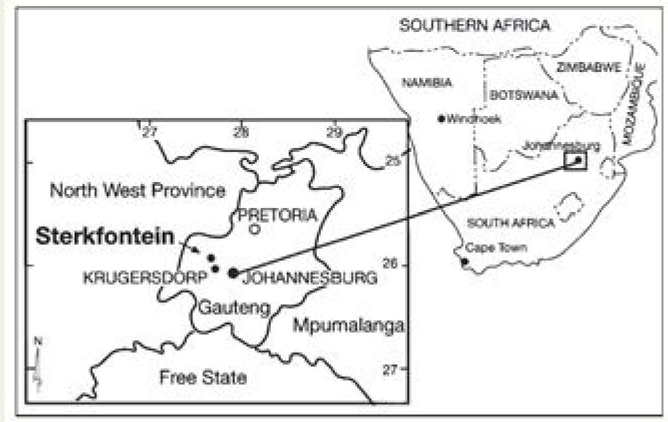
3D Digitization of the Excavation Site of a Fossil Hominid (StW 573 / "Little Foot", Sterkfontein, South Africa“)

Gérard Subsol, LIRMM, France & HOPE
Benjamin Moreno, IMA Solutions, France
Jean-Pierre Jessel, IRIT, France

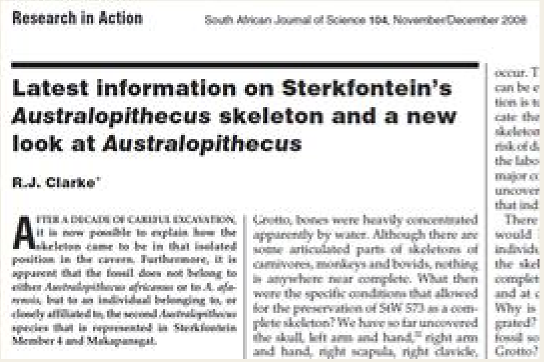
Laurent Bruxelles, INRAP / TRACES, France
José Braga, AMIS, France & HOPE
Ron Clarke, Univ. of Witwatersand, South Africa
Francis Thackeray, Univ. of Witwatersand, South Africa

The excavation site (1)



Sterkfontein is a set of limestone caves of special interest to paleo-anthropologists located near Johannesburg in South Africa.
Many *Australopithecus africanus* fossils have been found as STS5.

The excavation site (2)



Research in Action — South African Journal of Science 104, November/December 2008

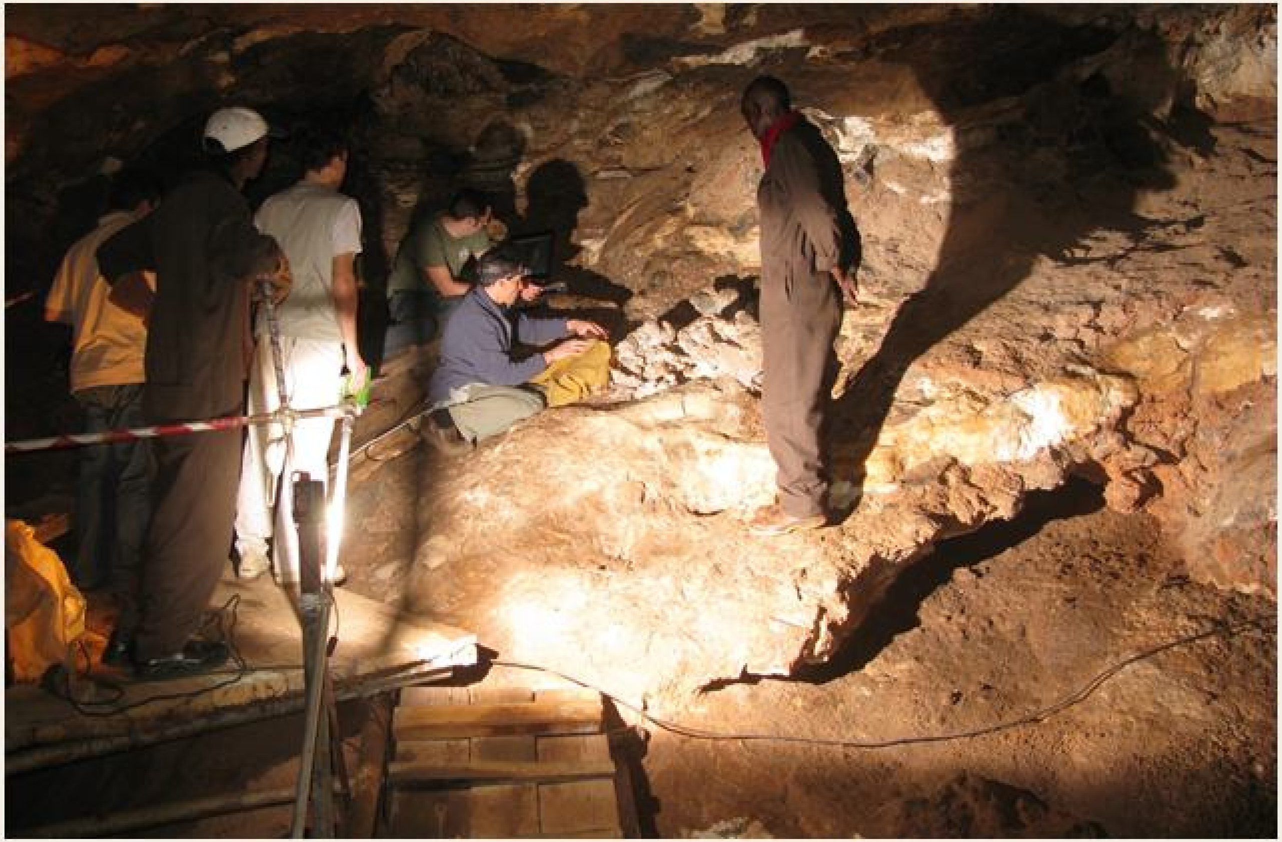
Latest information on Sterkfontein's *Australopithecus* skeleton and a new look at *Australopithecus*

R.J. Clarke*

After a decade of careful excavation, it is now possible to explain how the skeleton came to be in that isolated position in the cavern. Furthermore, it is apparent that the fossil does not belong to either *Australopithecus africanus* or to *A. afarensis*, but to an individual belonging to, or closely affiliated to, the second *Australopithecus* species that is represented in Sterkfontein Member 4 and Makapansgat.

Grotto, bones were heavily concentrated apparently by water. Although there are some articulated parts of skeletons of carnivores, monkeys and bovids, nothing is anywhere near complete. What then were the specific conditions that allowed for the preservation of StW 573 as a complete skeleton? We have so far uncovered the skull, left arm and hand,[2] right arm and hand, right scapula, right clavicle,

During more than 10 years of careful excavation, Ron Clarke and his colleagues exposed an almost complete hominid skeleton (*Stw 573*, nicknamed as "Little Foot") at Sterkfontein in South Africa, which is estimated to be about 3 Myear old.



▲
Distorted view!

The remains (1)

The bony remains of this individual are very well fossilized. They lie on a sloped area of around 3×3 meters.

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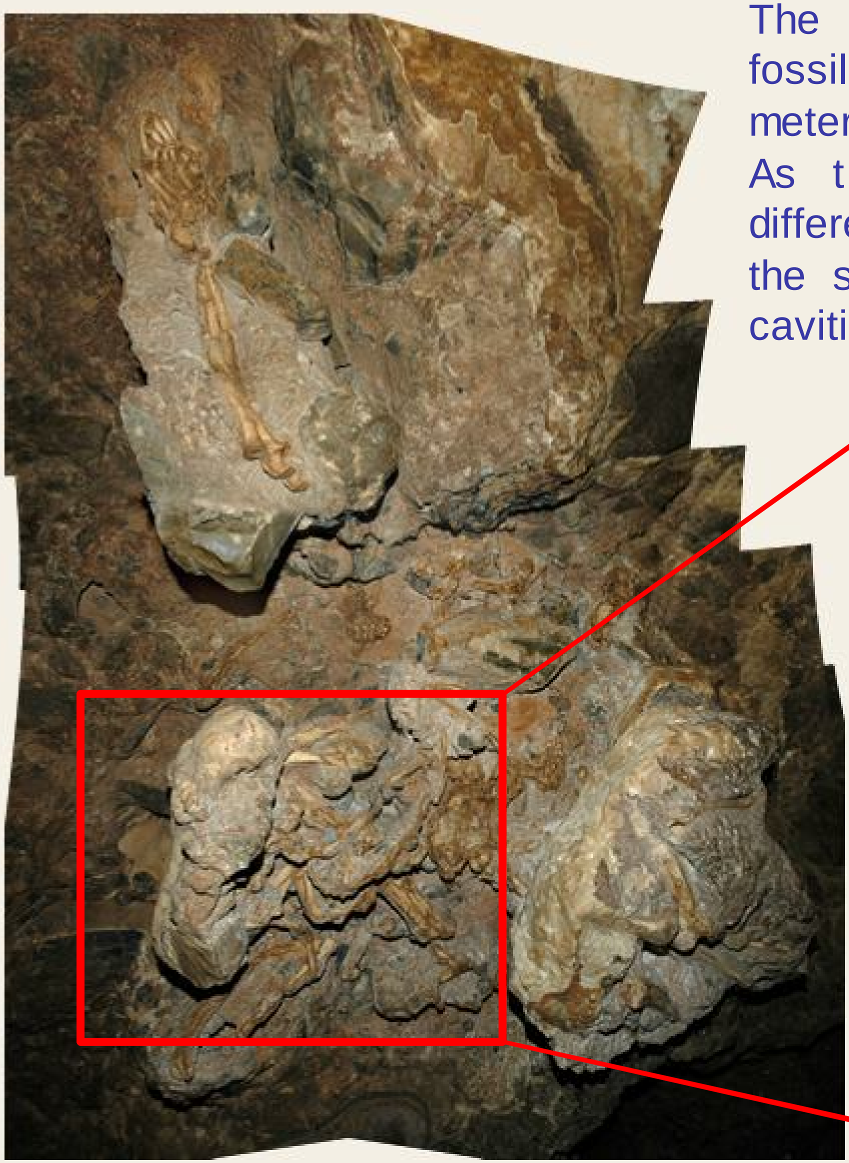
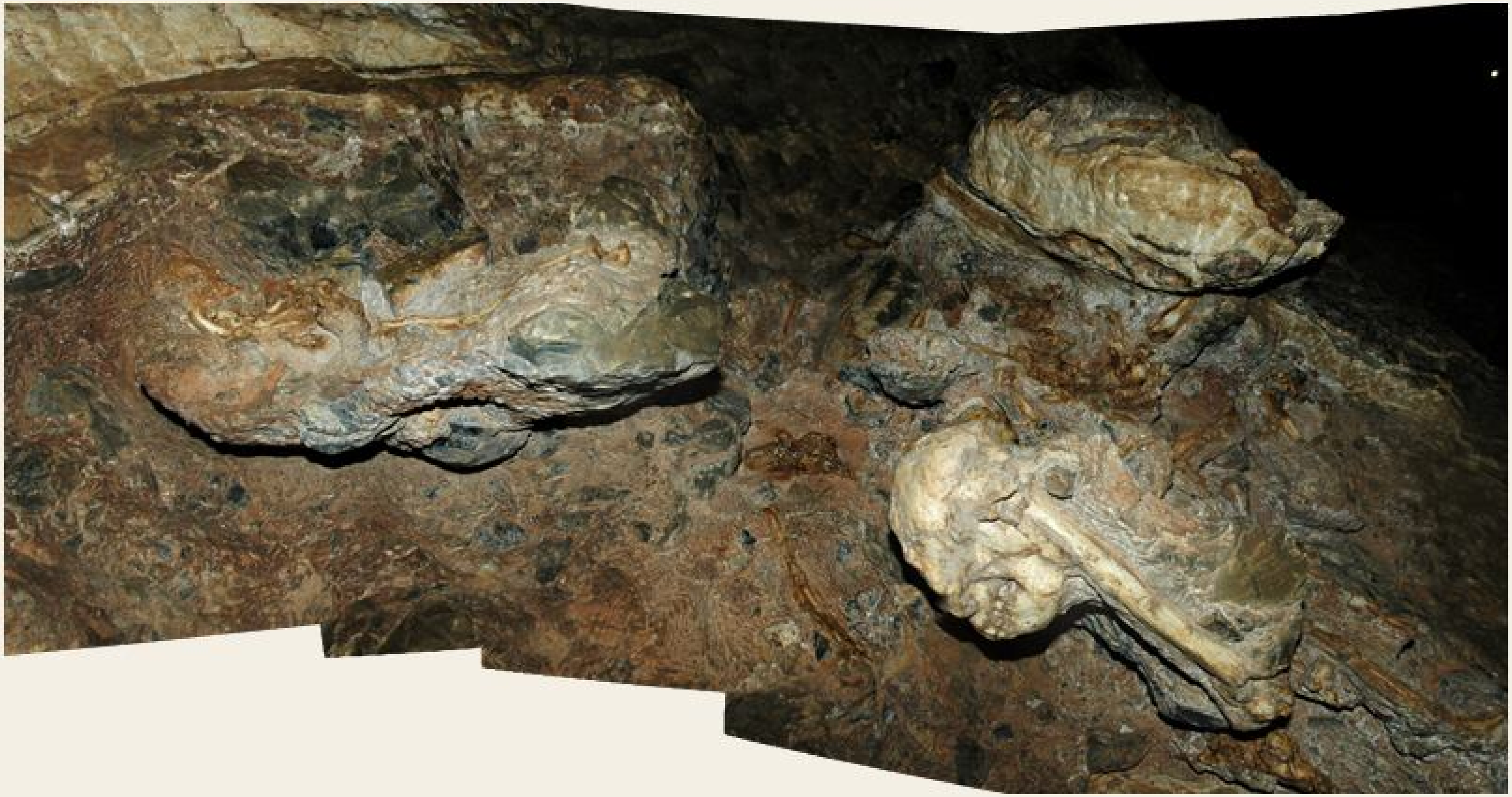
Distorted view!



The bony remains of this individual are very well fossilized. They lie on a sloped area of around 3×3 meters.
As the paleo-anthropologists dug out around the different elements in order to reach and identify them, the surface is very irregular with deep and narrow cavities.

The remains (2)

This specimen is exceptional by its completeness. Moreover, it is considered to represent a second species of South-African *Australopithecus* which has been ignored for many years (*Australopithecus Prometheus*, Dart 1948). Most of the elements of the skeleton have been uncovered.



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Objective

This skeleton and the associated faunal elements have been considered as accumulated at the site as the result of a natural deathtrap (i.e. by falling into a steep shaft)

A few anatomical parts show refossilization crushing, fragmentation, scattering and disarticulation due to an ancient collapse into a cavity beneath the skeleton.

ELSEVIER
Journal of Human Evolution 46 (2004) 279–297

The context of Stw 573, an early hominid skull and skeleton from Sterkfontein Member 2: taphonomy and paleoenvironment

Travis Rayne Pickering[a,b,c]*, Ron J. Clarke[c], Jason L. Heaton[a,b,c]

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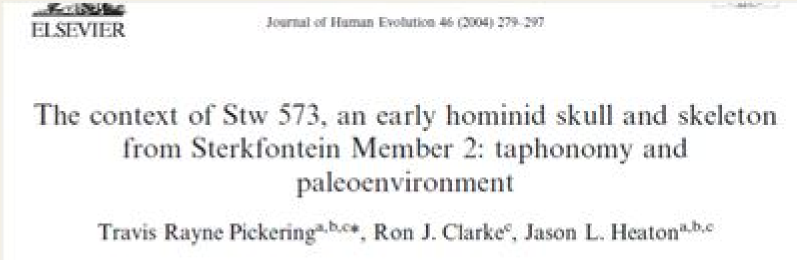
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→ **carefully record** the **3D orientation and location** of the bony elements **in their discovery state, before their definitive excavation.**

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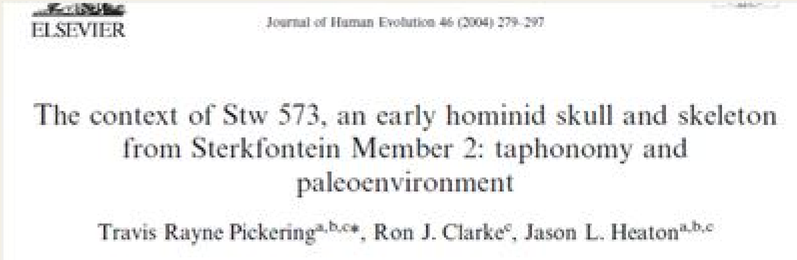
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→ **carefully record** the **3D orientation and location** of the bony elements **in their discovery state, before their definitive excavation.**

→ use of **3D portable scanners** for an as exhaustive and accurate digitization as possible

Some related work

- 3D digitization of caves (in particular wall paintings)

Journal of Archaeological Science 36 (2009) 1847–1856

Laser scanning for conservation and research of African cultural heritage sites: the case study of Wonderwerk Cave, South Africa

Heinz Rüther[a,*], Michael Chazan[b], Ralph Schroeder[a], Rudy Neeser[a], Christoph Held[a], Steven James Walker[c,f], Ari Matmon[d], Liora Kolska Horwitz[e]

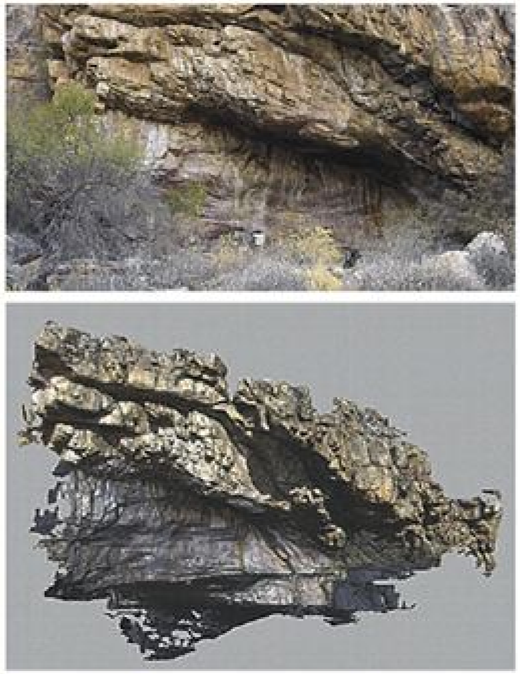


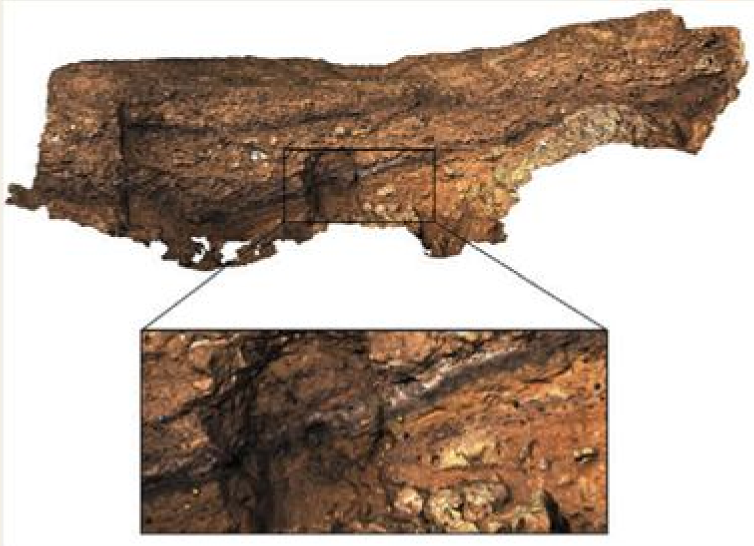
Fig. 2. Maidens Pool rock shelter in the Cederberg, South Africa containing Late Stone Age rock art. Top – photograph of the rock shelter; Bottom – 3D model of the rock shelter with texturing.

- But very few work on in-situ 3D digitization of artifacts

Journal of Archaeological Science 36 (2009) 19–24

Structured light scanning for high-resolution documentation of *in situ* archaeological finds

Shannon P. McPherron[a,*,1], Tim Gernat[b,1], Jean-Jacques Hublin[a]



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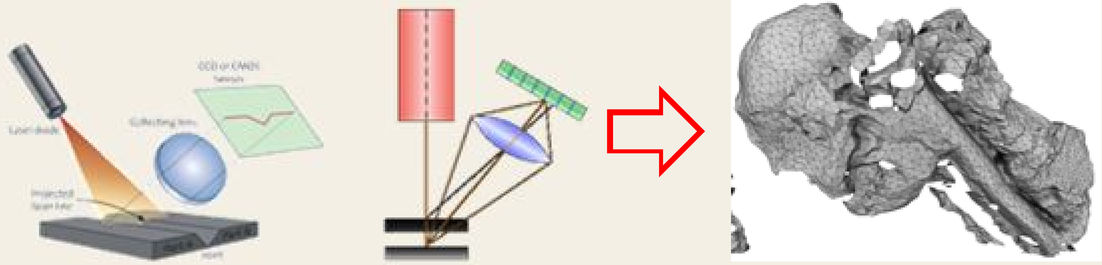
3D acquisition by projecting stripe(s), computing depth by triangulation and reconstructing a 3D mesh:



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Field of View	Up to 1.5×1.5 m with the Wide lens	Limited to 0.3×0.3 m in Wide mode
Color acquisition	Only 640×480 pixels, very sensitive to ambient lighting	3M pixels sensor with a built-in white light source
Scan time	3 s	3 min
Cost	$60,000	$2,995

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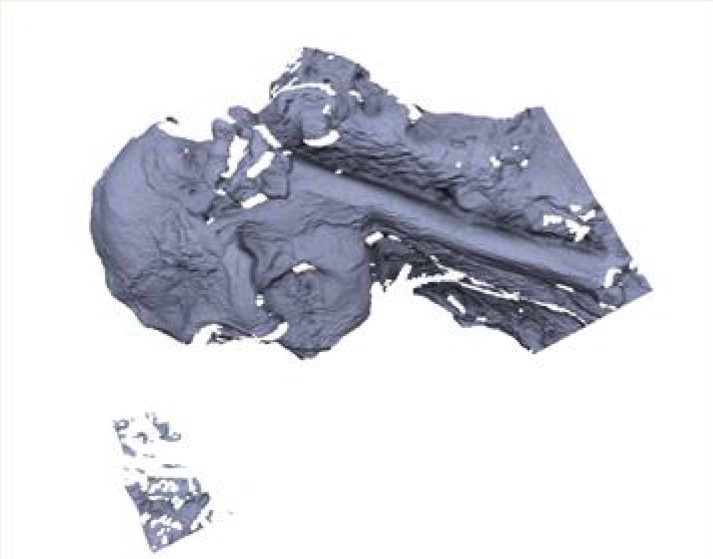
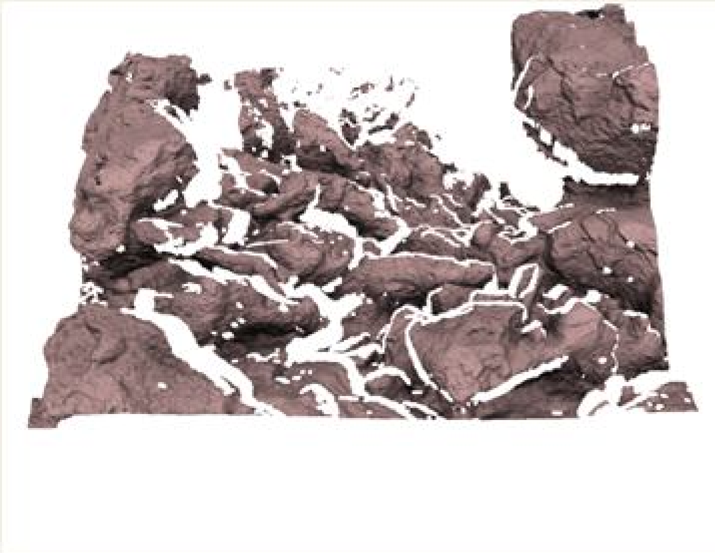
	→ Overall digitization	→ Textured details

Methodology

1. Perform many 3D acquisitions of the site taken from different point of views



Acquisition 1:
132,826 vertices / 259,082 faces



Acquisition 2;
194,056 vertices / 365,792 faces

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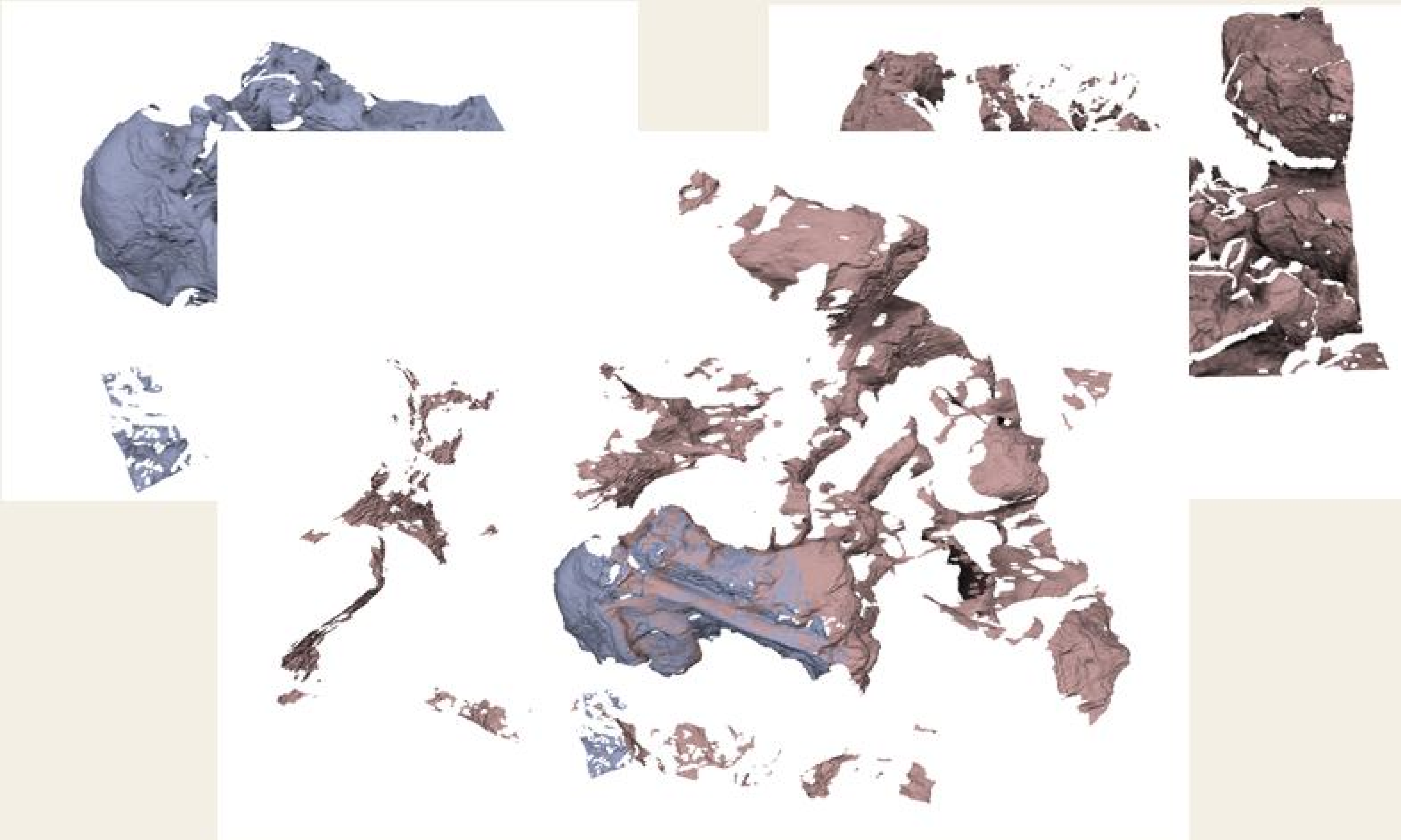
2. Align and merge the 3D acquisitions to get a global 3D reconstruction



Aligning & merging acquisitions 1 and 2:
326,882 vertices / 624,874 faces

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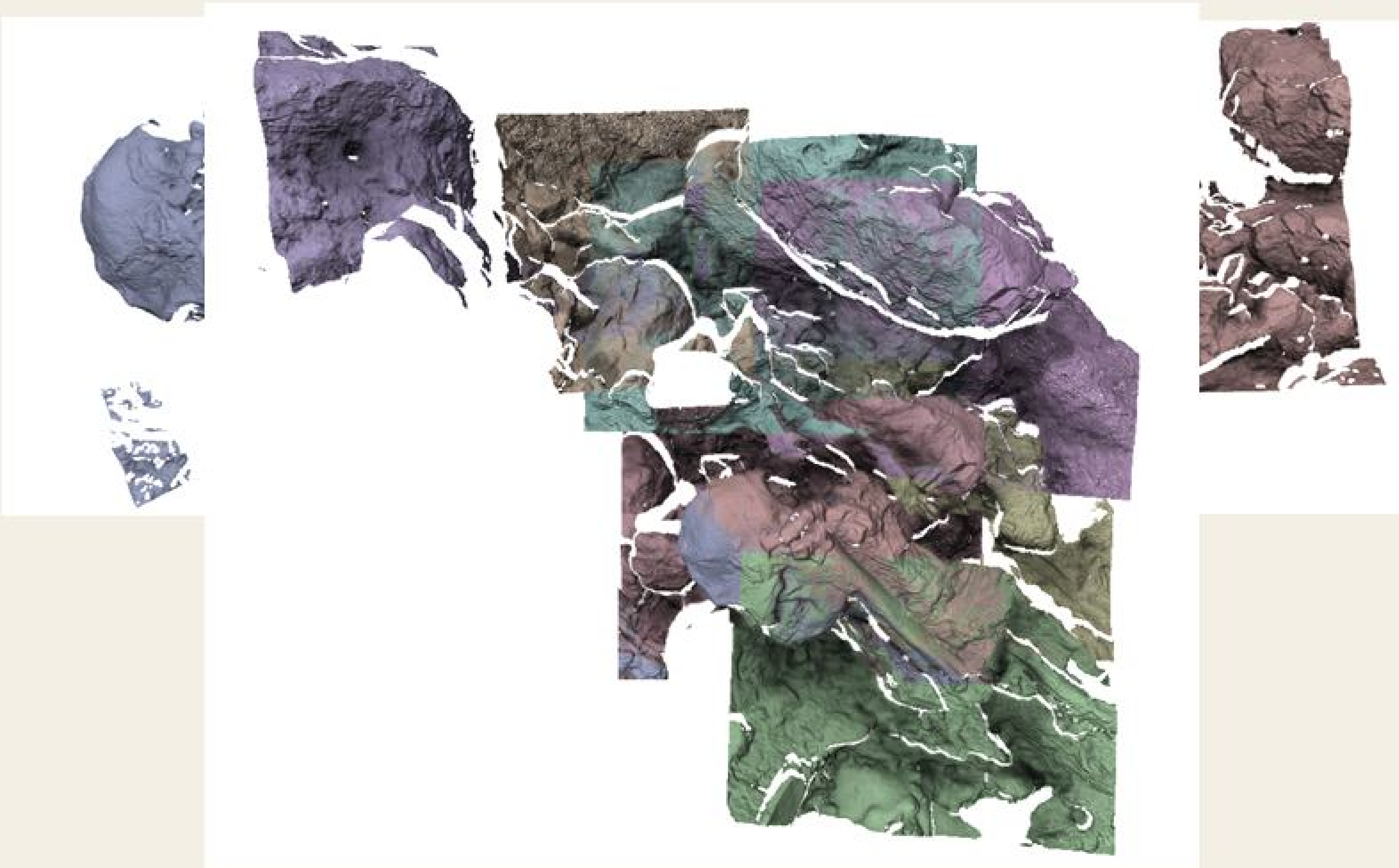

Aligning & merging 8 acquisitions:
1,510,362 vertices / 2,930,933 faces

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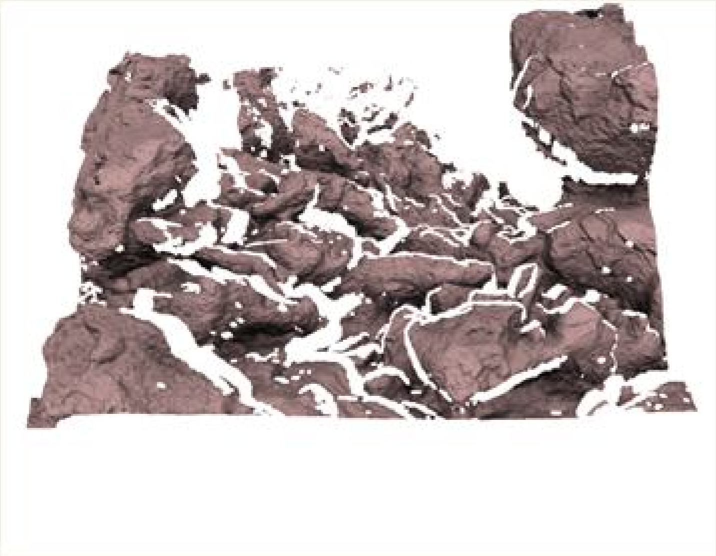
But…

- exhaustive 3D reconstruction
  → find the best points of view to limit as much as possible the occlusions



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Front view

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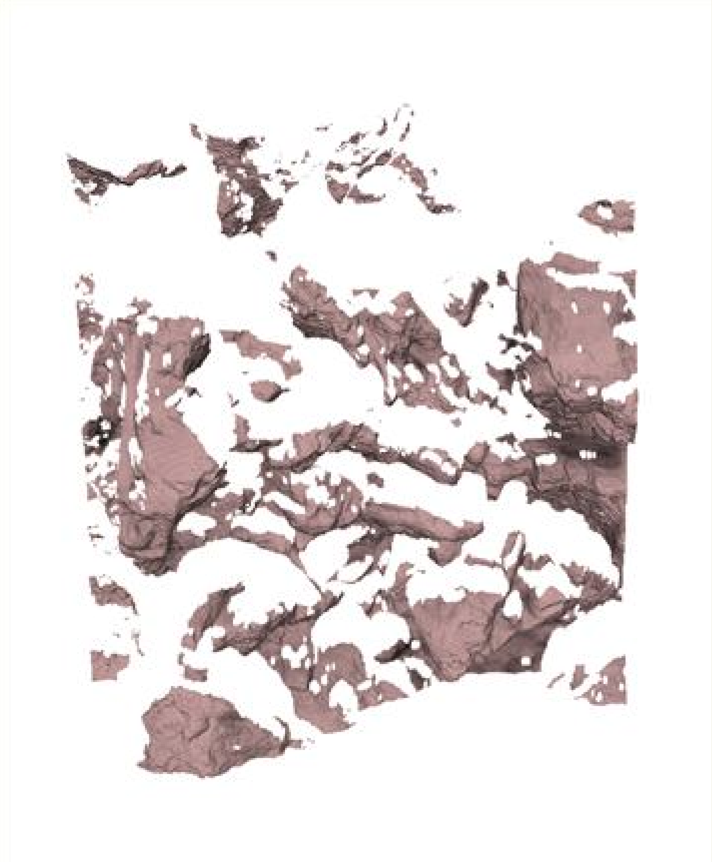

Acquisition 2;
194,056 vertices / 365,792 faces
Upper view

Methodology

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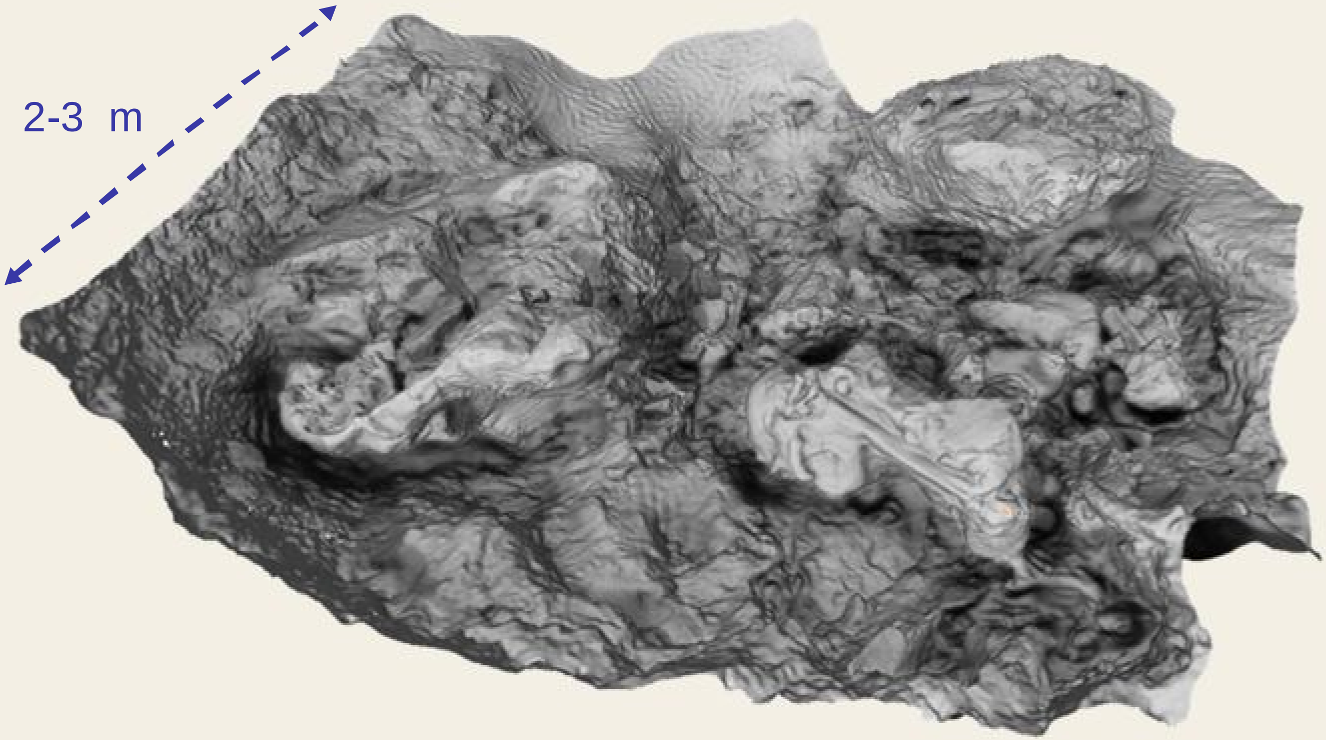
- minimize the scanning cost (time, data size)
  → planning the scanner positions (*!!!*)

On the ground… *overall acquisition (Minolta)*

- FOV ≈ 0.6×0.6 m (middle lens)
- No control of the light → no texture



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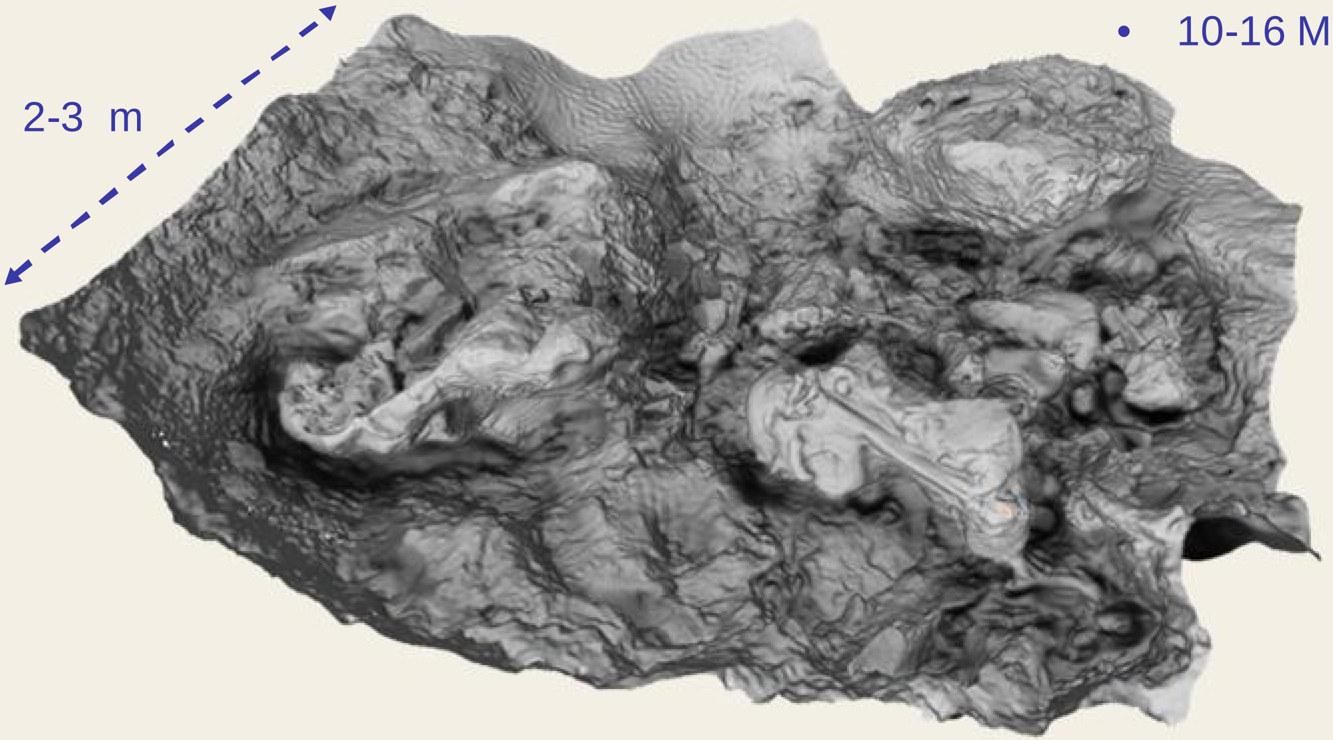
- 10-16 Mbytes in *obj* format



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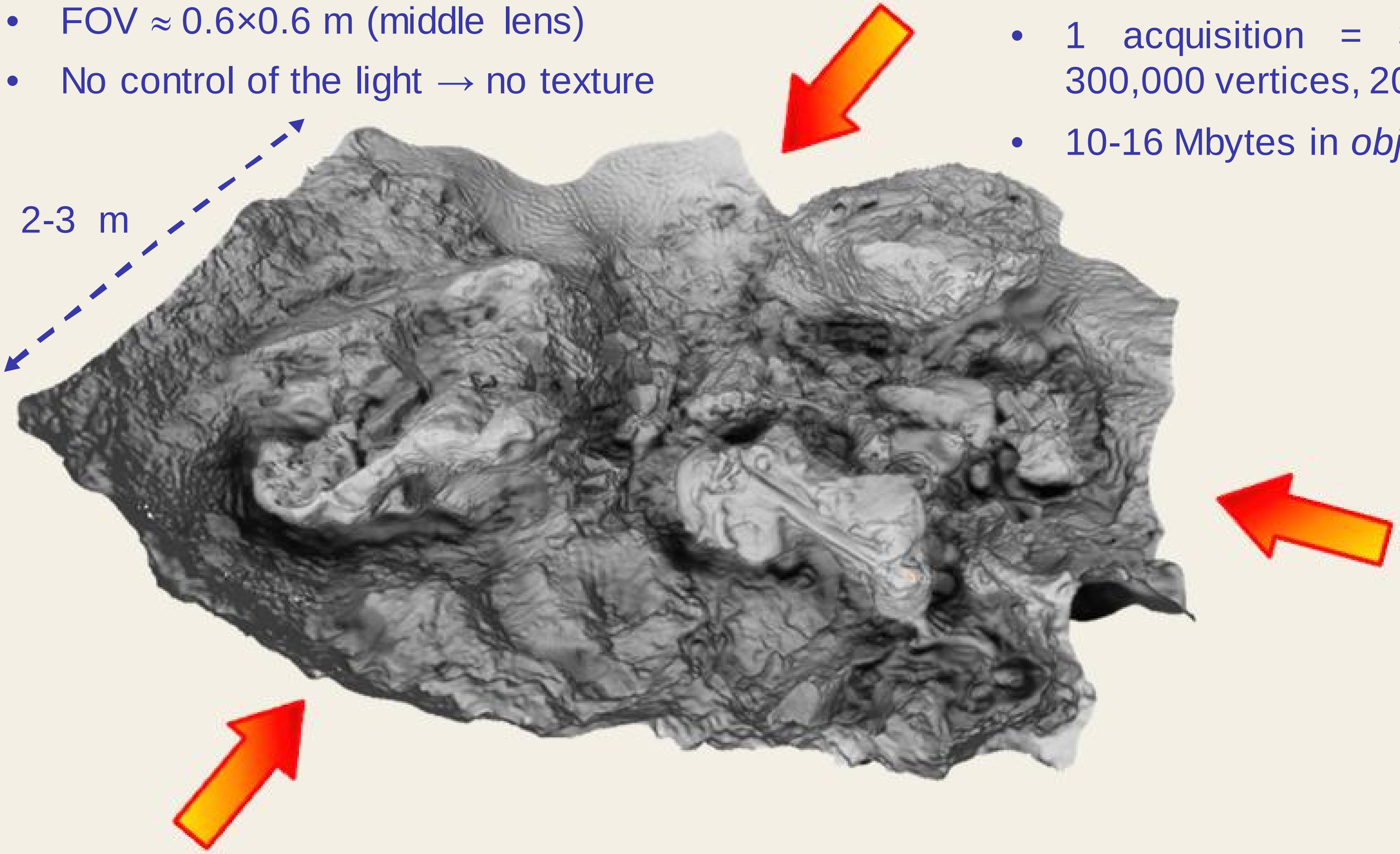
2-3 m



17 acquisitions
+
33 acquisitions
+
7 acquisitions

12 acquisitions

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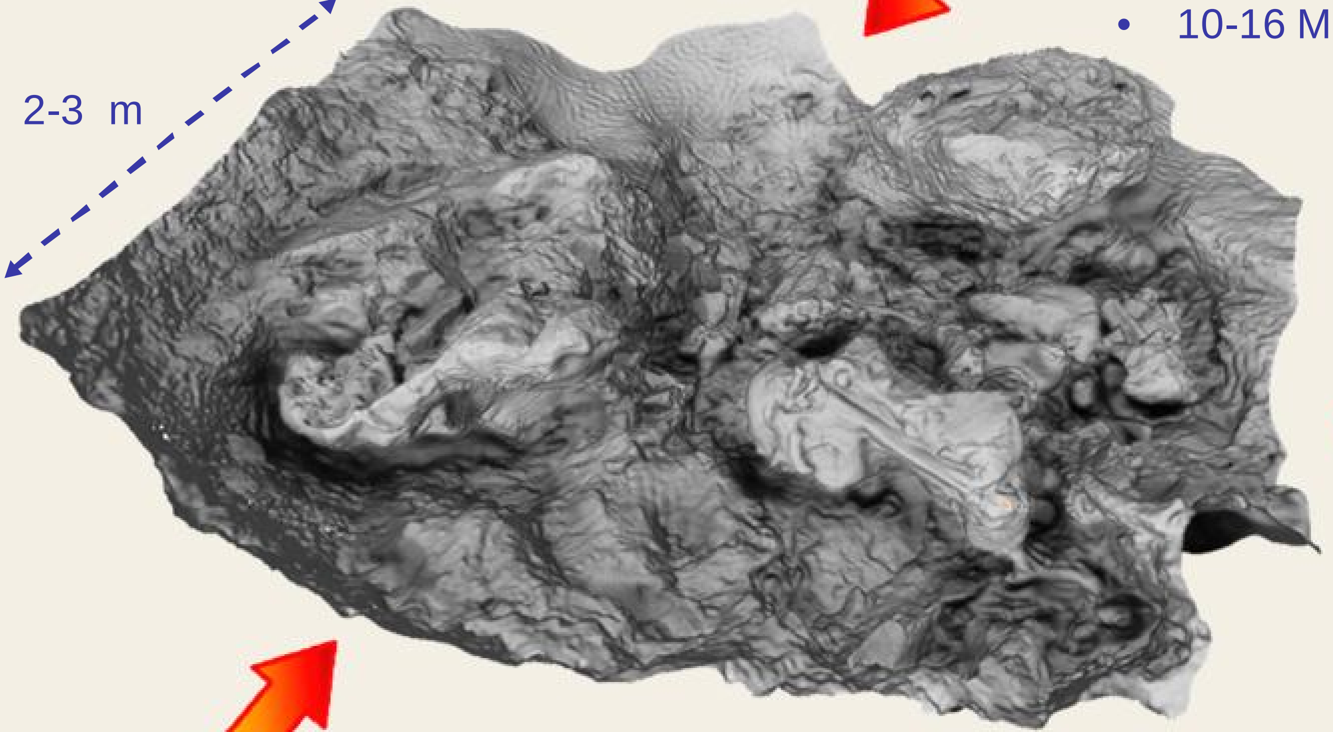

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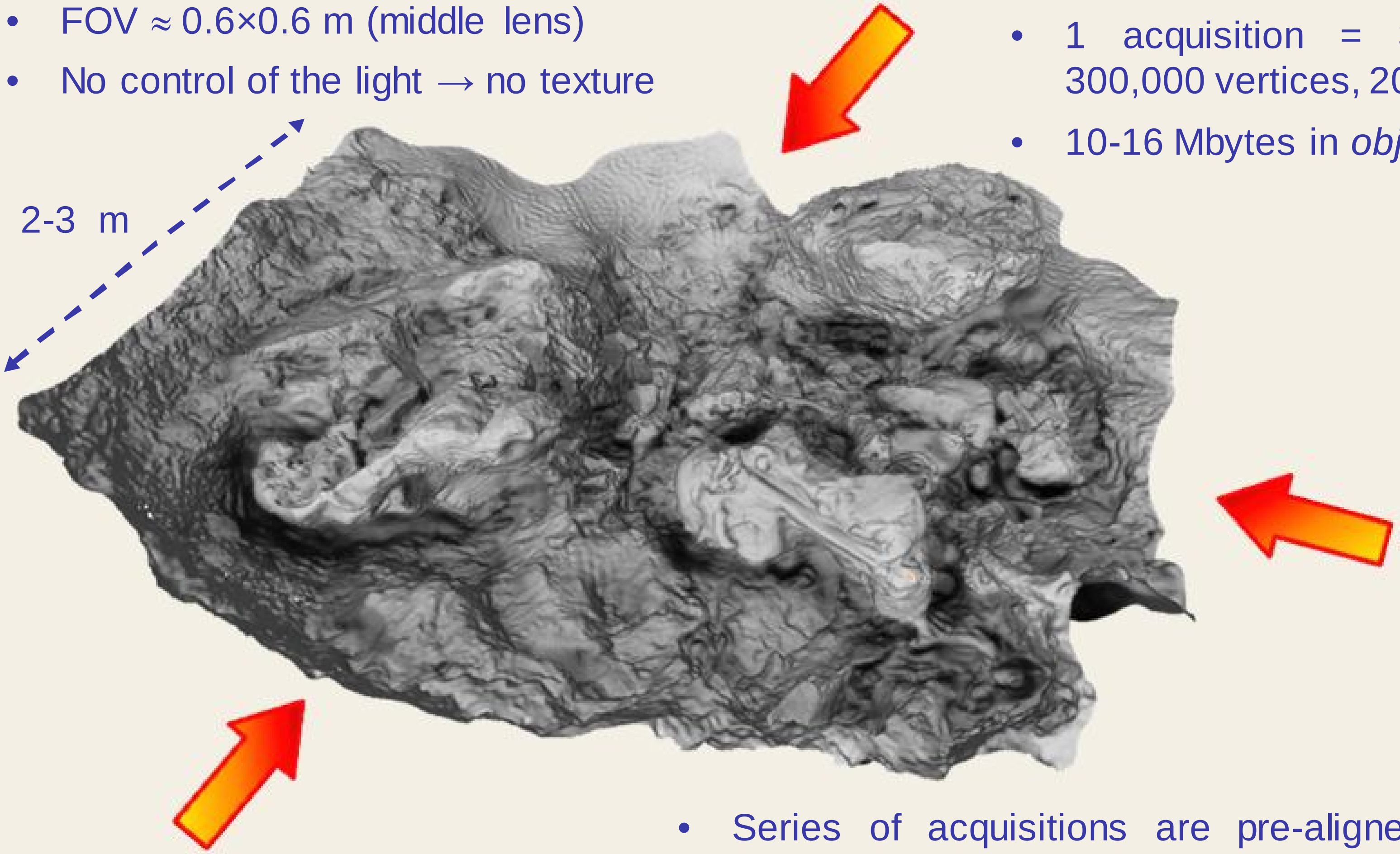

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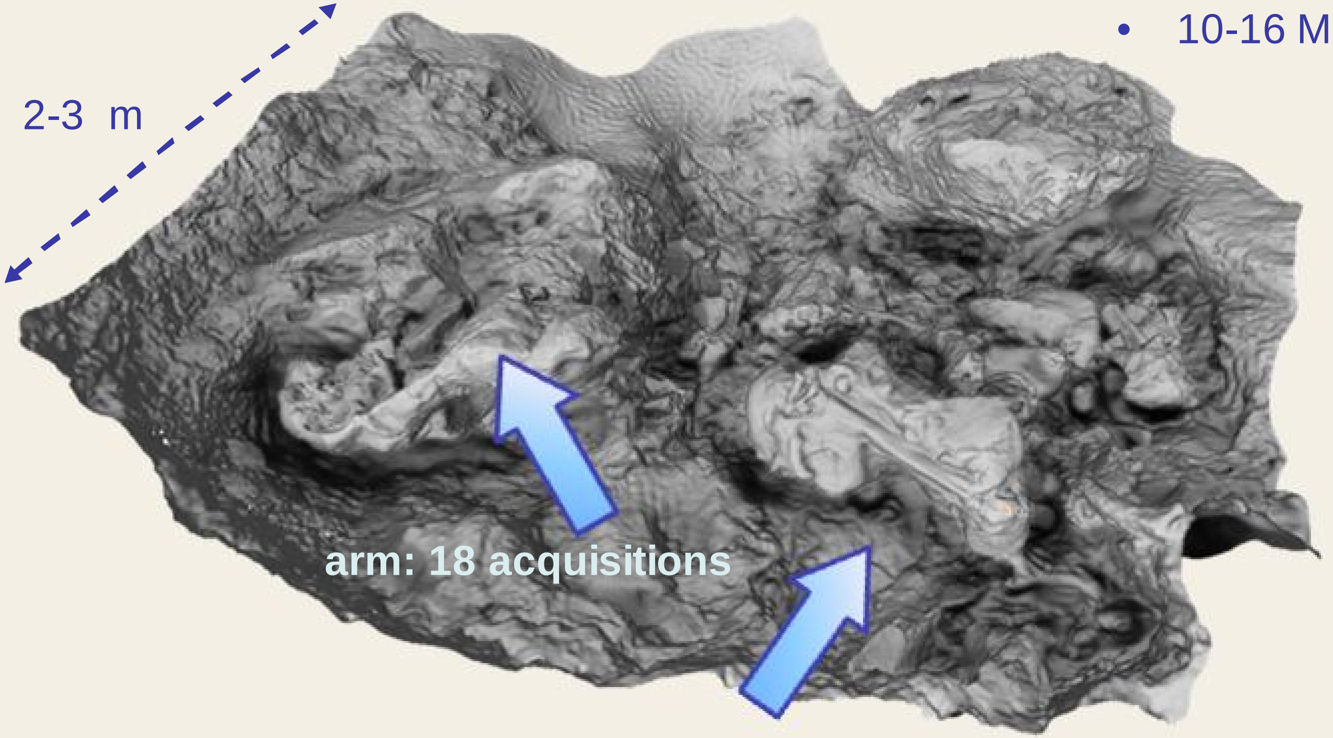
→ 3 work days by 2 trained people

On the ground… *textured details*
(NextEngine HD)

- FOV ≈ 0.3×0.3 m (wide modes)
- With texture (controlled white light)

- 1 acquisition = 3D mesh (100-300,000 vertices, 200-600,000 faces)
- 10-16 Mbytes in *obj* format



- No need of manual pre-alignment

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On the ground… *processing (1)*

- **Selection of 3D views**. To reject useless (redundant or no exploitable information due to occlusion).
- **Automatic global registration** by minimizing the average distance between the overlapping surfaces of two acquisitions.
- **Merging** registered 3D meshes. But, the vertices of the different 3D meshes are not exactly at the same position due to the quantification, the imprecision or the noise. A choice or an average has to be made. How to fuse the colors?
- **Simplification**. Reduce (by deletion or fusion of close points) the number of vertices and faces.
- **Smoothing** to remove visual defects (e.g. spikes).
- **Hole filling** to delete the holes induced by the occlusions. Some algorithms detect the holes in a 3D mesh and infer surface patches which lies on their boundaries. In order to not be too visually detectable, these patches must follow a curvature continuity constraint.
- **Rendering** i.e. displaying the final 3D reconstruction by defining the viewpoint, the lighting and more generally how a triangle of the mesh looks (reflection to the light, color, artificial texture).

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→ many work days by trained computer scientists…

On the ground… *processing (2)*

	MeshLab (GS)	*Commercial software (BM)*
Global registration	"Align tool" with default parameters	Several software were used according to the results: "Align tool" in the NextEngine software, and "Register/Fine" in RapidForm XOR2 (reverse engineering software)
Merging	"Flatten visible layers"	
Simplification	"Clustering decimation"	"Decimate" in Rapid-Form XOR2
Smoothing	"Smoothing fairing"	
Hole filling	Hole-filling command is too limited	"Fill hole/curvature method" in RapidForm XOR2
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→ comparable results except for rendering which is better with specific (commercial) software…

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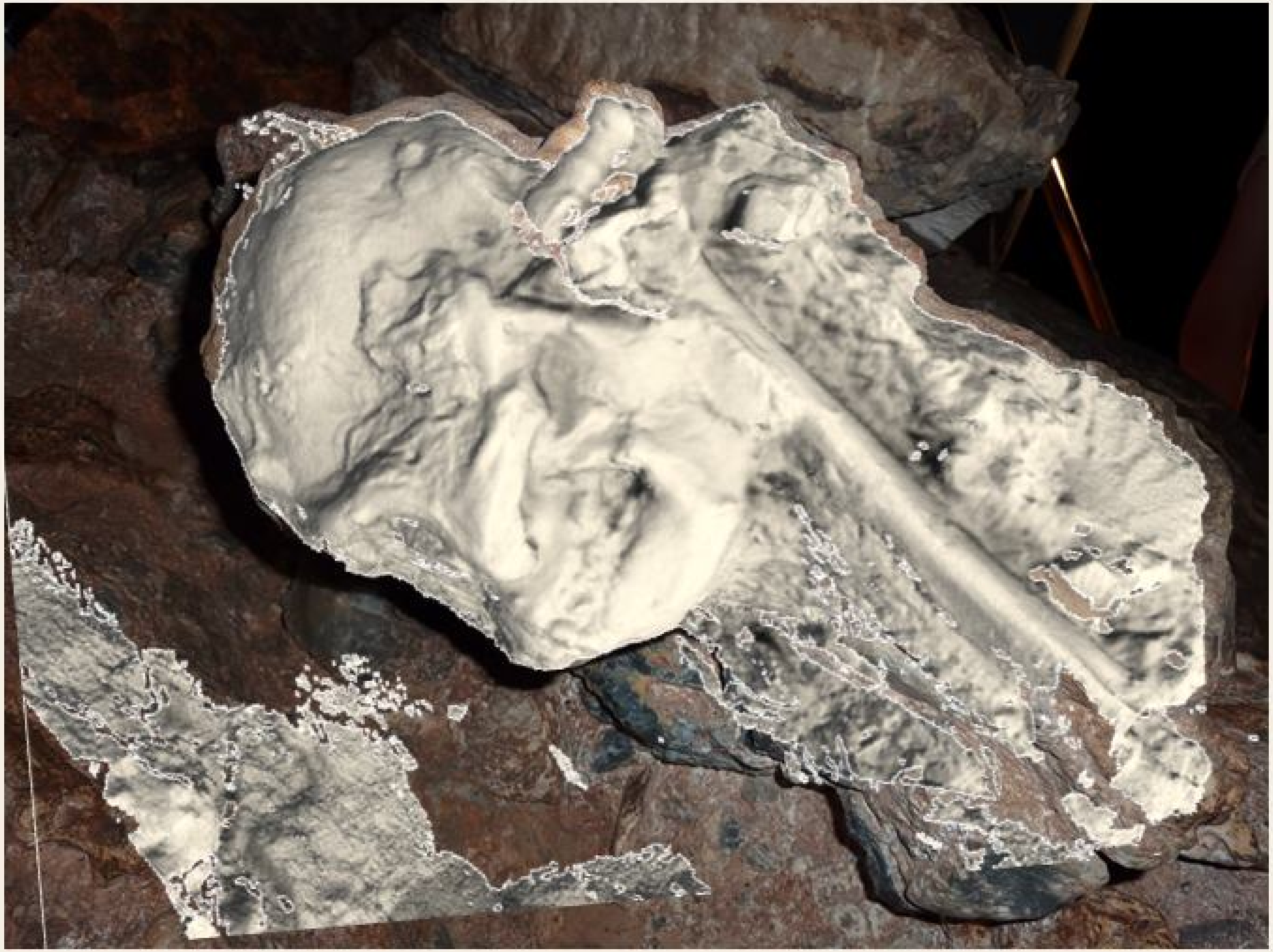
Cost	*MeshLab 1.3*: 0 $ (freeware)	*Rapidform XOR: ~10,000 $ (?)* *Zbrush 4.0*: 700$ (commercial price)

Some results *textured details (NextEngine HD)*

Photograph of the skull of “Little Foot”

Some results *textured details (NextEngine HD)*

3D reconstruction (1,125,446 vertices / 2,068,848 faces) based on 6 acquisitions, without texture



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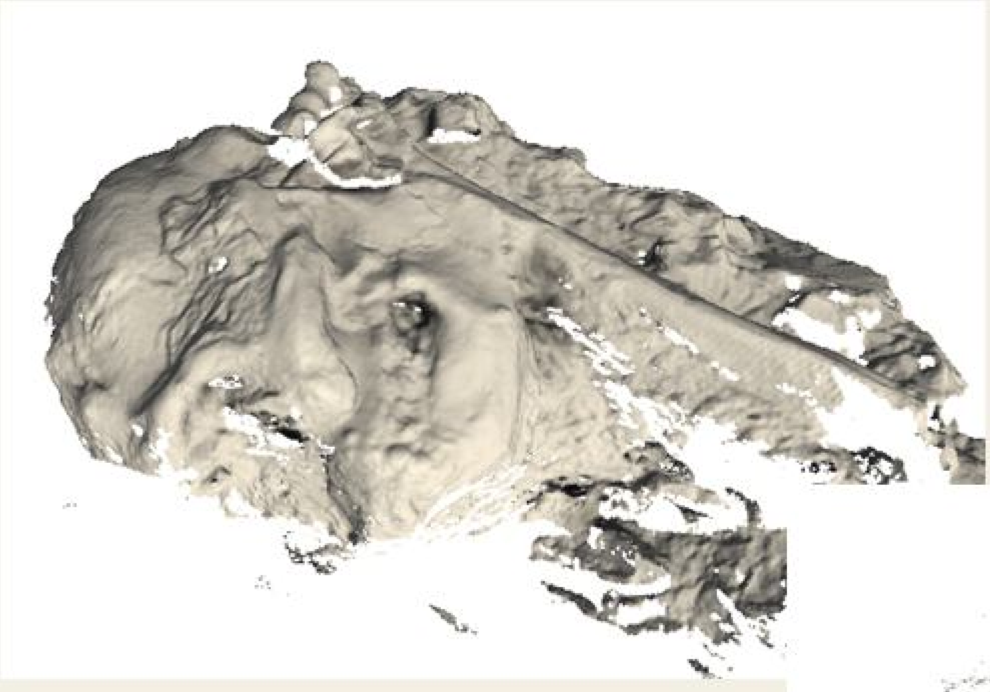
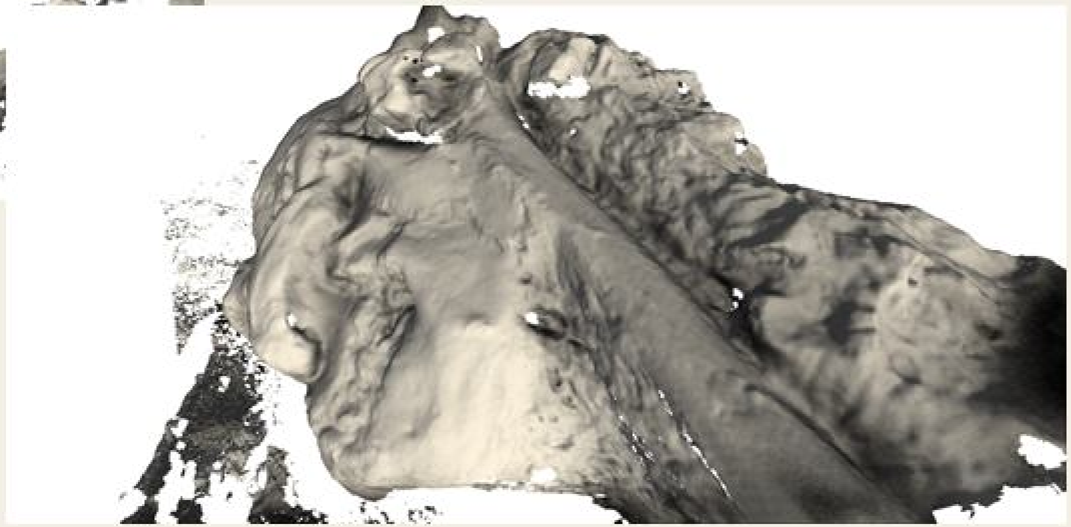


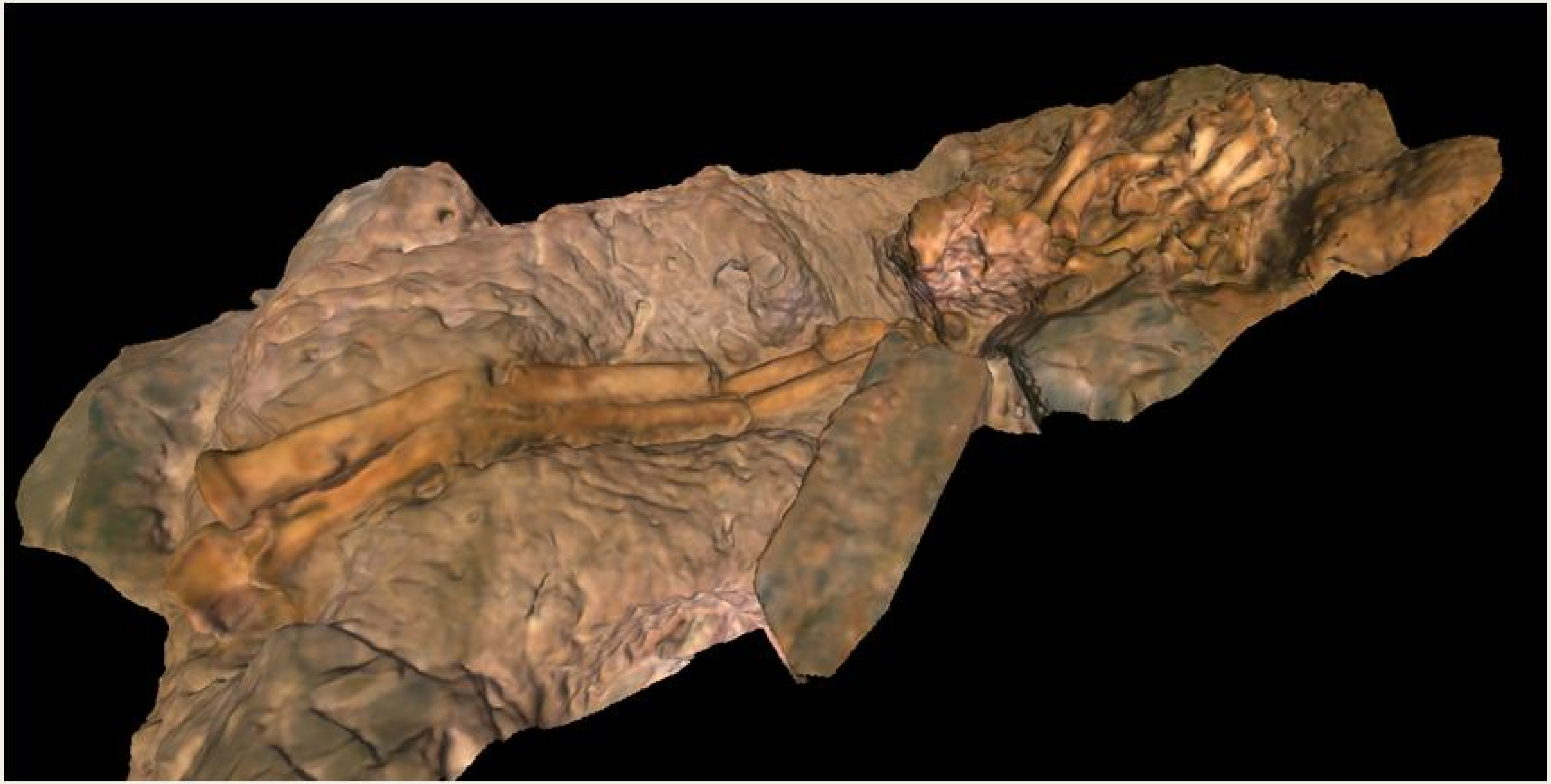


Some results *textured details (NextEngine HD)*

Photograph of the left arm of “Little Foot”

Some results *textured details*
(NextEngine HD)

3D reconstruction (535,668 vertices / 1,067,723 faces) based on 18 acquisitions with texture

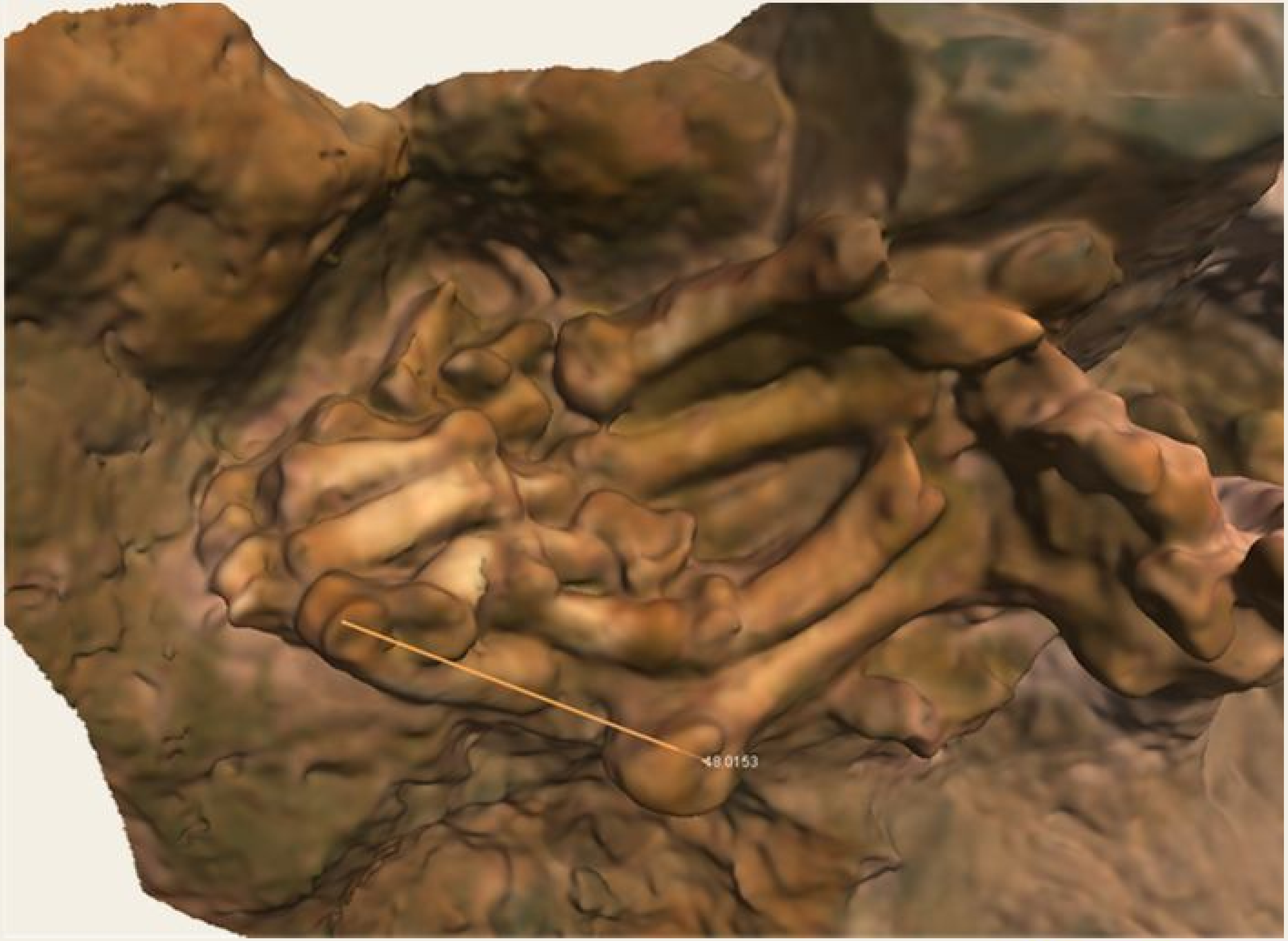


Some results *textured details (NextEngine HD)*

Photograph of the left hand

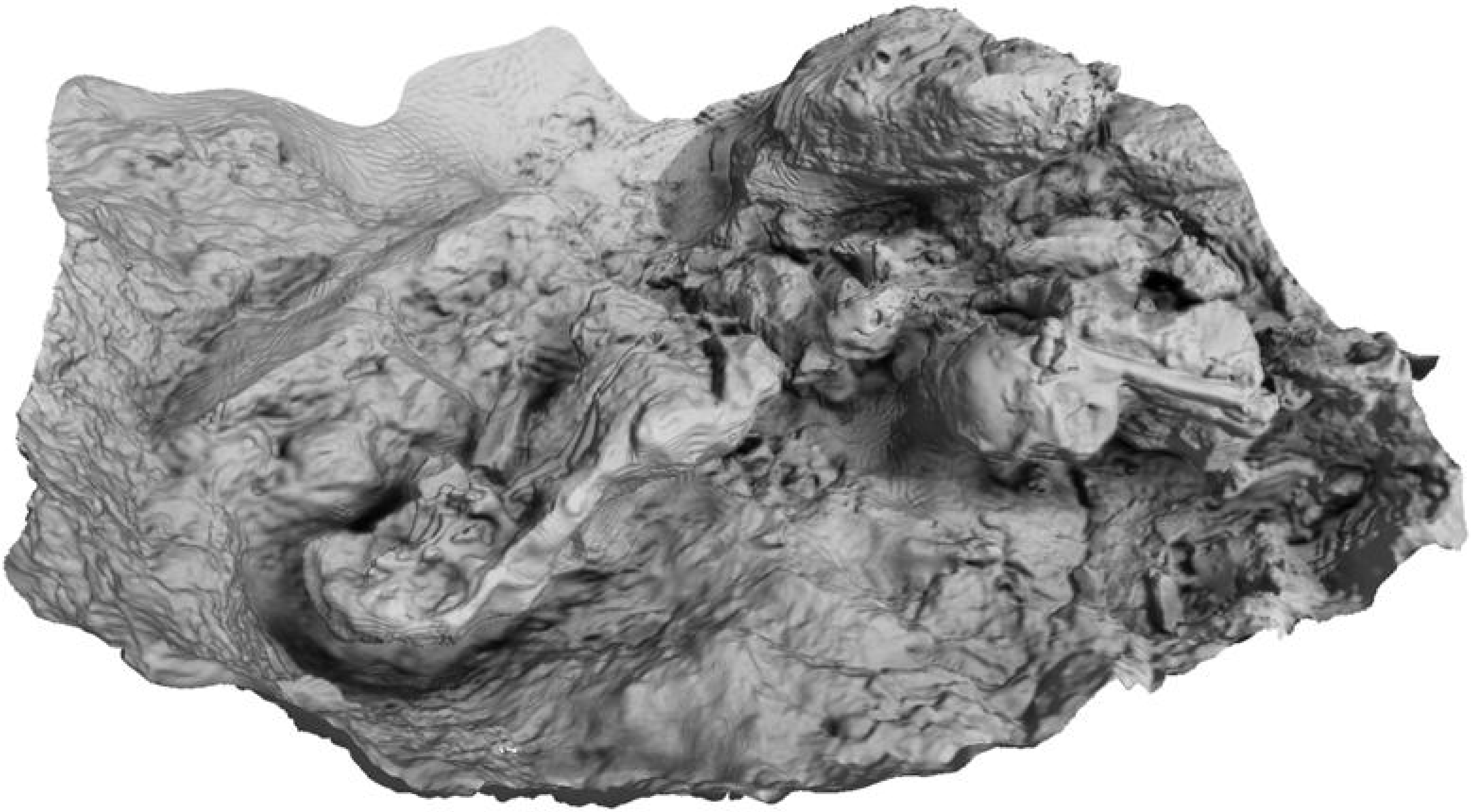
Some results *textured details*
(NextEngine HD)

Zoom of the 3D reconstruction (535,668 vertices / 1,067,723 triangles) of the arm with texture



Some results ***overall acquisition (Minolta)***

3D reconstruction of the site (1,224,885 vertices / 2,446,034 faces) based on 37 acquisitions



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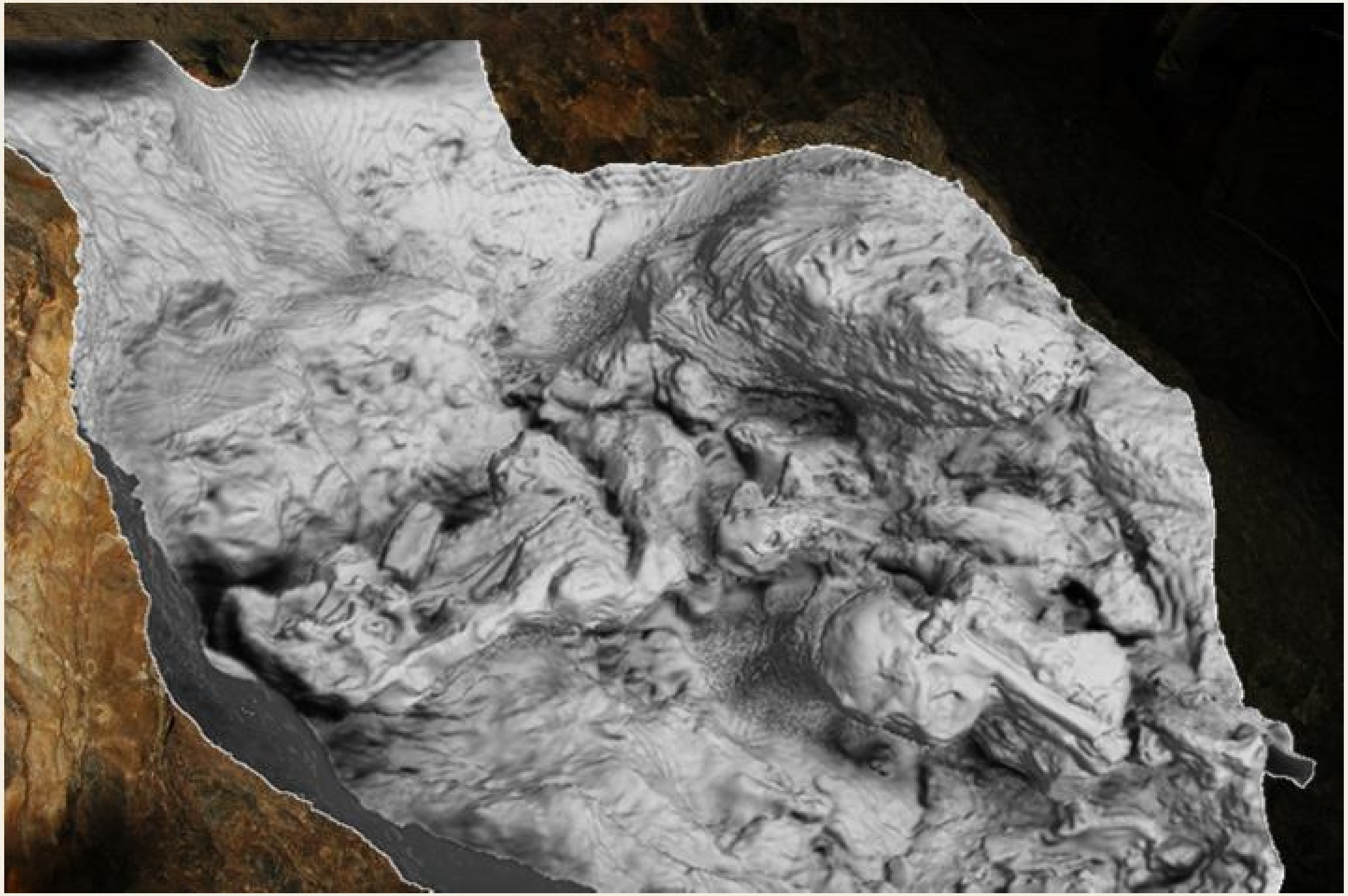

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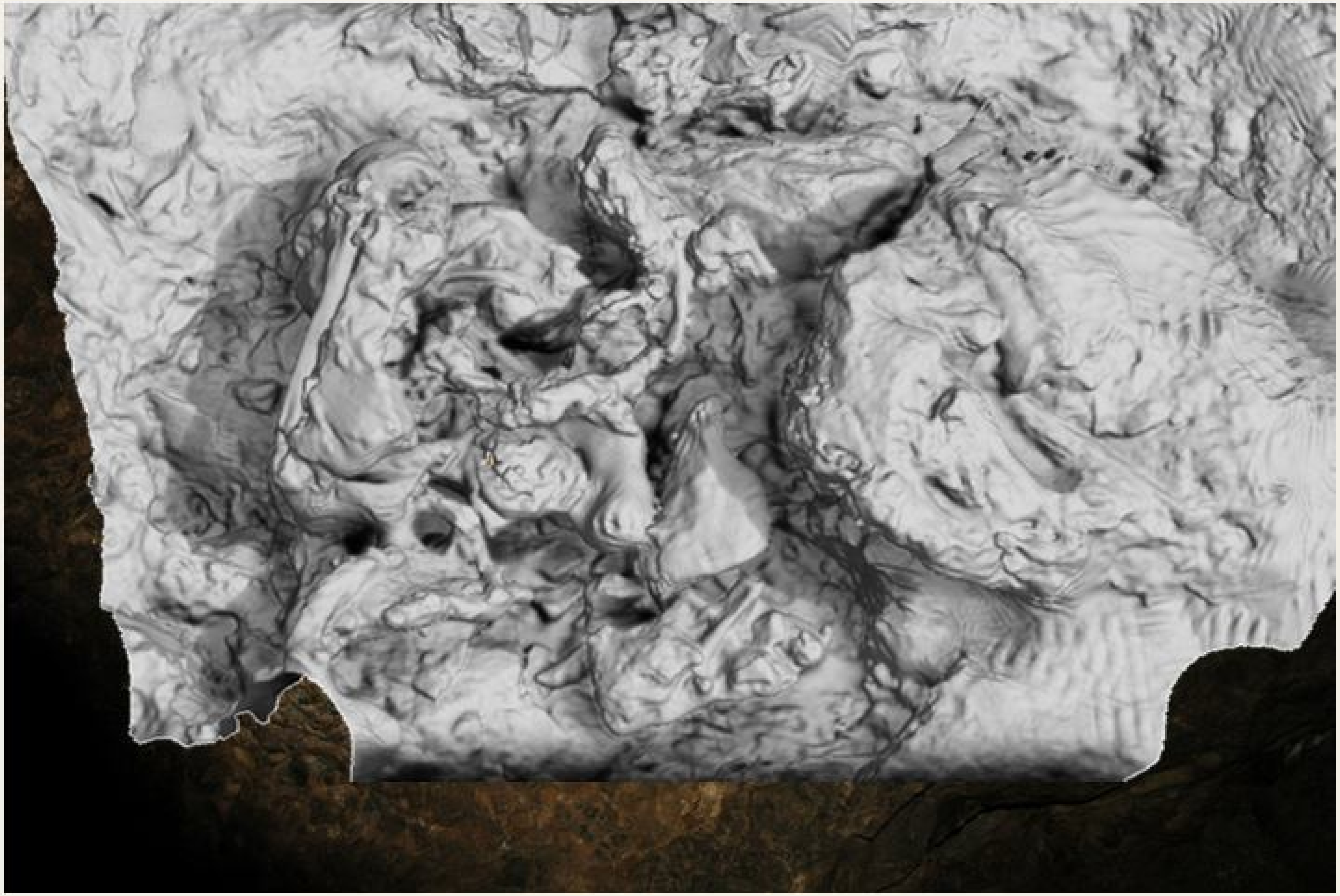

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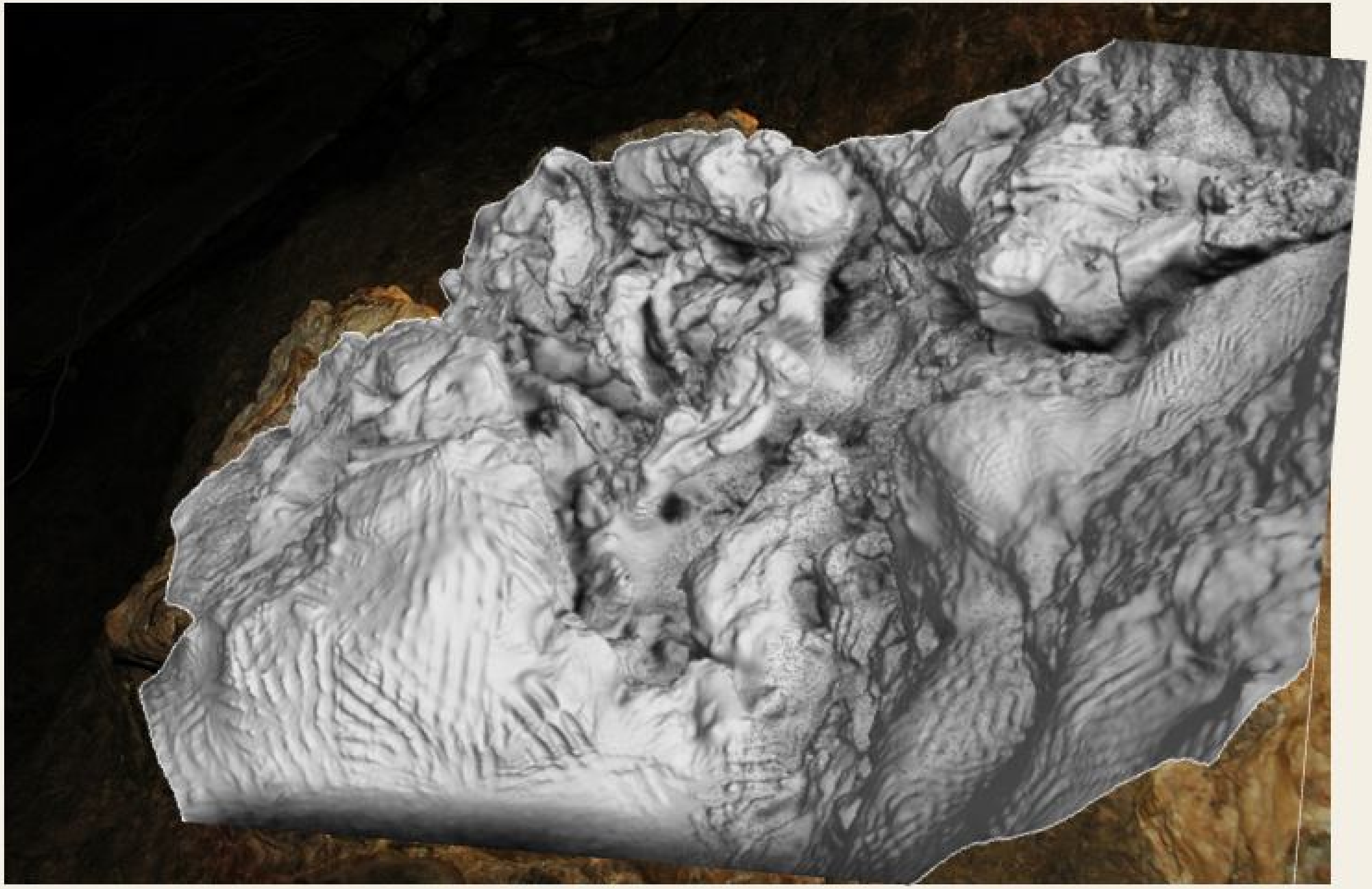
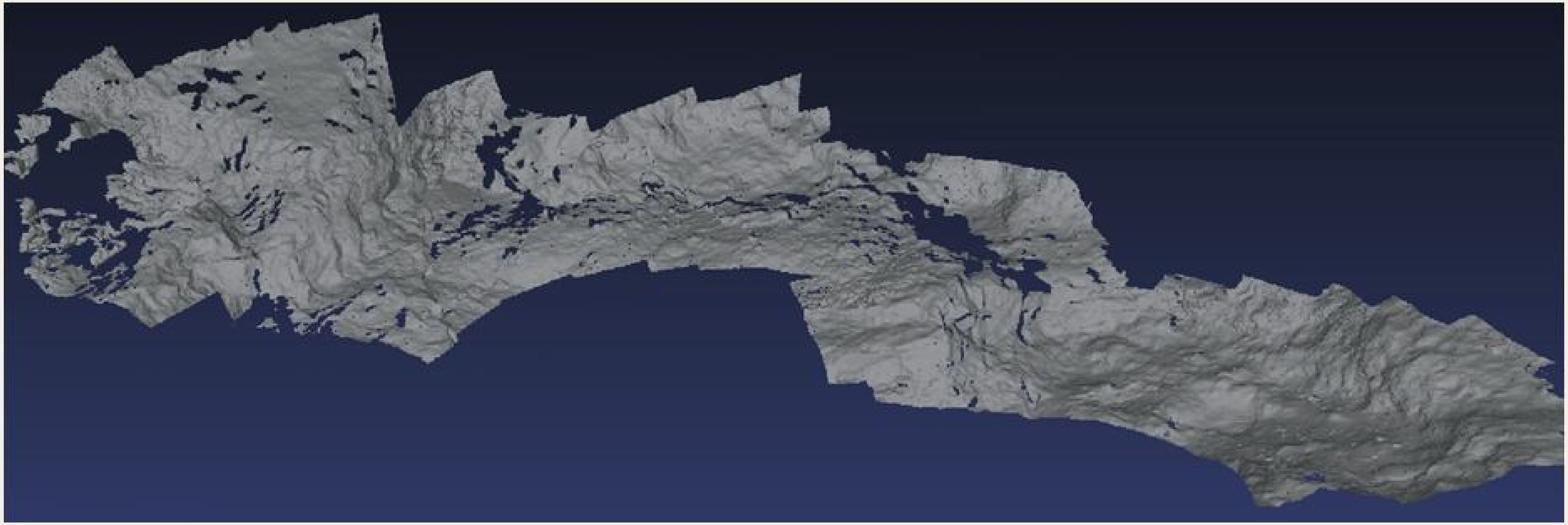


Some results ***overall acquisition (Minolta)***

Parts of the mesh have been manually painted with artificial texture (rock/bone)

Future work

- use the 3D models to **analyze the taphonomic processes**, e.g. how are the arm bones broken, how are positioned the hand bones, how are the different bones dispatched on the floor, etc.?
- **understand the 3D stratigraphy** by observing the geometry of rock layers. Possibility **to come back** to a non-interpretative view of the context.
- 3D scan the fossils at very high resolution (CT, μ-CT) and align these models in the "virtual" site to **combine high accuracy and exact positioning**.



Geometry of the rock layers on the right of the excavation site

The authors thank Nkwane Molefe and Stephen Motsumi for their help and advice during the 3D digitization.

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Kroomdrai excavation site (2 km E of Sterkfontein)