fault.

Each of the multiple layers of sand and synthetic materials was laid throughout the excavated area. In the case of Fault 3 and the graben, however, the layering sequence was altered or augmented to conform to the topography. The graben was filled to the level of the tuff to the north and south with two layers of fill (Layers 1 and 2) separated by geotextile (Fig. 20). The slope of Fault 3 was covered only with Layers 3, 4 and 5 (Fig. 20).

The layering sequence of the reburial is as follows (see Figs 20, 21; 25-27):

Layer 1: Following completion of conservation and documentation, the exposed trackway surface was brushed clean and then covered with a 5 cm layer of fine sand from both the Kakesio and Garusi Rivers (Fig. 25; Photo 56). The sand was sieved to eliminate material greater than 0.9 mm (which also eliminated acacia seeds) and mixed by volume 70% Garusi (dark colored) and 30% Kakesi (light colored) to achieve a sand layer visually distinct in color from the tuff surface, and with a size and grain shape (predominantly subrounded to subangular) to minimize embedding into the trackway surface due to overburden load. The function of this fine fill is to provide an inert, free draining layer in contact with the footprints, as well as to serve as a marker layer for any future re-excavation. As in 1995, there was concern not to place the geotextile in direct contact with the trackway lest cementing by precipitated calcite should occur.

Sand was placed first in the individual footprints and then to a depth of 5 cm over the trackway surface, within the boundaries of the 1996 trench. In the case of print G1-19 only, which was severely cracked from weathering, a lining of "artificial silk" (Mathews Artificial Silk used for the shelter) was placed in the print to prevent sand from penetrating into the cracks (Photo 57). Only the slope of Fault 3 did not receive Layer 1. The irregularity of the tuff surface in Trench 4 and throughout the middle trackway sector resulted in Layer 1 being of variable thickness in these areas.

Geotextile: Geotextile was placed over Layer 1 (Fig. 25). The sheets of geotextile were placed widthwise across the trench with a 3-5 cm overlap onto the sides of the trench walls (where these existed). The geotextile will function as a horizon marker and separator between reburial fill layers, and in the event of any roots circumventing the Biobarrier layers above, it will serve as a final defense by deflecting growth.

In the graben, the geotextile used to separate layers 1 and 2 was cut to conform to the shape of the graben and prevent overlap onto the sides of the graben, which are composed of the clay-rich tuff—a matrix to which the geotextile could be impressed and adhere when wet.

Layer 2: The second layer is composed of sieved Garusi River sand, mounded over the geotextile to a height of 20-25 cm at the center of the mound. Layer 2 extends beyond the 1996 trench to the perimeter wall, except north of N113.5 where the trench wall provided sufficient depth to retain the fill (Fig. 26). Layer 2 was built up along the perimeter wall so that the Biobarrier could be sloped up along the inside of the wall. At Fault 3, Layer 2 was placed directly on the slope (Fig. 20).

Biobarrier (1st layer): A layer of Biobarrier (each sheet 1.45 m wide), was laid directly over Layer 2, and overlapping the vertical sides of the perimeter wall or trench wall (Fig. 26).

Layer 3: Layer 3, identical in composition to Layer 2, was mounded over the first layer of Biobarrier to an average height of 20 cm at the center of the mound between the perimeter walls (Fig. 27).

Biobarrier (2nd layer): A second layer of Biobarrier covered Layer 3, between the perimeter walls (Fig. 27).

Enkamat: Strips of Enkamat, 1m wide, were placed directly on top of the Biobarrier. The strips were tied together with plastic ties and pinned to the Biobarrier with wire to prevent shifting during the work (Photo 60). The purpose of the Enkamat was to retain the final layer of sand in two ways: by reducing slippage of the soil layer on the somewhat slick surface of the Biobarrier, and by reducing loss of soil from the surface by erosion.

Layer 4: Sieved Garusi sand was placed over the Enkamat to a height of 15-20 cm. Layer 4 was hand-tamped into the 3-dimensional matrix of the Enkamat.

Layers 2 and 3 and the first layer of Biobarrier laid south of Fault 3 merge with Layer 3 north of the fault to provide a more gradual slope for the reburial mound; the 0.50m difference in elevation north and south of the fault was reduced to approximately 0.12m at Layer 4 from the high point at N103 to the low point at N108 where the mound levels out (Fig. 20).

Layer 5: Black cotton soil, skimmed from the surface on the eastern escarpment of the site, was laid over Layer 4 and tamped to break up clods (Photo 59). There are several purposes of this layer. Being a heavy, clay-rich soil it is expansive when wet and will not itself erode easily, and will function to protect Layer 4 from erosion; it will reduce water infiltration into the fill when the wet clay expands, thereby creating a more stable buried environment; it will support re-vegetation of the mound by grasses for a more natural appearance and stability of the mound against erosion; and finally, being high in calcium carbonate content, it will provide a further chemical buffer against calcite dissolution by infiltrating rainwater.

Lava Boulder Capping: The perimeter wall of large lava boulders was first established to define the limits of the mound on the east, west, and north, as mentioned above. A capping of medium-sized boulders was then placed over Layer 5, and chinked with small volcanic rocks and cotton soil. The lava boulders will provide additional protection for the trackway by serving as a physical barrier against animals and by reducing erosion of the mound (Photo 13).

The perimeter wall, which reached a height of 0.40m near Fault 3, was further stabilized with a buttress wall of lava boulders and soil. The wall was stabilized in this way on the west between N103 and N109.50 (Fig. 8) and along the northern edge of the wall as it turns westward at N108.50 (now covered by the stabilization of the area east of the northern half of the reburial mound). The northwest corner of the mound, where it crosses the NW gully, was reinforced with boulders. Additional stabilization measures related to erosion and control of drainage around the reburial mound are described in Part V.

Photo 12 shows a profile of the upper layers of the reburial mound from the boulder mounding (bottom/south) to Layer 2 (top/north). Photos 58 and 59 show the profile at different stages from the west. The completed reburial mound is approximately 4 m wide in the northern half and 5.50 m in the southern half.

EVALUATION OF THE 1995 REBURIAL MOUND

At the outset of the 1996 season, the 1995 reburial mound over the southern 10m was examined and photographed. Vegetation on the mound was sparse, mainly tall grasses around the perimeter of the mound, but very little on the mound itself. The principal type of vegetation growing on the mound was a low spreading weed concentrated in the southwest corner of the mound (Photo 61). The seeds of this weed were probably introduced with the black cotton soil or brought by mice (a pile of grass seeds amassed by mice was found adjacent to the mound on the east).

The cotton soil layer on the 1995 mound was dry and fairly loose, but there was no evidence of erosion. The boulders were well embedded and stable.

CONCLUDING REMARKS

The reburial of the 20m of trackway re-excavated and conserved in 1996 took 14 days of work by 11 persons during which some 53 m^3 of sieved fill was introduced onto the trackway. The 1996 reburial presented far more challenges than that in 1995. The 1996 reburial covered twice the area of the 1995 reburial and the irregular topography of the northern 20m of trackway required specialized layering and stabilization of the mound at critical points. Measures related to the stabilization of the mound are covered in Part V, but were aimed principally at reducing infiltration of surface water east of the trackway and ensuring an adequate buffer and drainage to prevent erosion to the northern end of the reburial mound.

Based on analysis of the <u>Biobarrier</u> in the reburial monitoring trench, it is estimated that the material has a life-expectancy of another 20 years (see Part V, Appendix A; and Part XII) before it will require renewal. At such time it would be important to renew the upper layer of <u>Biobarrier</u> only since this is the layer that is most crucial to serving the function as a second line of defense, and its replacement would be minimally disruptive to the reburial mound.

PART XI. SITE SECURITY, MONITORING AND MAINTENANCE

by Martha Demas and Neville Agnew

INTRODUCTION

Issues of security and monitoring and maintenance are of utmost importance for the long term protection of the trackway. No less significant has been communication with the local people and seeking their participation to achieve the objectives of preservation of the site. Measures taken to meet these objectives are discussed below.

SITE SECURITY

Two local Maasai guards from the village of Esere had been posted at the site by the Department of Antiquities in 1995. The guards were retained during the interim period and the 1996 field season and through 1997 and 1998. The Department of Antiquities has re-iterated its commitment to employ the site guards on a permanent basis. As a result, it was decided that a permanent guard house would be constructed near the site. The location selected is on the hillside south of the site. It consists of two small rooms, constructed of modified wattle and daub technique (using a cement based mortar) with a corrugated metal roof (Photo 63). A tool kit for basic cleaning and maintenance at the site, 50-gallon drums for collection of water and a visitors' log book were left at the house for use by the site guards and maintenance staff from the Olduvai Station.

INVOLVEMENT OF THE MAASAI COMMUNITY

A second traditional Maasai ceremony was held at the site on August 20, 1996 to bless the northern trackway and to reinforce the significance of the site for the local population. The ceremony was led by the local Oloiboni, or traditional leader, Mr Birikaa Ole Kereto, and was attended by the local Maasai people, official representatives of the Ministry of Education and Culture and the villages of Endulen and Esere, the regional Unesco representative, Dr Mam Biram Joof, NCAA representatives, Mary Leakey (Photo 65), and members of the project team. The ceremony consisted of a formal meeting with speeches by representatives of the local villages, Dr Daniel

Ndagala from the Ministry of Education and Culture, Mr. L. Mariki of the NCAA, and Neville Agnew from the GCI, followed by the site blessing, which unlike the 1995 ceremony, included women. Some 80 members of the community attended the ceremony (Photo 64). In accordance with the wishes of the Oloiboni, the press (CNN, BBC and AP) were allowed onto the site only at the end of the ceremony, for interviews and filming.

In another initiative aimed at local involvement, Martha Demas and Donatius Kamamba visited the village intermediate schools of Endulen, Esere, and Osononi to donate to each a cast replica of a segment of hominid prints from Site G (Photo 62). In addition to the casts, all surplus office supplies from the campaign were donated to the schools prior to departure. Medical supplies were given to the local mission hospital at Endulen.

The three-month residence of the project team in the Laetoli area led to many requests by the local community for assistance with transport, projects and schemes well outside the objectives of the project. Where possible, both the DoA and the GCI made every effort to assist the local residents. One such request - in song form - came from a group of Maasai women from the locality for provision of water, which is always a precious commodity. With the cooperation of the camp staff, the team provided two 50-gallon drums of water daily for the women.

SITE MONITORING AND MAINTENANCE

Responsibility for the long term care of Laetoli lies in the hands of the Department of Antiquities, which has statutory responsibility for cultural resources. The NCAA, which manages the Ngorongoro Conservation Area, will also play an important role in ensuring the future protection of the site. For this reason, the team has been in continuous dialogue with the NCA authorities since the inception of the project and relations between the DoA and NCAA have been improved and consolidated during field campaigns and the 1996 meeting of the Laetoli Consultative Committee on which the NCAA was represented.

In 1995 and again in 1996 the Laetoli team and the Consultative Committee provided input to the new General Management Plan for the Ngorongoro Conservation Area which was in its final stages of development. The implementation of the plan as it relates to cultural resources has, as yet, not been carried out since a structure calling for integration of cultural resource managers into the NCAA and better cooperation between the DoA and NCAA was not in place as of 1998. It is nevertheless a significant step that cultural resource issues were taken into consideration in the NCA Management Plan and the lack of coordination between the agencies was recognized and measures to rectify it were addressed. As a result of the Laetoli project, which brought senior personnel from the DoA and Ministry of Education and Culture frequently to the NCA and in contact with their NCAA counterparts, the development of professional and personal relationships between the two agencies was promoted and strengthened.

With the completion of the field conservation program in 1996, work began on development of the long-term monitoring and maintenance plan for the site to be implemented by the DoA through its staff at Olduvai Station. All aspects of the plan were developed with the DoA and Ministry of Education and Culture representatives and in discussion with NCA authorities.

The plan identifies and addresses major threats to the site, the roles of the local communities in protecting the site, reporting and communication lines between DoA and NCAA for the purposes of implementing the plan, and duties and responsibilities of site guards, Olduvai Station staff and DoA Head of Conservation. Checklists, monitoring and maintenance forms, schedules, and photographic protocols were all developed and form part of the final plan. The plan was adopted in June 1998 after a final review meeting with DoA in July 1997. Excerpts from the plan are appended to this section of the report as Appendix B.

A final meeting was held in June 1997 with local community members and local officials to formally present and discuss the plans for future protection of the site. The importance of the local community, especially the schools, in keeping the Laetoli story alive was emphasized. Participants in the meeting are listed in Appendix A.

CONCLUDING REMARKS

The long term survival of the trackway in unimpaired condition will depend upon scrupulous adherence to the monitoring and maintenance of the site. It should not be forgotten that the present six-year project of conservation was a consequence of the fact that simple maintenance was overlooked. Removal of acacia seedlings and prevention of erosion of the northern end of the site would have obviated the need for a long and expensive program of conservation. Ancillary benefits in the form of training and the Olduvai Museum exhibit have derived from the project it is true, but the inescapable fact of abandonment of the site after reburial in 1979 remains. Insofar as can be identified, the threats to the site have been addressed in the plan for security, monitoring and maintenance; it remains only to carry them out.

Appendix XI-A

Participants at the meeting with local community members

1. S. Waane	Director of Antiquities
2. D.K. Ndagala	Commissioner for Culture
3. M.B. Joof	Unesco Representative
4. G. Olle Moita	Conservation Assistant, Olduvai
5. J. Muzungu	Ward Officer, Endulen
6. J. Lazaro	Head Teacher, Esere
7. E. Bara	Head Teacher, Endulen
8. A. Kanunga	Security, Western Zone, NCAA
9. O.S. Kileo	Head of Station, Olduvai
10. D.K Kamamba	Architectural Conservator, DoA
11. S. Kasindo	Executive Officer, Endulen
12. M. Osokoni	Ward Executive Officer, Endulen
13. A. Pakaay Ollonyokye	Chairman, Endulen
14. L. Kuay	Head of Information Systems, NCAA
15. A.W. Melita	Head of Planning Development, NCAA
16. S. Matero	Site Guard, Laetoli
17. N. Agnew	Getty Conservation Institute
18. M. Demas	Getty Conservation Institute
19. A. Bass	Getty Conservation Institute

Endulen camp
June 27, 1996

Appendix XI-B

LAETOLI

THE HOMINID TRACKWAY AT SITE G

NGORONGORO CONSERVATION AREA
TANZANIA

[Excerpts from the]

MONITORING AND MAINTENANCE PLAN

June 1998

[Excerpted sections bolded]

CONTENTS

ATTACHMENTS

Attachment A	Excerpts from the NCA General Management Plan
Attachment B	Inspection checklists
Attachment C	**Reporting forms**
Attachment D	**Photographic monitoring: Datum Points**
Attachment E	Sample photo log
Attachment F	List of Tools for use during inspections and maintenance

MAPS

Map 1	Livestock Control
Map 2	Vegetation Buffer Zone
Map 3	**Drainage and Erosion Control**
Map 4	Detail of Drainage and Erosion Control Systems (1997)

LAETOLI, SITE G

Significance of Laetoli

Site G at Laetoli is one of many palaeontological fossil sites in the Laetoli-Ngarusi region of the Ngorongoro Conservation Area that provide extraordinary evidence for the diversity of life in the Pliocene savannas of East Africa some 3.6 million years ago. The Pliocene sites of Laetoli-Ngarusi preserve both hominid and faunal tracks, as well as hominid, animal and plant fossils, which have immense scientific and cultural value, especially for the study of human evolution. The trackway at Site G, preserved within layers of aeolian and airfall volcanic tuff, not only records the diversity of life in the Pliocene, but more significantly, offers unique evidence of bipedalism in hominids from 3.6 million years ago.

Along with the equally important palaeontological site of Olduvai Gorge, 30 km to the north, Laetoli contributes to the outstanding values that have made the Ngorongoro Conservation Area a World Heritage Site.

Background to the Laetoli Project

The hominid trackway at Laetoli, Site G, was excavated by Dr Mary Leakey in 1978-79. Following excavation, the trackway was documented and then reburied underneath a mantle of soil and lava boulders. After the trackway's reburial in 1979, acacia and other vegetation took root in the reburial fill, ultimately causing damage to the trackway and individual hominid prints. Erosion to the northern end of the 1978 reburial mound further resulted in the loss of two prints.

The project to conserve the Laetoli hominid trackway at Site G was jointly undertaken by the Department of Antiquities of the Tanzanian Ministry of Education and Culture and the Getty Conservation Institute, based in Los Angeles. The four-year project was completed in 1996. Annual reports for the 1993-1996 field campaign describe the aims, methodology and results of the work at Laetoli to conserve the trackway. Figures 1 and 2 show the trackway after conservation.

Purpose of the monitoring and maintenance plan

The purpose of this plan is to present the major threats to the Laetoli hominid trackway at Site G and the measures to be taken to ensure the long-term preservation of the site.

The plan is intended for use by the agencies responsible for the protection and care of cultural resources within the Ngorongoro Conservation Area, namely, the Department of Antiquities (DoA), Ministry of Education and Culture, and the Ngorongoro Conservation Area Authority (NCAA).

Responsibility for the protection of Laetoli

The DoA has responsibility for the protection and management of cultural resources within the Ngorongoro Conservation Area. The NCAA has primary responsibility for the administration and management of the conservation area, sharing responsibility for aspects of cultural resource management with the DoA. Responsibilities of the DoA and NCAA and plans for resolving areas of ill-defined authority, are discussed in the NCA General Management Plan (see Attachment A).

The reporting structure and lines of communication between the two agencies as it relates to the maintenance and monitoring of the Laetoli site is diagrammatically presented in Figure 3. The specific maintenance and monitoring activities and responsibilities for carrying them out are described in the plan and summarized in the checklist for use in the field (Attachment B).

Role of the local community

An important element in the protection of Site G is the local community of the Laetoli-Ngarusi region, under the guidance of the village government. A number of meetings with elders from these communities were held from 1994-1996 to explain the importance of the site and the work that was being done. From these meetings, other actions were taken to enhance the value and understanding of the site for the community.

Foremost among these was the acceptance by the religious leader (*Oloiboni*) of the region, Mr. Birikaa Ole Kereto, to conduct a blessing ceremony for the trackway in 1995 and 1996, which was attended by men and women from the surrounding villages. The continuing support of the *Oloiboni* will remain a significant resource for the protection of the site in the future.

The Chairmen of the villages of Endulen and Esere and the Ward Officer have also been instrumental in furthering the aims of the Laetoli project and constitute an important presence in the region for ensuring the site's protection. The site guards for Laetoli have been recruited from the village of Esere, which lies in closest proximity to Site G at Laetoli, and they further enhance the important role of the local community in protecting the site.

Status of Site G in 1997

The remote location of the trackway at Site G and its inaccessibility during much of the rainy season, combined with the very fragile nature of the tuff surface in which the tracks are imprinted, pose a considerable preservation challenge.

Allowing the site to be exposed is not a feasible option at this time and would surely result in rapid deterioration of the trackway. This has also been recognized in the 1996 General Management Plan for the Ngorongoro Conservation Area (see Attachment A).

For this reason, the long-term conservation strategy selected for the hominid trackway at Site G was reburial. Re-excavation of the 1978-79 burial mound showed clearly that where root intrusion and erosion of the mound had not damaged the trackway, the reburial had been an effective protector of the footprints. Failure of the 1978-79 reburial was due to lack of regular maintenance of the mound, in particular removal of acacia seedlings, and to the absence of drainage control measures.

The 1995-96 reburial of the 30-meter-long trackway was undertaken using multiple layers of sieved sand, separated by geotextile materials; one of the geotextiles, *Biobarrier*, contains herbicide nodules to deter root growth. These measures are a second line of defense against root growth into the reburial mound. <u>The long-term preservation of the trackway cannot rely on these materials alone, but must be based on regular maintenance and monitoring</u>. If regular maintenance and monitoring is not conducted, the hominid trackway at Site G will eventually suffer deterioration and damage.

The maintenance and monitoring plan that follows requires simple but regular actions, which, if carried out, will ensure the protection and preservation of the trackway.

Visitor Policy for Site G

The Laetoli-Ngarusi sites, including Site G, are located within a restricted area of the NCA. As sites with recognized cultural and scientific value, they are managed by the Department of Antiquities and legally protected by the Antiquities law. Both jurisdictions (DoA and NCAA) restrict access to the Laetoli sites.

Anyone wishing to visit the Laetoli sites must therefore obtain both a permit from the NCAA to enter this restricted area, and a letter of permission from the DoA. A visitor must be accompanied by a representative of the NCAA or DoA. Tourism is strictly prohibited within this area.

Reburial monitoring at Test Site 3

A test trench for monitoring reburial conditions was established at Test Site 3 (see Map 1) in 1995. Details of its excavation and contents are provided in the 1995 Laetoli Field Report. It replicates the reburial of the hominid trackway on a small scale of 2.5 x 2.5m. Its purpose is to serve as a long-term monitoring tool for the burial condition of the hominid trackway without having to disturb the trackway itself. The trench contains samples of acacia root stock and stem inserted into holes in the floor. Some are treated with preservatives others are not. Other samples of various kinds have also been included as indicators of the burial environment. The test site is divided into four quarters, with a similar set of samples in each.

Young acacias, naturally seeded prior to 1994, have been allowed to grow on the northern part of the test site. The purpose is to allow monitoring of the effectiveness of *Biobarrier* against root growth. The SE quarter of the trench was re-excavated in June1997 to assess conditions and the effectiveness of the reburial. After re-excavation, this part was reinstated (see Report of the 1996-1997 seasons at Laetoli for results of the re-excavation). The entire test site should remain undisturbed for the long term, with an assessment excavation again after 10 and 30 years.

Test Site 3 should be maintained exactly as the hominid trackway, with one exception: the live acacias at the northern end of the mound must be allowed to remain and must not be disturbed since they constitute an important component of the testing strategy.

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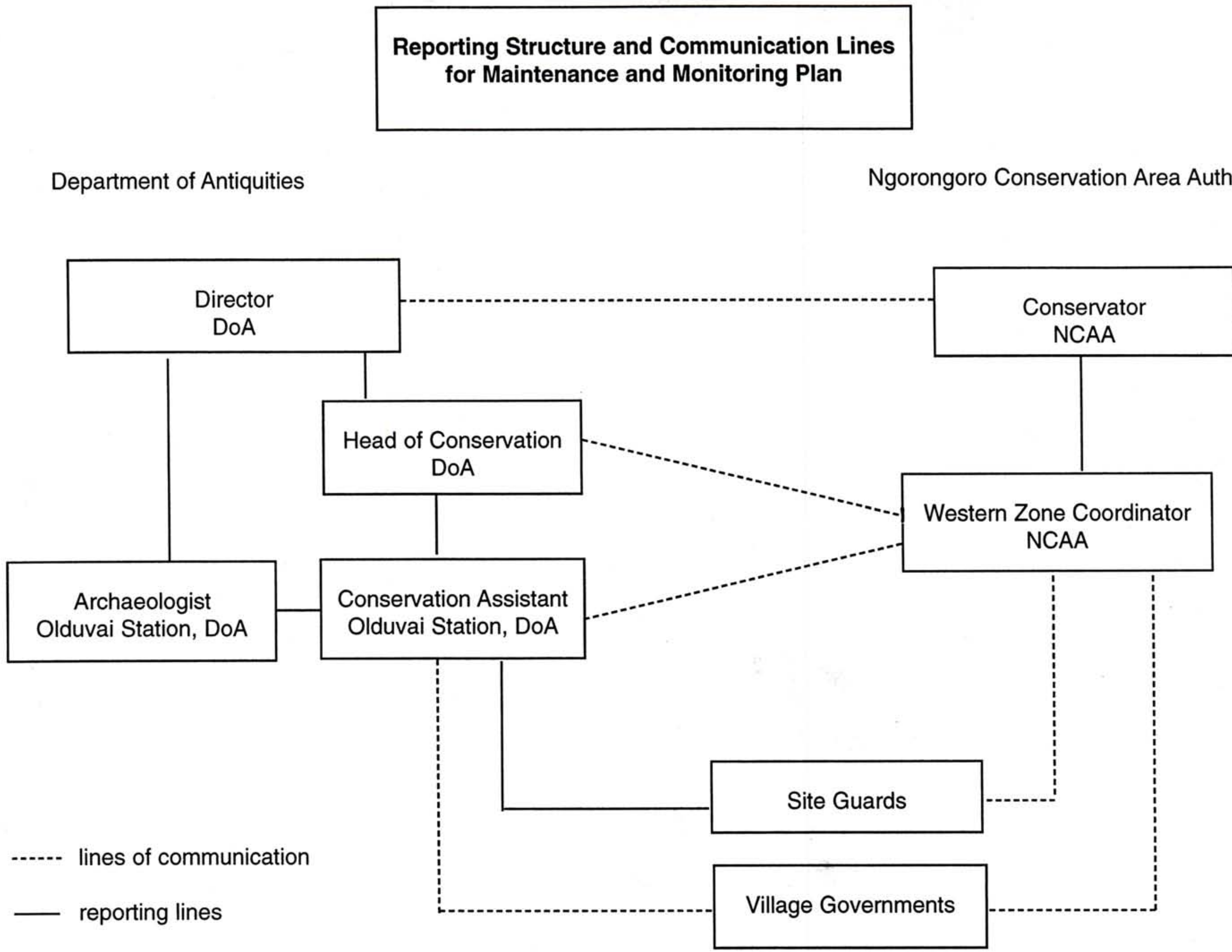
Figure 3



Reporting Structure and Communication Lines
for Maintenance and Monitoring Plan
Department of Antiquities
Ngorongoro Conservation Area Authority
Director
DoA
Conservator
NCAA
Head of Conservation
DoA
Western Zone Coordinator
NCAA
Archaeologist
Olduvai Station, DoA
Conservation Assistant
Olduvai Station, DoA
Site Guards
Village Governments
lines of communication
reporting lines

LAETOLI, SITE G
MONITORING AND MAINTENANCE PLAN

Threats to Laetoli, Site G

There are several threats to the Laetoli site that require security measures and regular maintenance and monitoring:

- Vegetation: Unchecked growth of vegetation on and near the trackway is the most significant long-term threat to the trackway. Failure to remove unwanted plant species will eventually damage the reburial materials and ultimately the trackway itself.

- Erosion: Surface erosion from water run-off and from cattle grazing also represent significant threats to the site. Water run-off to the NW gully has caused the loss of two hominid footprints, erosion of exposed Footprint Tuff along the gully edge, and has also contributed to the highly weathered condition of the tuff on the northern trackway. Cattle grazing causes damage and loss to exposed tuff, displacement of stabilization boulders, and may cause increased surface erosion by destroying grasses that stabilize the top soil.

- Disturbance and Vandalism: Site G at Laetoli has been twice disturbed (in 1993 and 1994), with the apparent aim of removing geotextile materials used in the protection of the site. Because the site is remote, there is opportunity for vandalism or interference.

Measures that have been adopted to address these various threats and the duties of those responsible for carrying them out are described below for the Site Guards (I); the Quarterly Inspection (II) and the Annual Inspection (III). A field checklist of maintenance and monitoring activities, site maps and the photographic protocols for use in the field follows.

I. SITE GUARD DUTIES

Responsibility: Site guards

Frequency: Daily

To ensure a daily presence at the site, two persons from the local community have been hired by the Department of Antiquities as site guards on a permanent basis. A guardhouse was constructed in 1996 east of the site for their use. The site guards' responsibilities are:

- **Security and use**

1. Visit and inspect the site daily and maintain a visible presence at or in the vicinity of the site.
2. Restrict all livestock from entering the site as defined by the perimeter thorn fence (Map 1).
3. Restrict visitation to only those with a permission letter from the DoA and NCAA. The Laetoli site is located within a restricted area of the NCA, and any visitor requires a permit from the NCAA Headquarters and must be accompanied by either a representative of the DoA or NCAA. Site guards will note names and vehicle registration of all visitors and report unauthorized visits to the Western Zone Coordinator, stationed at Endulen village.
4. Accompany visitors on site at all times.
5. Keep a register of all visitors names.

- **Maintenance**

1. Maintain the thorn fence around the site. Particular attention should be given to sections of the fence that can be easily breached by animals.
2. Keep drainage sump and channels clear of debris to allow for water to flow freely out to the Ngarusi River Gully.
3. Make temporary repairs of damaged berms, channels and gullies with soil and rocks. These actions are intended to prevent further damage until an inspection and more permanent repairs can be made by the Conservation Assistant
4. Maintain guardhouse and fence.

- **Reporting**

1. Submit a written report on a standard form once a month to the NCA Western Zone Coordinator at Endulen village for collection by the Conservation Assistant. Inform

him of disturbances, visits or other problems at the site. A sample standard form is appended as Attachment C.

2. Sign a register, kept by the Coordinator, on each visit.
3. Verbally report all activities, including observations of condition, repairs and serious problems, to the Conservation Assistant during the quarterly site inspection in March, June, September and December of each year.

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II. QUARTERLY INSPECTION AND MAINTENANCE

Responsibility: Conservation Assistant, DoA, Olduvai Station

Frequency: Quarterly (March, June, September, December)

Four times a year, maintenance and monitoring will be undertaken by the Conservation Assistant from Olduvai Station. His responsibilities will be directly supervised by the Archaeologist at Olduvai Station and the DoA Head of Conservation.

In addition to the quarterly visits to Laetoli, which will require inspections, maintenance activities and report writing, the Conservation Assistant will visit Endulen once a month to discuss the site with the NCA Western Zone Coordinator and pay the guards.

The quarterly inspections will take place in December, March, June and September. During each of these inspections, the Conservation Assistant will undertake the following:

- **Vegetation control**

The primary long-term threat to Laetoli, Site G, is from unchecked growth of vegetation (especially trees). Trees, shrubs and weeds frequently encountered at Site G are:

Trees	Shrubs and weeds
Acacia drepanolobium	*Asparagus (various species)*
Acacia mellifera	*Leonotis sp.*
Acacia seyal	*Solanum incanum*
Commiphora africana	*Tagetes minuta*
Rhus natalensis	*Baleria sp.*

The removal of all vegetation, EXCEPT GRASSES, on the trackway mound, in the buffer zone around the trackway, on drainage systems, and on Test Site 3 must be done at each inspection. Grasses should be allowed to grow on the reburial mound to provide stability and resistance to soil erosion.

A few acacia trees that were growing adjacent to the reburial monitoring trench, Test Site 3, were intentionally left alive to monitor their growth in relation to the use of herbicide-studded geotextiles in the trench. These trees should NOT be removed; however, all new growth of trees, shrubs and weeds should be removed from the Test Site 3 mound.

Vegetation control activities:

1. Inspect for trees, shrubs and weeds on the trackway, in the buffer zone (Map 2) and on Test Site 3.
2. Remove all trees, shrubs and weeds with the roots. This should be done carefully by hand with minimal disturbance to the trackway reburial capping.
3. Remove all trees, shrubs and weeds from Test Site 3 except those mature acacias on the northern half of the mound that were intentionally left alive for testing purposes.
4. Allow grasses to grow naturally at the site.
5. Identify and mark plants with flagging tape that cannot be uprooted for later inspection or treatment with herbicide (if needed). The DoA should be informed if herbicide treatment may be required. The wild asparagus in particular has an extensive root system and its location should be noted, if it cannot be removed.

• Insect and animal control

Controlling insect and animal activity will help maintain the stability of the reburial mound and reduce the risk of damage to the trackway and to the site. Termites and ants are prevalent at Site G. While ants are unlikely to be problematic in the trackway reburial mound, termites may pose a threat and should be eliminated if possible. Termites may attack remnant stump roots where preservative has not penetrated, leading to slumping or collapsing of resulting voids under load of overburden; and long-term resistance of geotextiles to termites is largely unknown. Small animals, e.g. rodents, may destabilize the mound by burrowing. Larger animals, particularly livestock, cause damage to the burial mound and berms by disrupting and destroying vegetation needed for soil stabilization.

Insect and animal control activities:

1. Inspect trackway and adjacent buffer zone for evidence of insect or animal activity, such as termite mounds, nests and burrows.
2. Infill disturbed areas with soil and remove nests.
3. Check thorn fence around site for gaps or low areas and renew fence as needed.
4. Report any problems, major activity or disturbances to the DoA for consultation and treatment during annual inspection. Termite mounds on the trackway and in the vegetation-free zone around the trackway should be eliminated and exterminated during the annual inspection.

- **Site stabilization**

Damage to the buried trackway as a result of erosion caused by water run-off was identified during the assessment of the site in 1993. The area east of the trackway has served as a drainage catchment for run-off from the high ground south and east of the site. For this reason, extensive work was undertaken to stabilize the site against erosion and to divert run-off from the trackway. To retain the stability of the site, the drainage control system and gully stabilization measures must be maintained and monitored.

Drainage control systems include Berms 1, 2 3 and 4; the sump and associated drainage pipe, inlets and outlet; and the NW and West gullies. Note in particular any changes in existing erosion paths as indicated in Map 3 and any pooling of water near Berm 3.

Berms 1-4

The berms function to divert surface water away from the northern trackway to the Ngarusi River gully. Maintenance of the berms is essential to preventing further erosional loss to the northern end of the trackway.

Activities related to maintenance of the berms:

1. Identify problems such as boulder displacement, undercutting of berm by erosion, and loss of cement mortar and lining in channels.
2. Make repairs to correct or stabilize damaged or weak areas and record what was done.

3. Report cement failures and damage to the berms to the DoA for repair during annual site inspection. Give an indication of the severity of the problem and materials needed for repair.
4. Check for areas of pooling water on both sides of Berm 3 (Map 3). Since standing water will attract animals, an effort should be made to manually remove any standing water to the Ngarusi River.

Sump, drainage pipe, inlets and outlet

Surface water is fed into the sump from the inlets and carried through the drainage pipe to the outlet and the Ngarusi River. The following tasks must be performed on a regular basis to keep the system functioning:

1. Identify problems, such as blockage of drainpipe and outlets with debris, and undercutting or loss of cement. Ensure that water is flowing into the sump and not by-passing it.
2. Clear sump, drain, and outlet of any debris to allow water flow.
3. Remove any plants growing on and obstructing drainage system.
4. Check area near outlet for deep erosional ditches, undercutting or other damage.
5. Make repairs to stabilize problems and record what was done.
6. Report cement failures and other damage to DoA.

West and NW Gullies

The gullies were stabilized with boulders and soil, and a weak cement mortar where the tuff was undercut by erosion. Stabilization must be maintained to prevent further loss of tuff since the edge of the gullies lie dangerously close to the hominid trackway.

1. Identify problems, such as boulder displacement, undercutting of tuff edge, tree and shrub growth, and soil loss from erosion.
2. Replace boulders and infill areas of soil loss with black cotton soil.
3. Stabilize undercut tuff with soil and rocks. Inform DoA if cement repair work is required.
4. Remove all trees, shrubs and weeds from the gully slopes. Inform DoA if herbicide treatment is needed.
5. Inspect cement-lined drainage channel in the NW gully and at the northern end of the trackway for undercutting or failure.

6. Report cement failures or other damage to DoA, noting especially the loss of stabilization supporting the gully edge.

• Maintenance of trackway mound

The reburial mound of the trackway consists of a lava boulder capping with black cotton soil and small stones filling the spaces between the boulders. At certain critical points around the edge of the mound, additional boulders and soil were installed as a reinforcement against erosion or to build up low points where water flowed prior to the berm construction (i.e. at the northeast part of the mound). The capping and reinforcement may be subject to erosion of soil and boulder displacement.

1. Replace areas of loss with black cotton soil and boulders.
2. Check for soil erosion north of the burial mound, where the tuff is covered by only a thin layer of soil.
3. Check perimeter of the trackway mound for loose or missing stones and replace where necessary.
4. Ensure that the stabilization north and east of the burial mound is positively graded to allow water to flow into the perimeter channel feeding into the NW gully.
5. Maintain the perimeter channel to ensure flow of water to the NW gully.

• Photographic Monitoring

Photographs of the site will provide an important record of its condition and any changes over time, and will allow the DoA to estimate the type and extent of repairs to be made during annual inspections. 35mm photographs should be taken from datum points established on the plans in Attachment D. This should be done twice a year during the rainy season (in December) and at the onset of the dry season (in June). Photographs of specific problem areas should be taken as required during each inspection.

Photographic monitoring activities:

1. Take photographs of the trackway and site according to established datum points in Attachment C.
2. Take photographs of other specific site problems as required, such as areas that will need repair or further inspection and treatment during the DoA annual inspection, or

that show evidence of serious change. If temporary repair is done, photograph it before and after the work is completed.

3. Maintain a photo log in which the photo datum point or subject and date of photography are recorded (see Attachment E for photo log).
4. Process two sets of photographs and include photographs with the corresponding quarterly report.
5. Store negatives at Olduvai Station for collection at the annual DoA site inspection.

- **Other activities**

1. Meet with the site guards to discuss site conditions and any problems. Report findings of inspection to NCA Western Zone Coordinator in Endulen village and discuss with him problems or changes to the site.
2. Inspect site for disturbances.
3. Collect visitor register from the site guards.
4. Inspect condition of the guardhouse and record any problems that require attention or repair during the annual inspection. Photograph problems if necessary.
5. Submit a report using a standard form after each quarterly inspection, and include information about any site visitors and two copies of the photographs. Report should be sent to the Head of Conservation, DoA and copied to the Archaeologist at Olduvai Station. The report should specify any problems the site guardians are having, need for repairs and materials required to do repairs. A standard form is appended as Attachment C.
6. Undertake a monthly visit to Endulen to meet with NCAA Western Zone Coordinator and pay gueards.

ANNUAL INSPECTION AND MAINTENANCE

Responsibility: Head of Conservation, DoA

Frequency: Annually (September)

An annual inspection of Laetoli Site G by the Head of Conservation of the DoA will take place in September of each year, during the dry season. The purpose of this visit is to inspect the site, discuss site conditions and problems with site guards, Conservation Assistant and NCA Western Zone Coordinator, take decisions on problems affecting the site that could not be addressed by the Conservation Assistant, and supervise repair work or other treatments on site.

The visit will be coordinated with the annual visit of technicians and masons to the site of Olduvai for maintenance and repair work. The Conservation Assistant will have provided the Head of Conservation with a list of repairs and materials needed in advance so that materials can be brought to the site and time allocated for the work.

During the annual visit, the Head of Conservation will undertake the following activities:

Site activities:

1. Discuss site activites and problems with Conservation Assistant and Archaeologist at Olduvai Station, and site guards.
2. Inspect condition of the trackway, thorn fence, Test Site 3, West and NW gullies, and drainage control systems.
3. Undertake repairs and record what was done.
4. Take photographs before and after major repair work.
5. Take action to eliminate insect activity, and undertake herbicide treatment of new vegetation growth that could not be manually removed.
6. Inspect guardhouse and conduct necessary repairs.

Other Activities:

1. Meet with Western Zone Coordinator and village governments of Endulen and Esere, and with the *Oloiboni*.
2. Collect photo negatives from Olduvai.
3. Ensure that site guards and Conservation Assistant have sufficient copies of all standard forms needed for recording photography and report writing.
4. Submit annual report to DoA Director, Conservator of NCAA, and the Getty Conservation Institute.

LONG-TERM MAINTENANCE CONSIDERATIONS

Two layers of *Biobarrier* have been placed in the reburial mound as a deterrent against root growth. Based on assessment of temperature within the burial mound, it is estimated that the effective life of the *Biobarrier* at Laetoli is 15-20 years. After that time, it will still be effective as a physical barrier, but will no longer release root-inhibiting herbicide. A decision to replace the old *Biobarrier* with new material should be made at that time in light of the experience of maintaining a vegetation-free environment on the trackway. The upper layer of *Biobarrier* is the more critical as a defense against root penetration. Prior to this decision, the *Biobarrier* and geotextile from Test Site 3 should be evaluated.

With the completion of the conservation intervention project at Laetoli, the future monitoring and maintenance of the site resides solely with the Tazanian government. The Getty Conservation Institute will continue to take a role in an advisory capacity should the need arise and should the government of Tanzania request its advice.

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LAETOLI SITE G

QUARTERLY INSPECTION REPORTING FORM

To be undertaken by the Conservation Assistant, Olduvai Gorge, and submitted to Head of Conservation, DoA

Inspection month (circle month): **YEAR______**

March/June/ September/ December

1. VEGETATION

Indicate number and types of tree seedlings removed from:	Mellifera	Seyal	Drepanolobium	Other
• Trackway mound	______	______	__________	______
• Buffer zone	______	______	__________	______
• Test Site 3	______	______	__________	______

Comments:

Indicate number and types of tree seedlings left *in situ* and flagged for herbicide treatment:	Mellifera	Seyal	Drepanolobium	Other
• Trackway mound	______	______	__________	______
• Buffer zone	______	______	__________	______
• Test Site 3	______	______	__________	______

Comments:

Was there significant weed growth removed from trackway mound, buffer zone, or Test Site 3?

YES ______ NO ______

Comments:

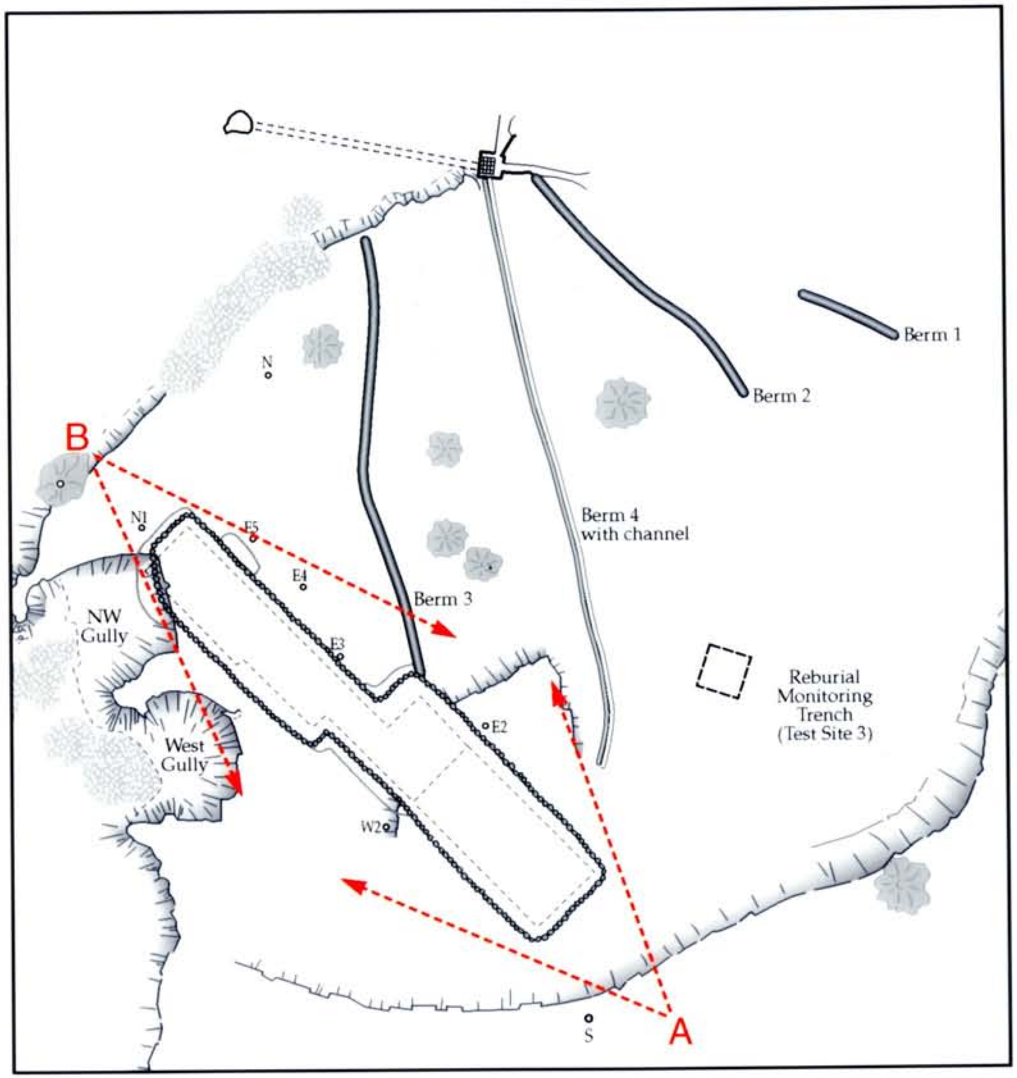
2. INSECTS & ANIMALS Was there any significant insect or animal activity noted on: • Trackway mound	YES____ NO______ Type of activity: ______________
• Buffer zone	YES____ NO______ Type of activity: ______________
• Test Site 3	YES____ NO______ Type of activity: ______________
3a. SITE STABILIZATION **Berms 1-4** Did you note any signs of boulder displacement, undercutting by erosion, cement failures or other problems to: • Berm 1	YES____ NO______ Type of problem: ______________
• Berm 2	YES____ NO______ Type of problem: ______________
• Berm 3	YES____ NO______ Type of problem: ______________
• Berm 4	YES____ NO______ Type of problem: ______________

Did you make any repairs?	YES____ NO______ Type of activity: ______________
Did you note any pooling of water at Berm 3?	YES____ NO______ Comments: ______________
3b. SITE STABILIZATION **Sump, drainage pipe, inlet and outlet**	
Did you note any signs of blockage of pipes or outlets with debris, water runoff bypassing sump, cement undercutting or loss, or other problems to sump system?	YES____ NO______ Type and location of problem: ______________
Was there any plant growth causing damage to or obstructing drainage systems?	YES____ NO______ Type and location of plant growth:___________
Did you make any repairs to stabilize problems?	YES____ NO______ Type and location of activity: ______________
3c. SITE STABILIZATION:	

3c. SITE STABILIZATION: West and NW gullies Did you note any boulder displacement, undercutting of tuff edge, tree and shrub growth, or soil loss from erosion to gullies?	YES____ NO______ Type of problem: ______________
Was there any damage, cement loss or undercutting of the channel in the NW gully?	YES____ NO______ Type of problem: ______________
Did you make any repairs to stabilize problems?	YES____ NO______ Type of activity: ______________
Did you remove trees, shrubs and weeds?	YES____ NO______ Type of activity: ______________
4. MAINTENANCE OF TRACKWAY MOUND Did you note areas of loss of black cotton soil and boulders?	YES____ NO______ Type of activity: ______________

Did you note any erosion at northern end of trackway?	YES_____ NO______ Comments: ______________
5. PHOTOGRAPHY Has photography been carried out according to Attachment D datum points?	YES_____ NO______ Comments:
6. OTHER ACTIVITIES Any other activities performed or problems noted during this inspection period?	YES_____ NO______ Comments:
Are there problems that require repair or treatment during the annual inspection?	YES_____ NO______ Comments:
If so, what materials are needed to undertake the repair or treatment?	Materials required:

LAETOLI TRACKWAY MONITORING
Photo datum points A and B



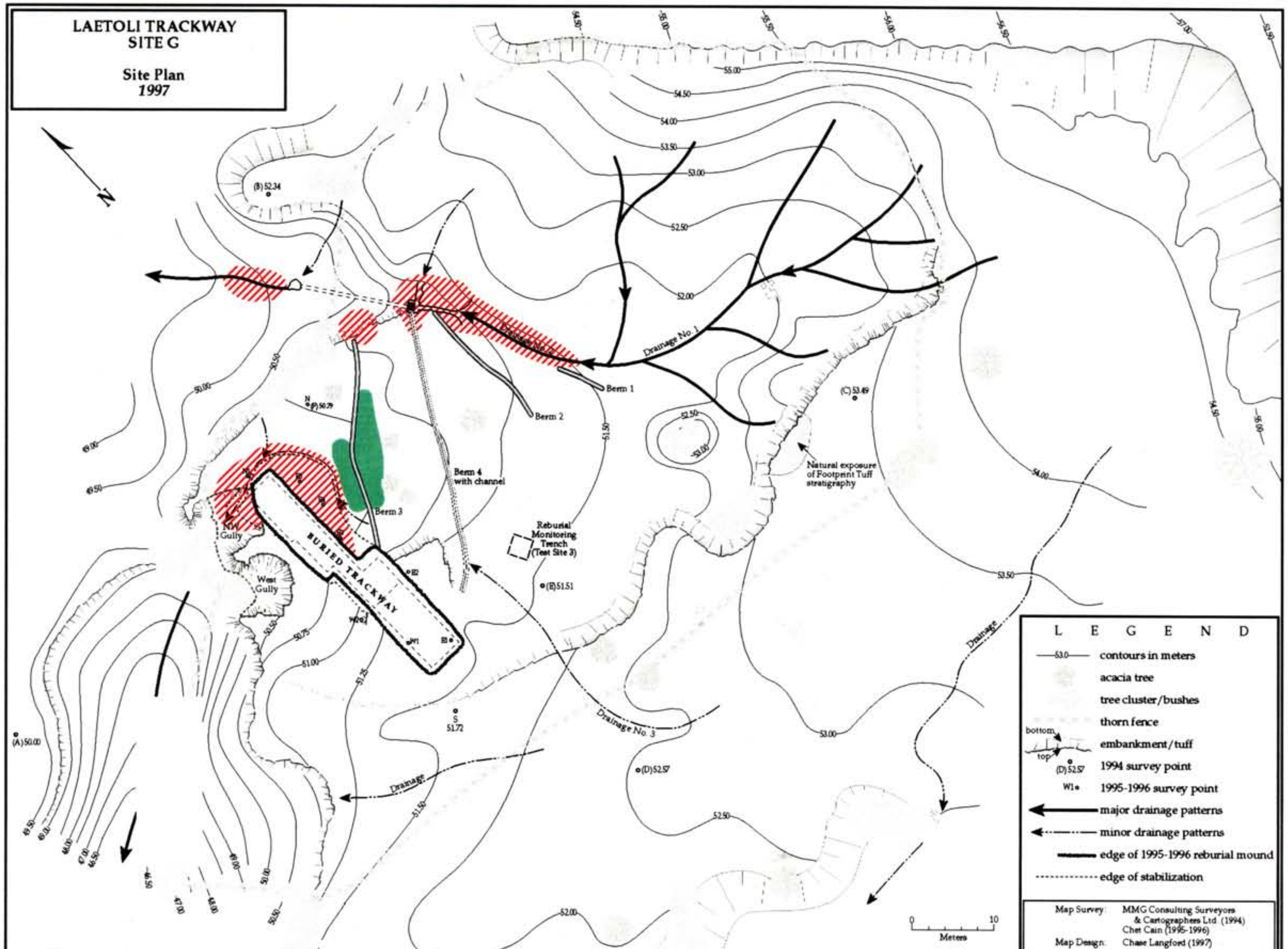
A

B

MAP 3

Area of Pooling Water

Area Prone to Erosion



PART XII. 1997 EVALUATION OF THE REBURIAL MONITORING TRENCH

by Neville Agnew and Martha Demas

INTRODUCTION

Excavation of part of the reburial monitoring trench at Test Site 3 during the 1997 field work had as its purpose an interim assessment of the conditions expected to pertain in the reburial of the hominid trackway. As stated in the 1995 field season report, the reburial monitoring trench is intended as a long-term resource, a proxy "window" on the trackway itself, to mimic the methods and materials used in the reburial of the hominid prints.

While the monitoring trench replicates the design, methodology, and materials of the trackway reburial, it differs in one important aspect. The trench is dug into the clayey stratum thought in 1995 to be stratigraphically below the Footprint Tuff. The results from augur holes placed in the vicinity of the monitoring trench in 1996 make that assumption less convincing (see Part V, Appendix A for discussion of these results), but does not change the nature of the material itself, which is essentially weathered clayey tuff, probably aeolian tuff. Because of the very high clay content of this material, the floor of the trench - by comparison with weathered Footprint Tuff - shows greater impermeability and plasticity when wet and more extensive cracking when dry. It was to be expected therefore that a higher moisture environment would pertain in the monitoring trench than on the trackway and that the overburden load of the mound might result in deformation of features incised on the floor. In fact, incised features were included specifically to assess deformation.

While the preference would have been to locate the monitoring trench on Footprint Tuff, this was not considered viable for two reasons. The extensive areas exposed through excavation in 1978-79 (see Fig. 5) beyond the areas of the hominid trails were covered at best with only a very shallow layer of sand. For the monitoring reburial to have been sited on previously excavated Footprint Tuff would, therefore, have required that it be constructed basically above ground – a configuration sufficiently different from the trackway reburial, especially the southern sector, to render interpretation of results ambiguous. Areas of Footprint Tuff with sufficient overburden to replicate conditions of the trackway reburial are those which have never been excavated and would have necessitated new excavation, which also was not acceptable. Excavation of a trench in the clayey tuff was considered, on balance, to be a more representative simulation of the trackway reburial than an on-ground monitoring trench; however, the difference in substrate between the trackway reburial and monitoring reburial should be borne in mind when considering results and discussion that follows.

After only two years since the establishment of the monitoring trench the information that might be derived from excavation would be expected at best to be only provisional; nonetheless, it was felt that it was important to have preliminary results before the completion of the project.

RE-EXCAVATION OF THE MONITORING TRENCH

The 1995 report should be consulted for full details of the design and implementation of the reburial monitoring trench at Test Site 3. Summary details only are provided here. Photo 66 shows the reburial trench with objects in place prior to reburial in 1995.

Excavation of part of the monitoring trench (the southeast quadrant and a small part of the northeast quadrant), and re-instatement of the mound, took place between June 28 and July 4, 1997.

Indicator objects

The monitoring trench is divided into two replicate sections (North and South), separated by a vertical barrier. Duplicate samples of different materials were prepared to provide a range of indicators of the reburial environment over the long term. These comprised wood (*A. drepanolobium* and *A. seyal*, stem and root) treated with preservative and untreated; geotextile; blocks of tuff variously treated with chemical consolidants and adhesives; cotton cloth; and steel nails (Photo 66).

Vegetation

Vegetation found growing on the mound included grasses, *Bidens pilosa* (a wild daisy), asparagus, and an unidentified leafy plant. During excavation vegetation was left *in situ* so as to be able to follow root growth. It was found that none of the above species had roots extending through the entire depth of the upper layer of fill. The five acacias (nos 24, 25, 27, 28, 29) that had been deliberately left growing on the north side of the mound to assess the effectiveness of Biobarrier against root intrusion into the mound were examined. No. 24, *A. seyal*, on the east side of the trench, was small, without much foliage, and did not look healthy; no. 25, *A. drepanolobium*, about 30cm high, appeared healthy but with scant foliage; no. 27, *A. seyal*, on the north side, has a double stem and was thriving with long new shoots, lush foliage and thorns; nos 28 and 29, *A. seyal*, which were growing close together, were healthy and had many low branches and lush foliage. Overall, the thriving condition of four of the five acacias showed again, as had been demonstrated previously by testing at Test Site 3, that vegetation in proximity to Biobarrier is not harmed. The active ingredient, trifluralin (an herbicide), does not migrate in soil beyond a few millimeters from the herbicide-release nodules on the geotextile; it serves only to inhibit root growth coming into contact with the geotextile. The unhealthy appearance of no. 24 is anomalous, but it was observed in the dry season and may have been dormant. Acacias elsewhere on the site show similar growth behavior: some may be flourishing while nearly others are dormant.

Fill layers

In the excavation of the southeast quadrant of the monitoring reburial, the boulder capping was first removed. The dry upper level of black cotton soil was removed with brushes to reach the harder packed layer of coarse sand (layer 4) which retained, on its upper surface, impressions of the capping boulders. The upper 10cm of this layer was dry, naturally consolidated, and came away in large chunks. Below, the sand was loose and slightly damp. At this level, dampness was most evident at the center and top of the mound and along the edges of the trench.

Layer 3, which is finer particle size fill than layer 4, was damp throughout. It was not consolidated and was easily removed. Layer 2, the same fill as layer 4, was also very damp, as was the fine sand of layer 1, which was removed slowly, allowing time for drying before resuming. The clayey tuff of the floor of the trench was wet (as it was found to be at the time of establishment of the monitoring reburial in 1995) and malleable and was allowed to dry before final cleaning. Samples of fill layers were taken to determine water content (see below).

Moisture content

While the coarse soil (black cotton) of layer 4 that caps the reburial mound was dry on excavation, the moisture content increased with depth, the highest values being found at the level of the base of the trench in the fine sand of layer 1 and immediately above the geotextile layer separating layers 1 and 2.

Samples of fill material from the excavation of the southeast quadrant were collected between 6/28 and 6/30/97 to determine water content at different levels within the overburden. Samples were taken to the laboratories at the GCI in tightly sealed containers to prevent moisture loss in transit. Moisture was determined gravimetrically according to ASTM D4959-89.

Sample Number:

No. 1: Coarse sieved sand; from layer 3 ....8.5%

No. 2: Coarse sieved sand; from layer 2 below Biobarrier 1..................8.2%

No. 3: Coarse sieved sand; from layer 2 near geotextile...................19.9%

No. 4: Fine sieved sand from layer 1; just below geotextile 14.6%

No. 5: Fine sieved sand; from layer 1 at tuff level 17.8%

It can be seen that the upper levels of the mound were quite dry (nos 1 and 2). Moisture increased markedly in the lower levels (nos 3, 4, 5), which were well below ground level. Saturation is around 20% moisture and this condition was found (no. 3) just above the geotextile, while immediately below the geotextile (no. 4) the moisture content was some 5% lower. At the tuff level (no. 5) moisture was increasing towards saturation.

Several inferences may be made: Samples 1 and 2 are within the zone subject to wetting and drying cycles, which accounts for their lower moisture levels at the time the field work was done. The high moisture content of sample 3 is the result of the geotextile acting to restrict to some degree infiltration of moisture to the lowest level of the trench – an advantageous situation vis-a-vis the trackway reburial. The differences in moisture content between samples 4 and 5 may be because the free-draining sand covering the floor of the trench facilitates removal of moisture, which however, in the present case is trapped by the impermeable clayey tuff. In the trackway reburial itself drainage conditions are expected to be better (except in certain areas such as the graben).

It was noted at the time of establishment of the monitoring reburial in 1995 that saturated conditions pertained in the clayey tuff. There was thus no reason to expect that conditions would be different within the trench, because capillarity from below and lateral migration of moisture through the adjacent weathered tuff into which the trench was dug would establish a moisture environment very similar to that of the surrounding sediment. The monitoring trench thus provides more exacting burial conditions than the reburial environment of the trackway itself. That it does so is due to the poor permeability of the clayey tuff and consequent higher ambient moisture.

EVALUATION OF RESULTS

Indicators

Of particular interest in the excavation of the monitoring reburial were, in order of significance, the following:

(a) Changes, if any, in the fine detail of the topography of the floor of the trench. These include both natural features such as undulations and cracks, and created ones such as the sharply incised triangles with surface score marks on the floor of the trench; and additionally, whether embedding of fine sand fill into the clayey tuff floor of the trench had occurred.

(b) Possible intrusion of roots into the burial mound from living acacias immediately adjacent to the test site.

(c) Changes in introduced samples of Footprint Tuff. Of interest too was the condition of chemical consolidants that had been applied to the samples. Note that two chemical consolidants were tested directly on the clayey tuff of the floor of the trench in 1995: Stone Strengthener OH (a silane) and *Acrysol* WS 24 (an acrylic emulsion). However, the test patches for these, being located in the northeast and southwest quadrants of the trench, were not accessible.

(d) The condition of the acacia samples (dry stems and roots) embedded in the base of the trench, some of which had been treated with the preservative PCP (pentachlorophenol, used under license of the Tanzanian government).

(e) The condition of the geotextile sample laid on the floor of the trench and its conformance to the uneven topography of the tuff; and also whether it adhered to the tuff.

(f) The fate of the cotton terry-cloth sample and iron nail. These had been included opportunistically. While neither of these materials has direct relevance to the trackway they were used to serve as probes to assess how aggressive the reburial environment was to an easily biodegradable material and ferrous metal.

Evaluation

Evaluation was based upon field notes and comparison with detailed close-up photographs taken in 1995 of all features and samples.

(a) Though wet and soft, the clayey tuff comprising the floor of the monitoring trench was essentially unchanged. Topographic features of the floor were well preserved; the incised triangle remained well-defined, with slight softening of the edges; score marks in the tuff from the edges of the triangle were still clear (Photo 68). Embedding of the fine sand of layer 1 into the surface of the floor of the trench was found. This was expected, both from the experience of re-excavation of the hominid trackway where sand from the original reburial was found to have embedded in the weathered tuff; and because, as already discussed, the stratum of clayey tuff is more plastic when wet than the Footprint Tuff.

Overall, the floor of the trench was essentially unchanged, the only observable difference being some loss of resolution of detail, a characteristic noted in the re-excavation of the northern trackway sector particularly.

(b) Fine rootlets were found apparently growing through the Biobarrier on the east side of the trench where the trench wall was lined with Biobarrier. Samples of Biobarrier were taken for subsequent analysis for trifluralin (see below).

On the basis of the above observation it was decided to open a small trench (80 x 100cm) on the northeastern corner of the mound adjacent to acacia no. 27 A-B to see how roots had grown in relation to the Biobarrier. This trench was excavated only into layer 2 adjacent to the Biobarrier lining the north trench wall. Acacia no. 27 has two stumps, one being in contact with the upturned Biobarrier at the trench wall; new root growth was observed, but not adjacent to the Biobarrier suggesting that the material is working to deflect root growth, an observation confirmed by the absence of root growth in the monitoring trench.

(c) Samples of introduced Footprint Tuff showed no deterioration or change, whether treated with consolidants or not. The consolidants Silbond 40, Stone Strengthener OH and Acrysol WS-24 were included in the trench to assess whether they deteriorated over time. The Silbond 40 treated block showed no discoloration and no difference in hardness compared with the untreated area as determined by a simple scratch test; Stone Stengthener OH treated sample showed no darkening or discoloration, and the same hardness as the untreated surface; the Acrysol WS-24 at full strength had a wet, opalescent, milky appearance, with adherent dirt which could not be brushed off; at 1:1 dilution with water: WS-24 the milky appearance was less marked, but dirt adhered. As described in the 1995 report, full strength WS-24 produced a very glossy surface on drying; when applied at 1:1 dilution with water the dry appearance was less markedly glossy. The difference in appearance of the retrieved samples was the opalescence, undoubtedly due to absorption of moisture from the wet environment at the trench floor. Some slight degree of reactivation of the WS-24 emulsion had clearly occurred which resulted in the adherence of dirt. Both WS-24 samples were harder than untreated areas of the samples, indicating that no deterioration of the WS-24, acting as a surface consolidant, had occurred.

On these findings WS-24 is an acceptable material for consolidation of the surface of the tuff, though preferably at aqueous dilutions higher than 1:1 in order to minimize adherence of particles. WS-24 was used on the trackway in 1995 and 1996 at dilutions of between 4 and 25%. Full bottle strength was only used in 1995 to consolidate areas around stumps that were to be extracted. Silbond 40 and Stone Strengthener OH appear also to be suitable as surface consolidants for Footprint Tuff.

A large block of Footprint Tuff, test block "I" in the southeast corner was recovered for evaluation. As described in the 1995 report, this had been treated with a variety of materials to test consolidation and void-filling properties. However, no results of the visual assessment are reported here. These tests, as originally conceived, were superceded by other field evaluations undertaken during the course of the 1996 campaign. Thus, gap-filling material used for infilling stump and root voids in the trackway used Acrysol WS-24 bulked with fine sieved fill from the 1978 reburial as described elsewhere in this report. This material showed entirely suitable properties, particularly in being shrink-free. Additionally, consolidant resistance to degradation was better evaluated on the Footprint Tuff samples, discussed above.

(d) Stumps and root samples, S1, S2, S4, S8, S9, and S13 were removed and evaluated. All had been treated with PCP preservative. In general, the upper approximately 3cm where preservative had thoroughly infiltrated were hard and perfectly preserved. Below this, severe degradation of the wood was found. This varied somewhat from disintegrated mush to soft though still intact wood. Degradation is undoubtedly due to microbiological activity, though alkaline hydrolysis of the cellulose under the high pH conditions of the tuff may be a contributing factor as well. No bioassay was undertaken.

The purpose in treating unextractable acacia stumps in the hominid trackway with PCP was to prevent collapse of adjacent surface into the void created by decay. The findings above are regarded as acceptable since a plug of solid wood, whether stem or root, can be expected to remain at the level of the Footprint Tuff though the lower part might decay.

(e) Geotextile sample that had been laid on the clayey tuff surface at the bottom of the trench was recovered in unchanged condition (Photo 67). It conformed to the contours of the tuff exactly, and did not adhere when dry; however, when lifted after drying, the tuff surface below was observed to show more noticeable reticulated cracking than before reburial. Cracking of clay-rich substrates is associated, of course, with drying. The inference is that over the period of a day or so, between exposure of the bottom of the trench and lifting, the conformation of the geotextile to the clay acted to facilitate rapid transpiration of moisture from the clayey tuff below, leading to more extensive cracking. In view of the observed surface cracking the decision originally taken when designing the trackway reburial to isolate the geotextile from the Footprint Tuff by a layer of fine sand was therefore well founded.

(f) The cotton cloth sample had disappeared completely (Photo 67), for the same reasons that the untreated wood decayed. In a newly established reburial the environment is oxygen-rich and where high moisture levels also exist biological activity is certain to be high. Only after a period of time, possibly several years, is stasis established as oxygen is depleted and the overburden settles and becomes compacted, limiting inward diffusion of air and permeation of water. Under these conditions equilibrium is slowly established and aerobic biological activity falls to a limiting level. Thus, it was to be expected that under the microbiologically aggressive conditions of the monitoring reburial trench, easily biodegradable materials like wood and cotton cloth would not survive.

(g) The iron nail was corroded and covered in hard concretion approximately 1mm thick. Part was removed to show a solid core of metal. Corrosion of iron in a buried environment is, like biological deterioration of degradable organic materials, mediated by oxygen and moisture. Unlike organics however, the concretion or corrosion product of iron, being adherent, acts to restrict diffusion of oxygen inward to fresh metal. Hence, corrosion slows to a low rate and core material can remain unchanged for a very long time. The finding of nails from the time of the Leakey excavation of the trackway in similar condition to the nail recovered from the monitoring trench is interpreted as above.

Analysis of Biobarrier for trifluralin

Two samples of Biobarrier were taken from the monitoring trench for analysis of trifluralin content. Analysis was done by the manufacturer, a subsidiary of Reemay Inc. Sample no. 1 contained 25.3% and sample no. 2, 25.8%. The range of production, according to the company, is 24.5 - 26.5% in the nodules on the polypropylene geotextile (18.9% by weight of the total fabric). Thus, not more than about 1% was lost over the two year period since burial. Based on this result the company estimated a 50 year life expectancy. Our own estimate, from soil temperature profiles is around 20 years for the hominid trackway (see Part V, Appendix A for soil temperature profiles)

Re-instatement of the trench

At the completion of the assessment of the indicator objects in the southeast quadrant of the monitoring trench, all the objects, with the obvious exception of the non-existent cotton cloth, were re-instated. The trench was then reburied with the same materials that were removed during excavation and capped with boulders.

CONCLUDING REMARKS

While the burial environment in the monitoring trench was different from that in the trackway reburial in two important respects: higher moisture regime and clayey aeolian tuff, the overall findings confirm the decisions taken for the reburial of the trackway. Key aspects of the trackway reburial design are the use of Biobarrier to prevent root intrusion and geotextile laid, not in contact with the Footprint Tuff, but isolated from it by a layer of fine, free-draining sand. It was gratifying to note that deformation of the wet, plastic aeolian tuff that forms the floor of the monitoring trench was negligible, though discernible as a slight "softening" of sharp detail. The harder Footprint Tuff is thus confidently expected not to be adversely affected in terms of deformation by the overburden load.

Microbiological activity in the monitoring trench was clearly at a high level during the two years since installation in 1997, but wood samples, in the parts infiltrated by preservative, survived unaffected. Parts not treated, and the cloth indicator were severely or completely degraded.

Geosynthetics showed no evidence of deterioration, and the chemical consolidants tested in the monitoring trench likewise were not degraded.

Based on the analysis of the Biobarrier which gives an estimated effective life expectancy of another 20 years, it is recommended that another quadrant be re-excavated and assessed at the 10-year mark (i.e. 2005).

XIII. EXHIBITION AT OLDUVAI GORGE

by Cynthia Godlewski and Kathleen Louw

INTRODUCTION

An integral part of the Laetoli project was the creation of a new exhibit that would highlight the significance and conservation of the Laetoli trackway.

When it was decided that the Laetoli trackway would be reburied and therefore inaccessible to the public after conservation, it was also agreed that a museum exhibit would be the best way to allow visitors to understand and experience the trackway and its conservation. Furthermore, a new exhibit would raise the awareness of the Tanzanian and international public about the importance of Laetoli in the context of human evolution and explain both the conservation measures taken at the site and why the trackway was not open for public visitation.

The venue selected as being most appropriate was the Olduvai Museum at Olduvai Gorge, some 30 km north of Laetoli, where Mary Leakey had installed a small exhibit on Laetoli after its discovery in 1978 adjacent to the exhibition on Olduvai Gorge. The desire for a second exhibition at the National Museum in Dar es Salaam could not be met by the project but an exhibition cast of the trackway was made for this museum where it is currently on display.

In planning the new exhibition, the goal was to retain the original focus of the museum by presenting the sites of Laetoli and Olduvai and their contributions to our understanding of human evolution. The museum and its exhibits, though, were in need of expansion and updating. It was agreed that the Department of Antiquities would be responsible for building repairs and expansion and the Getty Conservation Institute would be responsible for content, design and fabrication of the exhibit. Installation would be undertaken jointly.

Curatorial Assistance, Inc., a design firm based in Pasadena, California, was engaged to produce the new exhibit. The GCI undertook planning and coordination, writing new text, editing extant text and collecting images to be used in the exhibit. The new museum panels were installed in September 1998.

BACKGROUND – THE OLDUVAI MUSEUM

The Olduvai Museum was built in 1970 by Mary and Louis Leakey with the support of the National Geographic Society. It contained an exhibit on Olduvai Gorge and its archaeological sites and, after the discovery of the Laetoli trackway in 1978-79, the museum was enlarged to two rooms to include a small exhibition on Laetoli (Photo 70).

The stone structure (Photo 69) overlooks Olduvai Gorge within the Ngorongoro Conservation Area (NCA). Two open-air thatched huts on the rim of the gorge are adjacent to the museum. From these pavilions one can see where some of the Leakeys' important fossil and tool finds were made.

The Olduvai Museum and Gorge is administered by the Department of Antiquities of the Ministry of Education and Culture. The Ngorongoro Conservation Area Authority has jurisdiction over certain issues such as design and construction of buildings.

The museum is approximately 30 km north of Laetoli and lies 5.5 kilometers off the main road that takes visitors from Ngorongoro Crater to Serengeti National Park. Visitors to the Crater and Serengeti number approximately 80,000-100,000 a year. Many make a brief stop at Olduvai. Visitors range from local schoolchildren to world leaders and tourists from around the world. With the renovated museum and exhibits, the Department of Antiquities plans to broaden its outreach to local school children. The museum is the only place in the region where extensive information on the palaeoanthropological discoveries at Olduvai and Laetoli is presented.

Neither the building nor the exhibits had been updated since their original construction and installation. The museum building required repairs and the museum's exhibit panels were damaged or had deteriorated and some were no longer legible. In addition, some of the artifact replicas were missing.

PLANNING

The plan for the museum's renovation included adding a new room, installing a new roof, plastering the stone walls, installing a new ceiling, and painting the interior. The Department of Antiquities undertook this work, which was completed prior to the installation of the new exhibit panels.

Despite these improvements, there were several constraints that the designers had to keep in mind when preparing the new exhibit:

- There is no electricity on site, leaving only the ambient light from the windows in the museum.
- The windows take up considerable wall space, limiting the space available for displays.
- The staff of the museum is small in relation to the number of visitors to Olduvai. Their ability to monitor or assist visitors in the museum is very limited.
- There is no climate control inside the museum and exhibits must to be able to withstand extreme temperature fluctuations, insect infestation, dusty conditions, and visitors touching the panels.
- The museum is located in a remote area and there is no housing for guards in the immediate area. Security is therefore a factor and all display objects must be replicas or casts of the originals.

The exhibit proposal called for panels onto which full color photographs and text would be reproduced, the re-use of most of the casts of objects originally displayed in the Olduvai room, and display of the 4.25 meter-long cast of the hominid trail in the Laetoli room. The text was to be bilingual, in English and Swahili.

The Museum's New Exhibits

Orientation Room

A new room was added to orient visitors to the Gorge and to other cultural heritage sites in Tanzania. Visitors enter this room from the corridor adjacent to the ticket office. Panels in the Orientation Room (Photo 71) include a satellite image of the region; a map, photographs and descriptions of 10 other cultural sites in Tanzania; and an introduction to the museum, with explanations of the significance of Olduvai Gorge and the nearby Laetoli trackway.

An information desk -- where various park books, pamphlets and brochures are available -- is situated in this room. A one-page illustrated introduction to Olduvai and Laetoli, designed especially for children and printed in both English and Swahili, is also available at the information desk.

Olduvai Room

The Olduvai exhibit was well developed in its original installation. The exhibit furnishings and much of the displayed material in the form of casts of fossils and stone tools were re-used (with some editing of redundant artifacts) in the new exhibit. The intent was to retain the original focus and conception of the Olduvai exhibit, but to give it a "face-lift" and incorporate new interpretations as appropriate. Current work on reconstructing palaeoenvironments being undertaken by Rob Blumenschine (Rutgers University) was incorporated into a new panel. In addition, a panel focusing on Mary and Louis Leakey's work in Tanzania was created (Photo 72). This was especially important after the death of Mary Leakey in December 1996, when the planning team realized that the museum at Olduvai would become a testimony and tribute to the decades of work by the Leakeys at Olduvai and Laetoli.

Panels in the Olduvai Room (Photo 73) include:

1. The Significance of Olduvai Gorge and the Work of Louis and Mary Leakey
2. Louis and Mary Leakey: 60 Years of Field Work at Prehistoric Sites in Tanzania
3. Reconstructing Ancient Landscapes (Stratigraphy of Olduvai Gorge and Recent Work at Olduvai)

4. Formation of Olduvai Gorge (Plan of the Gorge, Geological Section through the Gorge, Raw Materials for Making Stone Tools)
5. Early sites: What do they mean for Human Evolution? (Plan of Debris on the FLK Zinjanthropus Living floor in Bed I, Plan of the Stone Circle on the DK Living Floor in Lower Bed I, Skeleton of an Elephant at FLK North, in Upper Bed I)
6. Bone Tools and Examples of Large Stone Tools (Photo 74)
7. Stratigraphic Timeline of Hominid Fossils, Geology and Environment and Stone Industries found at Olduvai Gorge (Photo 73)
8. Illustrations of Extinct Olduvai Fauna
9. Olduvai Fauna (fossil casts)

Laetoli Room

The original exhibition on Laetoli consisted mainly of photographs and a few individual casts of footprints. These were in poor condition and there was no material that could be re-used in the new exhibit.

The centerpiece of the new Laetoli exhibit is a 4.25 m x 1 m cast of a section of the southern part of the trackway (Photo 75). This was made during the 1995 field campaign, from Mary Leakey's original cast, under the direction of Ron Street from the Metropolitan Museum in New York. It was set into a wooden frame and displayed slightly inclined at waist level (one meter) for viewing ease. Above the cast is a 2.2 m x 1 m mural depicting a moment in time during the formation of the trackway. The image for the mural was provided by *Scientific American* magazine.

The new Laetoli Room (Photo 76) comprises the following:

1. The Hominid Trackway: Cast replica of the homind trackway at Laetoli Site G and a large mural of an artist's interpretation of the individuals who created the footprints during the eruption of Sadiman volcano.
2. The importance and value of the Laetoli hominid footprints
3. Location and geological setting of Laetoli
4. Discovery and Investigation
5. Formation of the Footprint tuff

6. Hominid Trackway (map and photos showing hominid prints, animal tracks and geological features)
7. What Can the Laetoli Hominid Footprints Tell Us? (Form and Function, Gait, Stature and Gender)
8. 1995-1996 Laetoli Project: The People
9. Faunal Prints of the Laetoli Area
10. Conservation of the Hominid Trackway
11. The Root of the Problem
12. Conservation (Investigation, Elimination of Trees, Re-excavation of the Trackway, Conservation Treatment)
13. Conservation (Stabilizing the Site, Documentation and Recording, Scientific Study, Reburial of the Trackway)
14. The Future (Laetoli Community, Blessing Ceremony, Education, Site Guardians, Future Maintenance and Monitoring)

CONTENT PREPARATION

The exhibit text was prepared by Martha Demas and Neville Agnew, with contributions from Robert Blumenschine, Craig Feibel, John Harris, Bruce Latimer, and Fiona Marshall, and reviewed by Donatius Kamamba of the Department of Antiquities. Translation of the text from English to Swahili was done by William Anyonge from the University of California, Los Angeles, and reviewed by Donatius Kamamba.

Photographs and graphics were provided by the Leakey family, the National Geographic Society, Robert I. M. Campbell, David Coulson, Kenneth Garrett, Richard Hay, Peter Jones, John Reader, Hugo van Lawick, Tim D. White, Donatius Kamamba, the Tanzania Department of Antiquities, and the Getty Conservation Institute. Jay Matternes provided illustrations of Olduvai fauna and *Scientific American* provided the illustration for the mural (by Al Kamejian) for the Laetoli Room.

The children's English-Swahili exhibition brochure was created by Kibuyu Partners (David Bygott and Jeanette Hanby) of Karatu, Tanzania.

EXHIBIT INSTALLATION

Daniel Koch, who was contracted by Curatorial Assistance, and Kathleen Louw, GCI project coordinator, traveled to Tanzania September 8-26, 1998 to install the new exhibition at the Olduvai Museum.

Due to unforeseen circumstances including equipment missing from the shipment, incomplete preparation work, and limited labor resources, the installation took longer than planned. In addition, the museum staff were determined that at least one room be open at all times, even with little to see, so as not to "cheat the visitors" who came in quite high numbers. (The number of visitors to the museum throughout the installation period was unusually high by low season standards. Most days the number reached the 100 mark, one day 243, and another over 200.)

The installers were therefore required to work around visitors and existing exhibits. The Orientation room, which temporarily housed most of the old exhibit material, was gradually emptied as work began on the Olduvai and Laetoli Rooms. Once the Olduvai room was ready, it was open to the public as work started in the Orientation room and continued in the Laetoli room.

Daniel Koch led the carpentry and panel installation work, supervising and instructing the local workers. Three local carpenters rotated to assist in the carpentry work (building of the cast frame, orientation desk, etc.). Three of the masons brought to the site by the Department of Antiquities for the museum's reconstruction also worked closely on the installation of the exhibit. Kathleen Louw handled planning and logistics, supervised installation and artifact removal, cleaning and placement, photographed daily activities, and kept the activity log.

Oliver Davidson, who ran the team's small camp, also assisted in the dismantling of old panels, sawing wood, sanding, supervising and communicating in Swahili with the masons. Nassra Czunyi, of Dar es Salaam, acted as liaison between the GCI and the Department of Antiquities throughout the planning, production, and installation phases as well as the official opening of the museum.

Museum staff, Ozias Kileo and Godfrey Olle Moita, were busy with visitors throughout the day, but were of great assistance in allocating workers for specific jobs, and contacting the Maasai community in preparation for the exhibit opening.

Comments on panel materials and exhibit layout

The panels, which ranged from 1 x 1.2 m to 2.4m x 3.1m in size, were made of Lexan laminated 6mm Sintra panels. Curatorial Assistance recommended the Lexan laminate because it protects the panels from abrasion, dust, humidity and UV radiation. The rigidity of 6mm Sintra allowed for the attachment of replicas of artifacts to the panels and prevented warping. Plywood backing was attached to the plastered stone walls using screws. The panels were then epoxied to the plywood. The panels not attached to the walls were attached to free-standing plywood walls. Panel 6, containing bone and fossil tools, was assembled in a wood and glass display case (Photo 74). The "panel" on Olduvai Fauna (Olduvai Room, panel 9) was not a single panel, but individual Sintra labels placed on wooden panel supports with the appropriate fossil cast. This was a recreation of the original display.

During the installation of the Sintra panels, a number of production flaws were noticed. These included problems with panel sizes and alignment, color matching, and lamination fragility at panel borders. Although nothing could be done with the lamination or to correct the panel colors, areas where the panels did not align properly were positioned centrally and the imperfections were less noticeable.

Some design changes were dictated by circumstances, but with no detrimental impact on the visual quality of the exhibition. In the Olduvai room, a new Case 6 was built because the original case did not fit in its designated space due to the new wall plaster layer having decreased the inside dimensions of the room. Also, the loose lava rock layer (part of the display) below Panels 7 and 2 was reduced in width to increase visitor floor space. In the Orientation room, panel locations were reconfigured because of changes in window placement during the construction phase. To satisfy the Olduvai staff's wish to have some photos from the old collection remain, a black-and-white photo of a 1931 expedition car of Louis Leakey and a photo of Hilary and Chelsea Clinton's visit to the museum were hung on the north wall.

Comments on Visitor flow

Once the exhibit panels were in place, it was evident that visitor flow inside the three rooms would be a challenge. To facilitate better traffic flow within the museum, the following suggestions were made to the museum staff:

- Synchronize the talks held at the overlook while other groups are in the Museum
- Indicate the room sequence as well as the panel sequence within each room
- Set a maximum capacity for the Olduvai and Laetoli rooms
- Move present parking area behind the museum, so that all visitors arrive through the south side and naturally flow to the cashier's window and Orientation room first.

EXHIBIT MAINTENANCE

Written maintenance guidelines for all items of the exhibit (panels, case, cast, floors, etc.) were provided to the Museum staff. Two trunks full of leftover installation supplies (epoxies, brushes, nails, screws, etc.) and maintenance supplies (brushes, dustpan, Windex, paper towels, paint for wall touch-ups, varnish, etc.) were also left. Because of the tremendous amount of dust that accumulates throughout the day, the museum staff was instructed to avoid using Windex for each cleaning and to simply wipe the panels with a dry cloth as needed during the day.

MUSEUM OPENING CEREMONY

The opening was held on Thursday, October 15, 1998. Vice President Omar Ali Juma, United Republic of Tanzania, officiated at the opening ceremony. Others in attendance were Prof. Juma Kapuya, Minister for Education and Culture, Ms. Zakia Mag, Minister for Natural Resources and Tourism, Dr. Daniel Ndgala, Commissioner for Culture, Mr. Donatius Kamamba, Acting Director, Antiquities Department, Mr. E.B. Chausi, Head

Conservator, Ngorongoro Conservation Area Authority (NCAA), Lazaro Mariki of the NCAA, and Neville Agnew and Martha Demas of the Getty Conservation Institute.

Over 100 Maasai villagers from nearby Endulen and Esere also attended, led by Martin Osokoni, executive officer of Esere; Isaya Alachausi, chairman of Esere; Augustine Pakaay Ollonyokye chairman of Endulen; Saitabau Ole Kereto, executive officer of Endulen; and Birikaa Ole Kereto, *Oloiboni* (traditional leader of the region). The opening ceremony included speeches by Vice President Juma and Neville Agnew, Maasai dances and a luncheon (see Photos 77 and 78).

PART XIV. CONCLUSIONS

by Neville Agnew and Martha Demas

Although the present report covers the 1996-1997 field seasons at Laetoli, Site G and the 1998 exhibition at the Olduvai Museum, it represents also the culmination of the project to conserve the hominid trackway. The detail of this six-year project is provided here and in the field campaign reports of 1993, 1994, and 1995, which should be consulted as appropriate.

The Laetoli project has achieved its objective of conserving the trackway so that it will survive in good condition for the foreseeable future, subject to continued monitoring and maintenance of the site. No less significant has been the full and meticulous documentation of the prints by detailed condition records, photographs, high resolution photogrammetry, and perhaps most importantly by replication of the casts from 1978-79, which remain the most exact records of the footprints as excavated as that time. Thirdly, because the site is reburied, and also not suitable for display to the public – its inaccessibility being the least of the reasons for the decision not to open it to visitors – the Olduvai Museum exhibition was undertaken as an educational resource for the Tanzanian people and international visitors. A year long undertaking in design, fabrication, and installation, the refurbished Olduvai Museum was opened in October 1998 by the vice president of Tanzania.

What still remains to be done after this long collaborative project of the GCI with the Tanzanian Department of Antiquities is to disseminate and make accessible to the conservation and scientific communities, and others who may have an interest, the data that were generated in the course of the project, especially on the hominid prints and their condition as revealed on re-excavation in the 1995 and 1996 field work. These tasks should be completed within the next 12 months or so.

Replica casts and molds (as well as originals) remain with the Tanzanian authorities; the GCI does not hold any molds or casts. Representative documentation of the project and its results, including all reports, have been provided to the Tanzanian

Department of Antiquities, the exception being the electronic data, which are only now being finalized.

The palaeoscientific study and interpretation of the hominid footprints was recognized as a critically important scientific undertaking, given the opportunity provided by re-excavation of the trackway for conservation. In 1995, the GCI commissioned a status report on the trackway to assist the team in assessing significance and understanding outstanding research questions.[1] Restudy of the trackway, however, was explicitly outside the intent and scope of the GCI project, which was the conservation and documentation of the trackway, not its interpretation. For this reason, the palaeoscientists conducted their study (morphological description, microstratigraphy and gait) under separate permit from the Department of Antiquities. The obligation of the GCI toward this study has been, and will remain, that of facilitation and providing access to all data; publication of the results is the responsibility of the palaeoscientists.

Tanzanian collaboration in the project must be acknowledged. Officials from the Ministry of Education and Culture and the Ngorongoro Conservation Area Authority (NCAA) participated in the Consultative Committee, and staff of the Department of Antiquities and the National Museums of Tanzania were involved in planning and fieldwork throughout the project. After a difficult beginning, a result of opposition within Tanzania and which included a number of members of the international scientific community, the project developed well under a formal agreement signed in June 1994 between the GCI and the Tanzanian government. As is always the case, the work ultimately succeeded owing to the good personal and professional relationships that developed. In particular, Donatius Kamamba provided the leadership, example and support from the Department of Antiquities without which the collaboration could not have prospered. During the course of the project relationships with the local communities of Esere and Endulen were assisted and fostered by village officials, the local NCAA coordinator and significantly, by the spiritual leader (*Oloiboni*) of the

[1] Lovejoy, C. Owen, with Carrie A. Kelly (1995). The Laetoli Footprints: A Review of their Scientific Status in 1995.

Maasai people of the region who conducted two blessing ceremonies at the site. We are proud that the joint team, through regular communication and meetings at all levels, built such good and supportive relationships.

It is certain that the trackway would eventually have been destroyed by the growth of the acacia trees, particularly the large and vigorous *Acacia seyal* introduced by seeds with the 1978-79 reburial fill brought to the site from the Garusi riverbed. Growth of this species to a height of 2-3m over the period of about 12 years is far more rapid than that of the small, ubiquitous *Acacia drepanolobium*. The project was thus timely, and though hominid prints were damaged where the Footprint Tuff was weathered, allowing easy penetration of roots, it was fortunate that in the best preserved southern sector of the trackway little root damage occurred.

While not fully realized at the outset, the project was also timely with regard to the detrimental impact of poor site drainage and erosion on the 1978 reburial of the northern sector. The consequence of erosion - most likely exacerbated by disturbance to the reburial mound after 1979 - was the loss of the two most northerly prints (G1-1 and G2/3-1). This was the single most significant change in the condition of the trackway over the 15 years of reburial.

More insidious was the continued weathering of the northern sector tuff since reburial in 1978. Print G1-19, one of the best defined prints in the northern sector in 1978, was most impacted by severe weathering, but other prints in the north were also affected, though to a lesser extent. Already heavily weathered when excavated in 1978, due to the thin overburden of soil, weathering of the tuff continued under the shallow 1978 reburial mound. Wetting and drying cycles on a seasonal basis, it is believed, were the principal cause of the continued weathering. This may be readily understood from an examination of the site drainage in the northern sector. When the northern sector was reburied in 1978, the mound partially dammed surface run-off on the eastern side. Sub-surface seepage from this low-lying area through the mound to the NW gully created saturated conditions, which dried rapidly and thoroughly after every rainfall due to the shallow 1978 reburial.

The shallow reburial of the northern sector also resulted in the trackway surface being within the root zone of grasses and perennials, which was a contributory cause of continued weathering. Seasonal vegetation of this kind, which generates extensive, fine root growth, undoubtedly contributed to biochemical conversion of tuff minerals into clays. It is significant that the heavily weathered strip of tuff in the southern sector did not undergo further weathering between 1979 and 1995 since it was buried more deeply and was, therefore, not so subject to frequent wetting and drying cycles, nor to the impact of extensive networks of rootlets.

The difference in preservation between the southern and northern sectors of the trackway surface and consequently the definition of individual prints in these areas is difficult to convey in words and can be difficult to interpret in photographs. The photogrammetric contour plans of the trackway sectors, which objectively capture the topography of the trackway and prints, provide another graphic tool for visualizing these differences at the scale of the entire trackway. The photogrammetric plans of the two trackway sectors reveal clearly – even at 5cm contour intervals - the weathered areas and the fractured and uneven surface with the lack of definition of the shallow underprints of the northern sector as compared with the smooth, gently sloping, surface of the well preserved part of the southern trackway with its defined prints.

In summarizing the problems with the 1978 burial of the northern sector, it is clear that three distinct issues may be identified. These were the introduction of acacia seeds with the fill (which was true also of the southern sector); absence of site drainage, with consequent erosional loss of two prints; and shallow reburial, which with both cycles of rapid wetting and drying and annual root growth led to continued weathering. Each of these has been addressed in the 1995-1996 reburial of the trackway.

The reburial monitoring trench at Test Site 3 will allow future assessment of the trackway condition without having to disturb the trackway itself. We view this as an innovative and important aspect of the project. In 1997, two years after the instatement of the monitoring reburial, a section was opened for examination of the test samples. As discussed in this report, the results are satisfactory, though the saturated moisture conditions in the trench presented a far more aggressive environment with regard to deterioration of organic materials than those in the trackway reburial itself. As recommended in Part XII, further examination of the monitoring reburial should be undertaken at the ten-year mark (i.e. 2005), mid-way to the estimated end of the effective life of the Biobarrier, which based on results obtained in 1997 is 20 years.

A statement of singular importance must once again be made here: for the Laetoli trackway to survive the site must be regularly monitored for condition and maintained to prevent re-vegetation and erosion. A detailed, yet straightforward monitoring and maintenance plan has been designed and tested. Staff of the Antiquities Department based at Olduvai have been trained in the application of the plan and will be responsible for its implementation. It must not be forgotten that for want of the most minimal effort and cost the trackway was placed in jeopardy. Annual removal of acacia seedlings after reburial in 1979, with attention to the integrity of the reburial mound, would have obviated the need for this long and costly conservation project and prevented the damage and loss that has occurred.

Security at the site is no less important. We know of disturbances to the site between campaigns, prior to the ceremonies held by the *Oloiboni* in 1995 and 1996. Responsibility for interference with work on the site was never satisfactorily explained. It may have been due to casual curiosity of local people. More serious was evidence of disturbance to the reburial mound at the northern end of the trackway. This apparently occurred sometime between 1979 and 1992, and contributed to loss through erosion of two hominid prints. To prevent recurrence, two permanent site guards from the local community have been appointed and trained in their duties by the Department of Antiquities.

In closing, it is worth emphasizing that this complex yet fascinating and challenging conservation project was much more than a technical intervention whose aim was to remove the threats to the site of vegetation and erosion and to conserve and document the trackway. As the project unfolded, the need for community participation and education became ever more apparent. The responsibility for the educational aspects of the project, both at the local school level and at the Olduvai Museum also was seen as an obligation of the GCI partnership with the Tanzanian authorities. Throughout the project training in various ways was incorporated into the work. This involved technician training for Tanzanian staff in molding and casting, including advanced training in the United States. On-site training through participation occurred in documentation and condition recording and the methodology of hands-on conservation work. We have addressed the many and varied issues pertaining to the conservation of the hominid trackway at Site G in innovative and thoroughly documented ways and are confident that this record of early bipedalism that has survived an astonishing 3.6 million years will be saved for the future.

PART XV. THE LAETOLI PROJECT BIBLIOGRAPHY

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Compiled by Linda Kincheloe

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Microstratigraphy and Taphonomy of Hominid Footprints at Laetoli, Tanzania

Second Season, 1996

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Report PRL 96.5

Microstratigraphy and Taphonomy of Hominid Footprints at Laetoli, Tanzania Second Season, 1996

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Abstract: Field work on the northern part of the Laetoli Site G hominid trackway this season centered on microstratigraphic problems associated with the relatively poor condition of the tuff surface there. Twenty-two hominid tracks were investigated. A few are preserved as primary impressions on the footprint surface, Horizon B, but most are undertracks preserved in one or (commonly) more than one of the underlying strata. These latter impressions record general aspects of pedal morphology but are unsuitable for any metric analysis. The northern portion of the trackway does, however, preserve interesting variations in the gait of the three hominid trace-makers. Overall, the Footprint Tuff in the northern area is rather poorly preserved. This is most likely due to a longer residence time in the near-surface environment prior to discovery, and to the effects of incipient pedogenesis on the tuff.

Geological investigations of the northern section of the Laetoli hominid trackway at Site G were undertaken over the period 4 - 10 August, 1996. This portion of the trackway, first excavated in 1978, presented a very different set of problems from those encountered on the southern sector in 1995. As a result, observations this season relate primarily to the microstratigraphic sequence and variable preservation of individual tracks, along with aspects of locomotion along the trail studied in conjunction with Dr. Bruce Latimer (Cleveland Museum of Natural History).

The surface of the trackway studied in 1996 presented two obstacles to study. Weathering and embedding of fill material in the tuff surface obscured many features, and small scale structural disruption or discontinuities in the surface complicated elucidation of stratigraphic relationships. In view of the importance of preserving the original trackway surface, the excavators and conservators were forced to leave areas of weathered tuff, or tuff with embedded backfill, and this made identification of the character and sequence of strata very difficult in some cases.

The northern section of the Site G trackway is strongly jointed in a NNE (primary) and WSW (secondary) rectilinear fashion. Joint spacing varies from 10-20 cm in the most heavily fractured areas to ca. 0.5 - 1 m in less disturbed regions. The blocks of Footprint Tuff and underlying aeolian tuff resulting from this jointing have been variably displaced. Settling and slumping of the blocks is most pronounced near the margins of the NW gully, where associated blocks have been displaced by 30 - 40 cm.

On the trackway surface, slumped blocks are typically offset by only a few centimeters. Some heaving of blocks upward, presumably due to expansion of underlying smectitic clays in the wet season, has also occurred.

In addition to the pervasive but low amplitude disruption of the trackway surface along joints, three minor faults offset the Footprint Tuff in the northern area. These faults are highly irregular in trace, cutting diagonally across the line of the prints. They have been numbered sequentially from north to south Faults 1, 2 and 3 (White, 1978). Fault 1 and Fault 2 drop a narrow block, termed the graben, down relative to the surfaces north and south of it. Fault 3 repeats the offset of Fault 2 , with a second raised block to the south of it being the primary trackway surface investigated in the southern sector in 1995. A N - S cross-section is sketched in Figure 1 to illustrate these relationships.

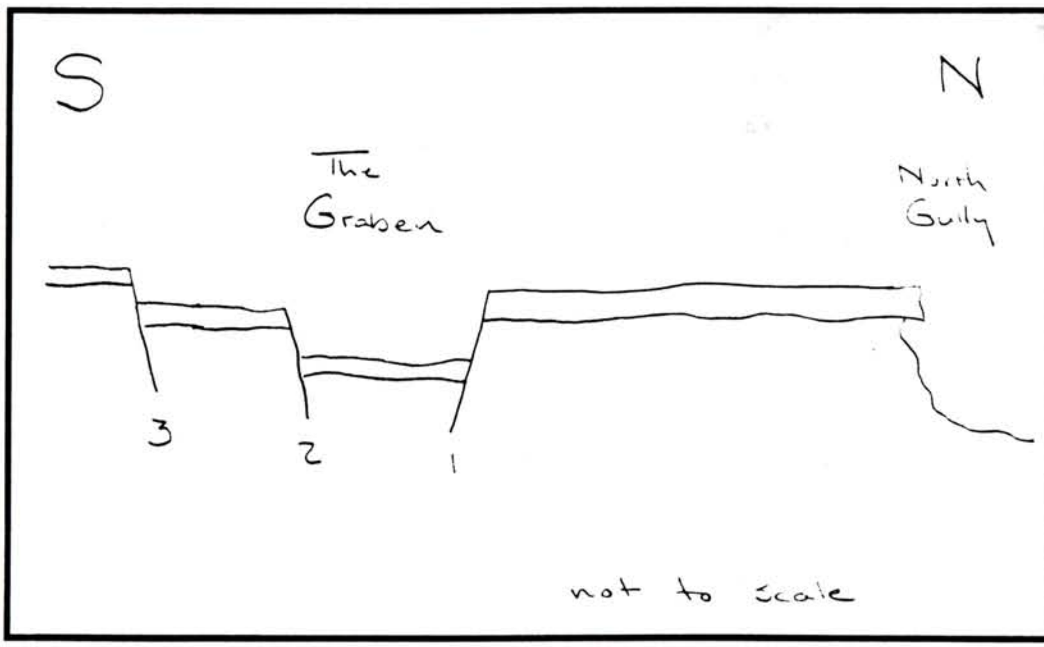

Figure 1. Sketch N-S Cross-Section of the Northern Sector of the Site G Hominid Trackway.

A total of forty-one hominid prints have been reported from the northern sector of the Site G trackway. Of these, twenty-two were recognizable and were investigated for both features and context this season. Fifteen of the reported prints could not be relocated with certainty, or else the reported position revealed no features clearly identifiable as impressions. Two of the prints had not been excavated in the 1978 season, and were left unexcavated. No trace could be found of the two northernmost prints, G1-1 and G2/3-1. The area where these prints should have been was heavily weathered and eroded, and it appears these prints were lost. The recognizable prints and features of the exposed trackway surface were investigated in detail to document the stratigraphic context of the preserved tracks and to identify and interpret features seen on extant photos and casts.

Microstratigraphy

The sequence and characteristics of strata associated with the Footprint Tuff as reported by Hay (1987; Hay and Leakey, 1982) are shown schematically in Figure 2. All of the components of Hay's sequence were recognized in an outcrop SE of the trackway in 1995, and this scheme fit with features observed on the southern sector of the trackway in that year. Details of the northern sector of the trackway were more difficult to reconcile with Hay's sequence, however, and the extensive but poor quality exposure presented by the surface this year required some modification of terminology. Four characteristics of the strata in this interval are most useful for field recognition and characterization. Color is useful in a few cases, especially where superposed strata contrast (e.g. the gray U1 over the cream colored L14). Texture (particle size) generally varies over a narrow range (very fine to fine sand), but again contrast between successive strata may be apparent. Fabric, particularly the presence or absence of burrows or tunnels and their size and density, is a key diagnostic character. Finally, sequence can be used in confirming the identity of particular strata where exposure allows.

The Augite Biotite Tuff and the upper layers (4, 3, +/- 2) of the Upper Unit of the Footprint Tuff were not encountered in the study area this season, presumably due largely to their excavation and removal in 1978. The basal layer of the Upper Unit, termed U1, is clearly recognizable in several areas, based on stratigraphic position, gray color, and its massive, relatively coarse-grained appearance. High relief tunnels on the surface of L14 locally protrude through this layer (these tunnels show the slightly finer texture and cream color of L14). The succeeding stratum, U2, may also be present locally, but if so is indistinguishable from U1.

The uppermost layer of the Lower Unit, L14, and its footprinted upper surface, Horizon B, are easily recognized. L14 is the only stratum within the Footprint Tuff which has a distinctive cream or off-white color. It is also relatively coarse-grained, and typically has both a macro- and micro-scale bioturbated fabric, with a dense network of intertwining burrows within the layer, and localized tunnels running on its surface. The U1/L14 couplet is the most easily recognized part of the sequence in the study area.

Field work in 1995 showed that the thin layer Hay termed L13 is commonly bioturbated along with L14, and is only rarely seen as a discrete stratum in the area of the trackway. Based on this observation and the apparent lack of a thin (0.3 cm) stratum at the base of L14, this layer was skipped in sequence counting downward from L14. The

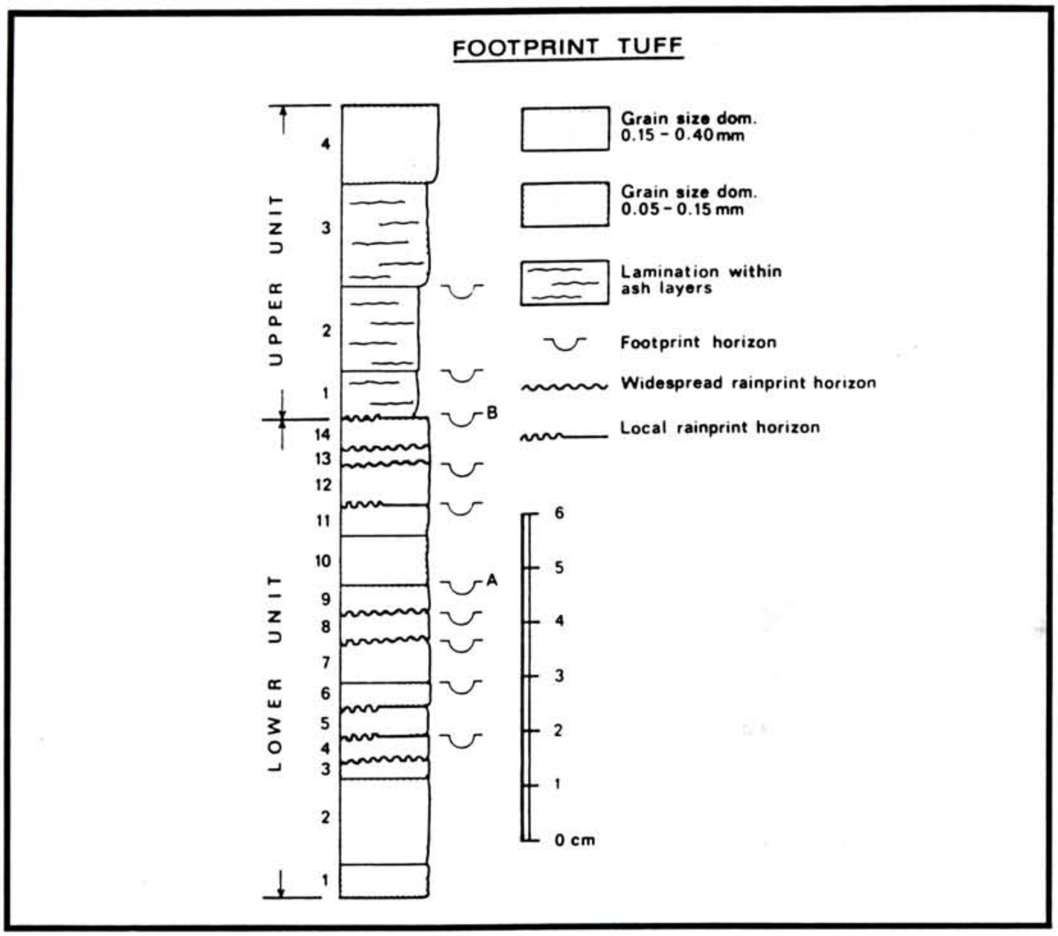

Figure 2. Schematic Diagram of Microstratigraphy of the Site G Trackway (from Hay, 1987).

underlying stratum observed here is typically thick (7 - 8 mm), gray, massive and very poorly consolidated. This layer was assigned to L12. It does not form any extensive surfaces on the trackway.

The prominent surface formed of strata below L12 is made up of a distinctive couplet. The upper layer is thin (ca. 0.3 cm), massive, fine and pale gray. It is here assigned to layer L11. It occurs as discontinuous patches on the surface of the more extensive underlying stratum. This layer, here L10, is indistinguishable from L11 in terms of color and texture, but has a moderately bioturbated fabric. Burrows are not as dense as in L14, but are otherwise similar. Prominent tunnels occur on the surface of L10 and commonly protrude through L11, or have eroded to leave tunnel-form grooves in L11. The surface of L10 is finely punctate in an irregular fashion. This feature is reminiscent of rainprints, but differs from the unquestioned rainprint surfaces seem elsewhere. This may reflect a detail of the burrowed fabric characteristic of this layer, or a different form of preservation of rainprints.

A few small surfaces stratigraphically below L10 are assigned to L9. This appears to be a massive, fine, light gray layer. It was not studied in detail. In the heavily eroded areas of the trackway, strata down to about the level of the aeolian tuff are exposed. However, due to heavy weathering and embedding of fill in these areas it was not possible to unambiguously identify or characterize strata lower in the sequence.

Taphonomy

While the hominid footprints in the southern sector, studied in 1995, presented an almost unbroken series preserved on Horizon B, the surface of L14, this was definitely not the case with the prints investigated this season. Of the twenty-four prints still recognizable, only six were preserved on L14, or had some portion of the track at that level. Investigation of the northern trackway features thus requires a careful consideration of the effects of erosion and excavation on apparent morphology, as most of the features seen here represent undertracks rather than the original imprint surface.

The heavily eroded character of much of the northern trackway surface, combined with the weathered and embedded nature of the tuff itself, made positive identification of individual layers of the Footprint Tuff impossible in many areas. Certain generalizations about the undertracks and aspects of the more prominent surfaces can be made, however. The primary impressions, made in L14, show most of the anatomical features associated with pedal morphology - a deep heel impression, positive arch, large impression for the first digit and lesser impression for the others, and often a well-defined metatarsal break. These features are variably preserved, even in L14, with the most prominent features occurring more often than the subtle ones. In addition to the anatomical features, several characteristics imparted at a later time, particularly burrowing overprints, are clearly recognizable as well. Undertracks, even those as deep as L6, are easily recognized as footprints, and their overall shape and position can be used to identify them as part of the hominid trails. Undertracks preserved in the upper strata of the Lower Unit may preserve the characteristic deep heel strike and toe-off features, and thus could be inferred to be of likely hominid origin even if they were not in context with better prints. Many of the impressions in the northern area, however, would be very problematic if found in isolation.

The poor condition of the Footprint Tuff in the northern area, which contrasts sharply with the excellent preservation seen in the south in 1995, appears to be primarily the result of weathering and incipient soil formation (pedogenesis). Although there is little direct record of the amount of overlying material excavated from this part of the trackway in 1978, the descriptions of the excavation in that year and the condition of the tuff seen this season show that weathering and fragmentation were well underway when the northern tracks were first uncovered. Relative to photographs and casts made in 1978, the tracks had not changed significantly. This is remarkable considering the poor condition of the tuff overall, and reflects the extreme care taken throughout the re-excavation.

Acknowledgments

I thank the Government of Tanzania and its Antiquities Unit for the invitation to join the scientific restudy at Laetoli. Participation in this project was made possible by the L. S. B. Leakey Foundation and the Koobi Fora Field School (Harvard University and the National Museums of Kenya), who funded my travel. The success of this study is largely due to the strong support provided by the Getty Conservation Institute. The extreme professionalism of their team was an inspiration, and permitted me to accomplish much in a short period of time. In particular, I thank Neville Agnew, Martha Demas and Angelyn Bass for their patience, encouragement and support throughout the project.

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Report PRL 96.5

PHOTOGRAPHS

1. General view of site looking northwest; white shelter at center marks the trackway.

2. 1978 photo of northern sector; black sand has been placed in the footprints (Photograph by J. Reader).

3. 1996 photo of northern sector; cotton sand bags have been placed in the footprints.

4. The 20 meters of excavated trackway in 1996 after completion of conservation; looking north.

5. General view of excavations in 1978; southern sector of trackway in lower half of photo with continuation of hominid trail in the trench to the right. (Photograph by T. White).

6. Northern and middle sectors of trackway prior to clearing vegetation; looking north.

7. Northern and middle sectors of trackway after initial clearing of vegetation and removal of boulders; looking north.

8. Northern and middle sectors of trackway after surface cleaning of reburial mound; looking north.

9. Northern and middle sectors of trackway with edge of graben just exposed and remaining baulk still in place north of graben; looking north.

10. Northern sector of trackway excavated to tuff level north of graben, which is only partially excavated; looking north.

11. Northern sector of trackway fully excavated, with cotton sand bags placed in footprints; looking north.

12. Middle sector of trackway showing profile of reburial layers from boulder capping (bottom) to Layer 2 (top); northern sector lies under shelter.

13. The 20 meters of trackway after final reburial and capping; looking north.

14. Northern sector of trackway with E-W transect excavated down to tuff and stumps *in situ*; looking south.

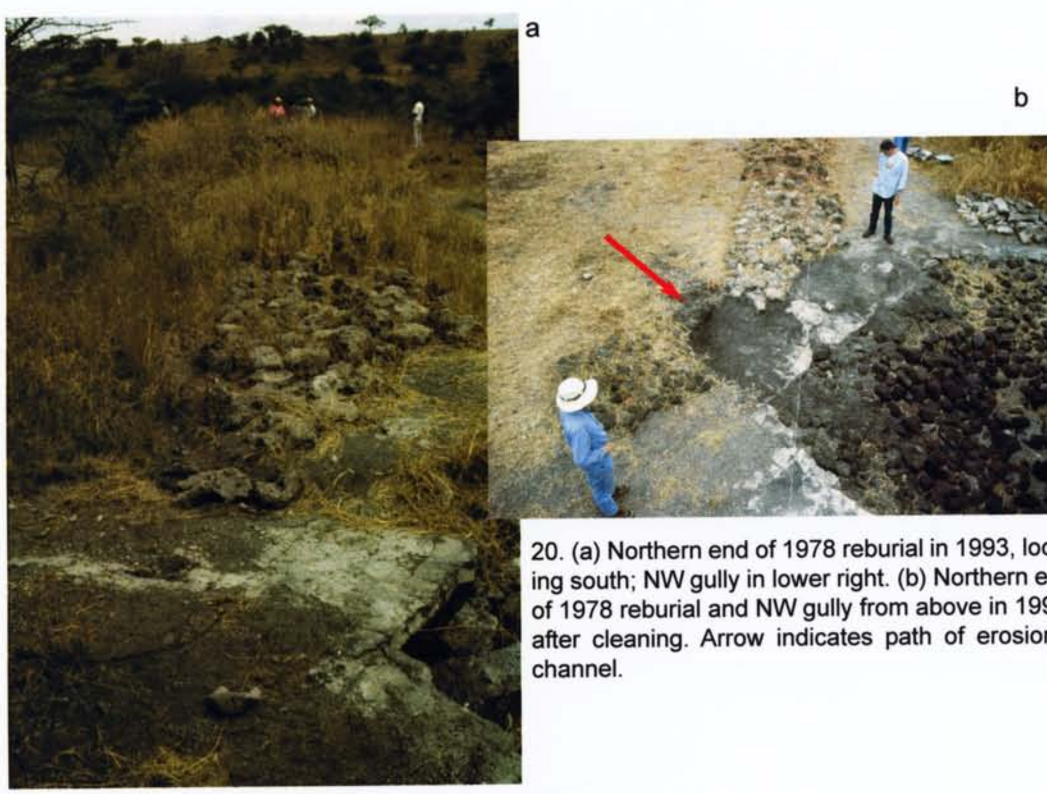
15. Excavation of northern sector; edge of graben defined in foreground and tree stumps around graben still *in situ*; looking north.

16. Print G1-22 in graben with copy of 1978 cast.

17. The northernmost section of southern sector (with kneeling figure), slope of Fault 3 with island of tuff at base; sand bags cover prints G1-24 and G2/3-15, 16, 17; looking south

18. Island of tuff in middle sector with prints G1-24 (left) and G2/3-17 (right).

19. Erosional channel at northern end of trackway; from ground-level, looking east to trench wall. Scale lies in the erosional channel.



a

b

20. (a) Northern end of 1978 reburial in 1993, looking south; NW gully in lower right. (b) Northern end of 1978 reburial and NW gully from above in 1996, after cleaning. Arrow indicates path of erosional channel.

21. Northern end of trackway with corresponding 1978 cast of prints G1-1, 2, 3 and G2/3-1, 2, 3. Area of loss of G1-1 and G2/3-1 is upper left part of photo where fragments of whitish tuff are floating. Footprints defined (red tape) but with fill still *in situ*.

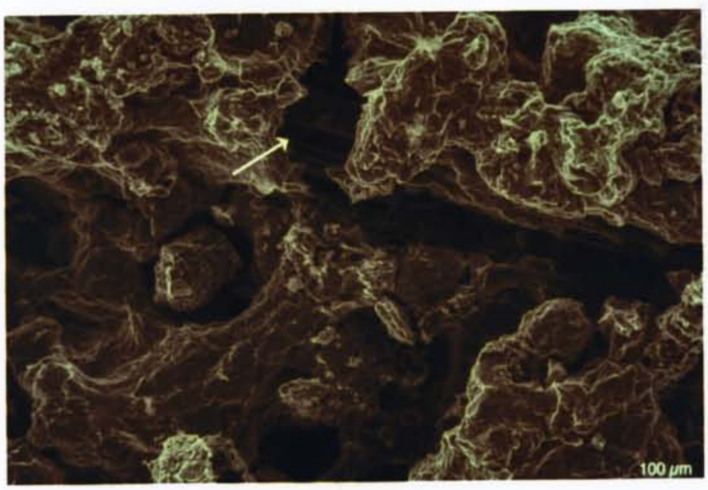
a

b

22. (a) Conservators cleaning prints; (b) Fill excavated from print G2/3-9, showing typical range of particle sizes in overburden.

23. Conservators marking localized areas of tuff on the northern sector requiring treatment.

24. Acacia tree and asparagus roots growing in the shallow reburial fill.



25. SEM (scanning electron microscope) image of rootlet penetrating footprint tuff (indicated by arrow).

26. Conservators cutting *Acacia mellifera* no. 54 located at the southern edge of the graben.

27. Irregular topography of the weathered tuff in the northern sector as seen from ground level.

28. Close-up of fractured tuff in the northern part of the southern sector (Trench 4).

29. Roots from an acacia tree outside the excavated area following cracks in tuff surface.

30. Detail of typical cracking pattern and embedding of sand in weathered tuff of northern sector.

31. Insect casing and larva of cut-worm found in the tuff of the northern sector.

32. Print G2/3-9 as excavated in 1978.(Photograph by P. Jones)

33. Print G2/3-9 as excavated in 1996.

34. Print G1-2 as excavated in 1978. (Photograph by T. White)

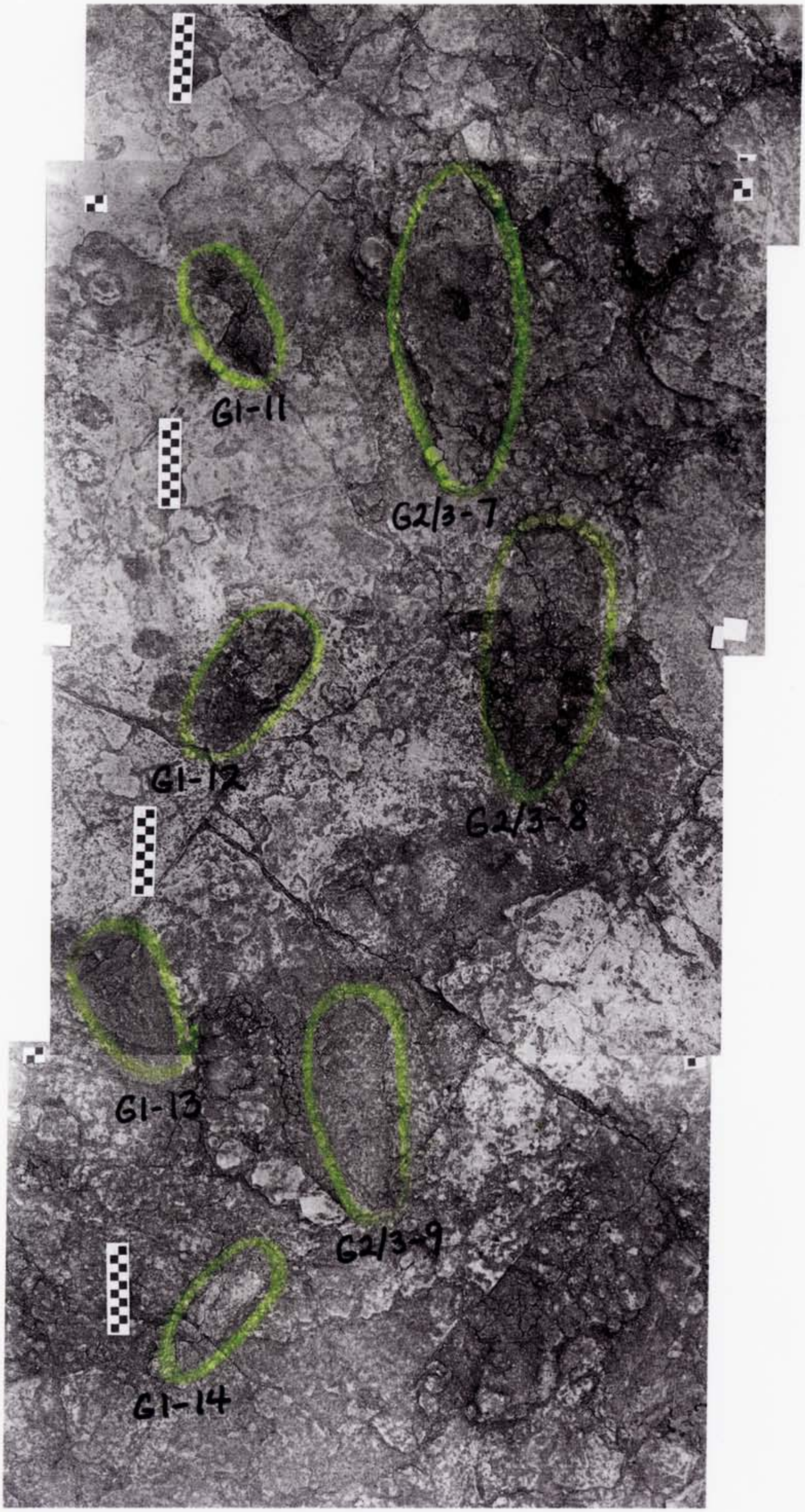
35. Print G1-2 as excavated in 1996.

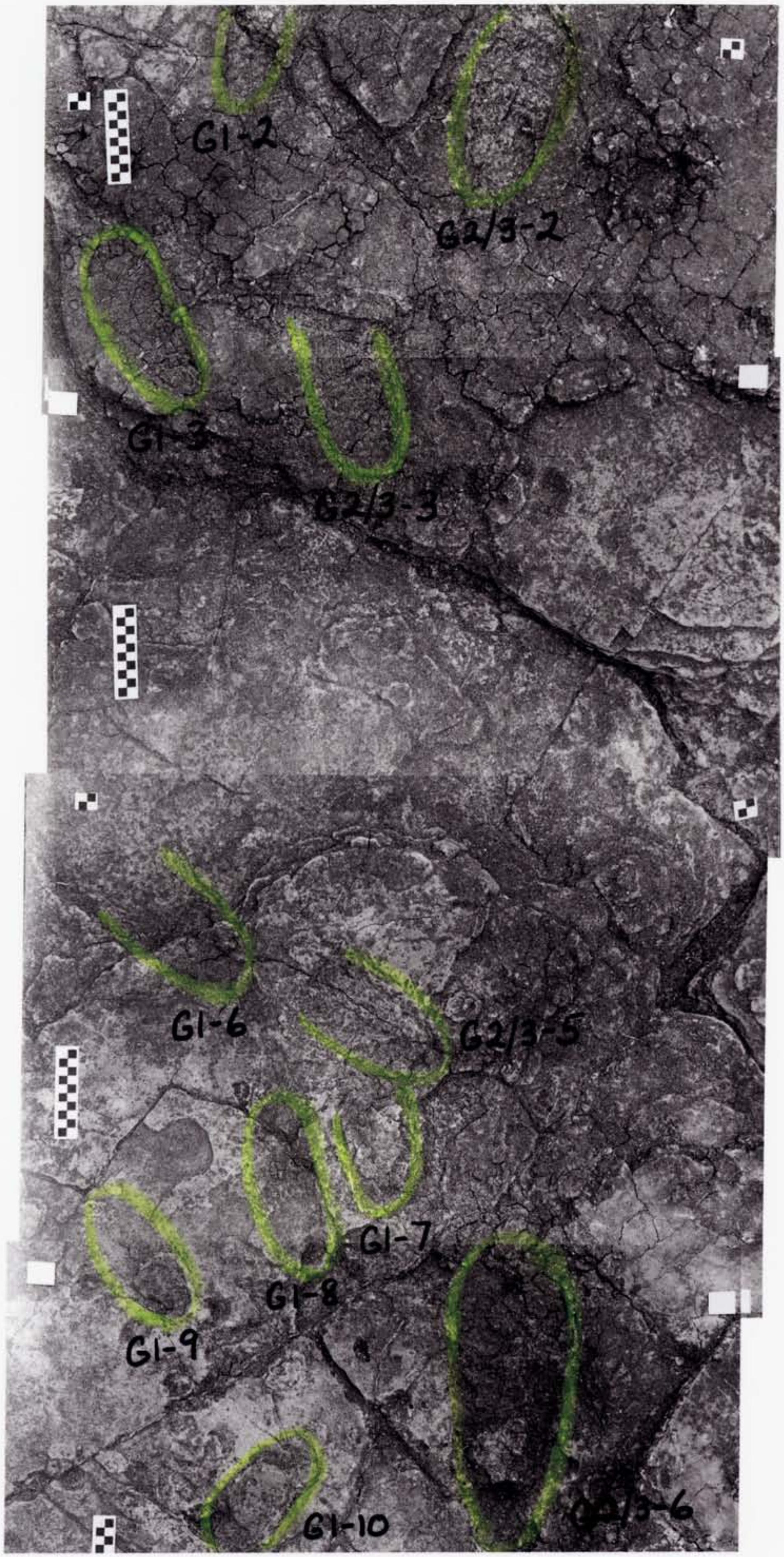
36. Print G1-19 as excavated in 1978. (Photograph by T. White)

37. Print G1-19 as excavated in 1996 showing cracking of weathered tuff and penetration by an acacia root.

38. (a) Unexcavated print G1-23 in the graben. (b) The graben, showing irregular topography.

39. Close-up of the hominid trail from G1-11 (top) through G1-14 (bottom) on the left and G2/3-7 through G2/3-9 on the right.


G1-11
G2/3-7
G1-12
G2/3-8
G1-13
G2/3-9
G1-14


G1-2
G2/3-2
G1-3
G2/3-3
G1-6
G2/3-5
G1-7
G1-8
G1-9
G1-10
G2/3-6

41. Stumps of *Acacia seyal* (nos. 56 and 57) at edge of graben trench.

42. Stump killed with herbicide but not treated with PCP, showing evidence of termite galleries and rot.

43. Stump tested off-site for efficacy of PCP treatment in preserving wood.

44. Solution of PCP being applied to stump by dropping-pipette.

45. Extensive growth of vegetation, both grasses and acacia trees, in low-lying area east of the northern part of 1978 reburial mound, as seen in 1994.

46. Sump with grate and drainage channel associated with Berm 4, looking west.

47. Site drainage control after completion: Berm 4 is in the center with Berm 2 on the left and Berm 3 on the right; looking west.

48. West gully (foreground) after stabilization, with reburied trackway in center and Berm 3 beyond.

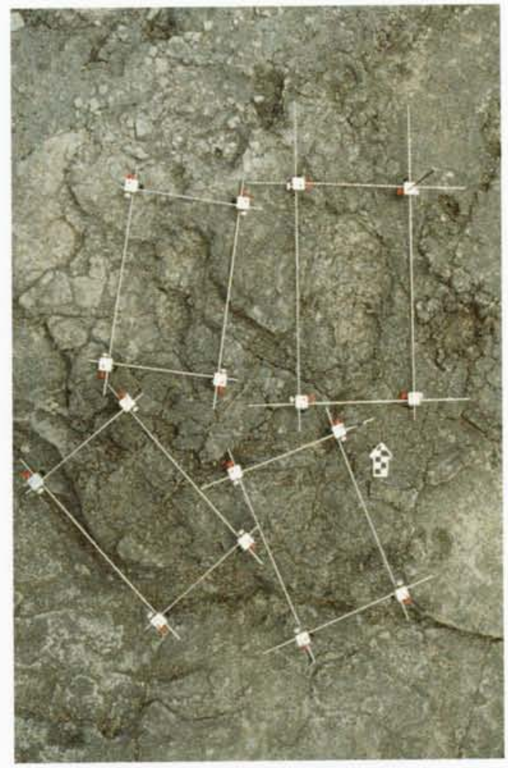
a

b

c

49. (a) Northern sector of reburied trackway in 1997 with low-lying area to the east (right) of the reburial mound, prior to intervention.
(b) Low-lying area with fill of waste tuff.
(c) At completion of drainage slope away from the rebuial mound; note *Acacia mellifera* at northern end of site has been removed.

50. 8x10 Polaroid camera mounted on crossbar for condition recording photography.



51. Delineation of prints with stainless steel wire frames for condition recording photography; prints G1-2 and 3 (left) and G2/3-2 and 3 (right).

52. UMK camera on crossbar used for photogrammetric recording of the trackway and footprints.

53. Patination of section "A" cast for display in the Olduvai Museum.

54. One of the two storage shelves at Olduvai with Laetoli materials from 1978, including molds and casts.

55. Storage shelves built by Jesuit Temba for new mold and cast replicas in the National Museum, Dar es Salaam.

56. Placing the first layer of sand on the middle trackway sector.

57. Artificial silk lining in G1-19 to prevent sand infiltrating cracks.

58. Layering of reburial fill and materials on middle sector: Layer 5 (right) to Layer 2 (left); looking east.

59. Tamping Layer 5 (cotton black soil); looking east.

60. Securing strips of Enkamat over Biobarrier, prior to placing Layer 4.

61. Southern sector of reburial mound in 1996, showing one year's growth of grasses and weeds; looking north.

62. Presenting section of replica cast to Esere school teachers.

63. Site guard house on slope of the hill south of the site.

64. Local Maasai inspecting trackway after blessing ceremony.

65. Mary Leakey with Maasai women during blessing ceremony.

66. Reburial monitoring trench with indicator objects and features in place prior to burial in 1995; SE quadrant in lower right.

67. SE quadrant of the monitoring trench after excavation in 1997 and removal of wood samples and tuff blocks.

a b

68. Incised triangle in floor of trench in 1995 (a) and as revealed in 1997 (b).

69. View of the Olduvai Museum.

70. The Laetoli room before renovation, with 1980s exhibition materials. The Olduvai exhibit can be seen through the doorway.

71. The Orientation room with new exhibits on the cultural heritage of Tanzania and the Ngorongoro Conservation Area.

72. Exhibit panel on the work of Louis and Mary Leakey in the Olduvai Room.

73. Display of the geological stratigraphy and stone tool industries of Olduvai Gorge.

74. Display case 6 with replica artifacts and fossil bone in the Olduvai room.

75. Exhibition cast of the well preserved southern sector trail and artist's re-creation mural in the Laetoli room.

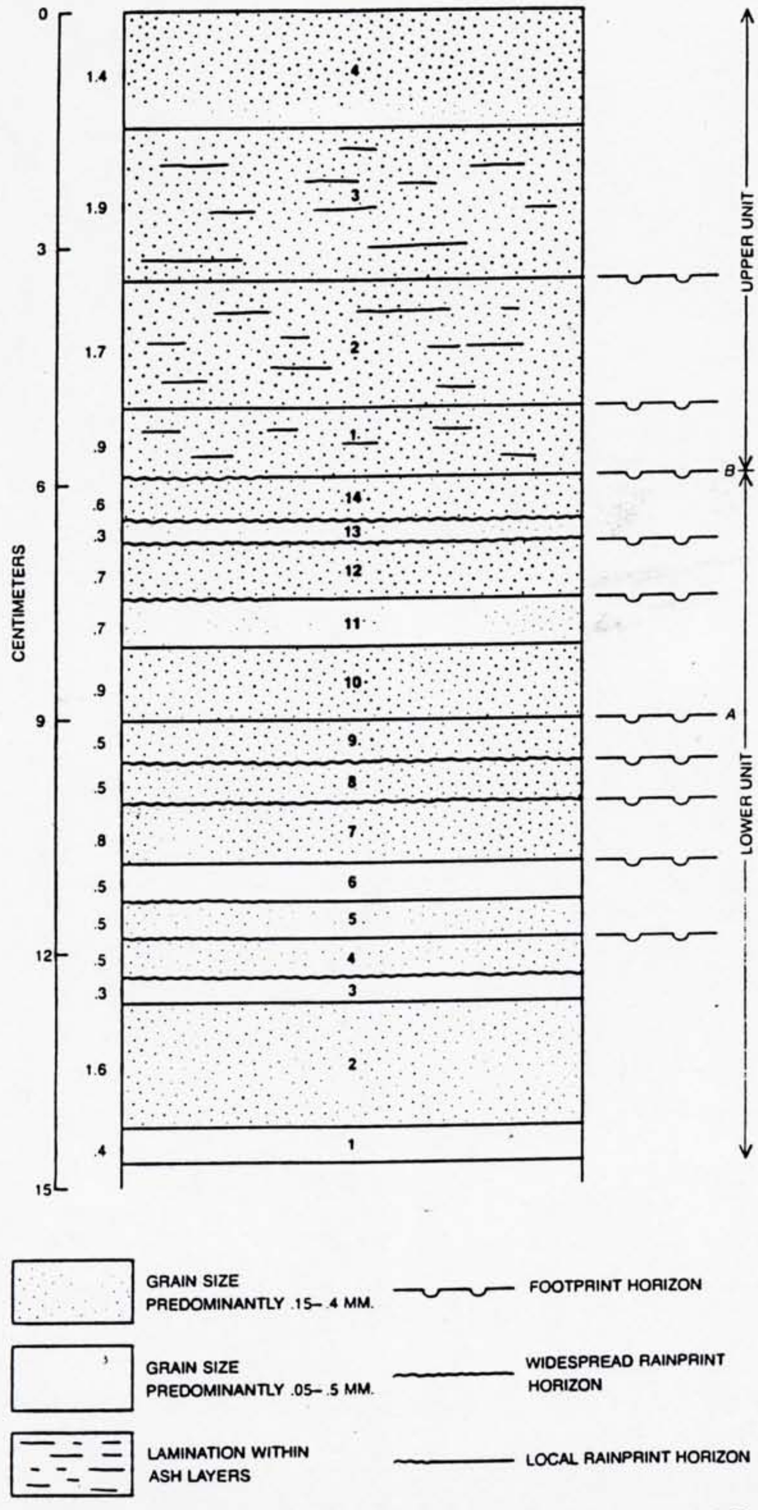
76. View of cast and other panels in the Laetoli room.

77. Donatius Kamamba (right) conducting Vice President of Tanzania through exhibit.

78. Vice President of Tanzania with Neville Agnew and local participants at the official opening ceremony.

FIGURES

Stratigraphy of Footprint Tuff

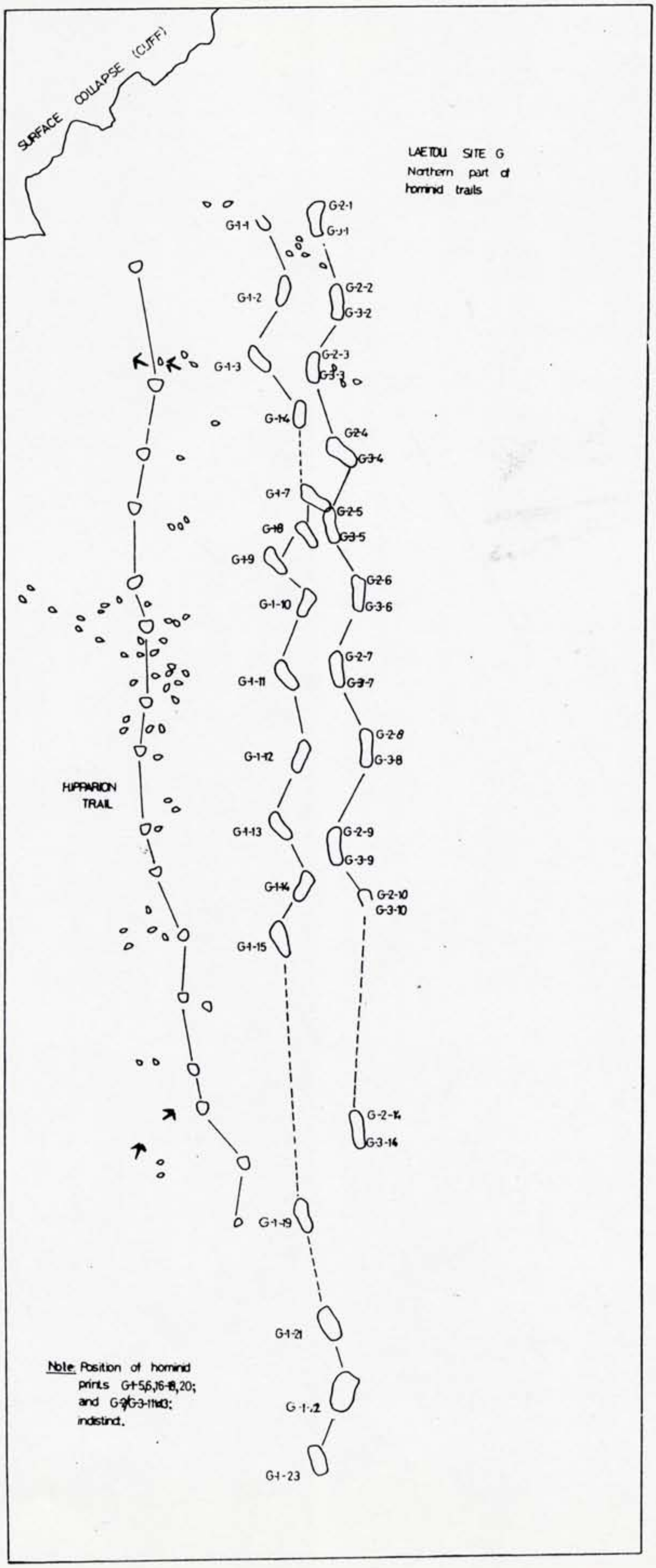


FOOTPRINT TUFF is seen in section at a point where it is almost 15 centimeters thick. Of the 14 subdivisions of the lower unit eight are imprinted with tracks; the tracks are most abundant on horizons *A* and *B*. Two of the upper-unit subdivisions also bear tracks. The hominid tracks appear on horizon *B*. Numerals indicate the average thickness of the layers at Site *A*.

From: Hay, R. L. and Leakey, M. D. 1982. The fossil footprints of Laetoli. Scientific American 246(2): 50-57.

Figure 2

Northern trackway, Day 1986



Southern trackway, Day 1986

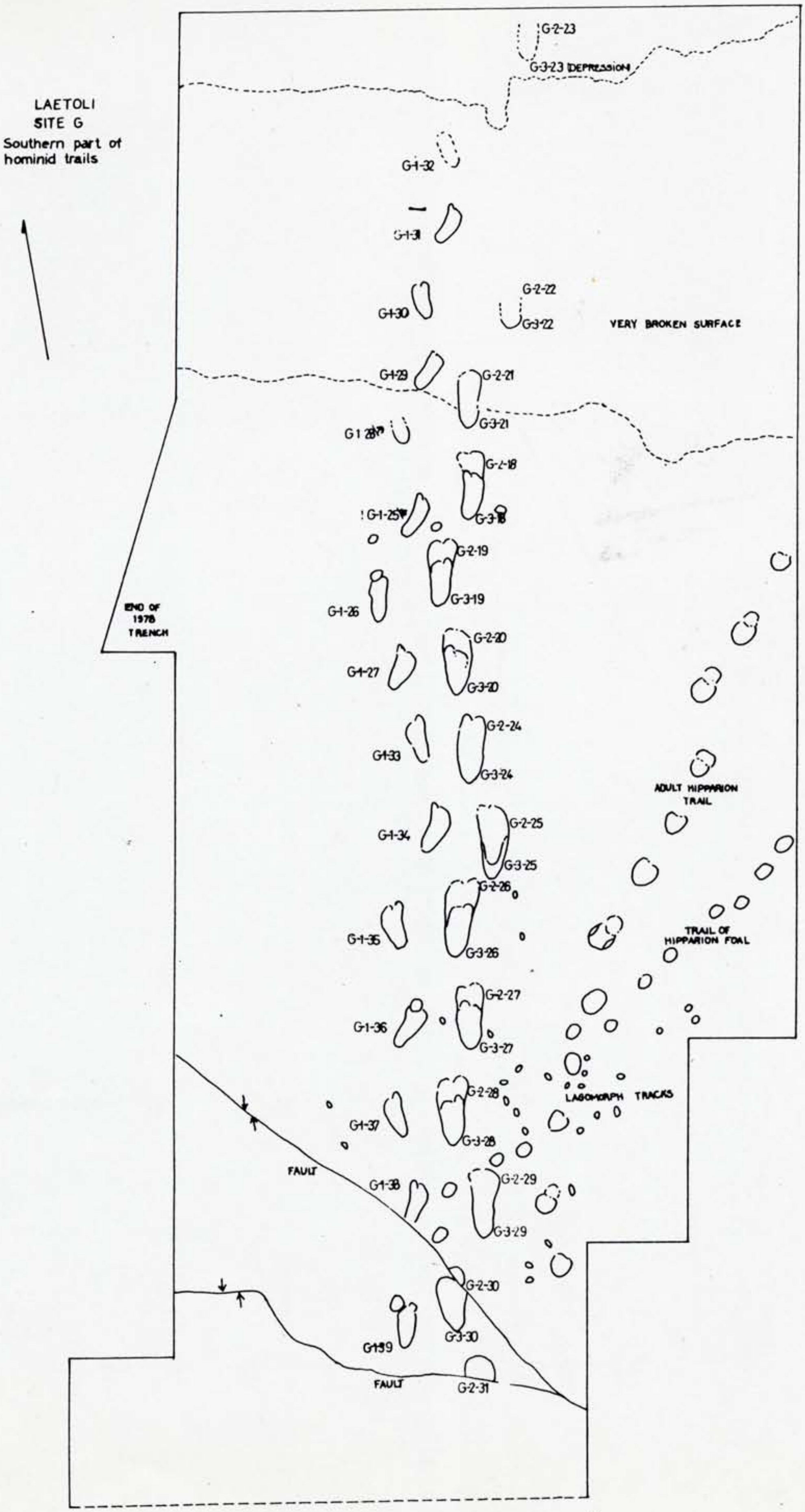
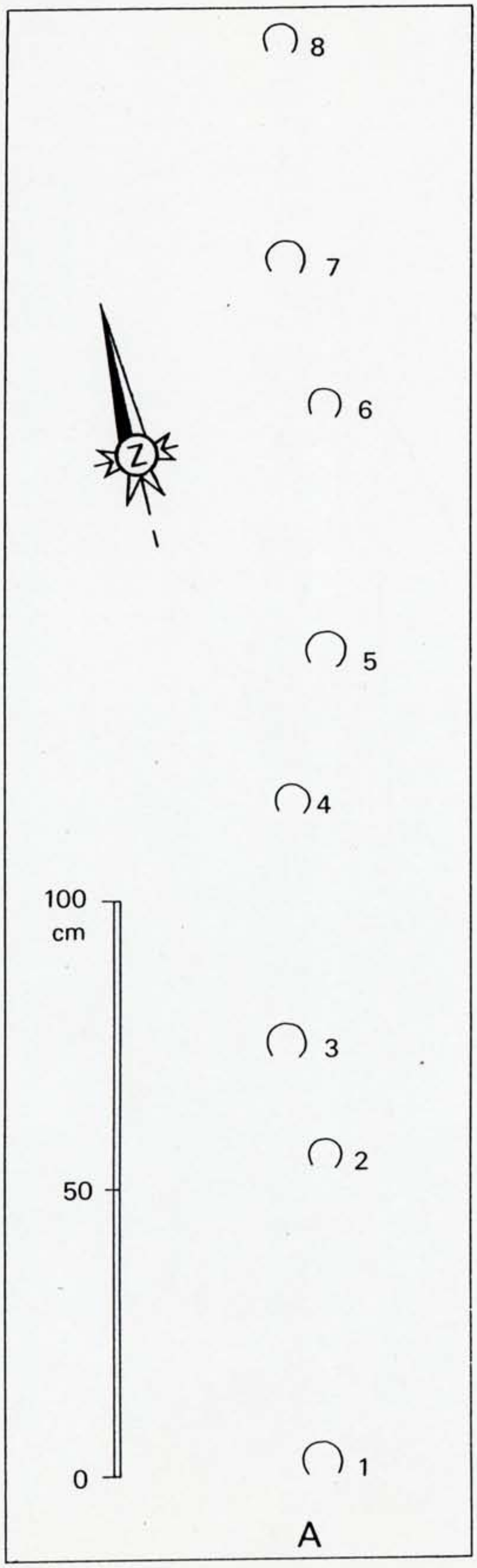
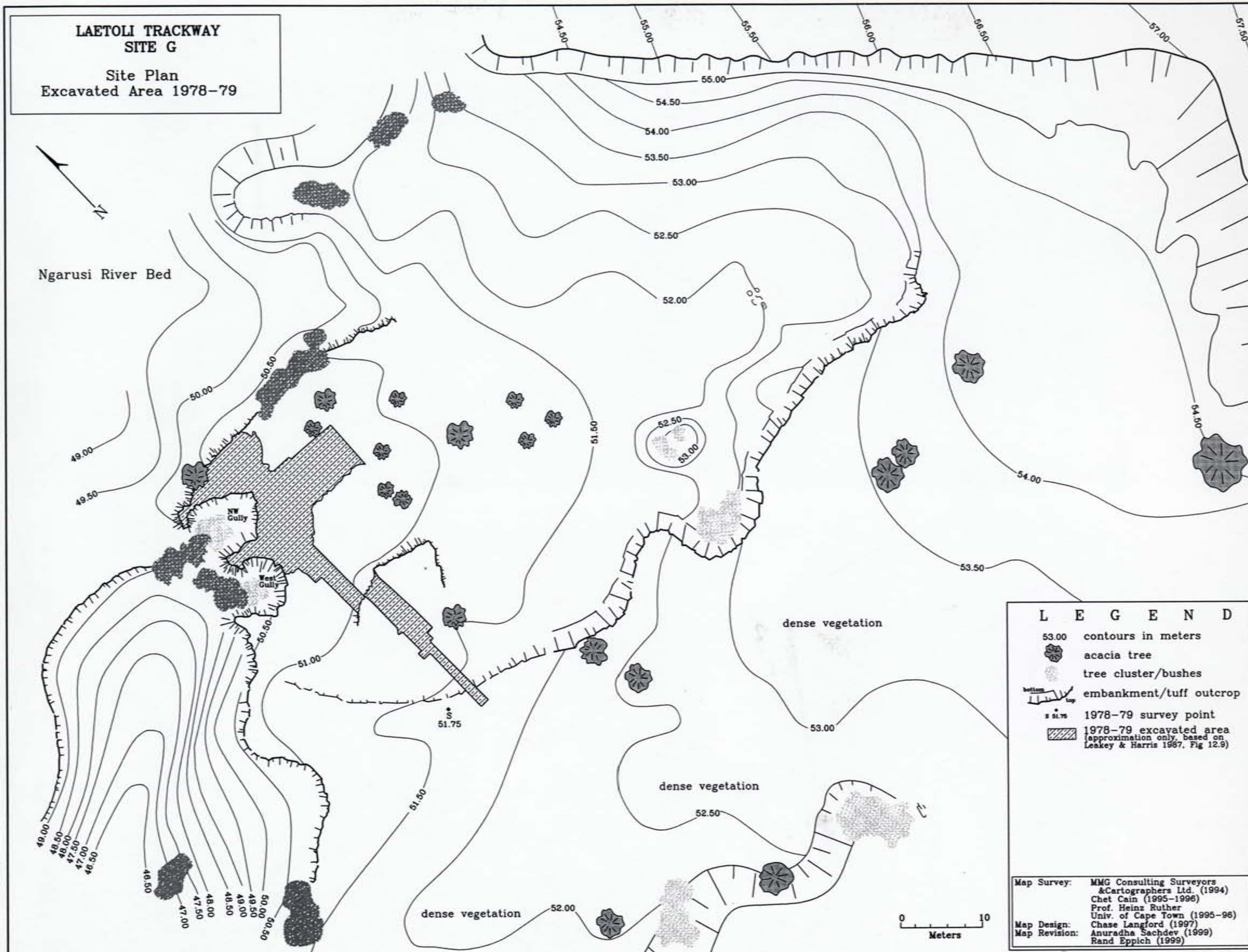


Figure 4



Plan of Hipparion trackway A from Leakey & Harris 1987, Fig. 12.16



LAETOLI TRACKWAY
SITE G
Site Plan
Excavated Area 1978-79
N
Ngarusi River Bed
NW Gully
West Gully
S
51.75
dense vegetation
dense vegetation
dense vegetation
54.50
55.00
55.50
56.00
56.50
57.00
57.50
55.00
54.50
54.00
53.50
53.00
52.50
52.00
51.50
51.00
50.50
50.00
49.50
49.00
52.50
53.00
54.50
54.00
53.50
53.00
52.50
52.00
51.50
48.50
47.00
47.50
48.00
48.50
49.00
49.50
50.00
50.50
L E G E N D
53.00 contours in meters
acacia tree
tree cluster/bushes
bottom
top
embankment/tuff outcrop
1978-79 survey point
1978-79 excavated area
(approximation only, based on Leakey & Harris 1987, Fig 12.9)
0
10
Meters
Map Survey: MMG Consulting Surveyors &Cartographers Ltd. (1994)
Chet Cain (1995-1996)
Prof. Heinz Ruther
Univ. of Cape Town (1995-96)
Map Design: Chase Langford (1997)
Map Revision: Anuradha Sachdev (1999)
Rand Eppich (1999)

Figure 5

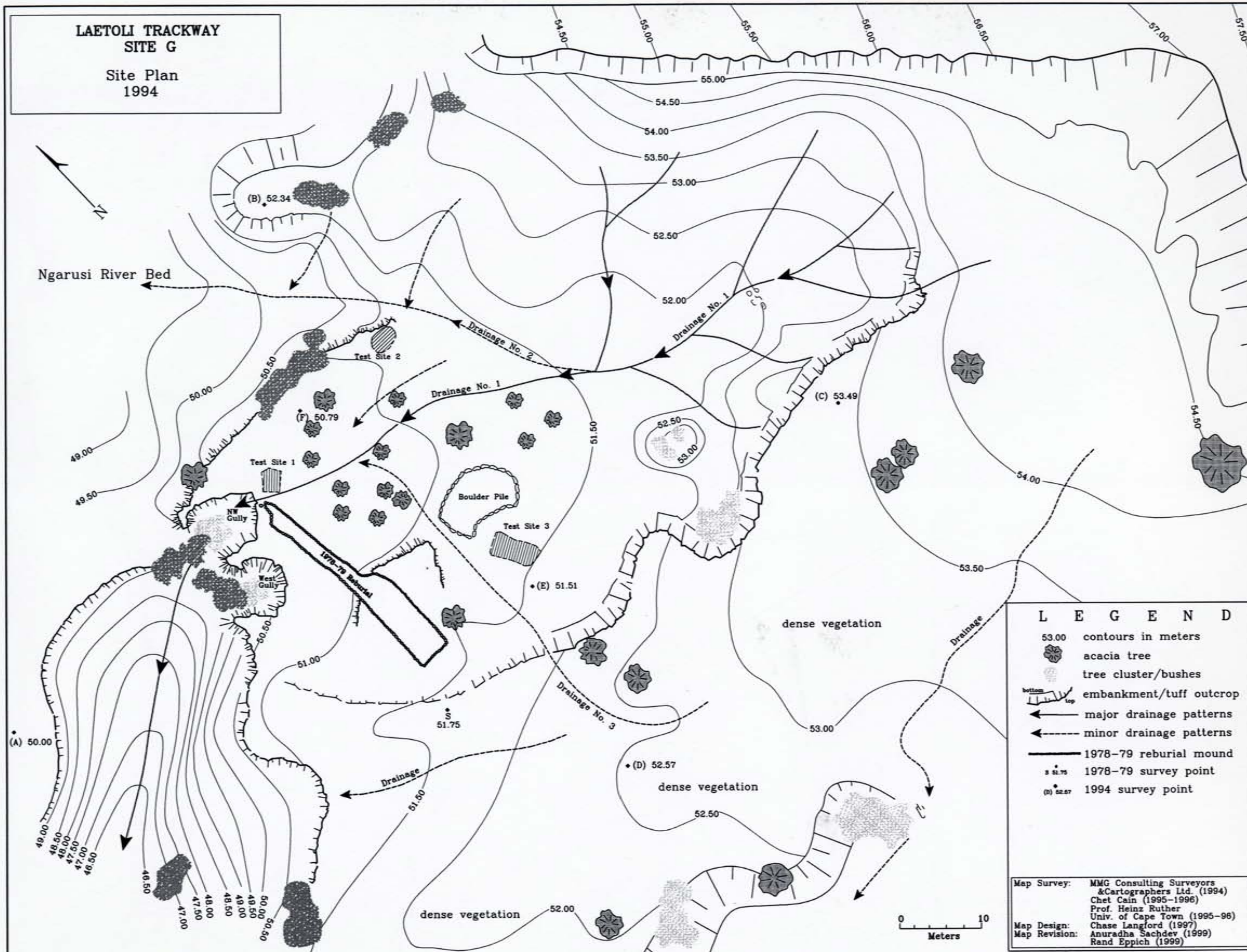

LAETOLI TRACKWAY
SITE G
Site Plan
1994
N
Ngarusi River Bed
(B) 52.34
(F) 50.79
(C) 53.49
(E) 51.51
(D) 52.57
(A) 50.00
S
51.75
Test Site 1
Test Site 2
Test Site 3
Boulder Pile
NW Gully
West Gully
1978-79 Reburial
Drainage No. 1
Drainage No. 2
Drainage No. 3
Drainage
dense vegetation
L E G E N D
53.00 contours in meters
acacia tree
tree cluster/bushes
bottom top embankment/tuff outcrop
major drainage patterns
minor drainage patterns
1978-79 reburial mound
1978-79 survey point
1994 survey point
Map Survey: MMG Consulting Surveyors &Cartographers Ltd. (1994)
Chet Cain (1995-1996)
Prof. Heinz Ruther
Univ. of Cape Town (1995-96)
Map Design: Chase Langford (1997)
Map Revision: Anuradha Sachdev (1999)
Rand Eppich (1999)
0 10
Meters

Figure 6

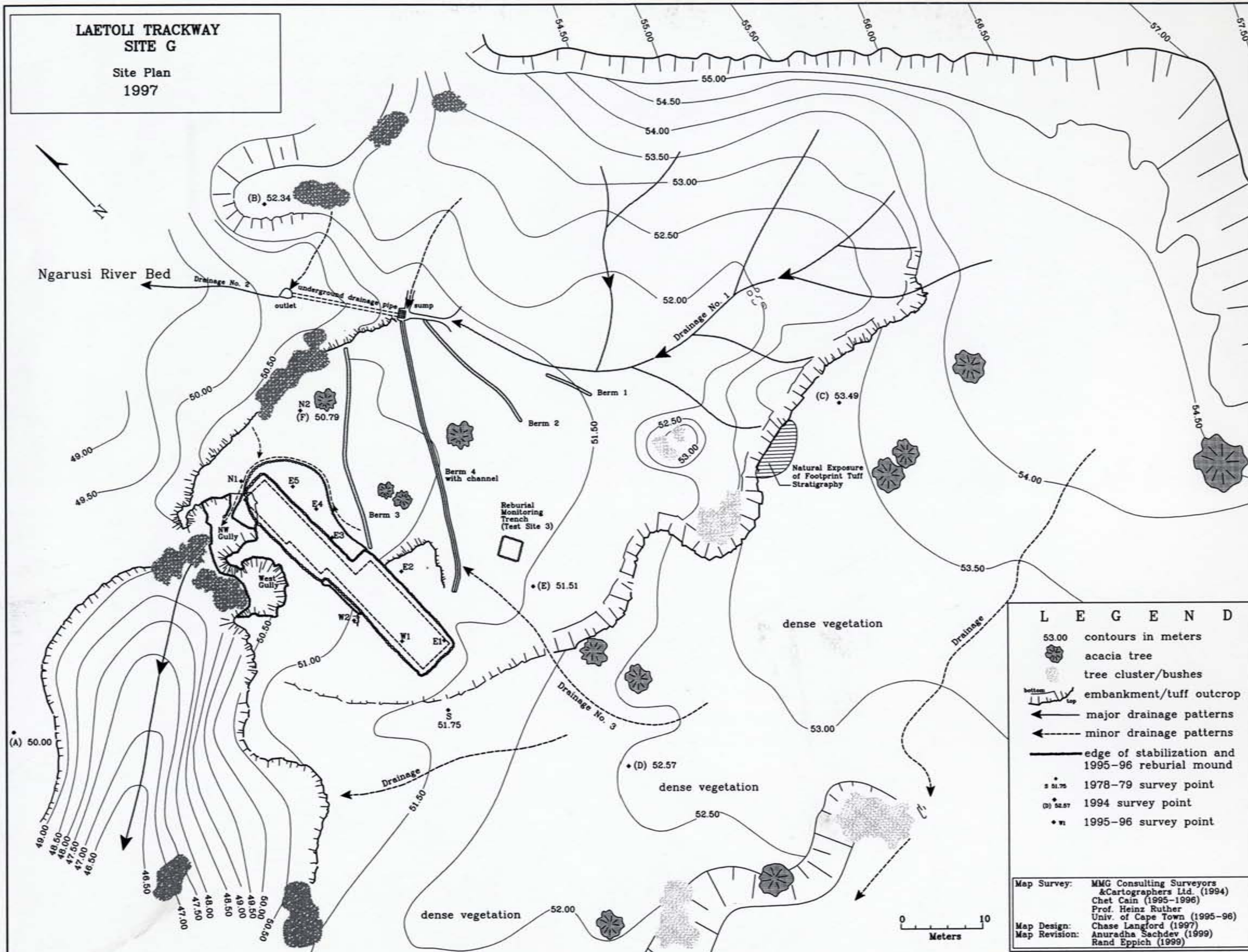

LAETOLI TRACKWAY
SITE G
Site Plan
1997
Ngarusi River Bed
Drainage No. 2
outlet
underground drainage pipe
sump
Drainage No. 1
Drainage No. 3
Drainage
Berm 1
Berm 2
Berm 3
Berm 4 with channel
Reburial Monitoring Trench (Test Site 3)
NW Gully
West Gully
Natural Exposure of Footprint Tuff Stratigraphy
(B) 52.34
(C) 53.49
(F) 50.79
N2
N1
E5
E4
E3
E2
E1
W1
W2
(E) 51.51
(A) 50.00
S 51.75
(D) 52.57
dense vegetation
dense vegetation
dense vegetation
L E G E N D
53.00 contours in meters
acacia tree
tree cluster/bushes
embankment/tuff outcrop
major drainage patterns
minor drainage patterns
edge of stabilization and 1995-96 reburial mound
1978-79 survey point
1994 survey point
1995-96 survey point
Map Survey: MMG Consulting Surveyors &Cartographers Ltd. (1994)
Chet Cain (1995-1996)
Prof. Heinz Ruther
Univ. of Cape Town (1995-96)
Map Design: Chase Langford (1997)
Map Revision: Anuradha Sachdev (1999)
Rand Eppich (1999)
0 10
Meters
N

Figure 7

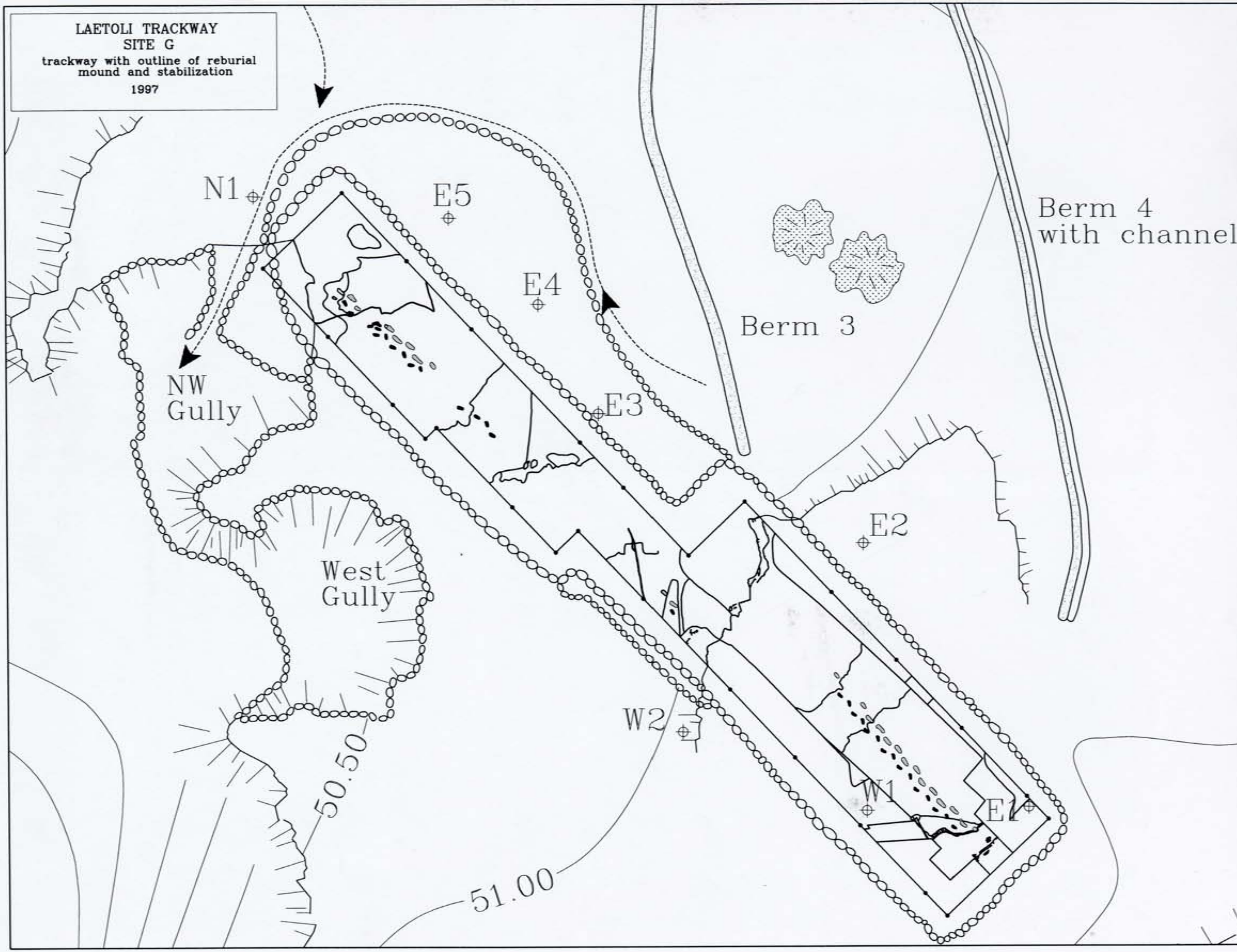
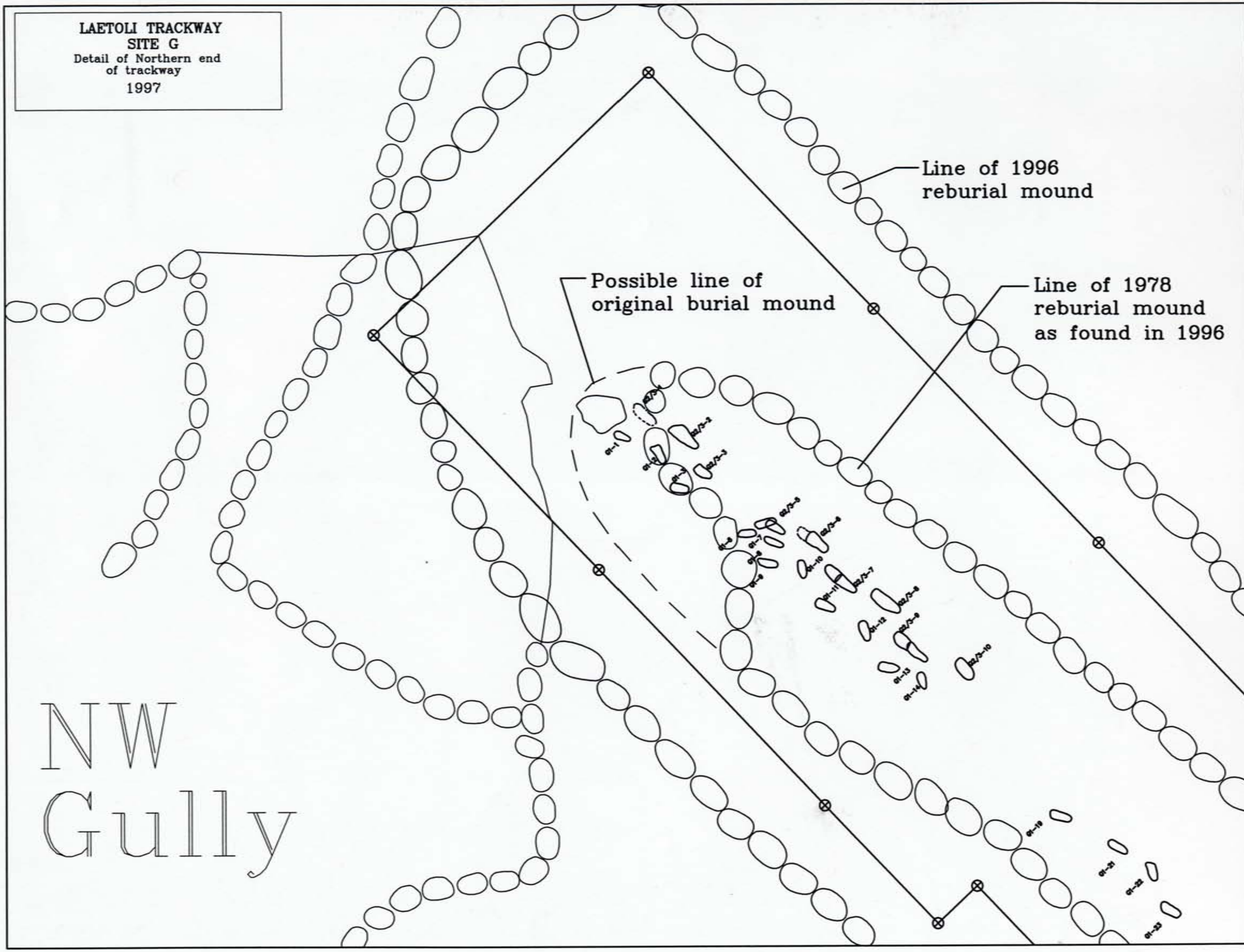

LAETOLI TRACKWAY
SITE G
trackway with outline of reburial mound and stabilization
1997
N1
E5
E4
E3
E2
E1
W1
W2
NW Gully
West Gully
Berm 3
Berm 4 with channel
50.50
51.00

Figure 8



LAETOLI TRACKWAY
SITE G
Detail of Northern end
of trackway
1997
Line of 1996
reburial mound
Possible line of
original burial mound
Line of 1978
reburial mound
as found in 1996
NW
Gully

Figure 9

Figure 10

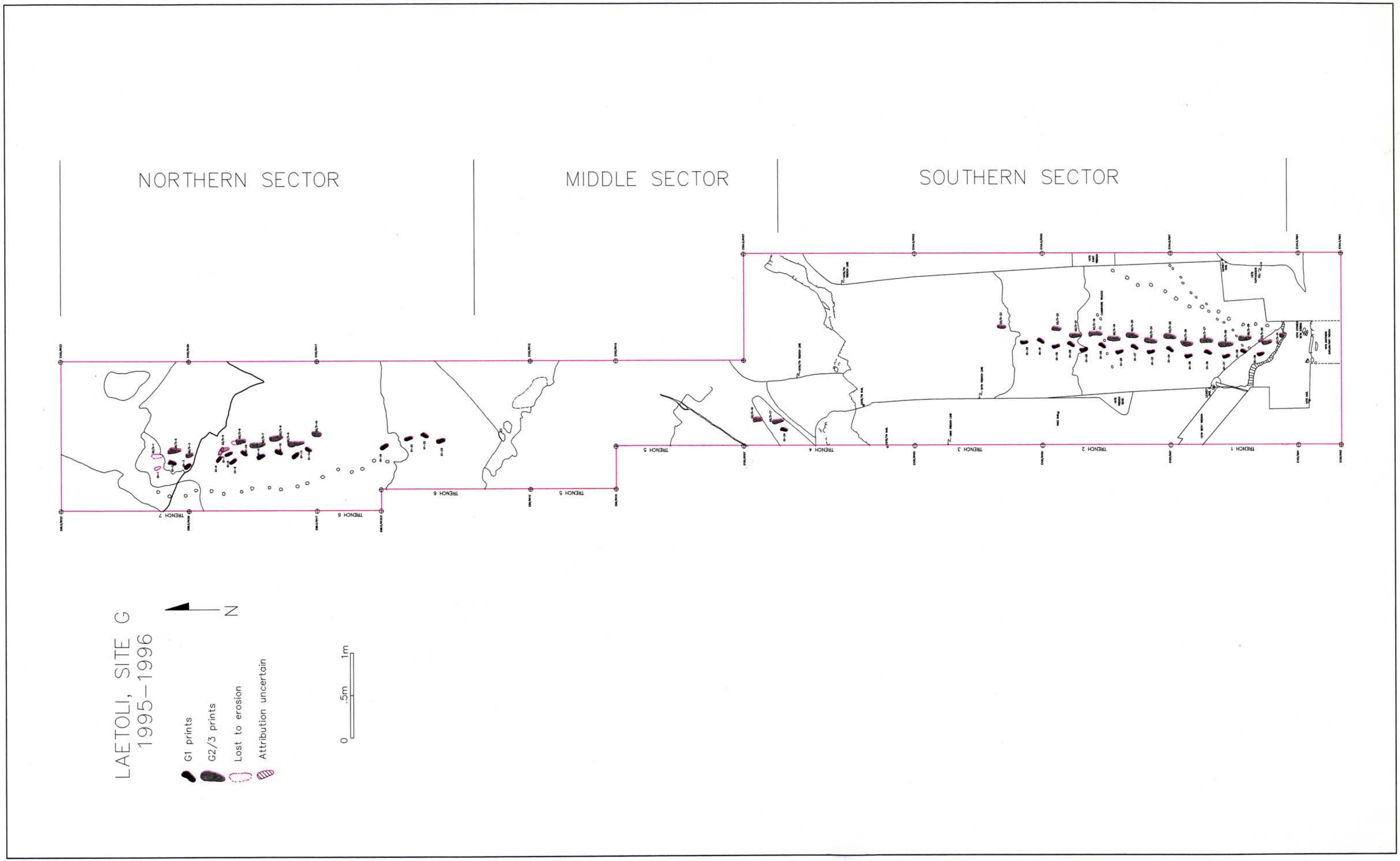

NORTHERN SECTOR
MIDDLE SECTOR
SOUTHERN SECTOR
LAETOLI, SITE G
1995–1996
N
G1 prints
G2/3 prints
Lost to erosion
Attribution uncertain
0
.5m
1m

Figure 11

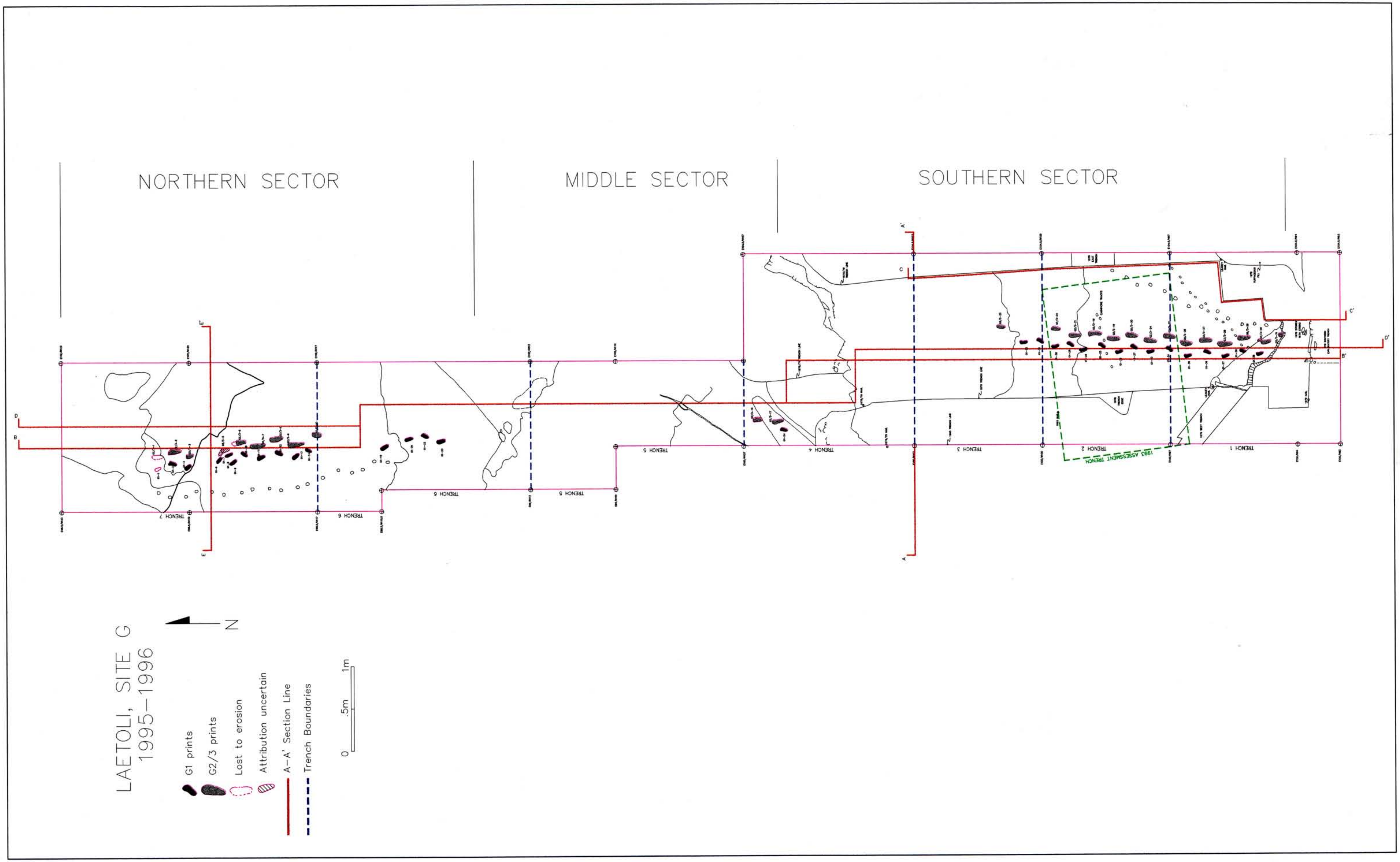
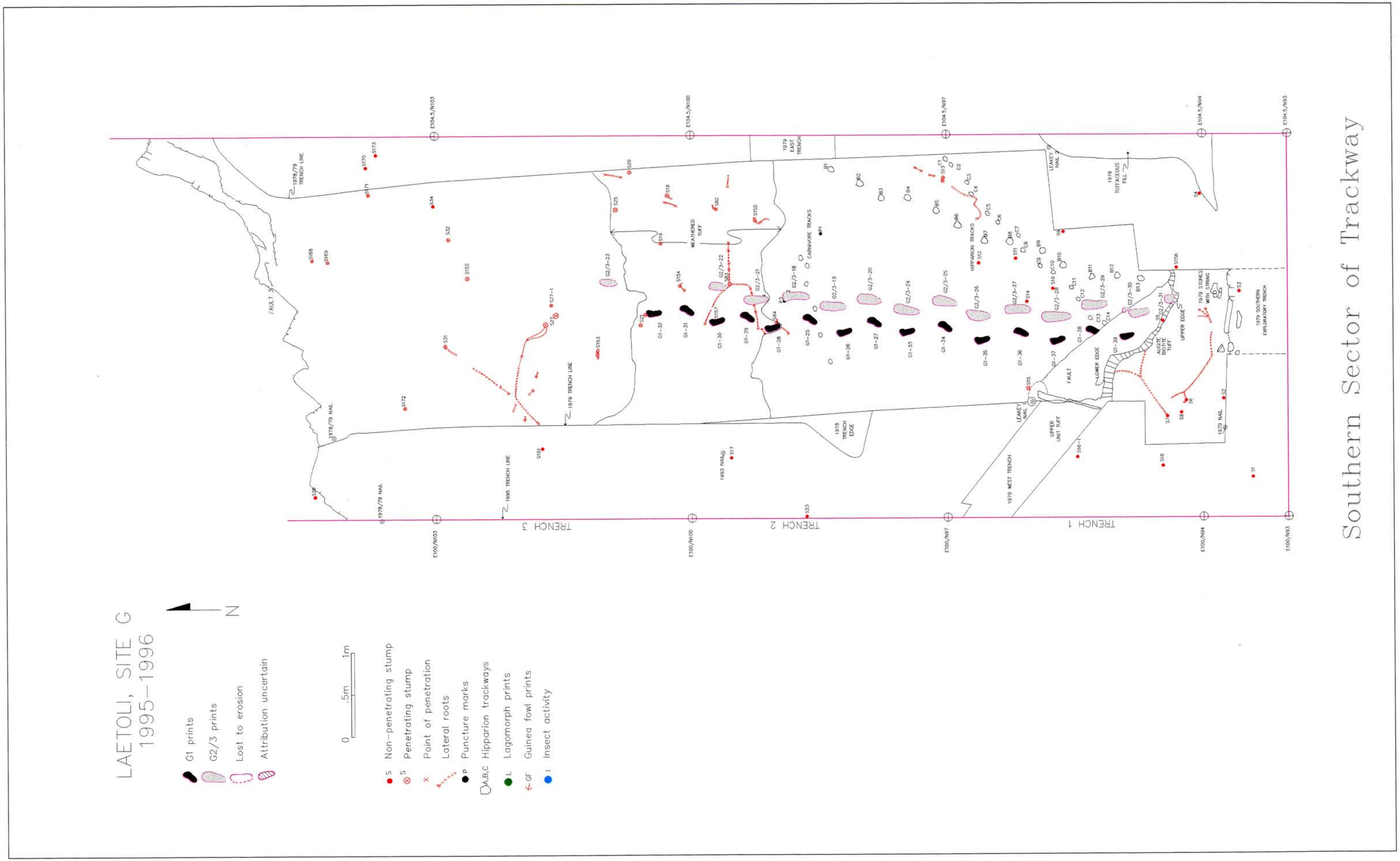
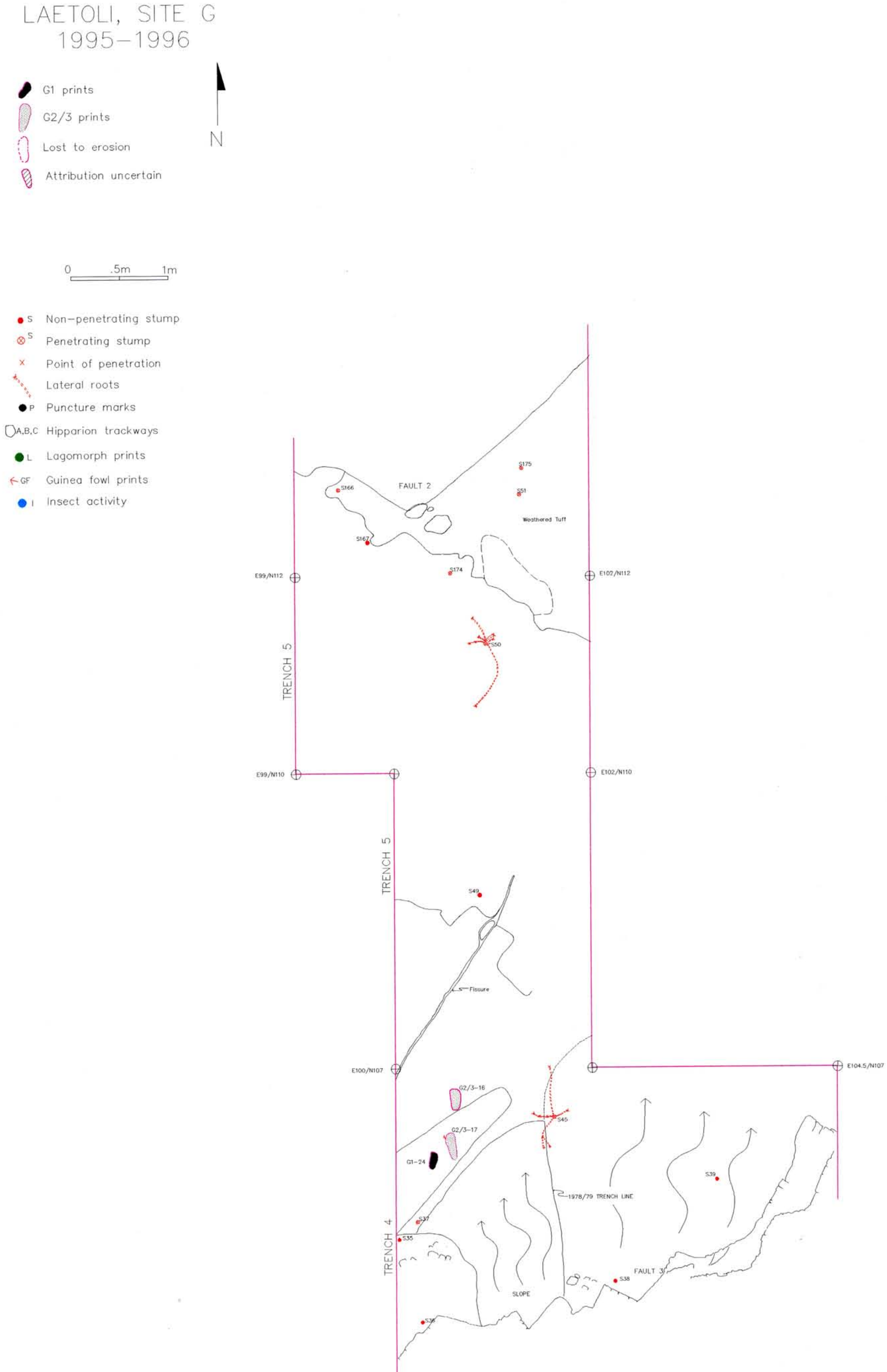

NORTHERN SECTOR
MIDDLE SECTOR
SOUTHERN SECTOR
TRENCH 1
TRENCH 2
TRENCH 3
TRENCH 4
TRENCH 5
TRENCH 6
TRENCH 7
1993 ASSESSMENT TRENCH
LAETOLI, SITE G
1995–1996
N
G1 prints
G2/3 prints
Lost to erosion
Attribution uncertain
A–A' Section Line
Trench Boundaries
0
.5m
1m

Figure 12



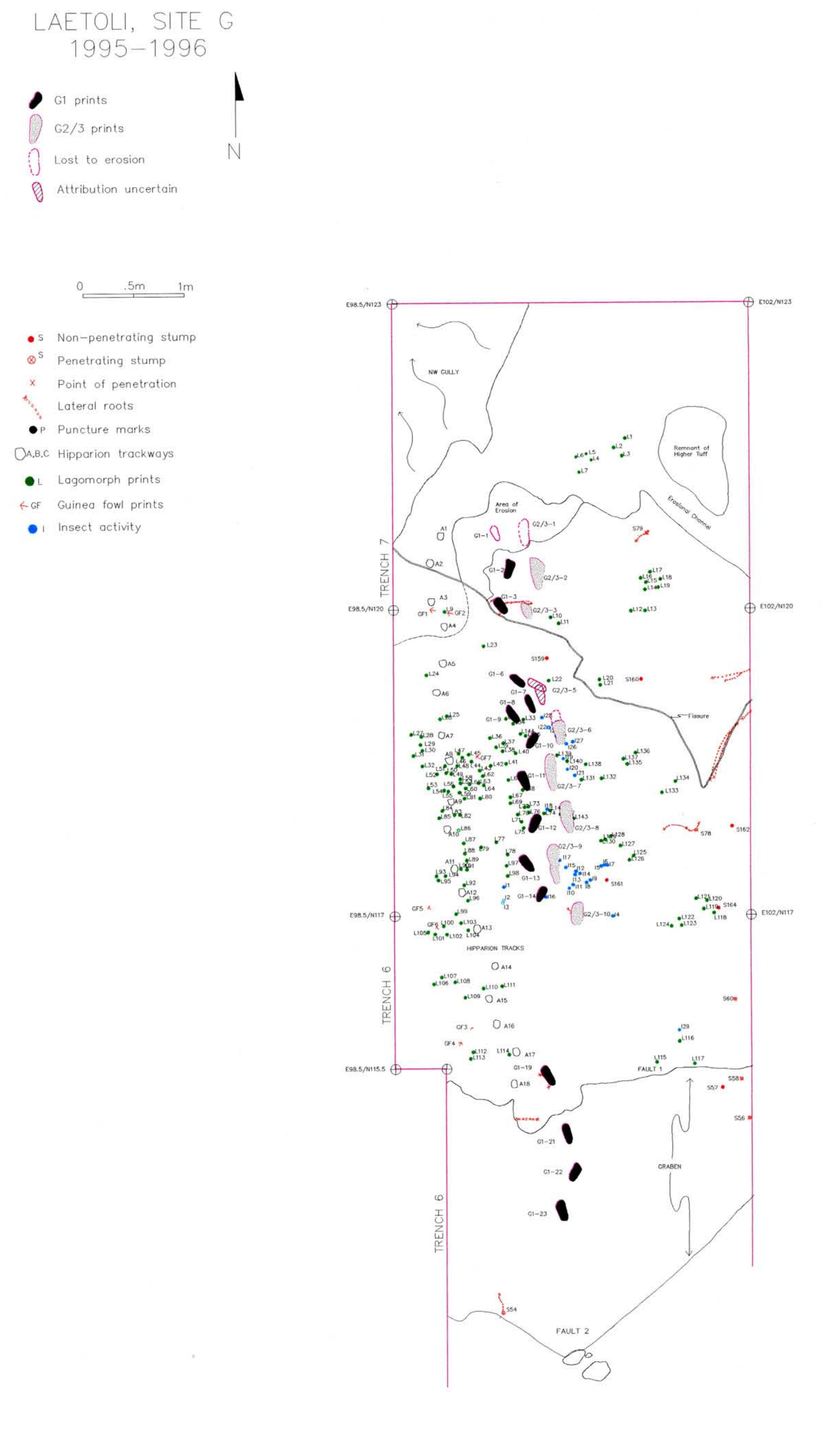
Southern Sector of Trackway
LAETOLI, SITE G
1995–1996
N
G1 prints
G2/3 prints
Lost to erosion
Attribution uncertain
0
.5m
1m
Non-penetrating stump
Penetrating stump
Point of penetration
Lateral roots
Puncture marks
Hipparion trackways
Lagomorph prints
Guinea fowl prints
Insect activity
TRENCH 1
TRENCH 2
TRENCH 3
FAULT
1979 WEST TRENCH
1979 EAST TRENCH
1978 TRENCH EDGE
1979 SOUTHERN EXPLORATORY TRENCH
HIPPARION TRACKS
CARNIVORE TRACKS
WEATHERED TUFF
UPPER UNIT TUFF
AUGITE BIOTITE TUFF
LEAKEY NAIL
1979 NAIL
1993 NAIL
1978/79 NAIL
1979 TRENCH LINE
1995 TRENCH LINE
1978/79 TRENCH LINE



Middle Sector of Trackway

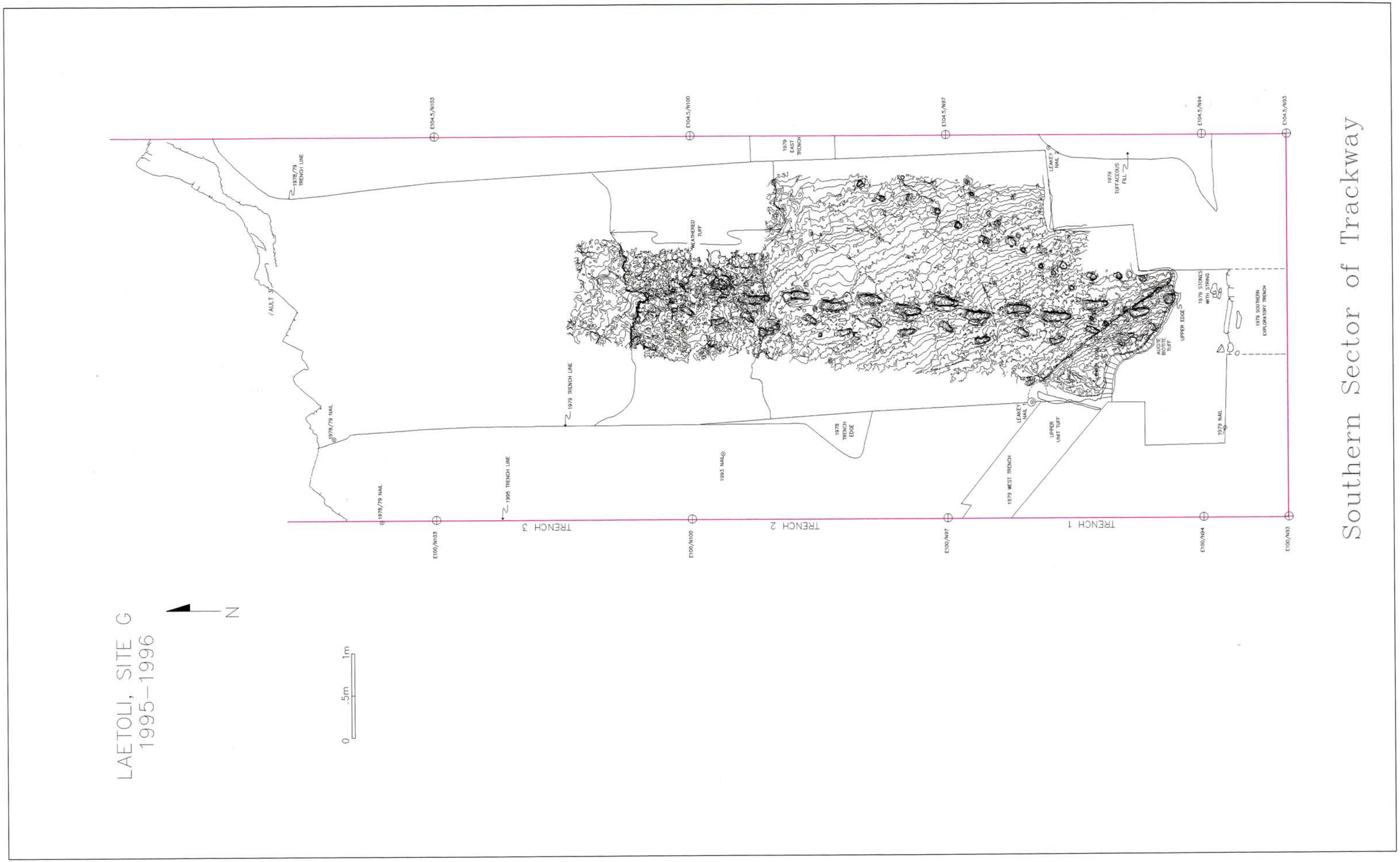
Figure 13

Figure 14



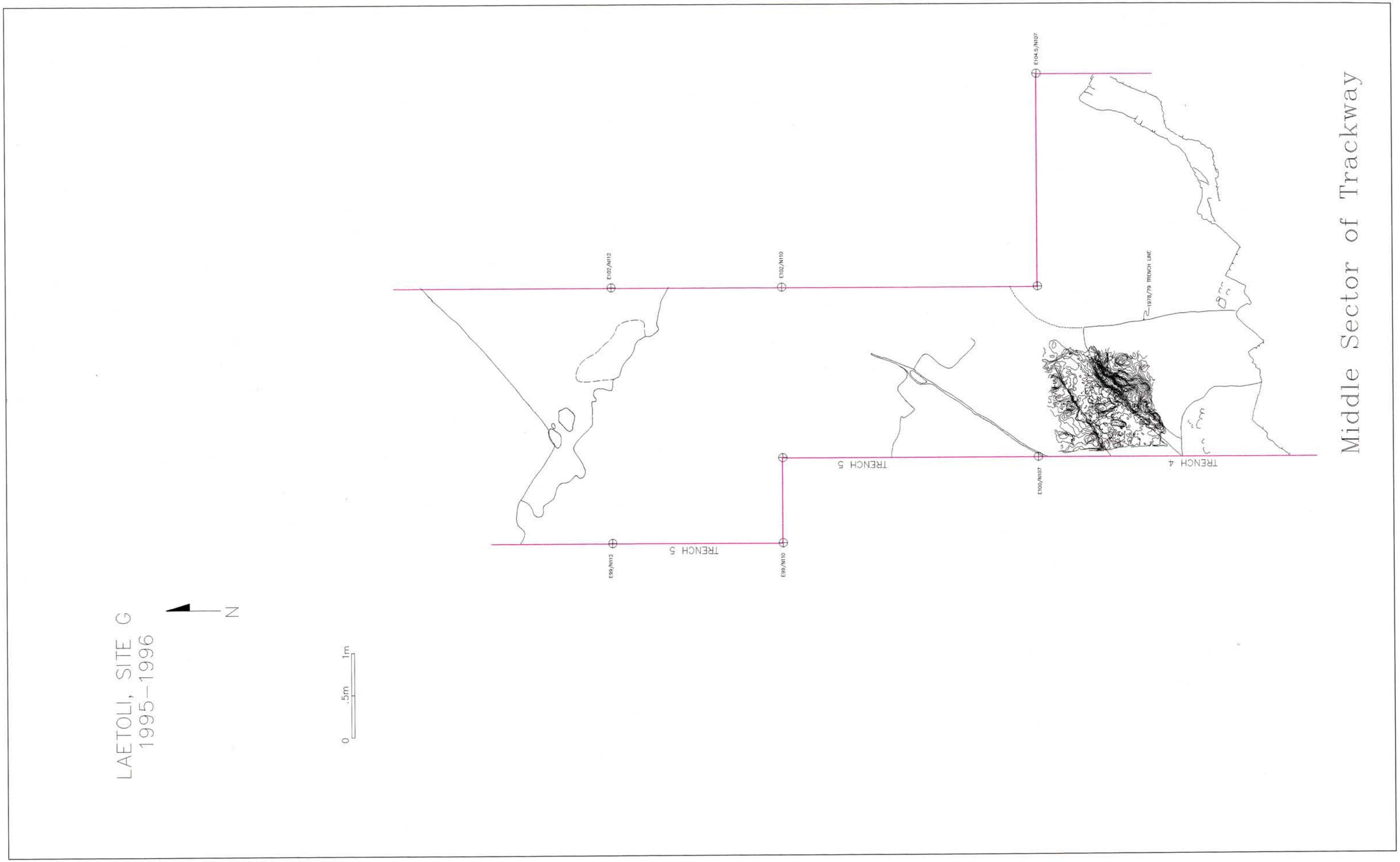
Northern Sector of Trackway

Figure 15



Southern Sector of Trackway
LAETOLI, SITE G
1995–1996
N
0
.5m
1m
TRENCH 1
TRENCH 2
TRENCH 3
FAULT 3
WEATHERED TUFF
1979 TRENCH LINE
1995 TRENCH LINE
1978/79 TRENCH LINE
1978/79 NAIL
1993 NAIL
1979 NAIL
1978 TRENCH EDGE
1979 EAST TRENCH
1979 WEST TRENCH
UPPER UNIT TUFF
LEAKEY NAIL 1
LEAKEY NAIL 2
1979 TUFFACEOUS FILL
AUGITE BIOTITE TUFF
UPPER EDGE
1979 STONES WITH STRING
1979 SOUTHERN EXPLORATORY TRENCH
E104.5/N103
E104.5/N100
E104.5/N97
E104.5/N94
E104.5/N93
E100/N103
E100/N100
E100/N97
E100/N94
E100/N93

Figure 16


Middle Sector of Trackway
LAETOLI, SITE G
1995–1996
N
0
.5m
1m
E104.5/N107
E102/N112
E102/N110
1978/79 TRENCH LINE
TRENCH 5
TRENCH 4
TRENCH 5
E100/N107
E99/N112
E99/N110

Northern Sector of Trackway

Figure 17

LAETOLI SITE G 1995
Section A-A[1]

E-W section through
the 1979 reburial mound

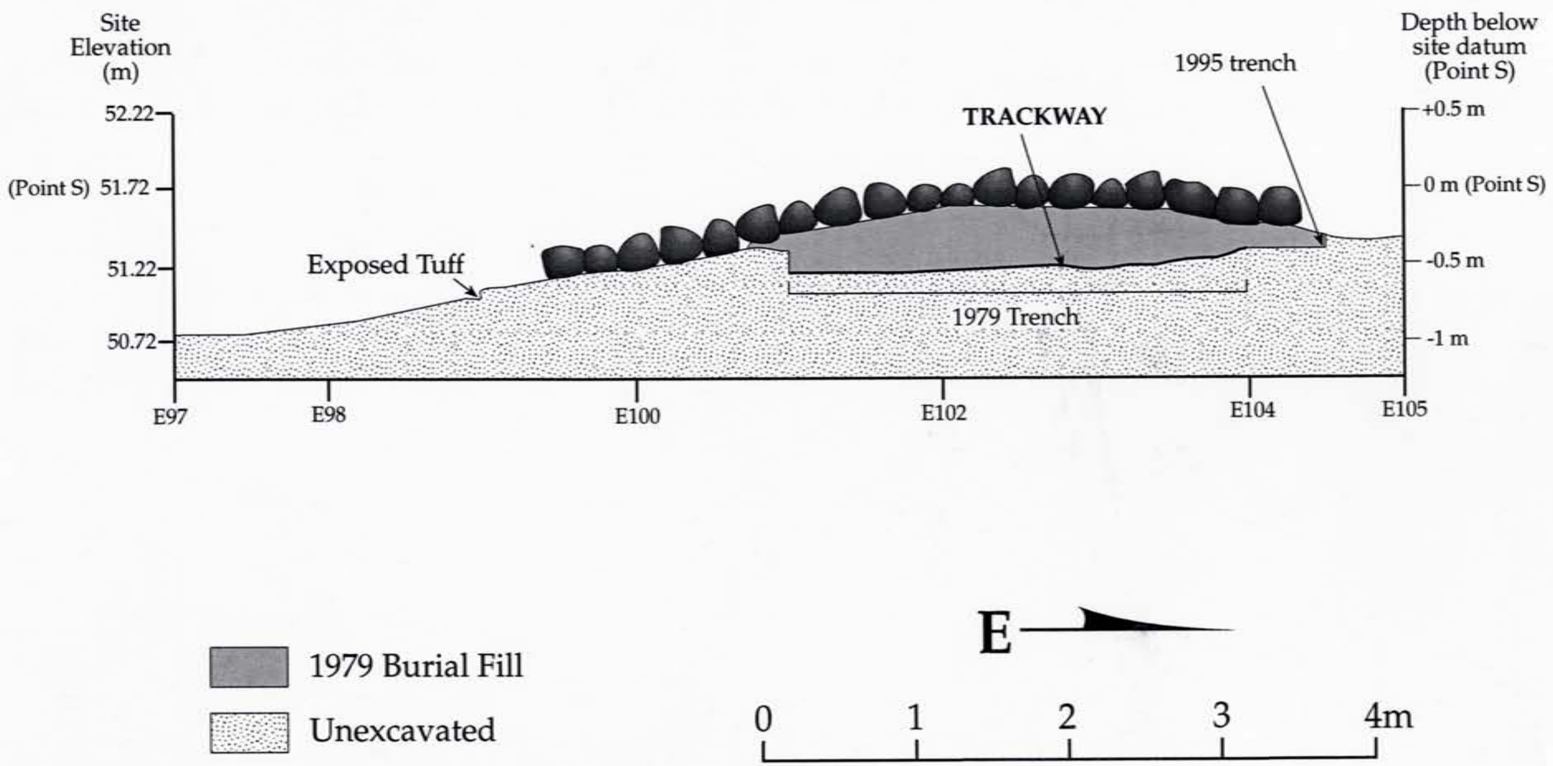
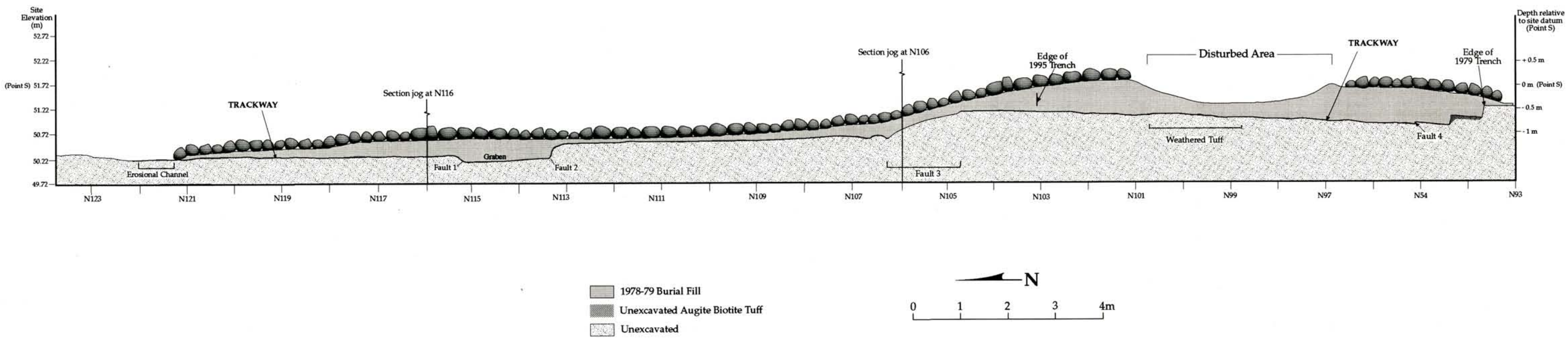


Figure 18

Figure 19

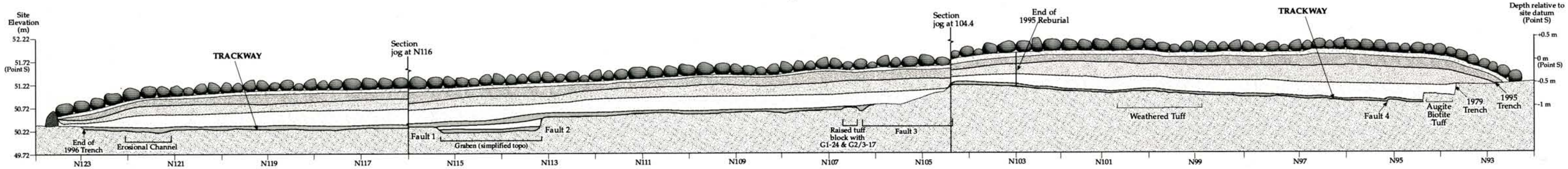
LAETOLI SITE G 1996
Section B-B[1]

N-S section showing 1978-1979 reburial mound,
1995 disturbance, and re-excavated trackway surface



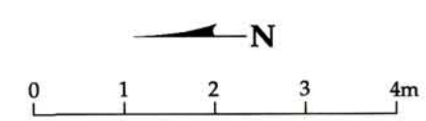
LAETOLI SITE G 1995-1996
Section D-D[1]

N-S section through the 1995-1996 reburial mound



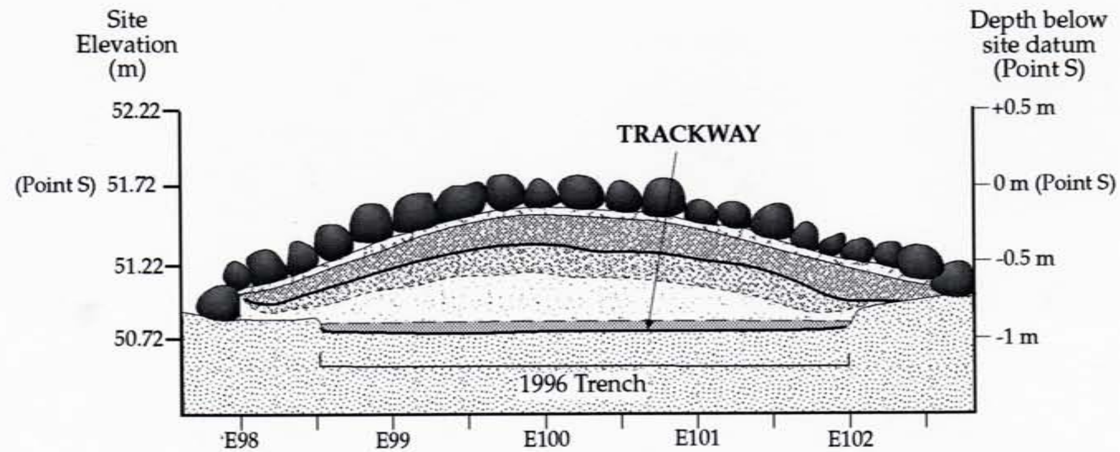
Reburial Layers:

- Lava Boulders
- Layer 5, Black cotton soil
- Layer 4, Coarse-sieved sand
- Layer 3, Coarse-sieved sand, covered with Biobarrier and Enkamat
- Layer 2, Coarse-sieved sand, covered with Biobarrier
- Layer 1, Fine-sieved sand, covered with Geotextile
- Unexcavated



LAETOLI SITE G 1996
Section E-E[1]

E-W section through 1996 reburial mound



Re-burial Layers:

Lava Boulders

Layer 5

Layer 4

Layer 3, Coarse-sieved sand, covered with Biobarrier and Enkamat

Layer 2, Coarse-sieved sand, covered with Biobarrier

Layer 1, Fine-sieved sand, covered with Geotextile

Unexcavated

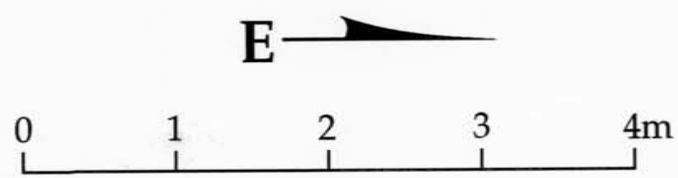
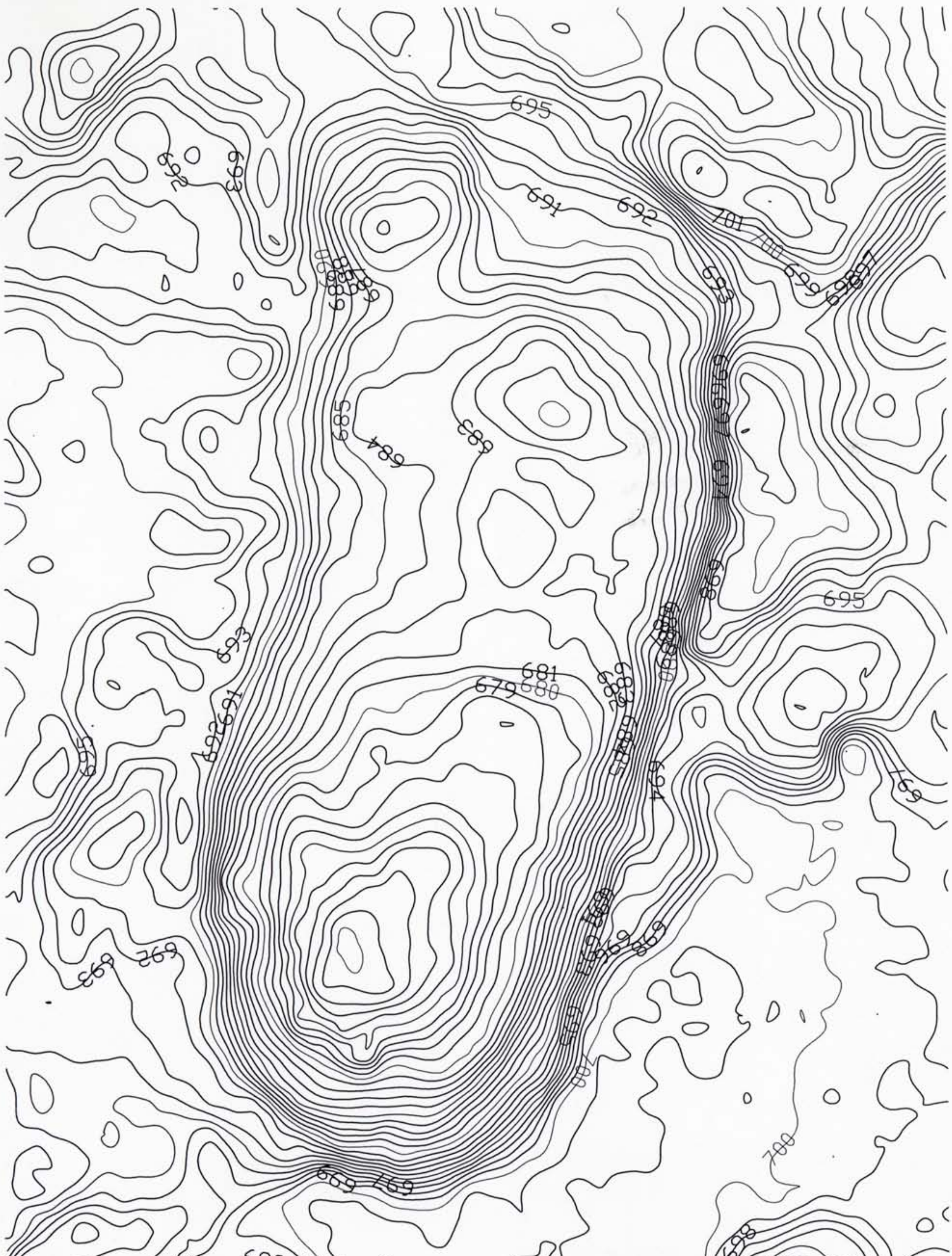


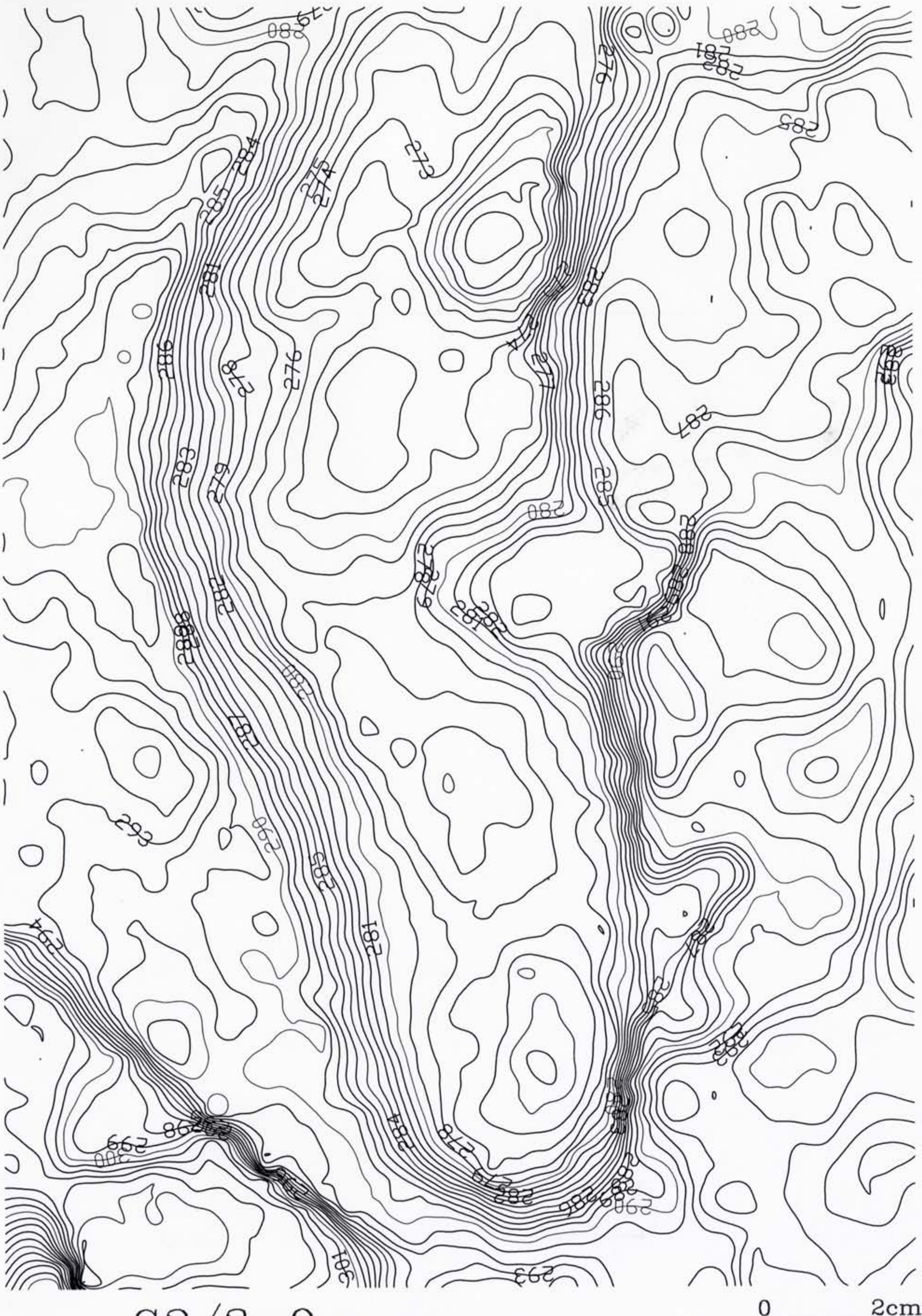
Figure 21

Figure 22



G1−24 Contours at 1mm

0 2cm



G2/3-9 Contours at 1mm

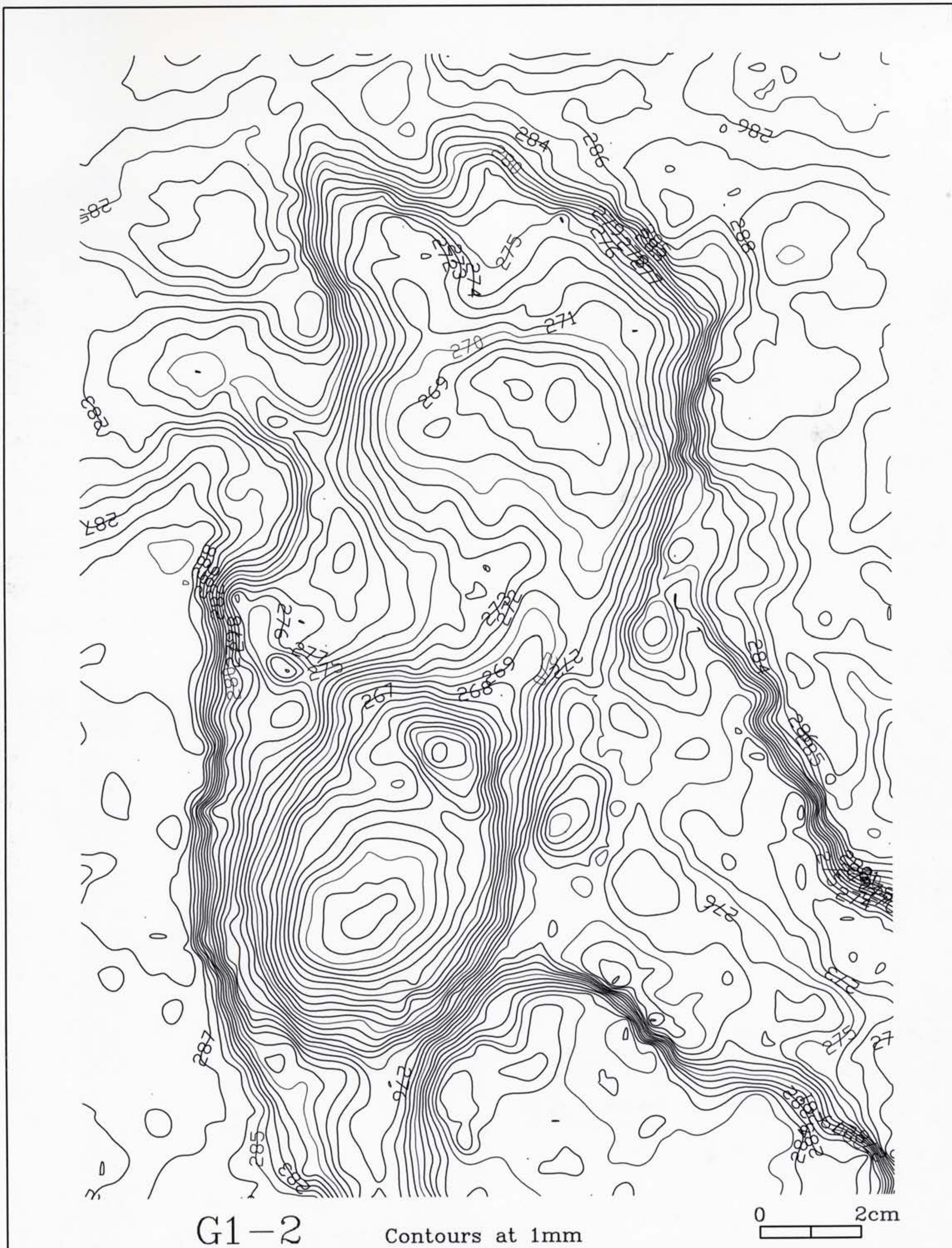
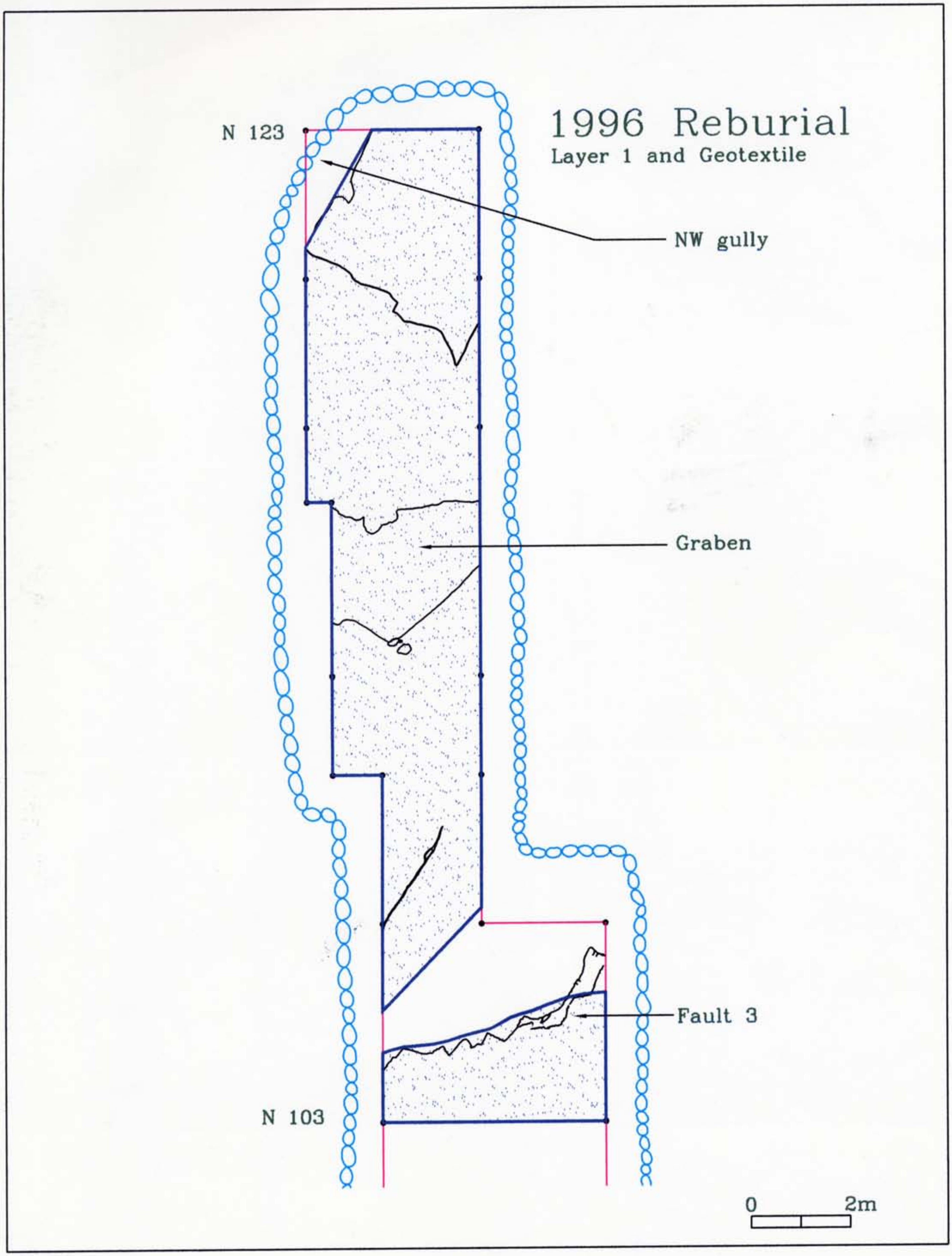
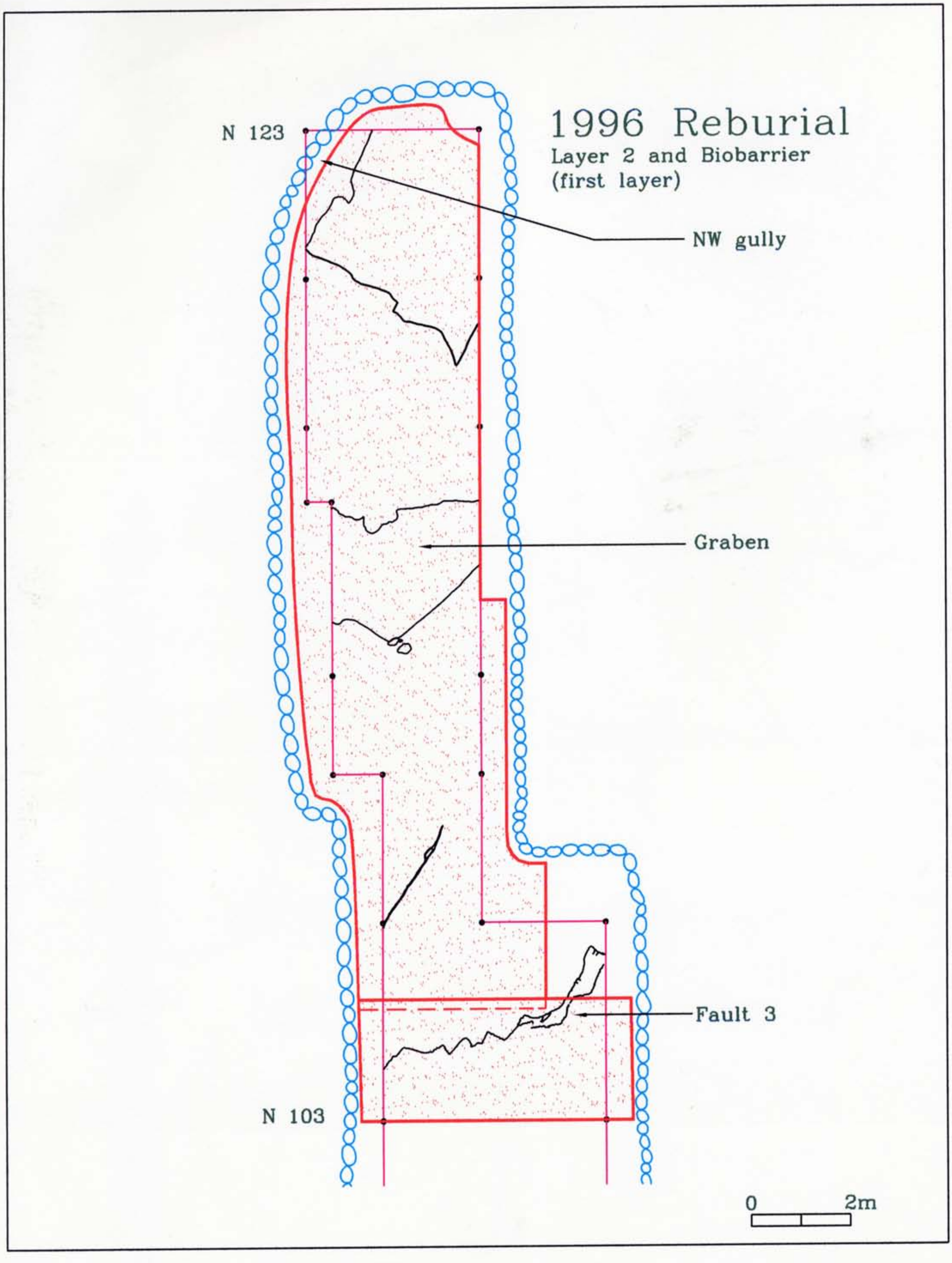
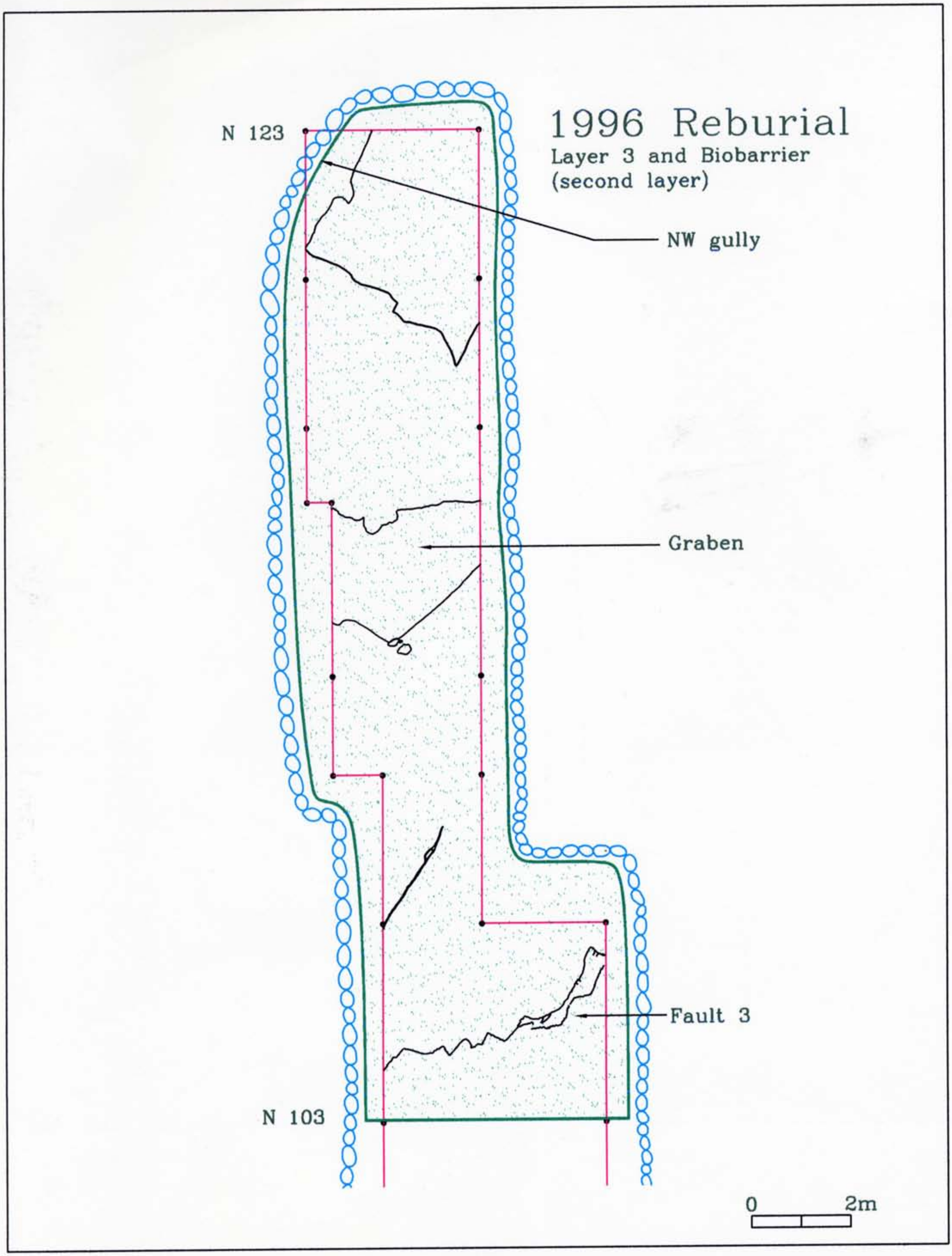

G1−2
Contours at 1mm
0
2cm

Figure 25



1996 Reburial
Layer 1 and Geotextile
N 123
NW gully
Graben
Fault 3
N 103
0
2m


1996 Reburial
Layer 2 and Biobarrier
(first layer)
N 123
NW gully
Graben
Fault 3
N 103
0
2m


1996 Reburial
Layer 3 and Biobarrier
(second layer)
N 123
NW gully
Graben
Fault 3
N 103
0
2m