Groundbreaking technologies in the Middle Paleolithic of the Levant: High resolution and multi-scale functional analysis of Ground Stone Tools

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Inauguraldissertation

zur Erlangung des Akademischen Grades

eines Dr. phil.,

vorgelegt dem Fachbereich 07 Geschichts- und Kulturwissenschaften

der Johannes Gutenberg-Universität

Mainz

von

Eduardo Paixão

aus Setúbal, Portugal

2021

TRACEOLOGY & CONTROLLED EXPERIMENTS TraCEr

Römisch-Germanisches Zentralmuseum Leibniz-Forschungsinstitut für Archäologie R|G|Z|M

MONREPOS Archäologisches Forschungszentrum und Museum für menschliche Verhaltensevolution

Leibniz Gemeinschaft

Supervisor: Professor Dr. Sabine Gaudzinski-Windheuser and Dr. João Marreiros

Dissertation defended on 15 December 2021

Bahnbrechende Technologien im mittleren Paläolithikum der Levante: Hochauflösende und multiskalige Funktionsanalyse von Ground Stone Tools

von

Eduardo Paixão

Groundbreaking technologies in the Middle Paleolithic of the Levant: High resolution and multi-scale functional analysis of Ground Stone Tools

Volume 2

Eduardo Paixão

This thesis represents research that was conducted in and supported by the following institutions:

MONREPOS
Archäologisches Forschungszentrum und Museum für menschliche Verhaltensevolution

TRACEOLOGY & CONTROLLED EXPERIMENTS
TraCEr

Römisch-Germanisches Zentralmuseum
Leibniz-Forschungsinstitut für Archäologie
RGZM

JG|U
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Leibniz Gemeinschaft

האוניברסיטה העברית בירושלים
THE HEBREW UNIVERSITY OF JERUSALEM
الجامعة العبرية في اورشليم القدس

ICArEHB
INTERDISCIPLINARY CENTER FOR ARCHAEOLOGY AND EVOLUTION OF HUMAN BEHAVIOUR

אוניברסיטת בן-גוריון בנגב
Ben-Gurion University of the Negev

IRENE LEVI SALA CARE
ARCHAEOLOGICAL FOUNDATION

Table of Contents (Volume 2)

1. R scripts

1.1. Archaeological techno-typological analysis

Paixão PhD - archaeological techno-typological analysis
EP

2021-02-26 13:40:27

Brief description of the script

This R markdown document reads, summarizes and plots data for the PhD dissertation *Paixão 2021. Groundbreaking technologies in the Middle Paleolithic of the Levant: High resolution and multi-scale functional analysis of Ground Stone Tools*

The document contains:

Tables
Plots (illustrations of the data analysis)
Supplementary material, including extra tables and figures (data analysis)

This R project and respective scripts follow the procedures described by Marwick et al. 2017.

To compile this markdown document, do not delete or move files from their original folders. Please note that most of the tables and figures in this file do not match the numbering in the PhD dissertation manuscript.

For any questions, comments and inputs, please contact:

Eduardo Paixão, paixao@rgzm.de

Load data into R project

Imported files are in: '../analysis/raw_data'

Figures are saved in: '../analysis/plots'

Tables are saved in: '../analysis/derived_data'

```
# Load required libraries

library(tidyverse)

## ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──

## ✓ ggplot2 3.3.3     ✓ purrr   0.3.4
## ✓ tibble  3.0.6     ✓ dplyr   1.0.4
## ✓ tidyr   1.1.2     ✓ stringr 1.4.0
## ✓ readr   1.4.0     ✓ forcats 0.5.1

## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```r
library(utils)
library(knitr)
library(janitor)

##
## Attaching package: 'janitor'

## The following objects are masked from 'package:stats':
##
##     chisq.test, fisher.test

library(flextable)

##
## Attaching package: 'flextable'

## The following object is masked from 'package:purrr':
##
##     compose

library(GGally)

## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2

library(doBy)

##
## Attaching package: 'doBy'

## The following object is masked from 'package:dplyr':
##
##     order_by

library(ggpubr)

##
## Attaching package: 'ggpubr'

## The following objects are masked from 'package:flextable':
##
##     border, font, rotate

library(tools)

# See your WD and update the following paths
# getwd()

# Load data from .csv
db1 <- read.csv("../raw_data/generaldb.csv", header=T, ",")

# On db1, convert strings to numeric and replace "," by "."
db1$length <- as.numeric(gsub(",", ".", db1$length))
db1$width <- as.numeric(gsub(",", ".", db1$width))
db1$thickness <- as.numeric(gsub(",", ".", db1$thickness))
db1$weight <- as.numeric(gsub(",", ".", db1$weight))

# Filter general datasets by site

# Far'ah II
db1fr <- filter(db1, site == "Fara II")
# Ein Qashish
```

```
db1eq <- filter(db1, site == "Ein Quashish")
# Nesher Ramla
db1nr <- filter(db1, site  == "Nesher Ramla")

data_file <- list.files("../analysis/raw_data/", pattern = "\\.csv$", full.names = TRUE)
```

Tables

General Inventory

```
# Nesher Ramla

inventory <- db1nr %>%
  group_by(raw_material, support) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "support",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Raw material" = raw_material, Boulder = boulder, Block = block)

## `summarise()` has grouped output by 'raw_material'. You can override using the `.groups`
argument.

write_csv(inventory, "../derived_data/generalinventory_nesher.csv")

table <- flextable(inventory)
table <- set_caption(table,caption = "General inventory of Grounds Stone tools
            from Nesher Layer 5")
knit_print(table)
```

General inventory of Grounds Stone tools from Nesher Layer 5

Raw material	Block	Pebble	Boulder	Total
Flint	1	5	0	6
Limestone	68	392	7	467
Nari	1	0	0	1
Total	70	397	7	474

```
# Far'ah
inventory <- db1fr %>%
  group_by(raw_material, support) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "support",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Raw material" = raw_material)

## `summarise()` has grouped output by 'raw_material'. You can override using the `.groups`
argument.

write_csv(inventory, "../derived_data/generalinventory_farah.csv")

table <- flextable(inventory)
table <- set_caption(table,caption = "General inventory of the Ground Stone tools from Far'
ah")
knit_print(table)
```

General inventory of the Ground Stone tools from Far'ah

Raw material	Pebble	block	Total
Flint	2	0	2
Limestone	16	8	24
Other	0	1	1
Total	18	9	27

```
# Ein Qashish
inventory <- db1eq %>%
  group_by(raw_material, support) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "support",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Raw material" = raw_material)

## `summarise()` has grouped output by 'raw_material'. You can override using the `.groups`
argument.

write_csv(inventory, "../derived_data/generalinventory_eq.csv")

table <- flextable(inventory)
table <- set_caption(table,caption = "General inventory of the Ground Stone Tools
            from Ein Qashish")
knit_print(table)
```

General inventory of the Ground Stone Tools from Ein Qashish

Raw material	block	Total
Limestone	8	8
Total	8	8

Typological inventory

```
# Nesher Ramla
type <- db1nr %>%
  group_by(raw_material, typology) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "typology",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Raw material" = raw_material)

## `summarise()` has grouped output by 'raw_material'. You can override using the `.groups`
argument.

write_csv(type, "../derived_data/typeinventory_nesher.csv")
```

```r
table <- flextable(type)
table <- set_caption(table,caption = "Typological inventory by raw material from Nesher Ram
la, Layer 5")
knit_print(table)
```

Typological inventory by raw material from Nesher Ramla, Layer 5

Raw material	Hammerstone	Manuport	Undefined	Abrader	Anvil	Chopper	Natural	Pestle	Total
Flint	1	4	1	0	0	0	0	0	6
Limestone	108	220	48	11	23	13	43	1	467
Nari	0	0	0	0	0	0	1	0	1
Total	109	224	49	11	23	13	44	1	474

```r
# Ein Qashish
type <- db1eq %>%
  group_by(raw_material, typology) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "typology",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Raw material" = raw_material)

## `summarise()` has grouped output by 'raw_material'. You can override using the `.groups`
argument.

write_csv(type, "../derived_data/typeinventory_eq.csv")

table <- flextable(type)
table <- set_caption(table,caption = "Typological inventory by raw material from Ein Qashis
h")
knit_print(table)
```

Typological inventory by raw material from Ein Qashish

Raw material	Anvil	Chopper	Hammerstone	Manuport	Total
Limestone	5	1	1	1	8
Total	5	1	1	1	8

```r
# Far'ah
type <- db1fr %>%
  group_by(raw_material, typology) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "typology",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Raw material" = raw_material)

## `summarise()` has grouped output by 'raw_material'. You can override using the `.groups`
argument.

write_csv(type, "../derived_data/typeinventory_fr.csv")

table <- flextable(type)
```

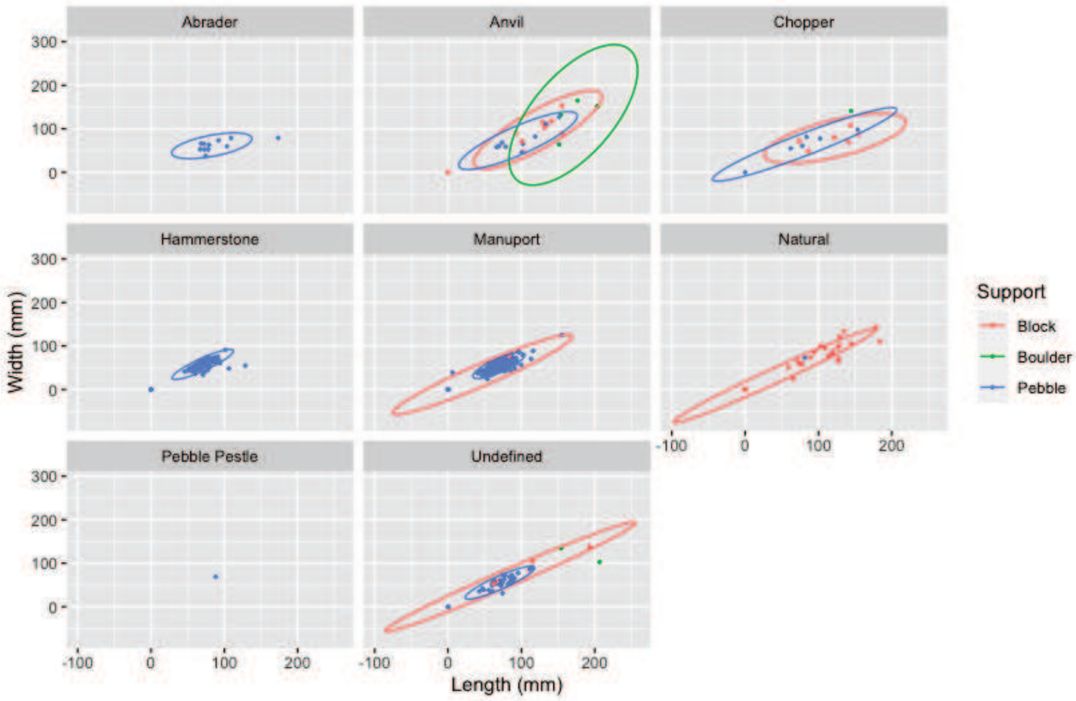
```r
table <- set_caption(table,caption = "Typological inventory by raw material from Far'ah")
knit_print(table)
```

Typological inventory by raw material from Far'ah

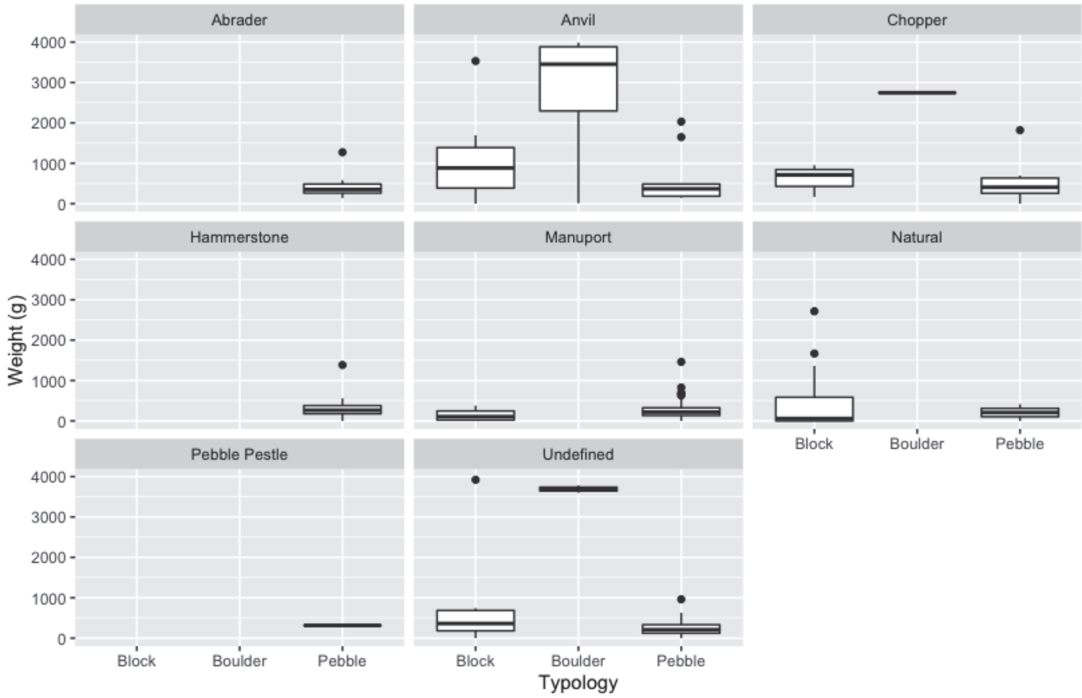
Raw material	Chopper	Manuport	Anvil	Hammerstone	Pebble Pestle	Undefined	Total
Flint	1	1	0	0	0	0	2
Limestone	1	5	2	11	1	4	24
Other	0	0	1	0	0	0	1
Total	2	6	3	11	1	4	27

Morphometric analysis

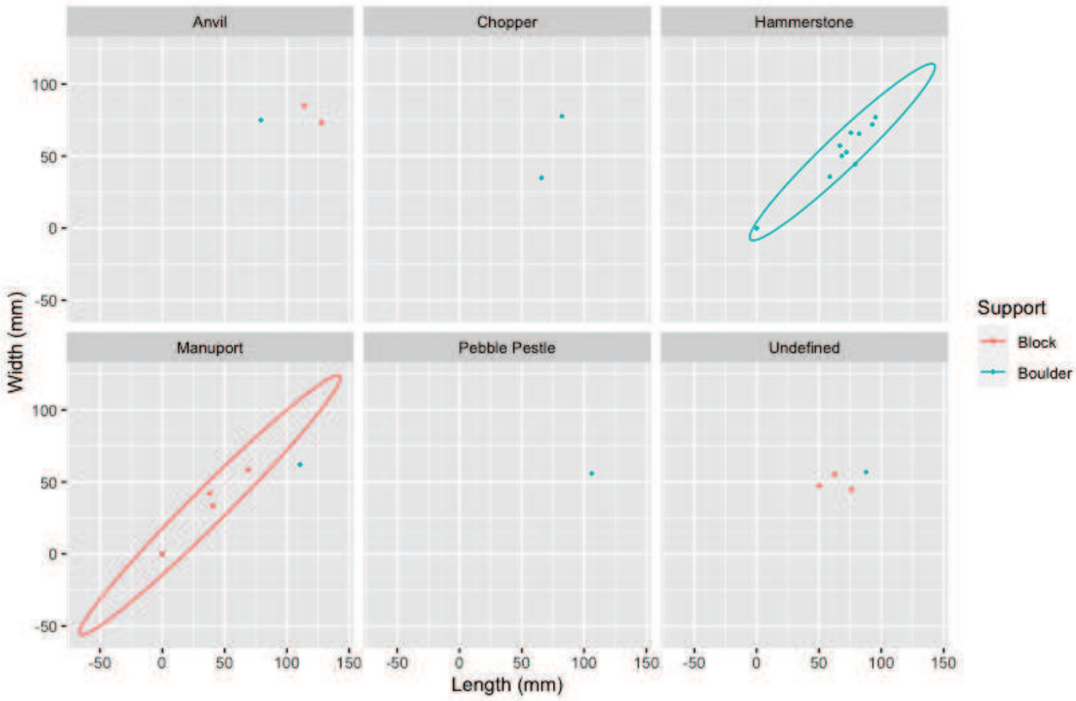
```r
# Nesher Ramla

ggplot(db1nr, aes (x = length, y = width, color = support)) +
  geom_point(size=0.5) +
  stat_ellipse() +
  labs(x="Length (mm)", y="Width (mm)", color = "Support") +
  facet_wrap(vars(typology)) +
  scale_color_discrete(labels = c("Block", "Boulder", "Pebble"))

## Warning: Removed 1 rows containing non-finite values (stat_ellipse).

## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse

## Warning: Removed 1 rows containing missing values (geom_point).

## Warning: Removed 2 row(s) containing missing values (geom_path).

## geom_path: Each group consists of only one observation. Do you need to adjust
## the group aesthetic?
```



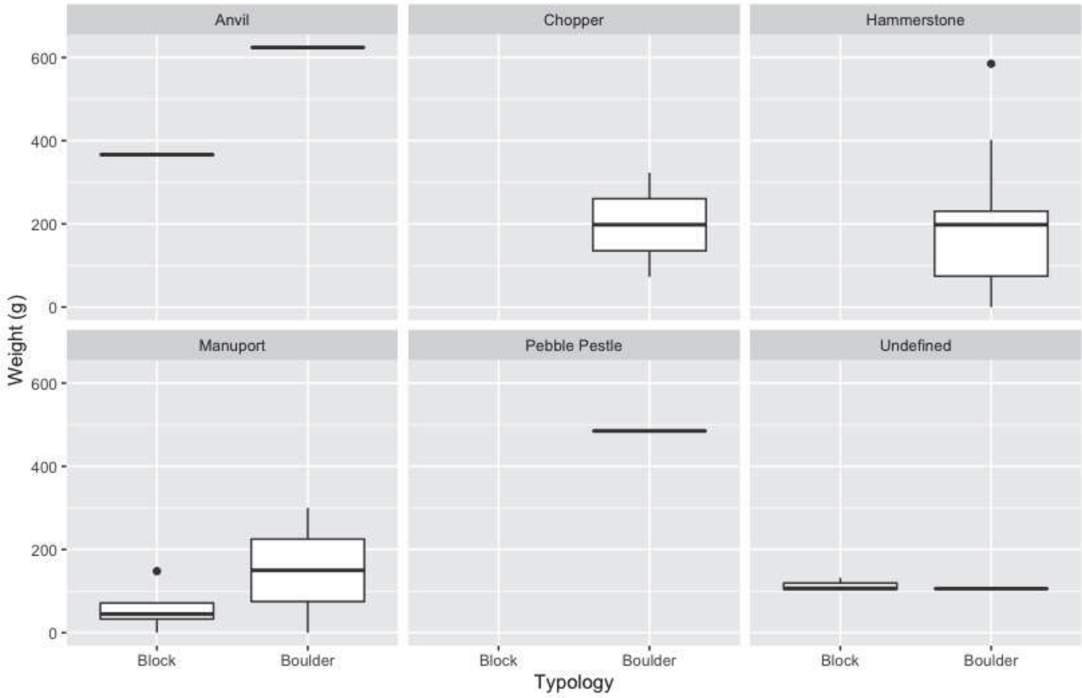

```
ggsave("../plots/metrics_nr.png")

## Saving 8.5 x 5.5 in image

## Warning: Removed 1 rows containing non-finite values (stat_ellipse).

## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse

## Warning: Removed 1 rows containing missing values (geom_point).

## Warning: Removed 2 row(s) containing missing values (geom_path).

## geom_path: Each group consists of only one observation. Do you need to adjust
## the group aesthetic?

ggplot(db1nr, aes(x = support, y = weight)) +
  geom_boxplot() +
  labs(x="Typology", y="Weight (g)") +
  facet_wrap(vars(typology)) +
    scale_x_discrete(labels = c('Block','Boulder','Pebble'))

## Warning: Removed 3 rows containing non-finite values (stat_boxplot).
```



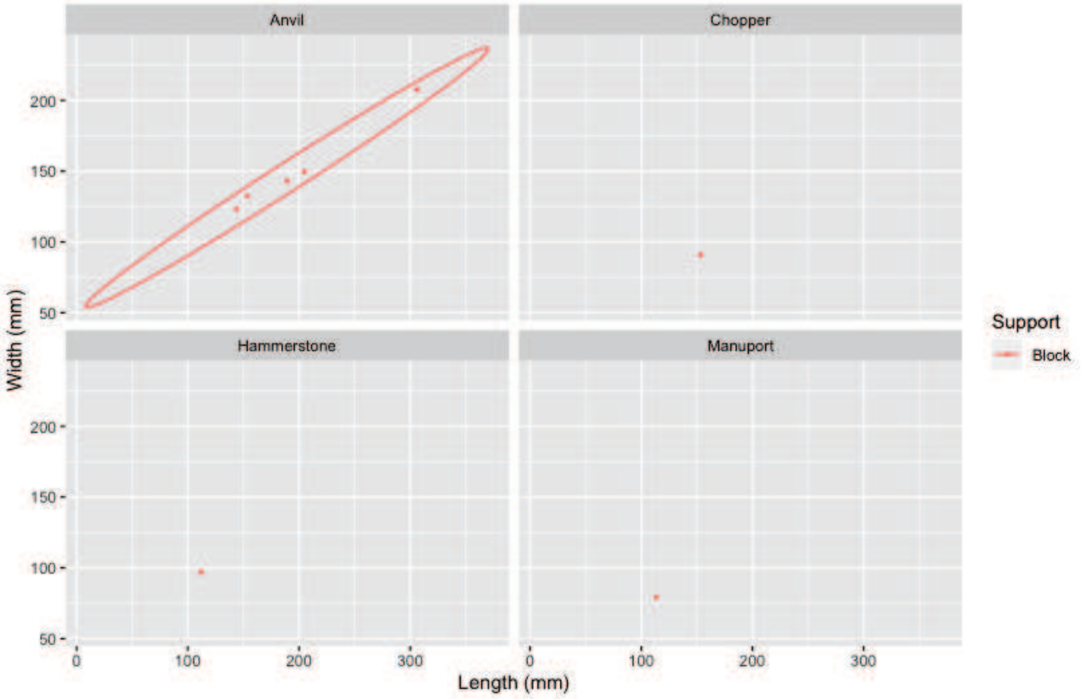

```
ggsave("../plots/weight_nr.png")

## Saving 8.5 x 5.5 in image

## Warning: Removed 3 rows containing non-finite values (stat_boxplot).

# Fa'rah
ggplot(db1fr, aes (x = length, y = width, color = support)) +
  geom_point(size=0.5) +
  stat_ellipse() +
  labs(x="Length (mm)", y="Width (mm)", color = "Support") +
  facet_wrap(vars(typology)) +
  scale_color_discrete(labels = c("Block", "Boulder", "Pebble"))

## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse

## Warning: Removed 7 row(s) containing missing values (geom_path).
```



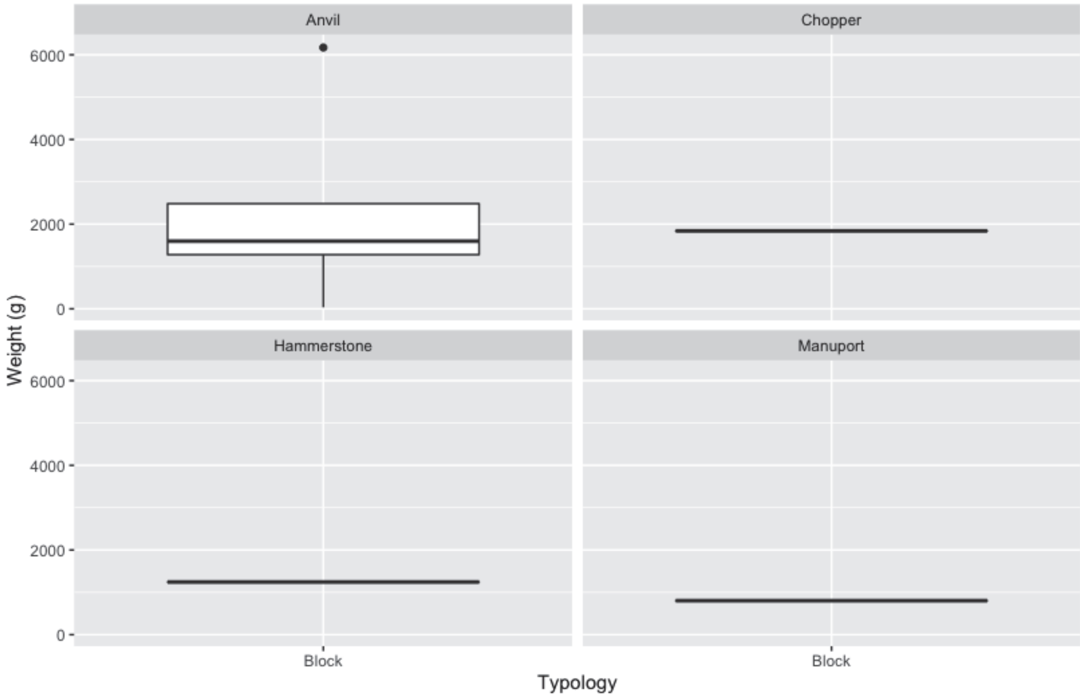

```
ggsave("../plots/metrics_fr.png")

## Saving 8.5 x 5.5 in image
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse

## Warning: Removed 7 row(s) containing missing values (geom_path).

ggplot(db1fr, aes(x = support, y = weight)) +
  geom_boxplot() +
  labs(x="Typology", y="Weight (g)") +
  facet_wrap(vars(typology)) +
    scale_x_discrete(labels = c('Block','Boulder','Pebble'))
```




```
ggsave("../plots/weight_fr.png")

## Saving 8.5 x 5.5 in image

# Ein Qashish

ggplot(db1eq, aes (x = length, y = width, color = support)) +
  geom_point(size=0.5) +
  stat_ellipse() +
  labs(x="Length (mm)", y="Width (mm)", color = "Support") +
  facet_wrap(vars(typology)) +
  scale_color_discrete(labels = c("Block", "Boulder", "Pebble"))

## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse

## Warning: Removed 3 row(s) containing missing values (geom_path).
```




```
ggsave("../plots/metrics_eq.png")

## Saving 8.5 x 5.5 in image
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse
## Too few points to calculate an ellipse

## Warning: Removed 3 row(s) containing missing values (geom_path).

ggplot(db1eq, aes(x = support, y = weight)) +
  geom_boxplot() +
  labs(x="Typology", y="Weight (g)") +
  facet_wrap(vars(typology)) +
    scale_x_discrete(labels = c('Block','Boulder','Pebble'))
```




```
ggsave("../plots/weight_eq.png")

## Saving 8.5 x 5.5 in image
```

End and Session info

```
sessionInfo()

## R version 4.0.4 (2021-02-15)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Catalina 10.15.7
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] tools     stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] ggpubr_0.4.0    doBy_4.6.8      GGally_2.1.0    flextable_0.6.3
##  [5] janitor_2.1.0   knitr_1.31      forcats_0.5.1   stringr_1.4.0
##  [9] dplyr_1.0.4     purrr_0.3.4     readr_1.4.0     tidyr_1.1.2
## [13] tibble_3.0.6    ggplot2_3.3.3   tidyverse_1.3.0
##
## loaded via a namespace (and not attached):
##  [1] httr_1.4.2         jsonlite_1.7.2     carData_3.0-4      modelr_0.1.8
##  [5] assertthat_0.2.1   highr_0.8          cellranger_1.1.0   yaml_2.2.1
##  [9] gdtools_0.2.3      pillar_1.4.7       backports_1.2.1    lattice_0.20-41
## [13] glue_1.4.2         uuid_0.1-4         digest_0.6.27      RColorBrewer_1.1-2
## [17] ggsignif_0.6.0     rvest_0.3.6        snakecase_0.11.0   colorspace_2.0-0
## [21] htmltools_0.5.1.1  Matrix_1.3-2       plyr_1.8.6         pkgconfig_2.0.3
```

```
## [25] broom_0.7.4         haven_2.3.1         scales_1.1.1        openxlsx_4.2.3
## [29] officer_0.3.16      rio_0.5.16          farver_2.0.3        generics_0.1.0
## [33] car_3.0-10          ellipsis_0.3.1      withr_2.4.1         cli_2.3.0
## [37] magrittr_2.0.1      crayon_1.4.0        readxl_1.3.1        evaluate_0.14
## [41] fs_1.5.0            MASS_7.3-53         rstatix_0.6.0       xml2_1.3.2
## [45] foreign_0.8-81      data.table_1.13.6   hms_1.0.0           lifecycle_0.2.0
## [49] munsell_0.5.0       reprex_1.0.0        zip_2.1.1           compiler_4.0.4
## [53] Deriv_4.1.2         systemfonts_1.0.0   rlang_0.4.10        grid_4.0.4
## [57] rstudioapi_0.13     labeling_0.4.2      base64enc_0.1-3     rmarkdown_2.6
## [61] gtable_0.3.0        abind_1.4-5         DBI_1.1.1           reshape_0.8.8
## [65] curl_4.3            R6_2.5.0            lubridate_1.7.9.2   stringi_1.5.3
## [69] Rcpp_1.0.6          vctrs_0.3.6         dbplyr_2.1.0        tidyselect_1.1.0
## [73] xfun_0.20
```

1.2. Archaeological functional data analysis

Paixão PhD - archaeological functional data analysis

EP

2021-02-08 11:33:05

Brief description of the script

This R markdown document reads, summarizes and plots data for the PhD dissertation *Paixão 2021. Groundbreaking technologies in the Middle Paleolithic of the Levant: High resolution and multi-scale functional analysis of Ground Stone Tools*

The document contains:

1. Tables
2. Plots (illustrations of the data analysis)
3. Supplementary material, including extra tables and figures (data analysis)

This R project and respective scripts follow the procedures described by Marwick et al. 2017.

To compile this markdown document do not delete or move files from their original folders. Please note that most of the tables and figures in this file do not match the numbering in the Phd disseration manuscript.

For any questions, comments and inputs, please contact:

Eduardo Paixão, paixao@rgzm.de

Load data into R project

Imported files are in: '../analysis/raw_data'

Figures are saved in: '../analysis/plots'

Tables are saved in: '../analysis/derived_data'

```
# Load required libraries

library(tidyverse)

## ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──

## ✓ ggplot2 3.3.3     ✓ purrr   0.3.4
## ✓ tibble  3.0.6     ✓ dplyr   1.0.4
## ✓ tidyr   1.1.2     ✓ stringr 1.4.0
## ✓ readr   1.4.0     ✓ forcats 0.5.1

## Warning: package 'ggplot2' was built under R version 4.0.2

## Warning: package 'tibble' was built under R version 4.0.2

## Warning: package 'readr' was built under R version 4.0.2
```

```
## Warning: package 'dplyr' was built under R version 4.0.2

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(utils)
library(knitr)
library(janitor)

## Warning: package 'janitor' was built under R version 4.0.2

##
## Attaching package: 'janitor'

## The following objects are masked from 'package:stats':
##
##     chisq.test, fisher.test

library(flextable)

## Warning: package 'flextable' was built under R version 4.0.2

##
## Attaching package: 'flextable'

## The following object is masked from 'package:purrr':
##
##     compose

library(GGally)

## Warning: package 'GGally' was built under R version 4.0.2

## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2

library(doBy)

## Warning: package 'doBy' was built under R version 4.0.2

##
## Attaching package: 'doBy'

## The following object is masked from 'package:dplyr':
##
##     order_by

library(ggpubr)

## Warning: package 'ggpubr' was built under R version 4.0.2

##
## Attaching package: 'ggpubr'

## The following objects are masked from 'package:flextable':
##
##     border, font, rotate

library(tools)

# See your WD and update the following paths
```

```r
# getwd()

# Load data from .csv
db1 <- read.csv("../raw_data/generaldb.csv", header=T, ",") # general database
db2 <- read.csv("../raw_data/functionaldb.csv", header=T, ",") # dataset related to functio
nal

# Filter general datasets by site

# Far'ah II
db1fr <- filter(db1, site == "Fara II")
db2fr <- filter(db2, SITE == "FaraII")
# Ein Qashish
db1eq <- filter(db1, site == "Ein Quashish")
db2eq <- filter(db2, SITE == "Ein Quashish")
# Nesher Ramla
db1nr <- filter(db1, site == "Nesher Ramla")
db2nr <- filter(db2, SITE == "Nesher Ramla")

data_file <- list.files("../raw_data/", pattern = "\\.csv$", full.names = TRUE)
```

Use-wear macro damage, first observations

```
# Nesher Ramla

# sampling observation with macro wear traces
damagenr <- filter(db1nr, usewear_macro == 'yes')

# Use-wear damage by tool typology

macrodamage <- damagenr %>%
  group_by(typology, usewear_type) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "usewear_type",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Typology" = typology, Mixed = mix, "Impact marks" = pecking,
         Polish = polish, Striations = striations)

## `summarise()` has grouped output by 'typology'. You can override using the `.groups` arg
ument.

write_csv(macrodamage, "../derived_data/macrodamage_nr.csv")

table <- flextable(macrodamage)
table <- set_caption(table,caption = "Use-wear damage
            organized by typology, Nesher Ramla - Layer 5")
knit_print(table)
```

Use-wear damage organized by typology, Nesher Ramla - Layer 5

Typology	Impact marks	Polish	Striations	Mixed	Total
Abrader	1	8	2	0	11
Anvil	19	0	1	2	22
Chopper	11	0	0	0	11
Core	1	0	0	0	1
Hammerstone	106	0	0	2	108
Pebble Pestle	1	0	0	0	1
Undefined	7	16	3	7	33
Total	146	24	6	11	187

```
# Far'ah

# sampling observation with macro wear traces
damagefr <- filter(db1fr, usewear_macro == 'yes')

# Use-wear damage by tool typology

macrodamage <- damagefr %>%
  group_by(typology, usewear_type) %>%
  summarize(total = n()) %>%
```

```
  pivot_wider(names_from = "usewear_type",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Typology" = typology)

## `summarise()` has grouped output by 'typology'. You can override using the `.groups` arg
ument.

write_csv(macrodamage, "../derived_data/macrodamage_fr.csv")

table <- flextable(macrodamage)
table <- set_caption(table,caption = "Use-wear damage
            organized by typology, Far'ah")
knit_print(table)
```

Use-wear damage organized by typology, Far'ah

Typology	Impact	striations	mix	polish	Total
Anvil	3	0	0	0	3
Chopper	2	0	0	0	2
Core	2	1	0	0	3
Hammerstone	10	0	1	0	11
Pebble Pestle	0	0	1	0	1
Undefined	2	0	0	2	4
Total	19	1	2	2	24

```
# Ein Qashish

# sampling observation with macro wear traces
damageeq <- filter(db1eq, usewear_macro == 'yes')

# Use-wear damage by tool typology

macrodamage <- damageeq %>%
  group_by(typology, usewear_type) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "usewear_type",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Typology" = typology)

## `summarise()` has grouped output by 'typology'. You can override using the `.groups` arg
ument.

write_csv(macrodamage, "../derived_data/macrodamage_eq.csv")

table <- flextable(macrodamage)
table <- set_caption(table,caption = "Use-wear damage
            organized by typology, Ein Qashish")
knit_print(table)
```

Use-wear damage organized by typology, Ein Qashish

Typology	mix	Impact	Total
Anvil	1	3	4
Chopper	0	1	1
Hammerstone	0	1	1
Total	1	5	6

Macro wear analysis

```
# Nesher Ramla

# Macro wear traces by tool typology

macrowear <- db2nr %>%
  filter(!is.na(MACROTYPE)) %>%
  group_by(TYPOLOGY, MACROTYPE) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "MACROTYPE",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Typology" = TYPOLOGY, "Type 1" = "1", "Type 2" = "2")

## `summarise()` has grouped output by 'TYPOLOGY'. You can override using the `.groups` arg
ument.

write_csv(macrowear, "../derived_data/macrowear_nr.csv")

table <- flextable(macrowear)
table <- set_caption(table,caption = "Macro wear traces
            organized by typology, Nesher Ramla - Layer 5")
knit_print(table)
```

Macro wear traces organized by typology, Nesher Ramla - Layer 5

Typology	Type 1	Type 2	Total
Pestle	1	1	2
Anvil	1	10	11
Chopper	3	4	7
Hammerstone	21	65	86
Pestle	1	0	1
Undefined	1	2	3
Total	28	82	110

```
# Far'ah
macrowear <- db2fr %>%
  filter(!is.na(MACROTYPE)) %>%
  group_by(TYPOLOGY, MACROTYPE) %>%
```

```r
  summarize(total = n()) %>%
  pivot_wider(names_from = "MACROTYPE",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Typology" = TYPOLOGY, "Type 1" = "1", "Type 2" = "2")
```

```
## `summarise()` has grouped output by 'TYPOLOGY'. You can override using the `.groups` arg
ument.
```

```r
write_csv(macrowear, "../derived_data/macrowear_fr.csv")

table <- flextable(macrowear)
table <- set_caption(table,caption = "Macro wear traces
            organized by typology, Far'ah")
knit_print(table)
```

Macro wear traces organized by typology, Far'ah

Typology	Type 2	Type 1	Total
Hammerstone	8	0	8
Undifined	3	1	4
Total	11	1	12

```r
# Ein Qashish
macrowear <- db2eq %>%
  filter(!is.na(MACROTYPE)) %>%
  group_by(TYPOLOGY, MACROTYPE) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "MACROTYPE",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "") %>%
  rename("Typology" = TYPOLOGY, "Type 2" = "2")
```

```
## `summarise()` has grouped output by 'TYPOLOGY'. You can override using the `.groups` arg
ument.
```

```r
write_csv(macrowear, "../derived_data/macrowear_eq.csv")

table <- flextable(macrowear)
table <- set_caption(table,caption = "Macro wear traces
            organized by typology, Ein Qashish")
knit_print(table)
```

Macro wear traces organized by typology, Ein Qashish

Typology	Type 2	Total
Hammerstone	1	1
Total	1	1

Micro wear analysis

```
# Using db2 dataset, which contains all micro wear observations
# This only applies to Nesher Ramla (see Methods and Results chapter for more info)

microwear <- db2nr %>%
  filter(MICROTYPE %in% c("A", "B","C","D")) %>%
  group_by(TYPOLOGY, MICROTYPE) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "MICROTYPE",
              values_from = "total",
              values_fill = 0) %>%
  adorn_totals(where = c("row", "col"), fill = "")%>%
  rename("Typology" = TYPOLOGY)

## `summarise()` has grouped output by 'TYPOLOGY'. You can override using the `.groups` arg
ument.

write_csv(microwear, "../derived_data/tab6.csv")

table <- flextable(microwear)
table <- set_caption(table,caption = "Micro wear type
            organized by typology, Nesher Ramla - Layer 5")
knit_print(table)
```

Micro wear type organized by typology, Nesher Ramla - Layer 5

Typology	D	A	B	C	Total
Pestle	1	0	0	0	1
Abrader	0	4	1	1	6
Anvil	0	0	1	0	1
Chopper	0	0	1	0	1
Hammerstone	0	1	2	1	4
Undifined	8	3	5	0	16
Total	9	8	10	2	29

Correlation between macro and micro wear traces

```
# sampling observation with macro wear traces type 1
# This only applies to Nesher Ramla (see Methods and Results chapter for more info)

macro1 <- db2nr %>%
  filter(MACROTYPE == "1", MICROTYPE %in% c("A", "B","C","D")) %>%
  group_by(TYPOLOGY, MICROTYPE) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "MICROTYPE",
              values_from = "total",
              values_fill = 0) %>%
  rename("Typology" = TYPOLOGY) %>%
  adorn_totals(where = c("row", "col"), fill = "")

## `summarise()` has grouped output by 'TYPOLOGY'. You can override using the `.groups` arg
ument.
```

```
write_csv(microwear, "../derived_data/macro1&micro_nr.csv")

table <- flextable(macro1)
table <- set_caption(table,caption = "Micro wear traces associated with Macro traces type 1
, and organized by typology, Nesher Ramla - Layer 5")
knit_print(table)
```

Micro wear traces associated with Macro traces type 1, and organized by typology, Nesher Ramla - Layer 5

Typology	D	B	C	Total
Pestle	1	0	0	1
Chopper	0	1	0	1
Hammerstone	0	0	1	1
Total	1	1	1	3

```
# sampling observation with macro wear traces type 2
# This only applies to Nesher Ramla (see Methods and Results chapter for more info)

macro2 <- db2nr %>%
  filter(MACROTYPE == "2", MICROTYPE %in% c("A", "B","C","D")) %>%
  group_by(TYPOLOGY, MICROTYPE) %>%
  summarize(total = n()) %>%
  pivot_wider(names_from = "MICROTYPE",
              values_from = "total",
              values_fill = 0) %>%
  rename("Typology" = TYPOLOGY) %>%
  adorn_totals(where = c("row", "col"), fill = "")

## `summarise()` has grouped output by 'TYPOLOGY'. You can override using the `.groups` arg
ument.

write_csv(microwear, "../derived_data/macro2&micro_nr.csv")

table <- flextable(macro2)
table <- set_caption(table,caption = "Micro wear traces associated with Macro traces type 2
, and organized by typology, Nesher Ramla - Layer 5")
knit_print(table)
```

Micro wear traces associated with Macro traces type 2, and organized by typology, Nesher Ramla - Layer 5

Typology	B	Total
Hammerstone	1	1
Total	1	1

Relation between different active areas and macro wear traces within and between tools

```
# Nesher Ramla
# 2 impact areas

a <- filter(db2nr, WEAR2 == "yes")
a <- select(a, TYPOLOGY, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE)
b <- a %>%
```

```
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(TYPOLOGY, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Tools with 2 active areas
            with macro wear traces, Nesher Ramla - Layer 5")
knit_print(table)
```

Tools with 2 active areas with macro wear traces, Nesher Ramla - Layer 5

TYPOLOGY	Impact/ Impact	Impact/ Polish	Impact/ Polish &Striation	Impact/ Striation	Polish/ Impact	Polish/ Polish	Striation /Impact	Total
Anvil	5	1	0	2	0	0	0	8
Hammerstone	14	0	0	0	1	0	0	15
Pestle	0	0	0	0	0	0	1	1
Undifined	0	0	1	1	1	1	0	4
Total	19	1	1	3	2	1	1	28

```
# 3 impact areas

a <- filter(db2nr, WEAR3 == "yes")
a <- select(a, TYPOLOGY, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(TYPOLOGY, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

threeimpac <- sampled %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(threeimpac)
table <- set_caption(table,caption = "Tools with 3 active areas
            with macro wear traces, Nesher Ramla - Layer 5")
knit_print(table)
```

Tools with 3 active areas with macro wear traces, Nesher Ramla - Layer 5

TYPOLOGY	Impact/Impact/Impact	Impact/Striation/Impact	Total
Anvil	0	1	1
Hammerstone	5	0	5
Total	5	1	6

```
# 4 impact areas

a <- filter(db2nr, WEAR4_ == "yes")
a <- select(a, TYPOLOGY, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE,
            WEAR3_MARKS_TYPE, WEAR4_MARKS_TYPE)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE,
        WEAR4_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(TYPOLOGY, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

fourimpac <- sampled %>%
  adorn_totals(where = c("row", "col"), fill = "")


table <- flextable(fourimpac)
table <- set_caption(table,caption = "Tools with 4 active areas with
            macro wear traces, Nesher Ramla - Layer 5")
knit_print(table)
```

Tools with 4 active areas with macro wear traces, Nesher Ramla - Layer 5

TYPOLOGY	Impact/Impact/Impact/Impact	Total
Hammerstone	2	2
Total	2	2

```
# Use-wear location, files for GIS spatial analysis

# Hammerstones

a <- filter(db2nr, TYPOLOGY == "Hammerstone")

a <- select(a, WEAR1_LOCATION, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR2_LOCATION,
            WEAR3_MARKS_TYPE, WEAR3_LOCATION,
            WEAR4_MARKS_TYPE, WEAR4_LOCATION)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE,
        WEAR4_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(WEAR1_LOCATION, WEAR2_LOCATION,
```

```
       WEAR3_LOCATION, WEAR4_LOCATION, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
  rename("1st area" = WEAR1_LOCATION, "2nd area" = WEAR2_LOCATION, "3rd area" = WEAR3_LOCAT
ION,
         "4th area" = WEAR4_LOCATION) %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Location of use-wear traces on Hammerstones, Nesher R
amla")
knit_print(table)
```

Location of use-wear traces on Hammerstones, Nesher Ramla

1st area	3rd area	4th area	Impact/	Impact/ Impact/	Impact/ Impact/ Impact/	Impact/ Impact/ Impact/ Impact	Impact/ Striation//	Polish /Impact//	Total
A1			3	0	0	0	0	0	3
A1	A3		0	0	1	0	0	0	1
A1			0	7	0	0	0	0	7
A1			0	2	0	0	0	0	2
A1	B4	B2	0	0	0	1	0	0	1
A1			0	1	0	0	0	0	1
A1			0	2	0	0	0	0	2
A2			13	0	0	0	0	0	13
A2	A3		0	0	1	0	0	0	1
A2			0	11	0	0	1	0	12
A2			0	1	0	0	0	0	1

1st area	3rd area	4th area	Imp act/	Impact/ Impact/	Impact/ Impact/ Impact/	Impact/ Impact/ Impact/ Impact	Impact/ Striatio n//	Polish /Impa ct//	T o t a l
A2			0	4	0	0	0	0	4
A2			0	2	0	0	0	0	2
A2			0	1	0	0	0	0	1
A3			8	0	0	0	0	0	8
A3			0	12	0	0	0	0	1 2
A3			0	0	0	0	1	0	1
A3			0	2	0	0	0	0	2
A3	A9		0	0	1	0	0	0	1
A3			0	3	0	0	0	0	3
A3			0	1	0	0	0	0	1
A3			0	3	0	0	0	0	3
A3			0	1	0	0	0	0	1
A3			0	2	0	0	0	0	2
A4			1	0	0	0	0	0	1
A4			0	1	0	0	0	0	1
A5			2	0	0	0	0	0	2
A5	A5		0	0	1	0	0	0	1
A5			0	3	0	0	0	0	3

1st area	3rd area	4th area	Impact/	Impact/Impact/	Impact/Impact/Impact/	Impact/Impact/Impact/Impact	Impact/Striation//	Polish/Impact//	Total
A5			0	1	0	0	0	0	1
A5	B4	A8	0	0	0	1	0	0	1
A6			1	0	0	0	0	0	1
A6			0	1	0	0	0	0	1
A6			0	1	0	0	0	0	1
A6			0	1	0	0	0	0	1
A9			1	0	0	0	0	0	1
A9			0	0	0	0	0	1	1
Total			29	63	4	2	2	1	101

```r
# Choppers
a <- filter(db2nr, TYPOLOGY == "Chopper")

a <- select(a, WEAR1_LOCATION, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR2_LOCATION)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(WEAR1_LOCATION, WEAR2_LOCATION,a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
  rename("1st area" = WEAR1_LOCATION, "2nd area" = WEAR2_LOCATION) %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Location of use-wear traces on Choppers, Nesher Ramla
")
knit_print(table)
```

Location of use-wear traces on Choppers, Nesher Ramla

1st area	2nd area	Impact/	Impact/Impact	Total
A1	A3	0	1	1
A2	A3	0	1	1
A2	A6	0	1	1
A3		1	0	1
A3	A3	0	1	1
A3	A5	0	2	2
A5		1	0	1
A6		1	0	1
Total		3	6	9

```
# Anvils
a <- filter(db2nr, TYPOLOGY == "Anvil")

a <- select(a, WEAR1_LOCATION, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR2_LOCATION,
            WEAR3_MARKS_TYPE, WEAR3_LOCATION)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE,
        WEAR3_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(WEAR1_LOCATION, WEAR2_LOCATION,
       WEAR3_LOCATION, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
  rename("1st area" = WEAR1_LOCATION, "2nd area" = WEAR2_LOCATION, "3rd area" = WEAR3_LOCAT
ION) %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Location of use-wear traces on Anvils, Nesher Ramla")
knit_print(table)
```

Location of use-wear traces on Anvils, Nesher Ramla

1st area	2nd area	3rd area	Impact	Impact/Impact	Impact/Polish	Impact/Striation	Impact/Striation/Impact	Polish/Impact	Total
A1			1	0	0	0	0	0	1
A4	A3		0	1	0	0	0	0	1

1st area	2nd area	3rd area	Impact	Impact/Impact	Impact/Polish	Impact/Striation	Impact/Striation/Impact	Polish/Impact	Total
A4	A5		0	1	0	0	0	0	1
A4	A5	A5	0	0	0	0	1	0	1
A4	A6		0	2	0	0	0	0	2
A4	B4		0	1	0	0	0	0	1
A5			3	0	0	0	0	0	3
A5	A3		0	1	0	0	0	1	2
A5	A5		0	0	1	1	0	0	2
A5	B5		0	3	0	0	0	0	3
A8			1	0	0	0	0	0	1
Total			5	9	1	1	1	1	18

```r
# Far'ah
# 2 impact areas

a <- filter(db2fr, WEAR2 == "yes")
a <- select(a, TYPOLOGY, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(TYPOLOGY, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Tools with 2 active areas
            with macro wear traces, Far'ah")
knit_print(table)
```

Tools with 2 active areas with macro wear traces, Far'ah

TYPOLOGY	Impact/Impact	Polish/Polish	Polish&Striation/Impact	Total
Anvil	0	1	0	1
Hammerstone	3	0	0	3
Undifined	0	0	1	1

TYPOLOGY	Impact/Impact	Polish/Polish	Polish&Striation/Impact	Total
Total	3	1	1	5

```
# 3 impact areas

a <- filter(db2fr, WEAR3 == "yes")
a <- select(a, TYPOLOGY, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(TYPOLOGY, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

threeimpac <- sampled %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(threeimpac)
table <- set_caption(table,caption = "Tools with 3 active areas
            with macro wear traces, Far'ah")
knit_print(table)
```

Tools with 3 active areas with macro wear traces, Far'ah

TYPOLOGY	Impact/Impact/Impact	Total
Hammerstone	2	2
Undefined	1	1
Total	3	3

```
# 4 impact areas

a <- filter(db2fr, WEAR4_ == "yes")
a <- select(a, TYPOLOGY, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE,
            WEAR3_MARKS_TYPE, WEAR4_MARKS_TYPE)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE,
        WEAR4_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(TYPOLOGY, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

fourimpac <- sampled %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(fourimpac)
table <- set_caption(table,caption = "Tools with 4 active areas with
            macro wear traces, Far'ah")
knit_print(table)
```

Tools with 4 active areas with macro wear traces, Far'ah

TYPOLOGY	Impact/Impact/Impact/Impact	Total
Hammerstone	1	1
Total	1	1

```
# Use-wear location, files for GIS spatial analysis

# Hammerstones
a <- filter(db2fr, TYPOLOGY == "Hammerstone")

a <- select(a, WEAR1_LOCATION, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR2_LOCATION,
            WEAR3_MARKS_TYPE, WEAR3_LOCATION,
            WEAR4_MARKS_TYPE, WEAR4_LOCATION)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE,
        WEAR4_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(WEAR1_LOCATION, WEAR2_LOCATION,
       WEAR3_LOCATION, WEAR4_LOCATION, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
  rename("1st area" = WEAR1_LOCATION, "2nd area" = WEAR2_LOCATION, "3rd area" = WEAR3_LOCAT
ION,
         "4th area" = WEAR4_LOCATION) %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Location of use-wear traces on Hammerstones, Far'ah")
knit_print(table)
```

Location of use-wear traces on Hammerstones, Far'ah

1st area	2nd area	3rd area	4th area	Impact	Impact/ Impact/ Impact/	Impact/ Impact/ Impact/ Impact	Total
A1	A1	B1	B9	0	0	1	1
A1	A9	B1		0	1	0	1
A3				2	0	0	2
A5				1	0	0	1
A5	A2	A5	B9	0	0	1	1
A5	A8	A5	B9	0	0	2	2
Total				3	1	4	8

```
# Anvils
a <- filter(db2fr, TYPOLOGY == "Anvil")
```

```
a <- select(a, WEAR1_LOCATION, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR2_LOCATION,
            WEAR3_MARKS_TYPE, WEAR3_LOCATION,
            WEAR4_MARKS_TYPE, WEAR4_LOCATION)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE,
        WEAR4_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(WEAR1_LOCATION, WEAR2_LOCATION,
       WEAR3_LOCATION, WEAR4_LOCATION, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
  rename("1st area" = WEAR1_LOCATION, "2nd area" = WEAR2_LOCATION, "3rd area" = WEAR3_LOCAT
ION,
         "4th area" = WEAR4_LOCATION) %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Location of use-wear traces on Anvils, Far'ah")
knit_print(table)
```

Location of use-wear traces on Anvils, Far'ah

1st area	2nd area	3rd area	4th area	Impact	Impact/ Impact/ Impact/ Impact	Polish/ Impact/ Impact/ Impact	Polish/ Polish	Total
A1	A1			0	0	0	1	1
A3				1	0	0	0	1
A3	A2	A5	B9	0	1	1	0	2
A5				2	0	0	0	2
Total				3	1	1	1	6

```
# Choppers
a <- filter(db2fr, TYPOLOGY == "Chopper")

a <- select(a, WEAR1_LOCATION, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR2_LOCATION,
            WEAR3_MARKS_TYPE, WEAR3_LOCATION,
            WEAR4_MARKS_TYPE, WEAR4_LOCATION)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE,
        WEAR4_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(WEAR1_LOCATION, WEAR2_LOCATION,
       WEAR3_LOCATION, WEAR4_LOCATION, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
```

```
  rename("1st area" = WEAR1_LOCATION, "2nd area" = WEAR2_LOCATION, "3rd area" = WEAR3_LOCAT
ION,
         "4th area" = WEAR4_LOCATION) %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Location of use-wear traces on Choppers, Far'ah")
knit_print(table)
```

Location of use-wear traces on Choppers, Far'ah

1st area	2nd area	3rd area	4th area	Impact	Polish& Striation /Impact/ Impact/I mpact	Total
A2	A2	A5	B9	0	1	1
A3				1	0	1
A5				1	0	1
Total				2	1	3

```
# Ein Qashish
# 2 impact areas

a <- filter(db2eq, WEAR2 == "yes")
a <- select(a, TYPOLOGY, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(TYPOLOGY, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

twoimpac <- sampled %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(twoimpac)
table <- set_caption(table,caption = "Tools with 2 active areas
            with macro wear traces, Ein Qashish")
knit_print(table)
```

Tools with 2 active areas with macro wear traces, Ein Qashish

TYPOLOGY	Impact/Impact	Total
Anvil	1	1
Hammerstone	1	1
Total	2	2

```
# 3 impact areas
```

```
a <- filter(db2eq, WEAR3 == "yes")
a <- select(a, TYPOLOGY, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE)
b <- a %>%
  unite(a, WEAR1_MARKS_TYPE, WEAR2_MARKS_TYPE, WEAR3_MARKS_TYPE, sep = "/")

amostra <- b %>%
 count(TYPOLOGY, a)

sampled <- spread(amostra, key = a, value = n)
sampled[is.na(sampled)] <- 0

threeimpac <- sampled %>%
  adorn_totals(where = c("row", "col"), fill = "")

table <- flextable(threeimpac)
table <- set_caption(table,caption = "Tools with 3 active areas
            with macro wear traces, Ein Qashish")
knit_print(table)
```

Tools with 3 active areas with macro wear traces, Ein Qashish

TYPOLOGY	Impact/Impact/Impact	Total
Hammerstone	1	1
Total	1	1

End and Session info

```
sessionInfo()

## R version 4.0.0 Patched (2020-05-04 r78358)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Catalina 10.15.7
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] tools     stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] ggpubr_0.4.0    doBy_4.6.8      GGally_2.1.0    flextable_0.6.3
##  [5] janitor_2.1.0   knitr_1.31      forcats_0.5.1   stringr_1.4.0
##  [9] dplyr_1.0.4     purrr_0.3.4     readr_1.4.0     tidyr_1.1.2
## [13] tibble_3.0.6    ggplot2_3.3.3   tidyverse_1.3.0
##
## loaded via a namespace (and not attached):
##  [1] httr_1.4.2         jsonlite_1.7.2     carData_3.0-4      modelr_0.1.8
##  [5] assertthat_0.2.1   cellranger_1.1.0   yaml_2.2.1         gdtools_0.2.3
##  [9] pillar_1.4.7       backports_1.2.1    lattice_0.20-41    glue_1.4.2
## [13] uuid_0.1-4         digest_0.6.27      RColorBrewer_1.1-2 ggsignif_0.6.0
## [17] rvest_0.3.6        snakecase_0.11.0   colorspace_2.0-0   htmltools_0.5.1.1
## [21] Matrix_1.3-2       plyr_1.8.6         pkgconfig_2.0.3    broom_0.7.4
## [25] haven_2.3.1        scales_1.1.1       openxlsx_4.2.3     officer_0.3.16
## [29] rio_0.5.16         generics_0.1.0     car_3.0-10         ellipsis_0.3.1
```

```
## [33] withr_2.4.1        cli_2.3.0          magrittr_2.0.1     crayon_1.4.0
## [37] readxl_1.3.1       evaluate_0.14      fs_1.5.0           MASS_7.3-53
## [41] rstatix_0.6.0      xml2_1.3.2         foreign_0.8-81     data.table_1.13.6
## [45] hms_1.0.0          lifecycle_0.2.0    munsell_0.5.0      reprex_1.0.0
## [49] zip_2.1.1          compiler_4.0.0     Deriv_4.1.2        systemfonts_1.0.0
## [53] rlang_0.4.10       grid_4.0.0         rstudioapi_0.13    base64enc_0.1-3
## [57] rmarkdown_2.6      gtable_0.3.0       abind_1.4-5        DBI_1.1.1
## [61] reshape_0.8.8      curl_4.3           R6_2.5.0           lubridate_1.7.9.2
## [65] stringi_1.5.3      Rcpp_1.0.6         vctrs_0.3.6        dbplyr_2.1.0
## [69] tidyselect_1.1.0   xfun_0.20
```

1.3. Confocal surface texture analysis of experimental samples

Paixão PhD - Confocal surface texture analysis of experimental samples

EP

2021-02-08 10:32:26

Brief description of the script

This R markdown document reads, summarizes and plots data for the PhD dissertation *Paixão 2021. Groundbreaking technologies in the Middle Paleolithic of the Levant: High resolution and multi-scale functional analysis of Ground Stone Tools*

The document contains:

1. Tables
2. Plots (illustrations of the data analysis)
3. Supplementary material, including extra tables and figures (data analysis)

This R project and respective scripts follow the procedures described by Marwick et al. 2017.

To compile this markdown document do not delete or move files from their original folders. Please note that most of the tables and figures in this file do not match the numbering in the PhD dissertation manuscript.

For any questions, comments and inputs, please contact:

Eduardo Paixão, paixao@rgzm.de

Load data into R project

Imported files are in: '../analysis/raw_data'

Figures are saved in: '../analysis/plots'

Tables are saved in: '../analysis/derived_data'

```
# Load required libraries

library(tidyverse)

## ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──

## ✓ ggplot2 3.3.3     ✓ purrr   0.3.4
## ✓ tibble  3.0.6     ✓ dplyr   1.0.4
## ✓ tidyr   1.1.2     ✓ stringr 1.4.0
## ✓ readr   1.4.0     ✓ forcats 0.5.1

## Warning: package 'ggplot2' was built under R version 4.0.2

## Warning: package 'tibble' was built under R version 4.0.2

## Warning: package 'readr' was built under R version 4.0.2

## Warning: package 'dplyr' was built under R version 4.0.2
```

```
## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(utils)
library(knitr)
library(janitor)

## Warning: package 'janitor' was built under R version 4.0.2

##
## Attaching package: 'janitor'

## The following objects are masked from 'package:stats':
##
##     chisq.test, fisher.test

library(GGally)

## Warning: package 'GGally' was built under R version 4.0.2

## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2

library(doBy)

## Warning: package 'doBy' was built under R version 4.0.2

##
## Attaching package: 'doBy'

## The following object is masked from 'package:dplyr':
##
##     order_by

library(ggpubr)

## Warning: package 'ggpubr' was built under R version 4.0.2

library(tools)

# See your WD and update the following paths
# getwd()

# Load data from .csv
confocaldataexp <- read.delim("../raw_data/confocalexp/confocaldataexp.csv", header = T, ",
")
data_file <- list.files("../raw_data/confocalexp", pattern = "\\.csv$", full.names = TRUE)
md5_in <- md5sum(data_file)
info_in <- data.frame(file = basename(names(md5_in)), checksum = md5_in, row.names = NULL)
```

Confocal micro surface texture data

Import and summarize data

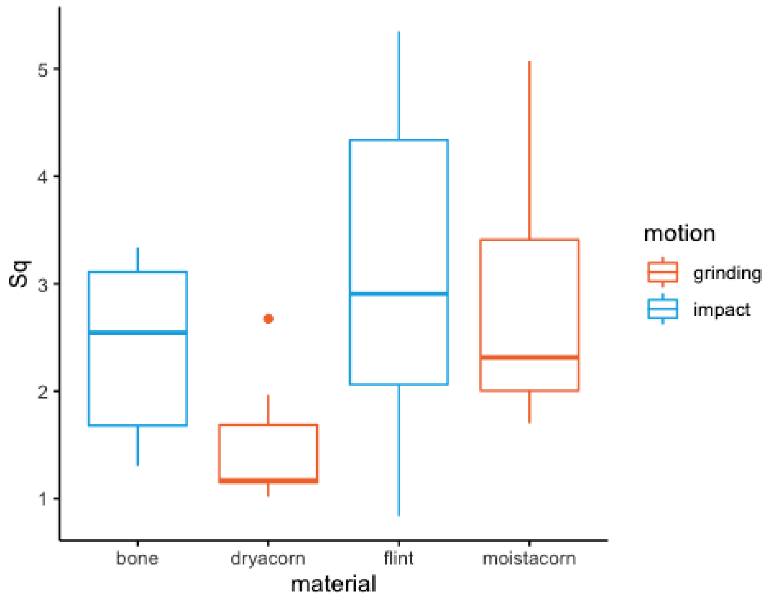
```
# compute descriptive statistics

nminmaxmeanmedsd <- function(x){
    y <- x[!is.na(x)]
    n_test <- length(y)
    min_test <- min(y)
```

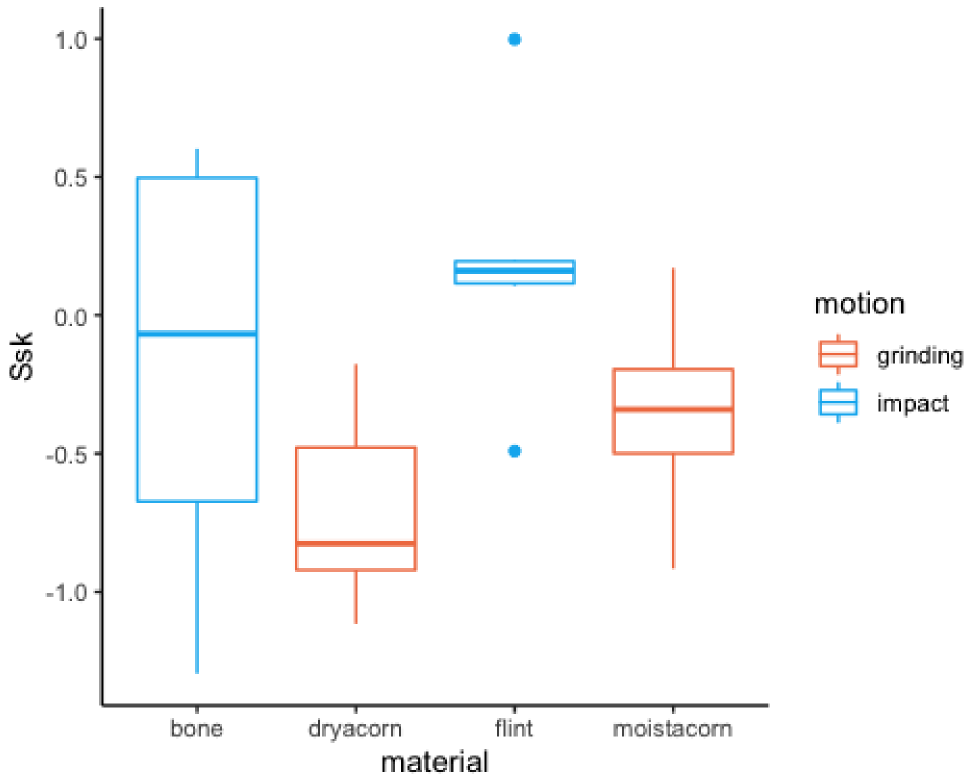
```r
    max_test <- max(y)
    mean_test <- mean(y)
    med_test <- median(y)
    sd_test <- sd(y)
    out <- c(n_test, min_test, max_test, mean_test, med_test, sd_test)
    names(out) <- c("n", "min", "max", "mean", "median", "sd")
    return(out)
}

num.var <- 21:length(confocaldataexp)

confostatsexp <- summaryBy(.~sample + motion + workedmaterial, data=confocaldataexp[c("samp
le", "motion","workedmaterial", names(confocaldataexp)[num.var])], FUN=nminmaxmeanmedsd)

write_csv(confostatsexp, "../derived_data/confostatsexp.csv")
```

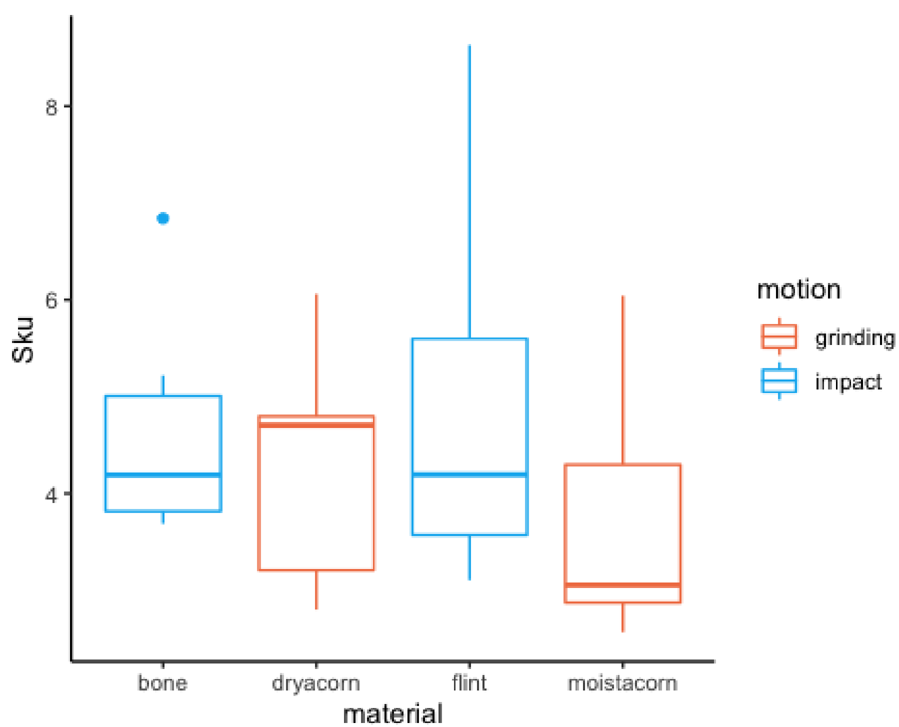
Plot all paramaters

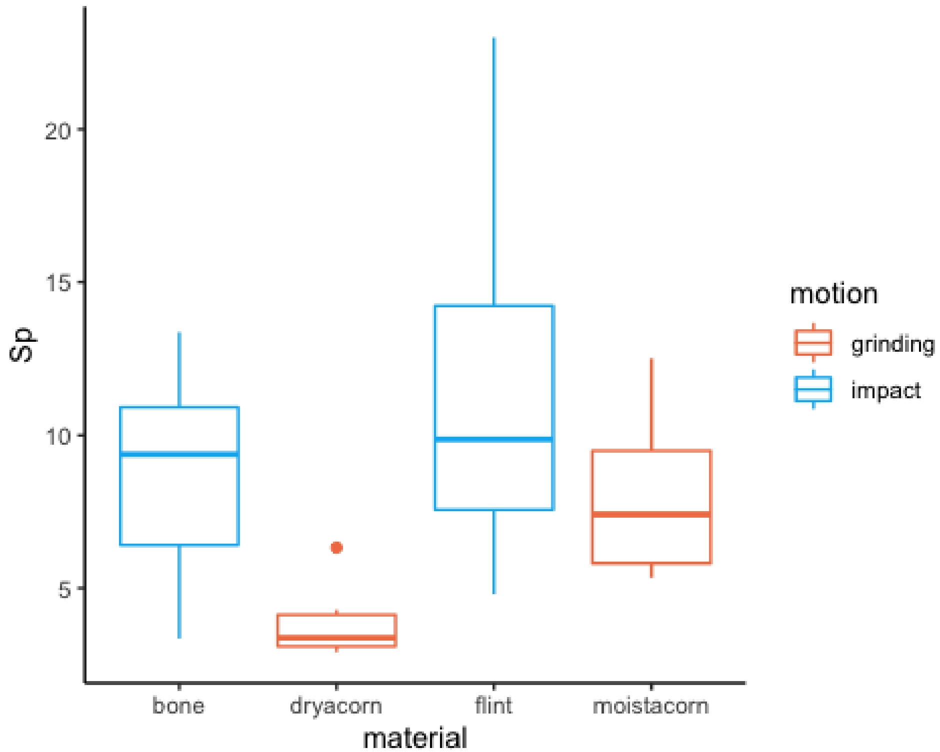
```r
# Loop for plotting all surface texture parameters

for (i in num.var) cat("[",i,"] ", names(confocaldataexp)[i], "\n", sep = "")

## [21] Sq
## [22] Ssk
## [23] Sku
## [24] Sp
## [25] Sv
## [26] Sz
## [27] Sa
## [28] Smr
## [29] Smc
## [30] Sxp
## [31] Sal
## [32] Str
## [33] Std
## [34] Sdq
## [35] Sdr
## [36] Vm
## [37] Vv
## [38] Vmp
## [39] Vmc
## [40] Vvc
## [41] Vvv
## [42] Maximum.depth.of.furrows
## [43] Mean.depth.of.furrows
## [44] Mean.density.of.furrows
## [45] First.direction
## [46] Second.direction
## [47] Third.direction
## [48] Isotropy
## [49] Lengthscale.anisotropy.Sfrax.epLsar
## [50] Lengthscale.anisotropy.NewEplsar
## [51] Fractal.complexity.Asfc
## [52] Scale.of.max.complexity.Smfc
## [53] HAsfc9
## [54] HAsfc81

for (i in num.var) {
  p <- ggplot(data = confocaldataexp, aes_string(x = "workedmaterial", y = names(confocalda
taexp)[i],
                                            colour = "motion")) +
```

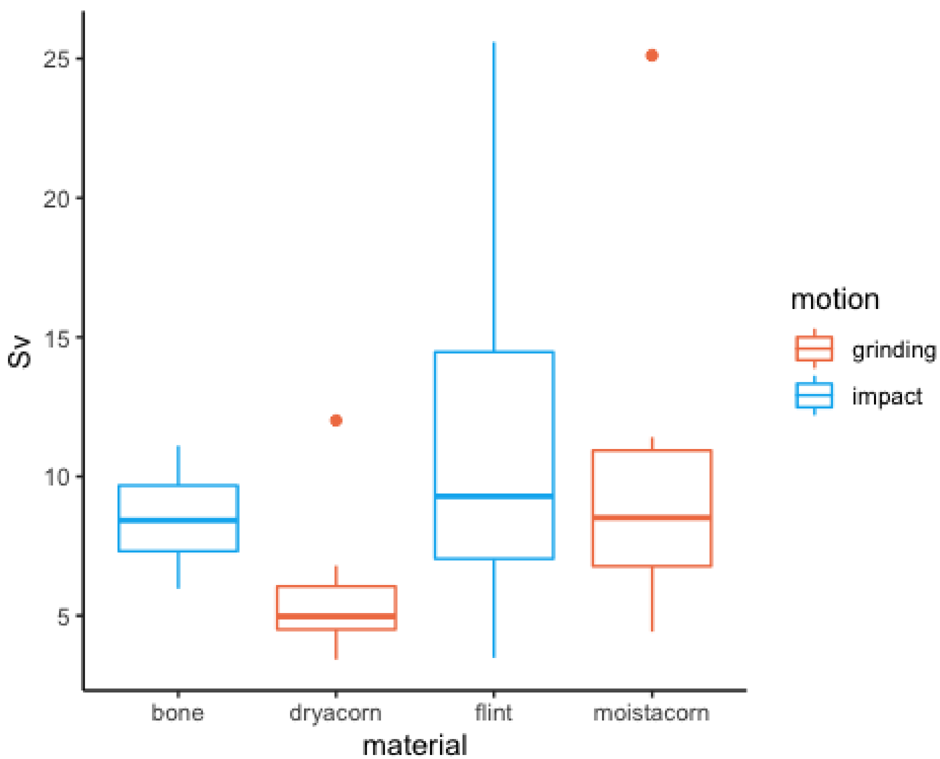
```r
        geom_boxplot() +
        # geom_line(aes(group = motion)) +
        theme_classic() +
        labs(colour = "motion") +
        # facet_wrap(~ sample) +
        labs(x = "material", y = gsub("\\.", " ", names(confocaldataexp)[i])) +
        scale_colour_hue(h = c(25,225), limits = levels(confocaldataexp[["motion"]]))
  print(p)

  # saves the plots
  file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_plot_",
                     names(confocaldataexp)[i], ".pdf")
    ggsave(filename = file_out, plot = p, path = "../plots/confocalexp", device = "pdf", wi
dth = 26,
           height = 21, units = "cm" )
}
```

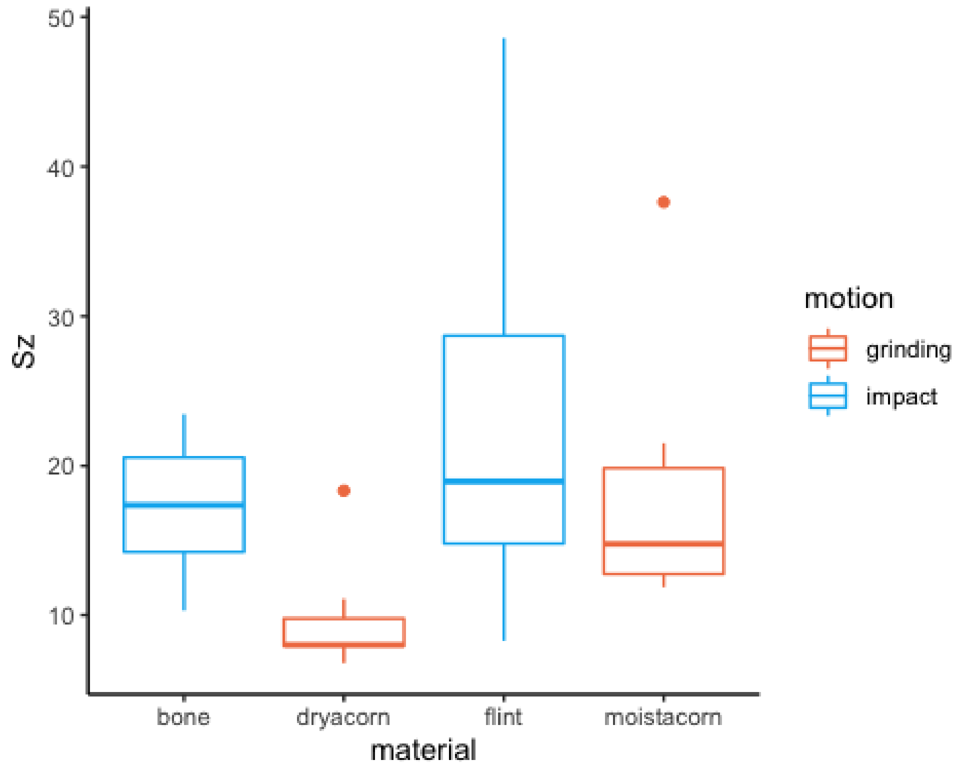



1.0
0.5
0.0
-0.5
-1.0
Ssk
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

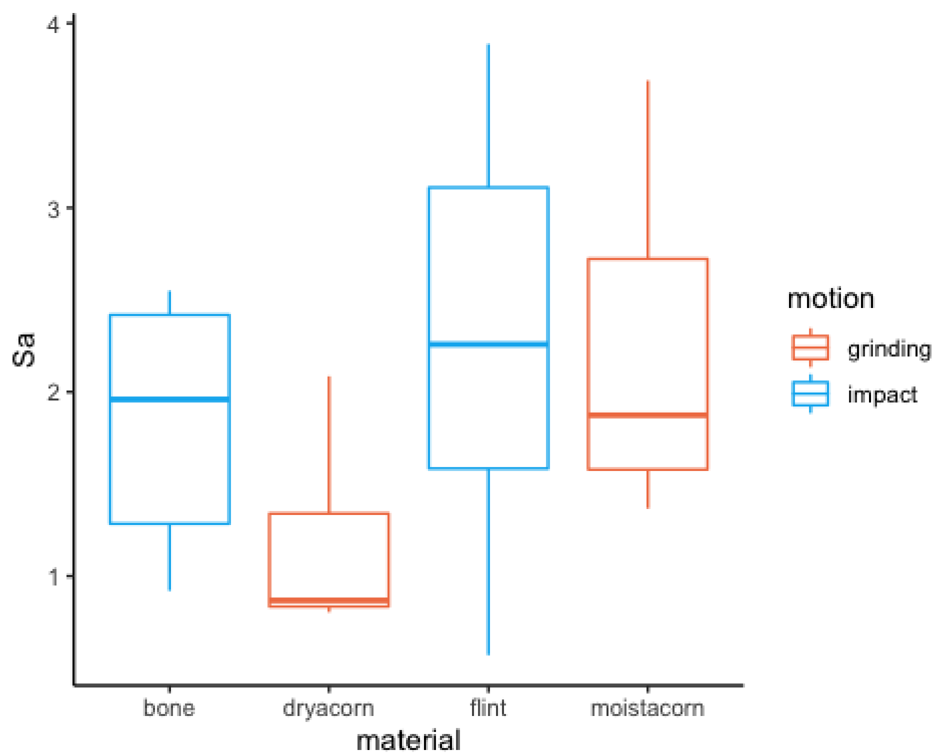

8
6
4
Sku
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


20
15
10
5
Sp
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

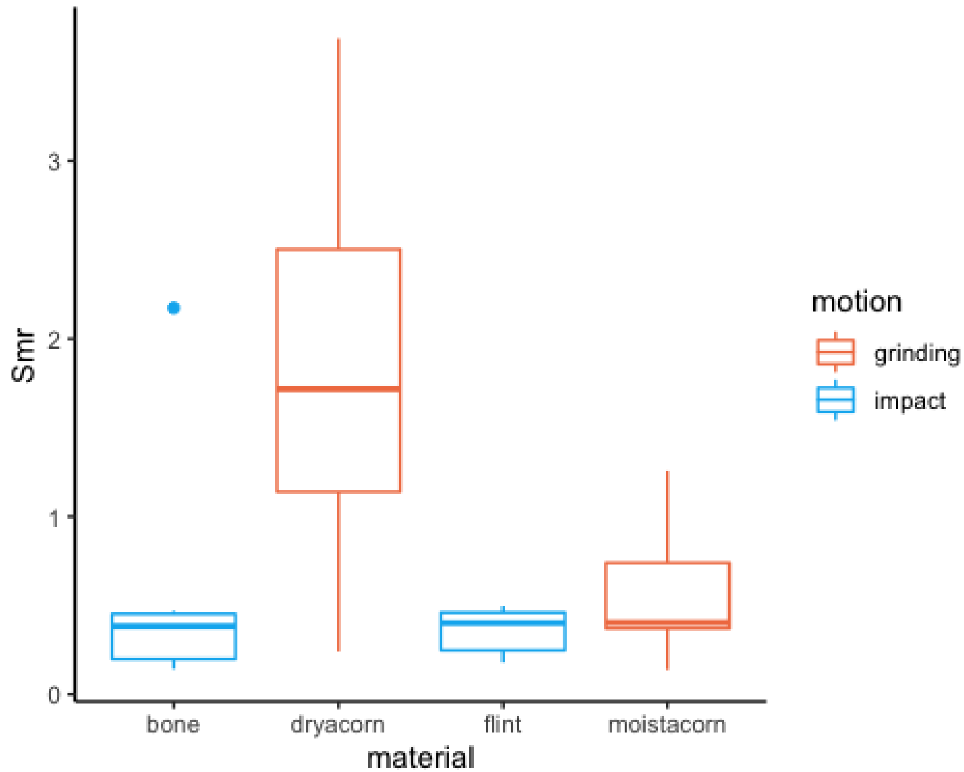

25
20
15
10
5
Sv
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact



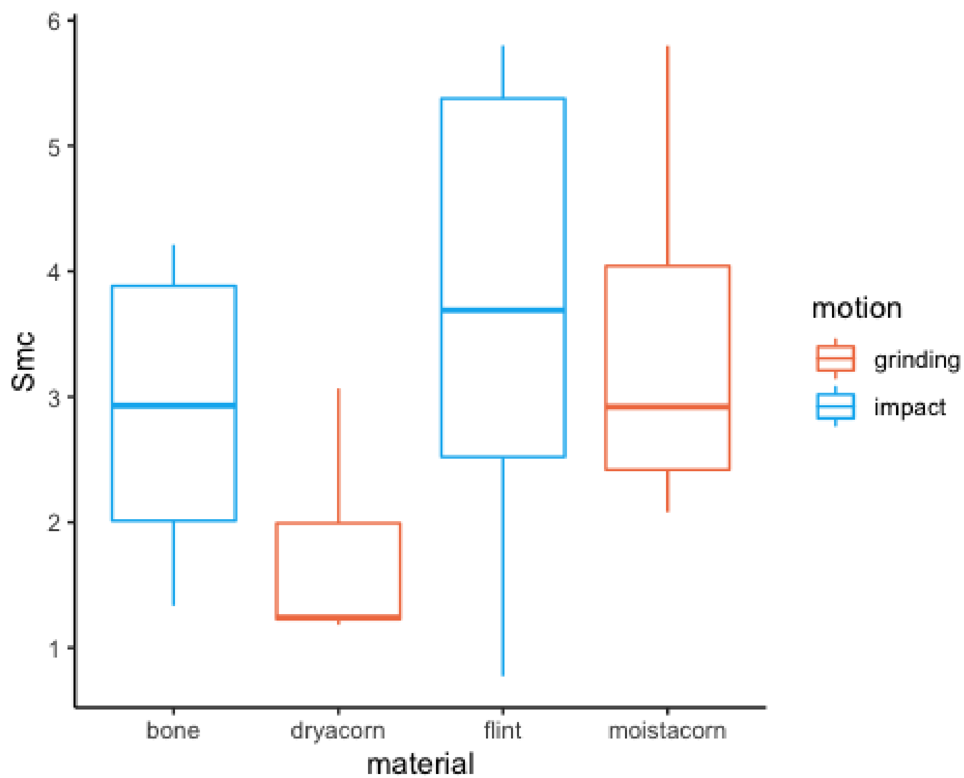
50
40
30
20
10
Sz
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact



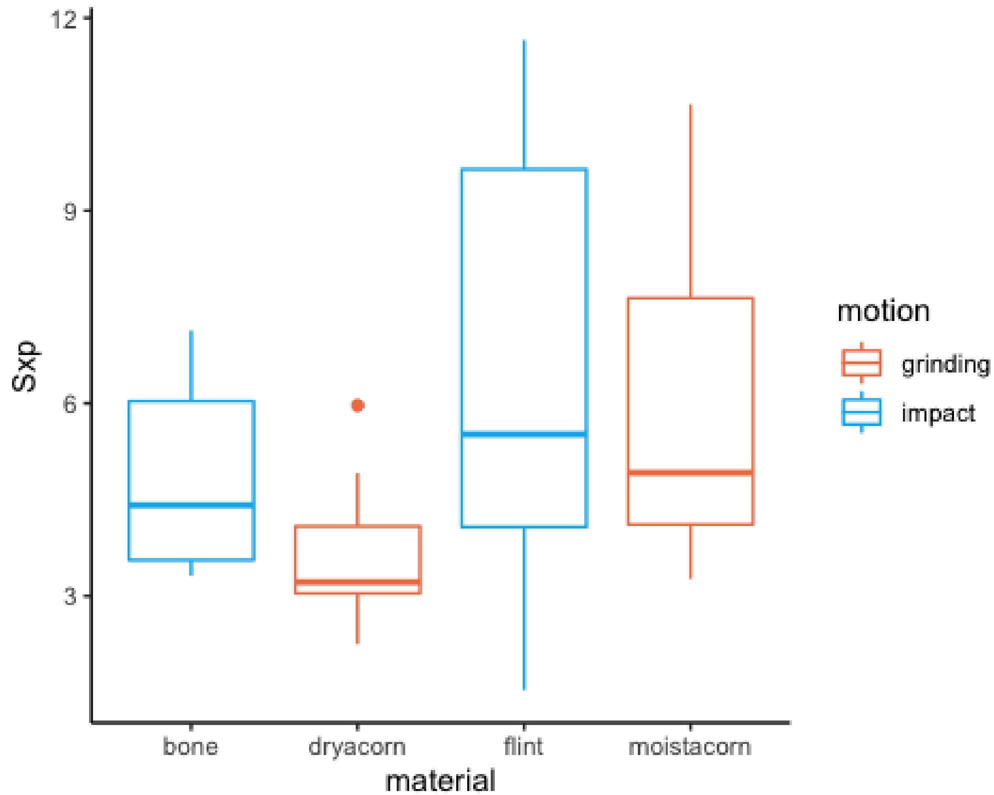
4
3
2
1
Sa
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

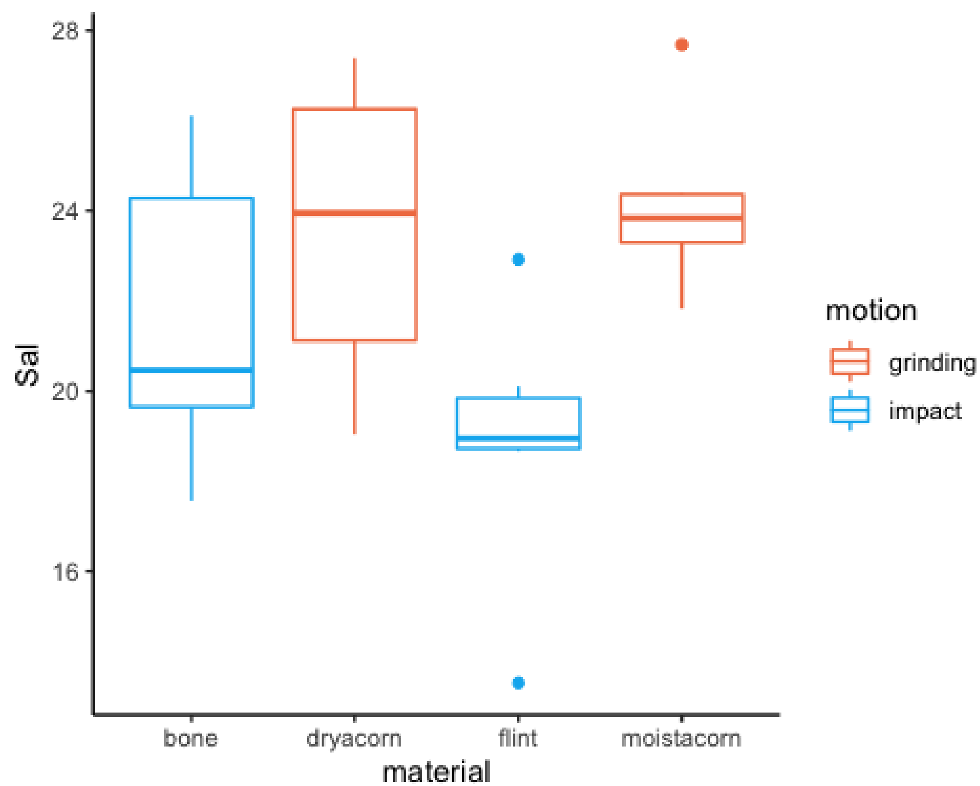


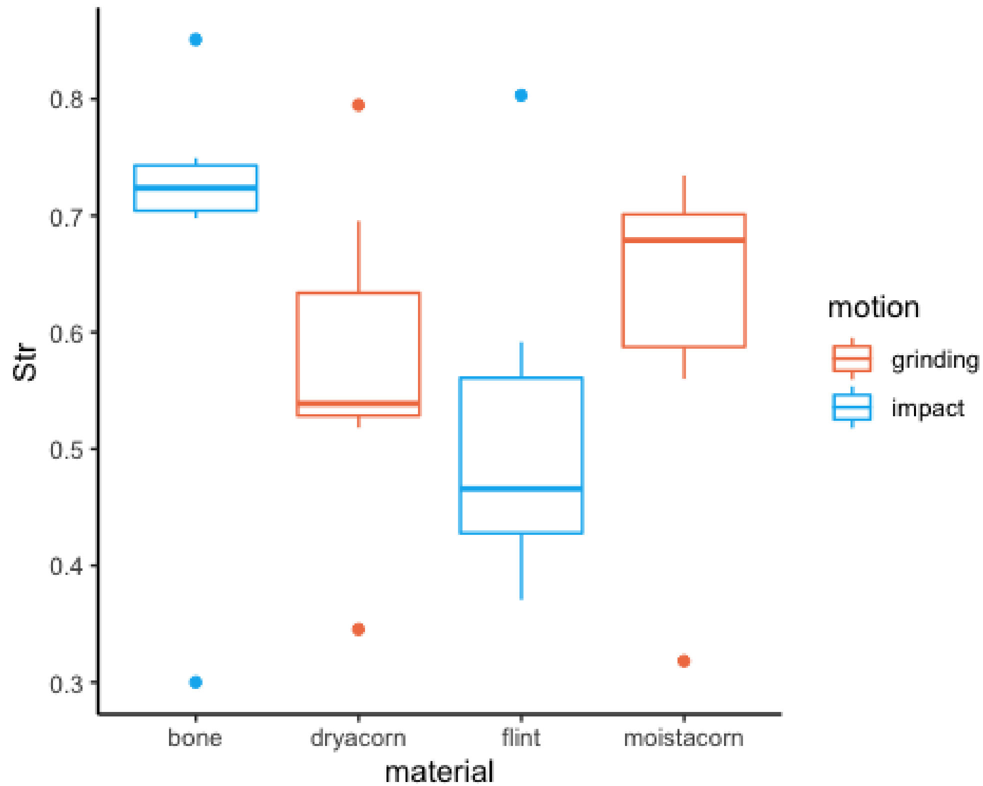
3
2
1
0
Smr
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

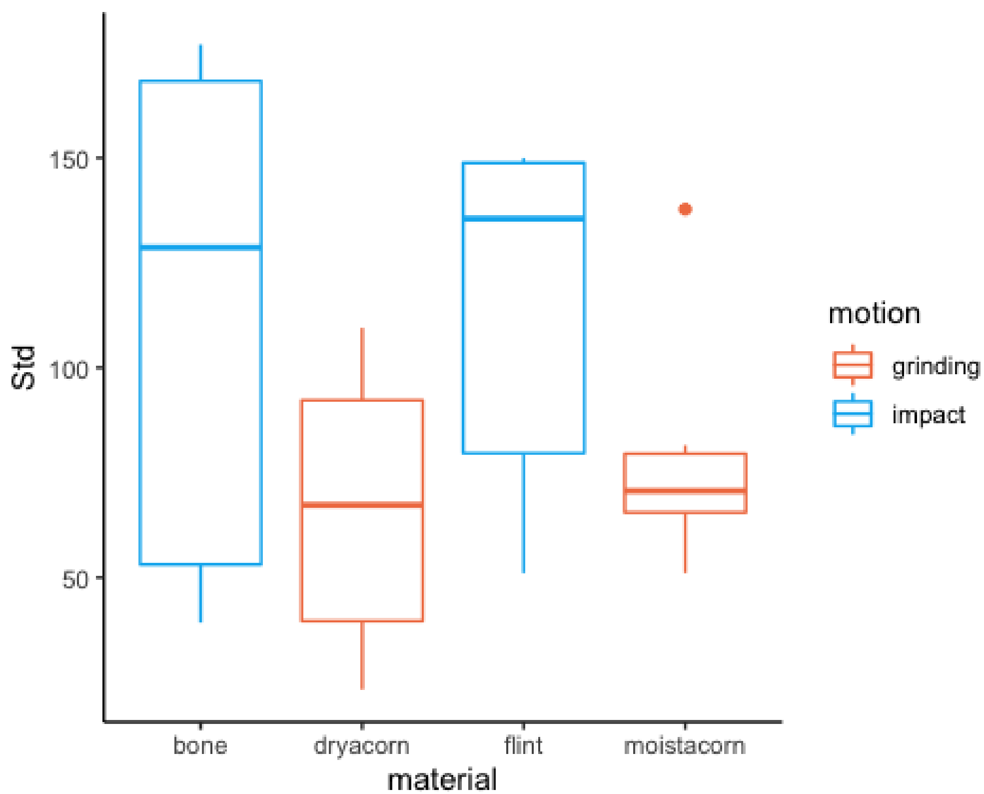


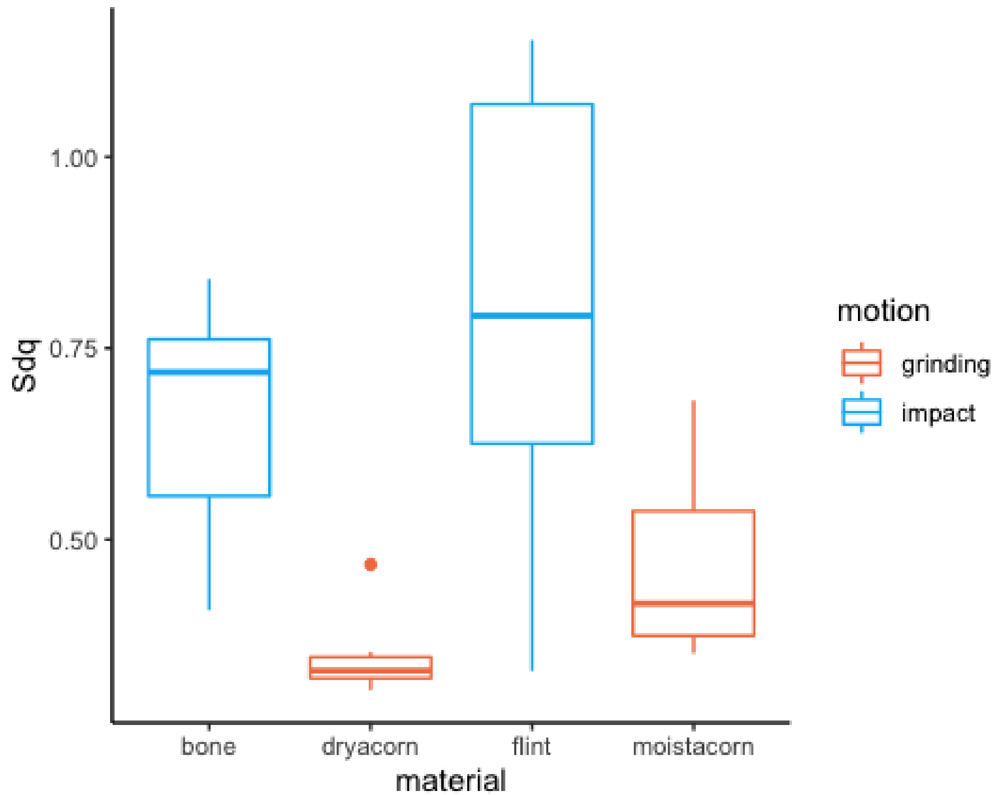
6
5
4
3
2
1
Smc
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

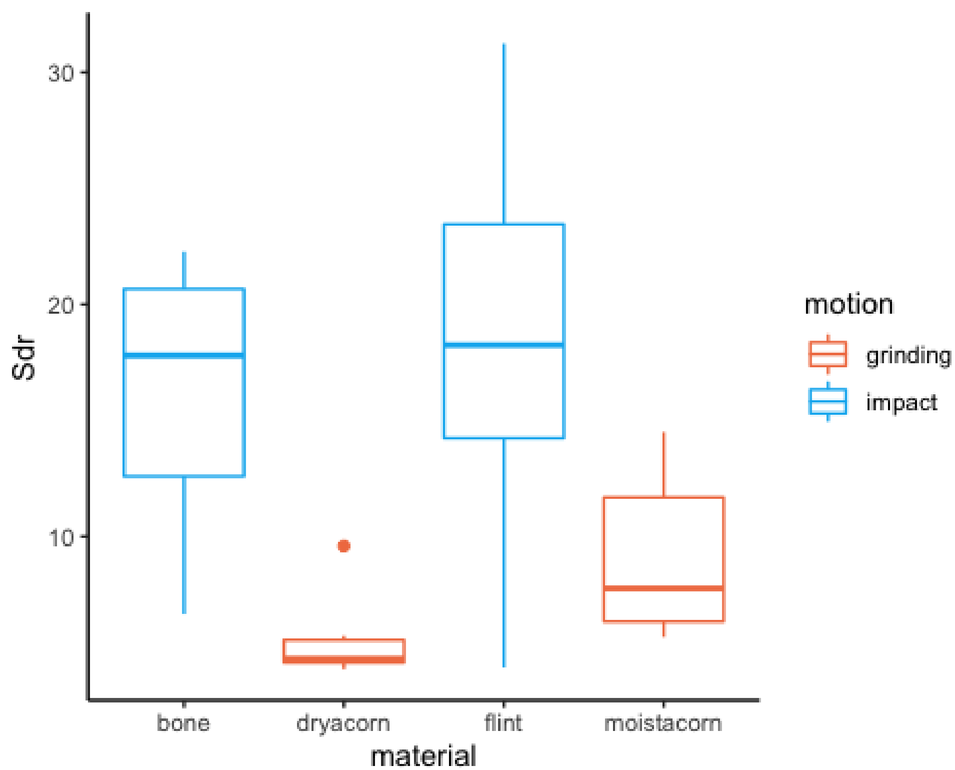

12
9
6
3
Sxp
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

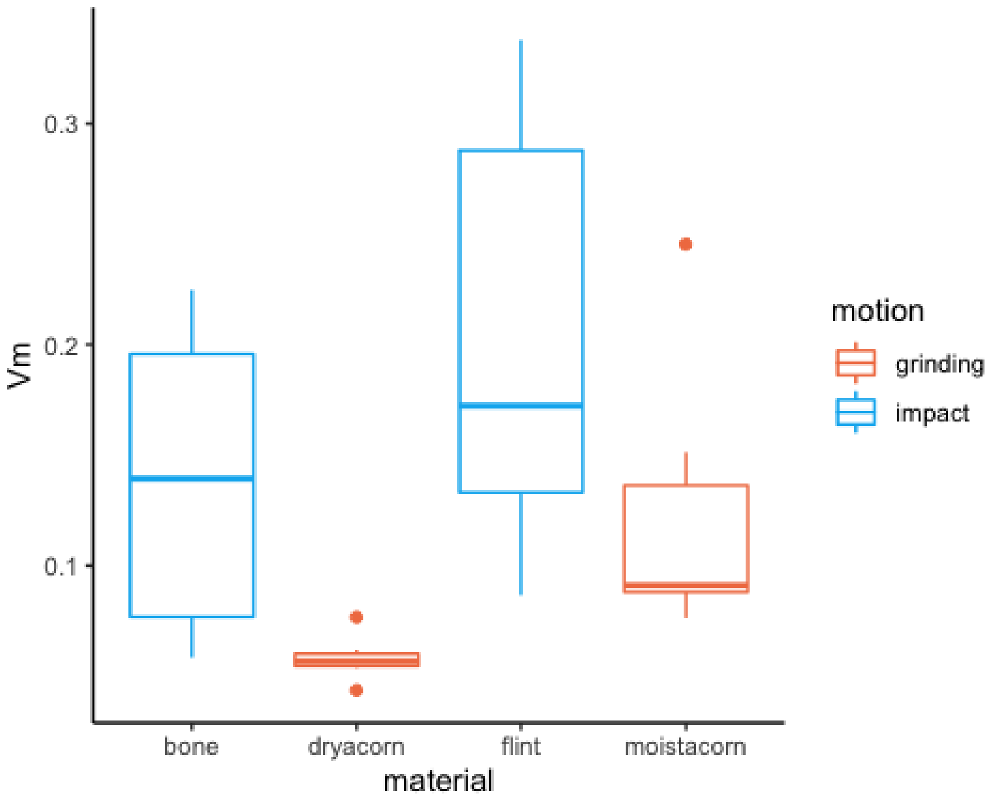

28
24
20
16
Sal
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

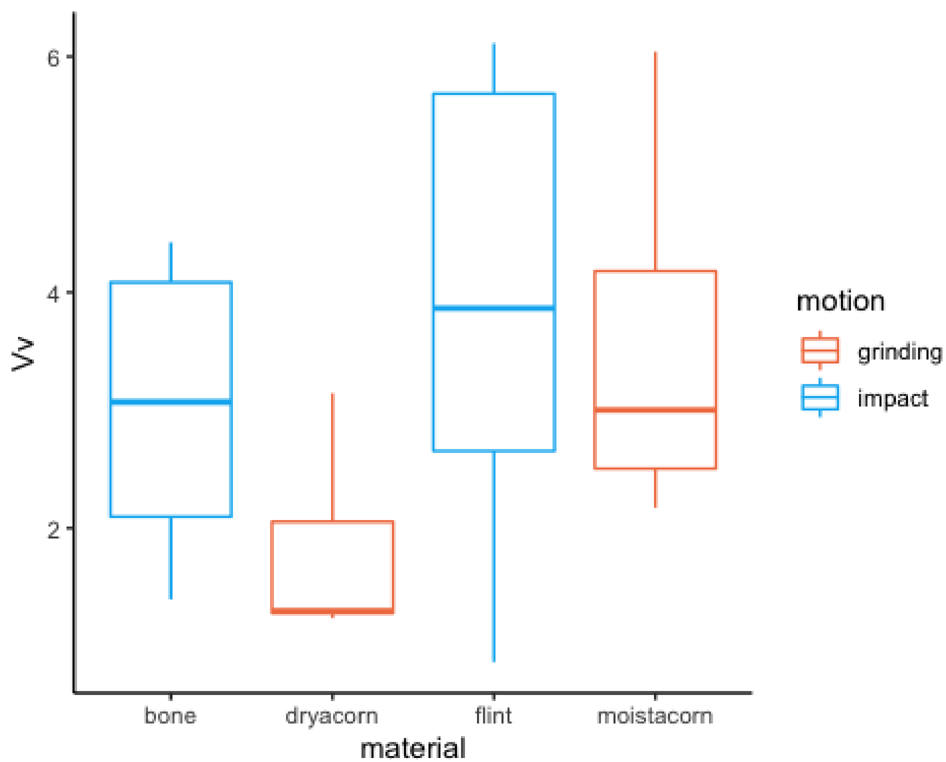

Str
0.8
0.7
0.6
0.5
0.4
0.3
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

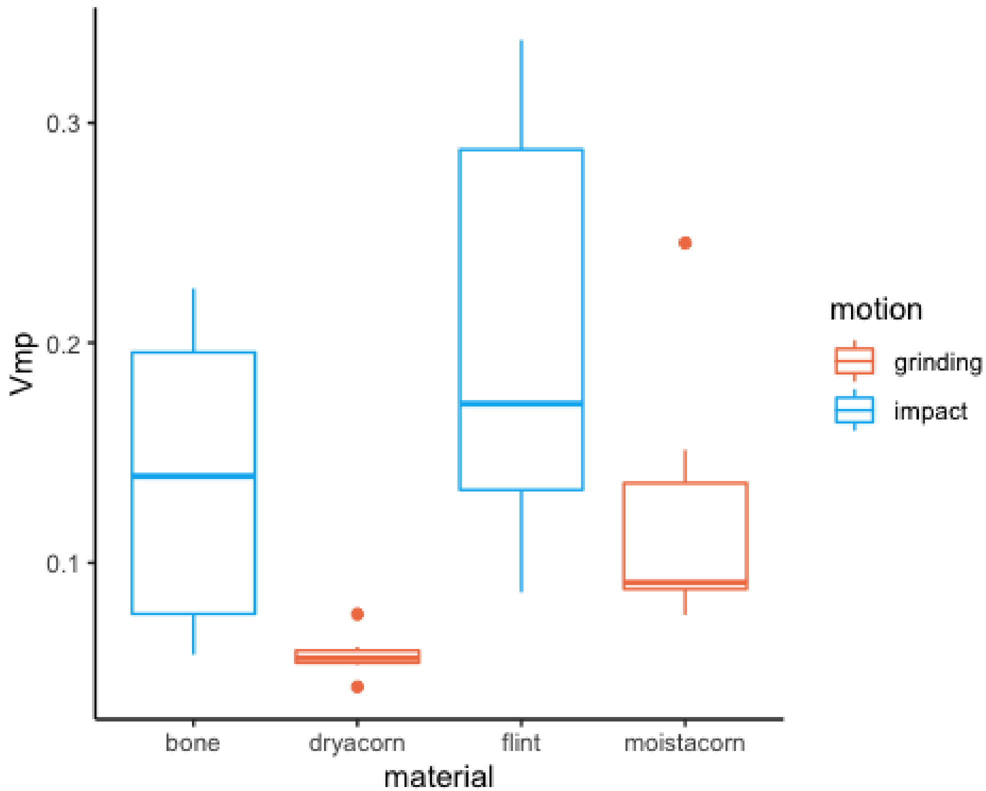

Std
150
100
50
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

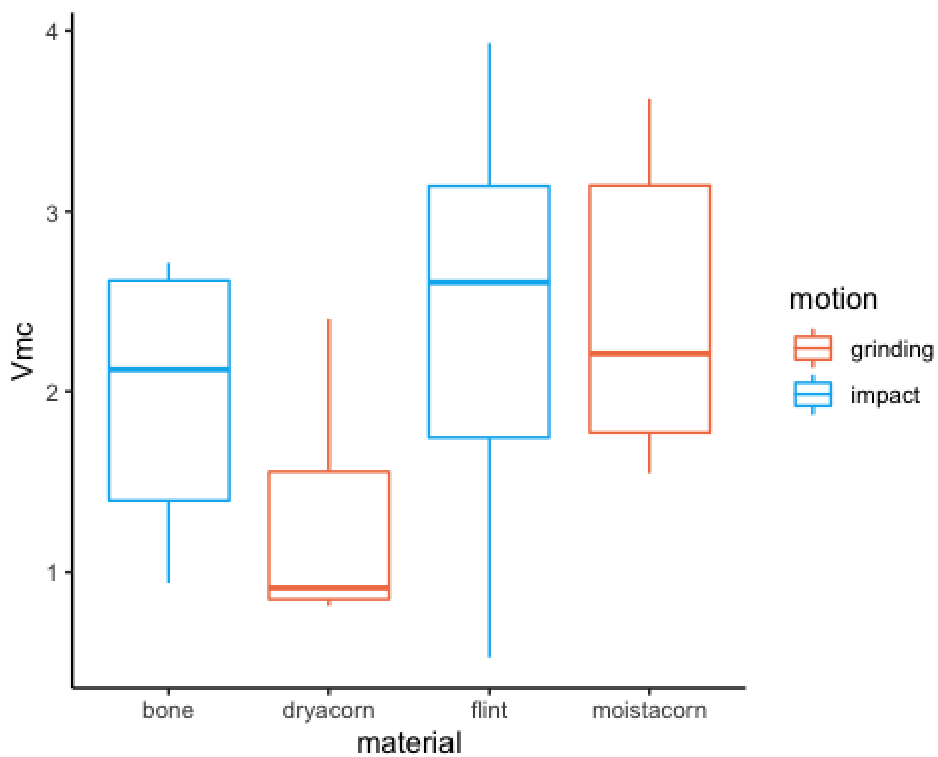

Sdq
1.00
0.75
0.50
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

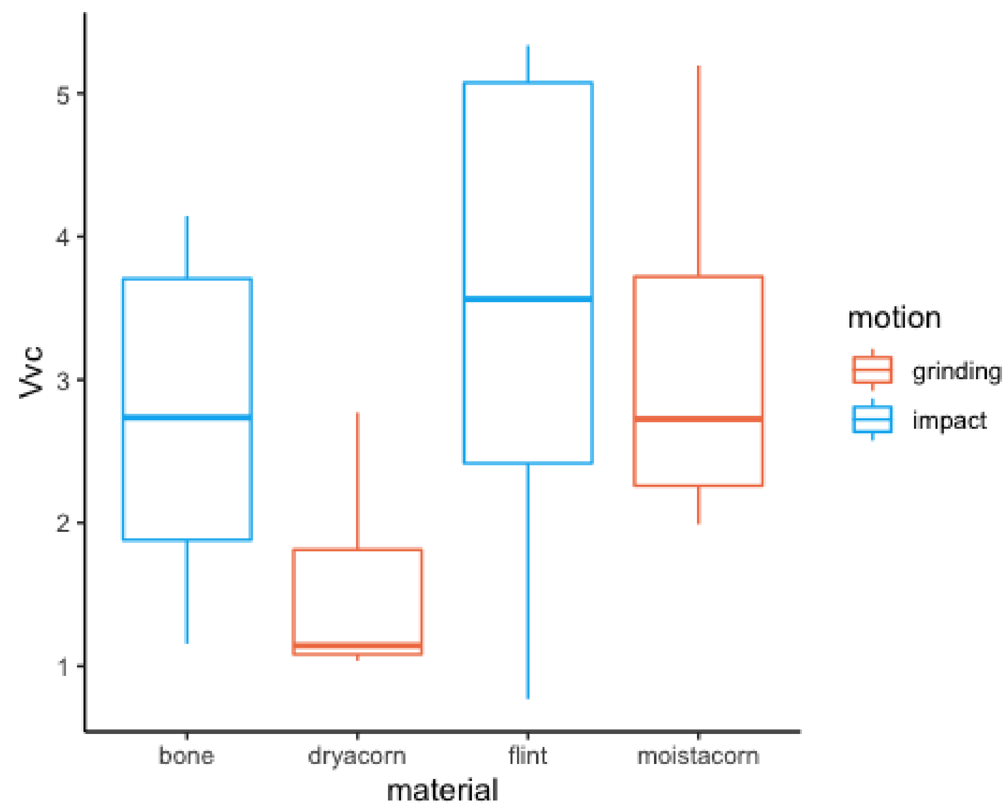

Sdr
30
20
10
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

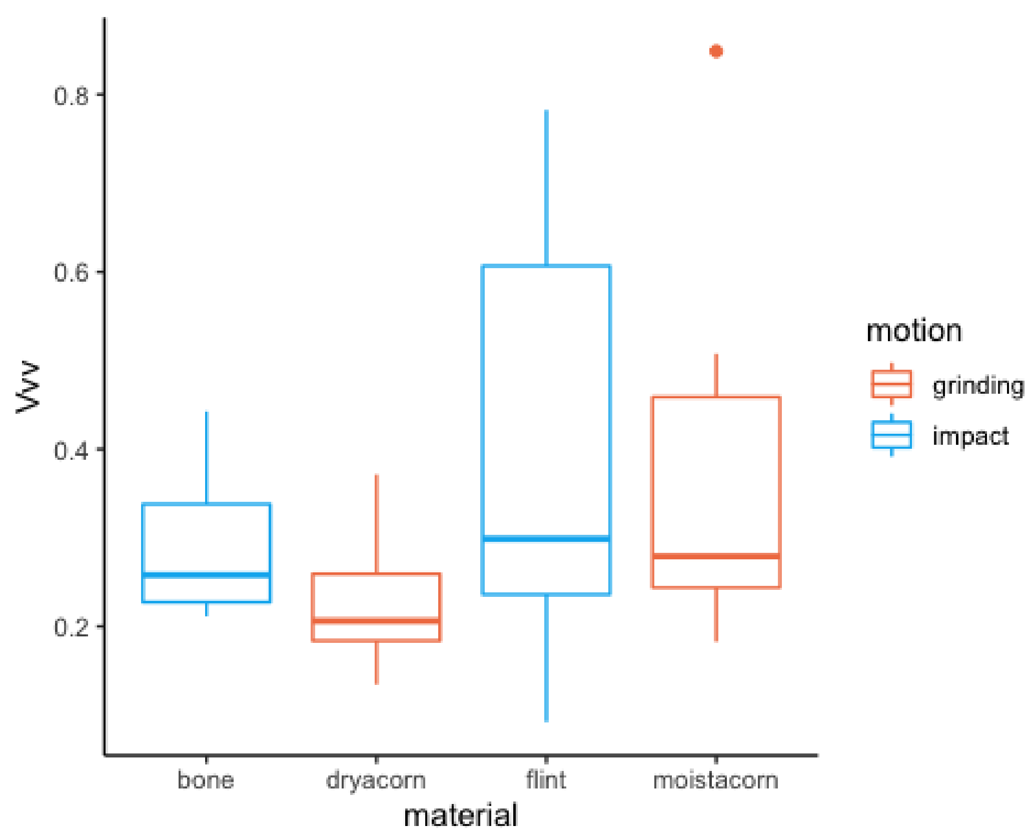

0.3
0.2
0.1
Vm
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

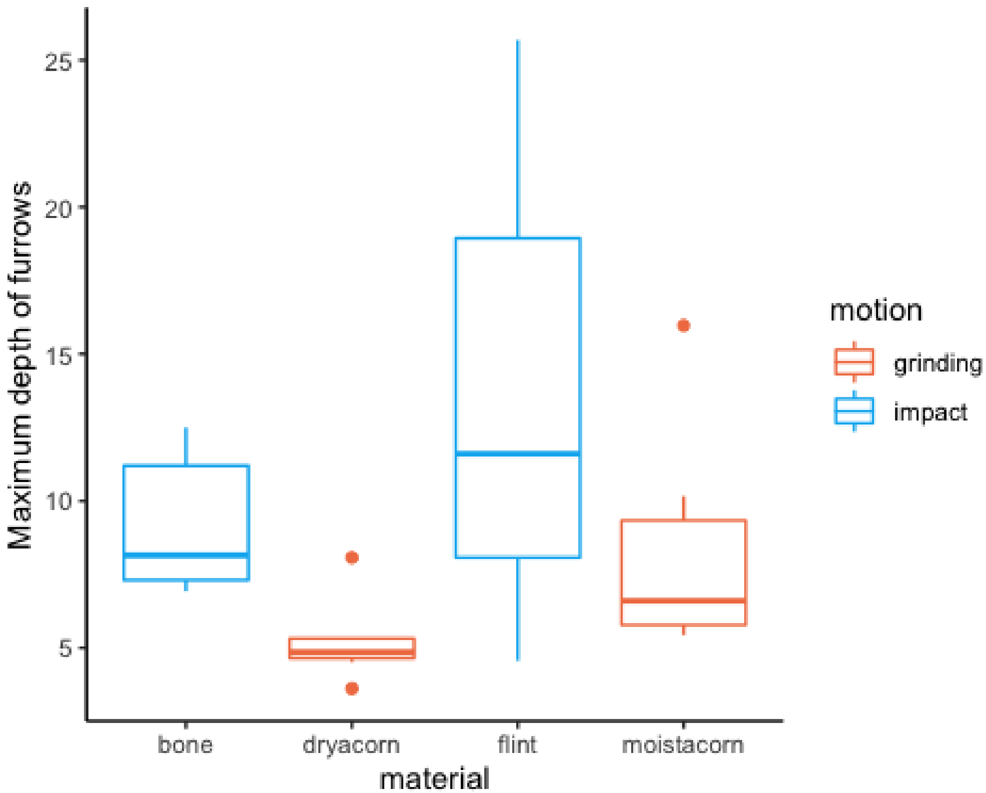

6
4
2
Vv
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

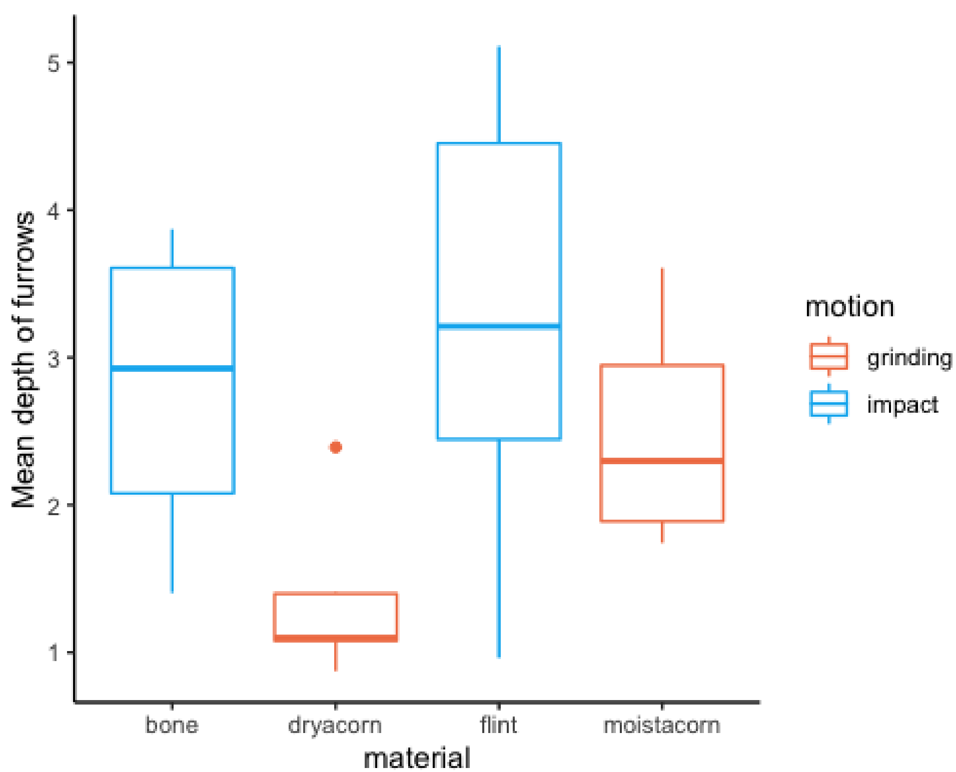

Vmp
0.3
0.2
0.1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

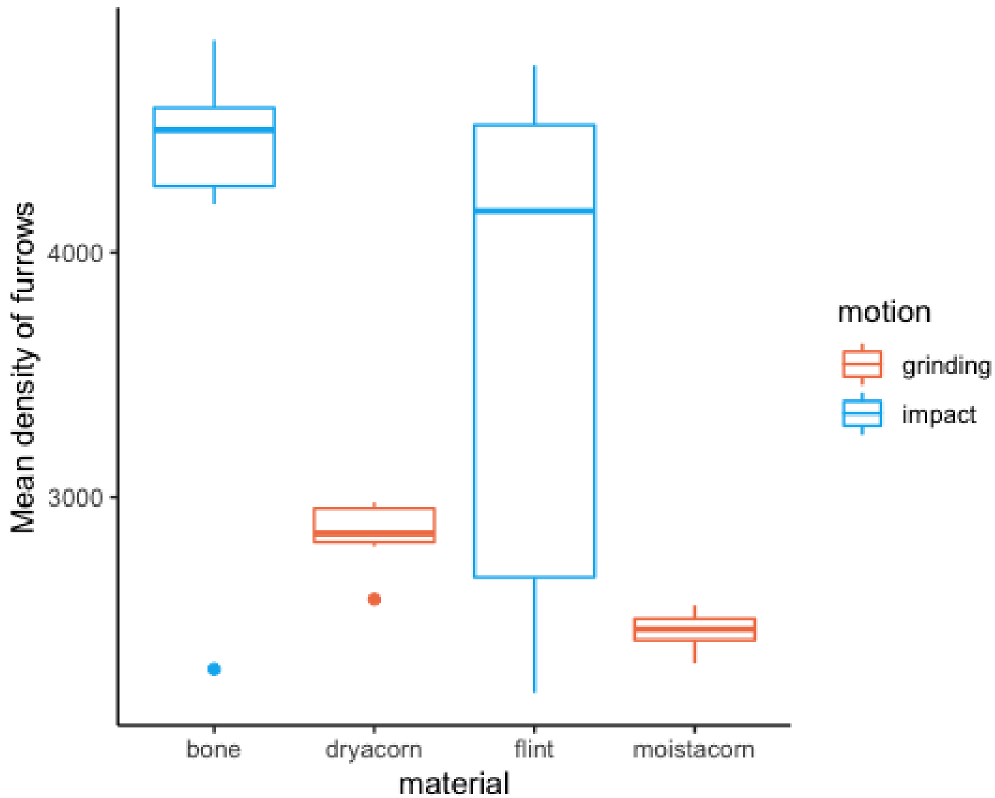

Vmc
4
3
2
1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


Vvc
5
4
3
2
1
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

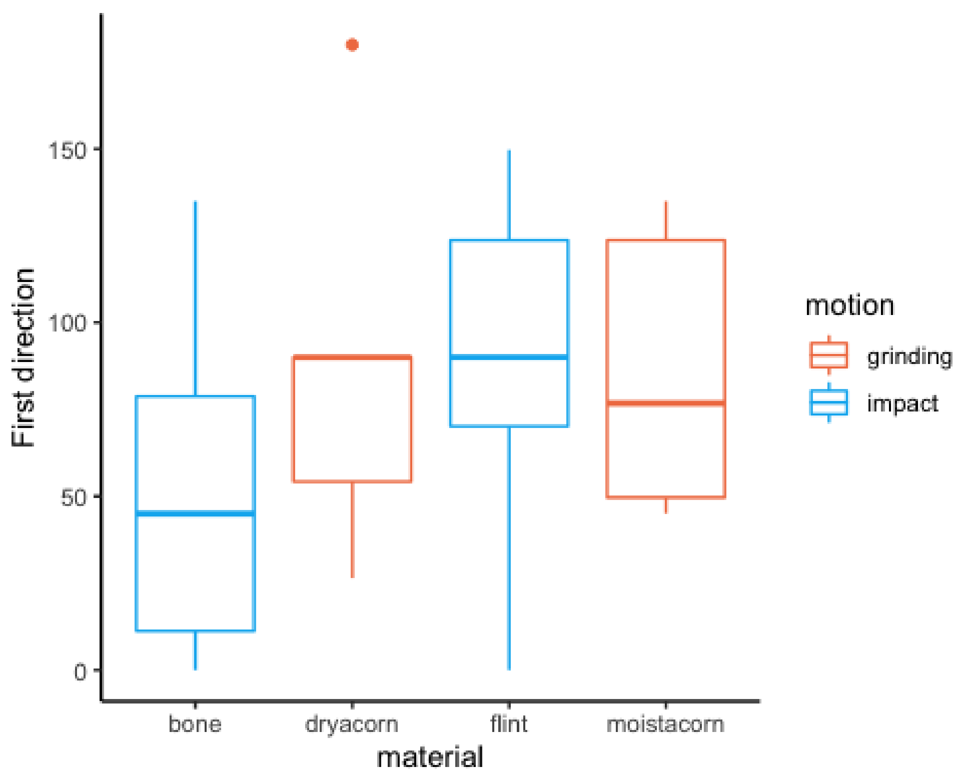

Vvv
0.8
0.6
0.4
0.2
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


25
20
15
10
5
Maximum depth of furrows
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

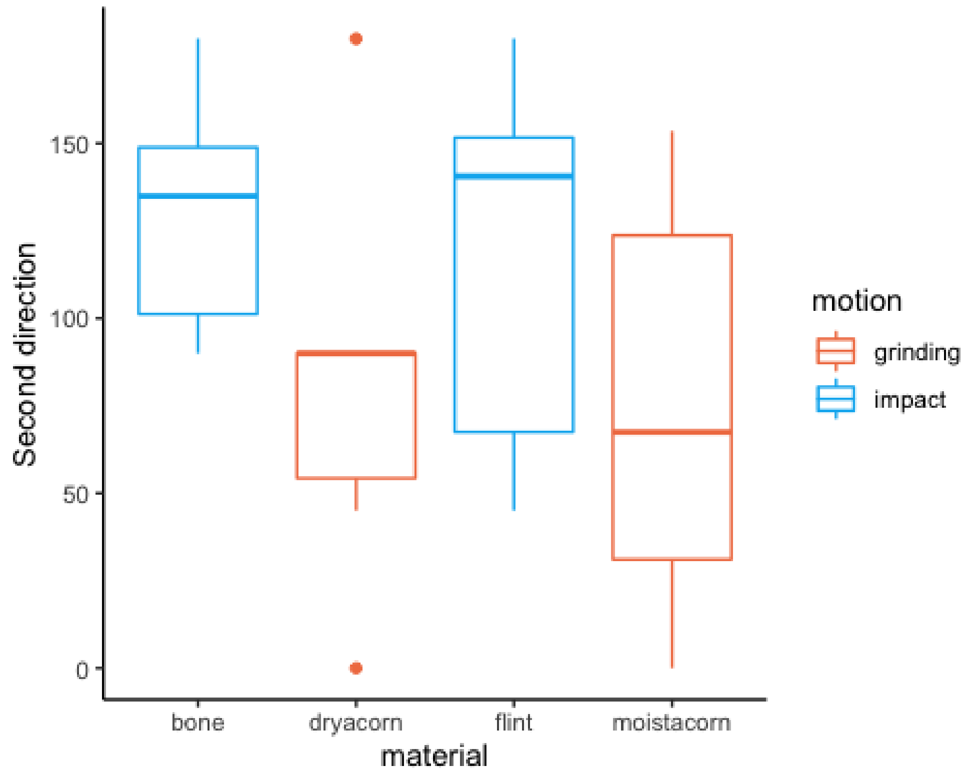

5
4
3
2
1
Mean depth of furrows
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

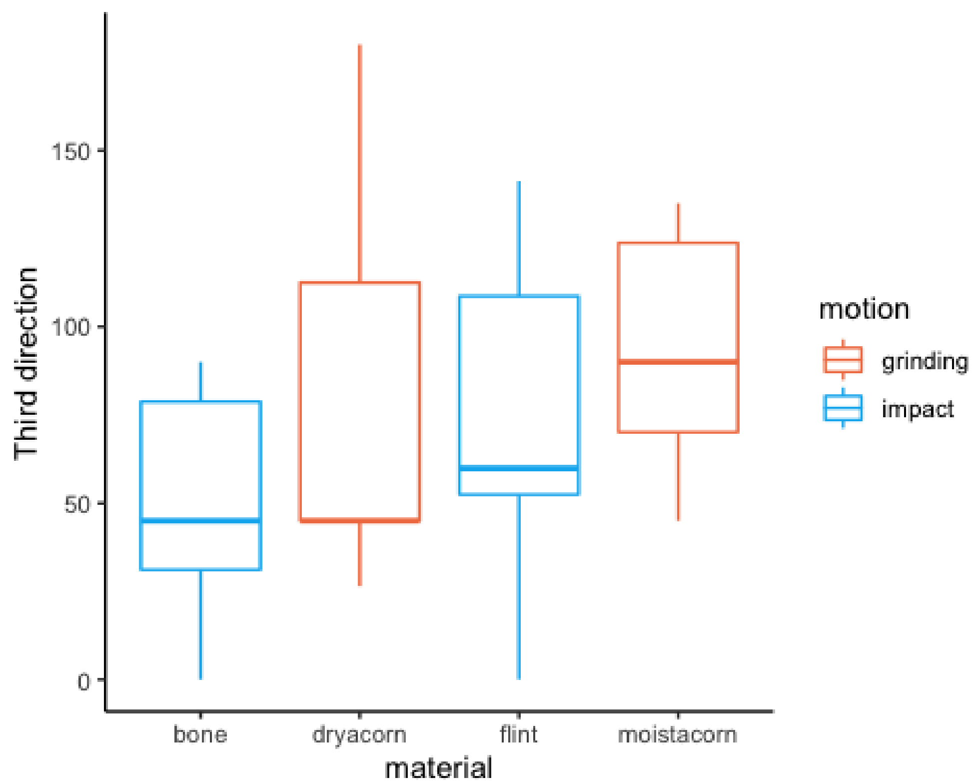


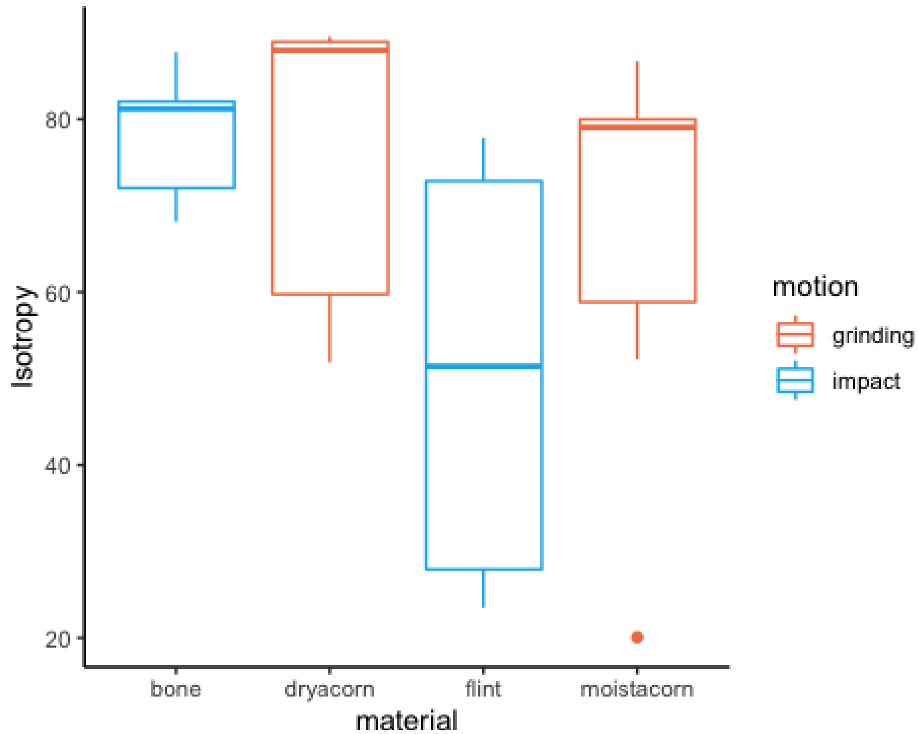
Mean density of furrows
4000
3000
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact



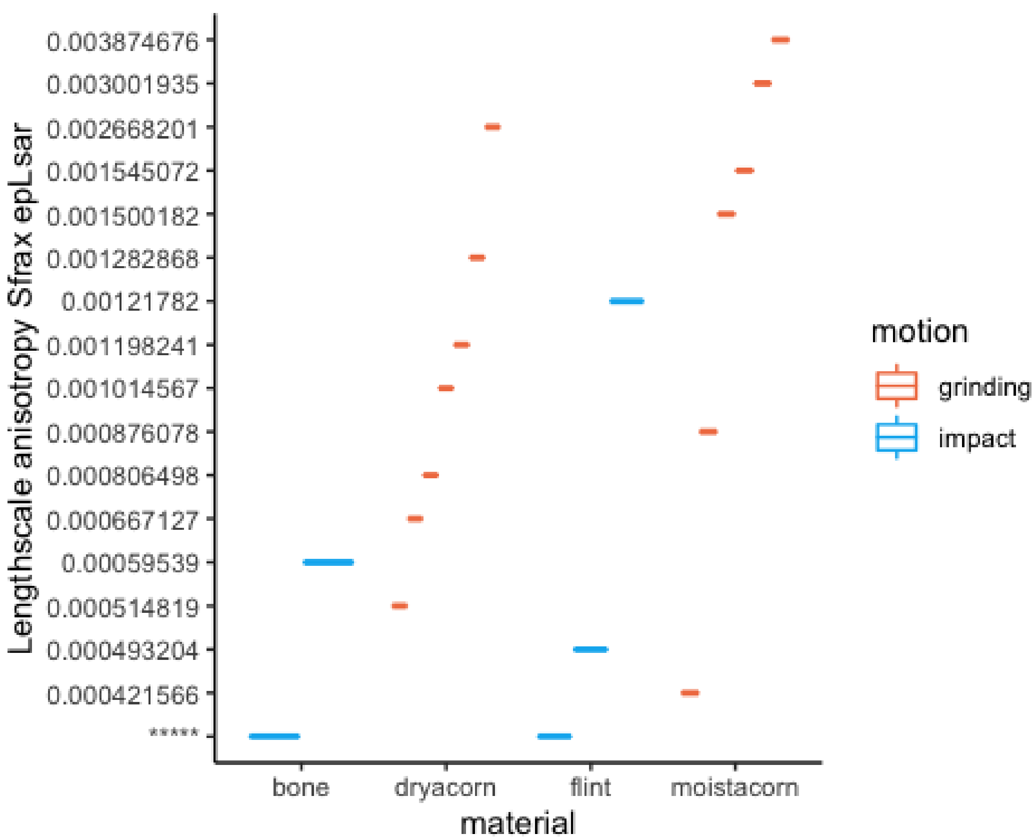
First direction
150
100
50
0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


Second direction
150
100
50
0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

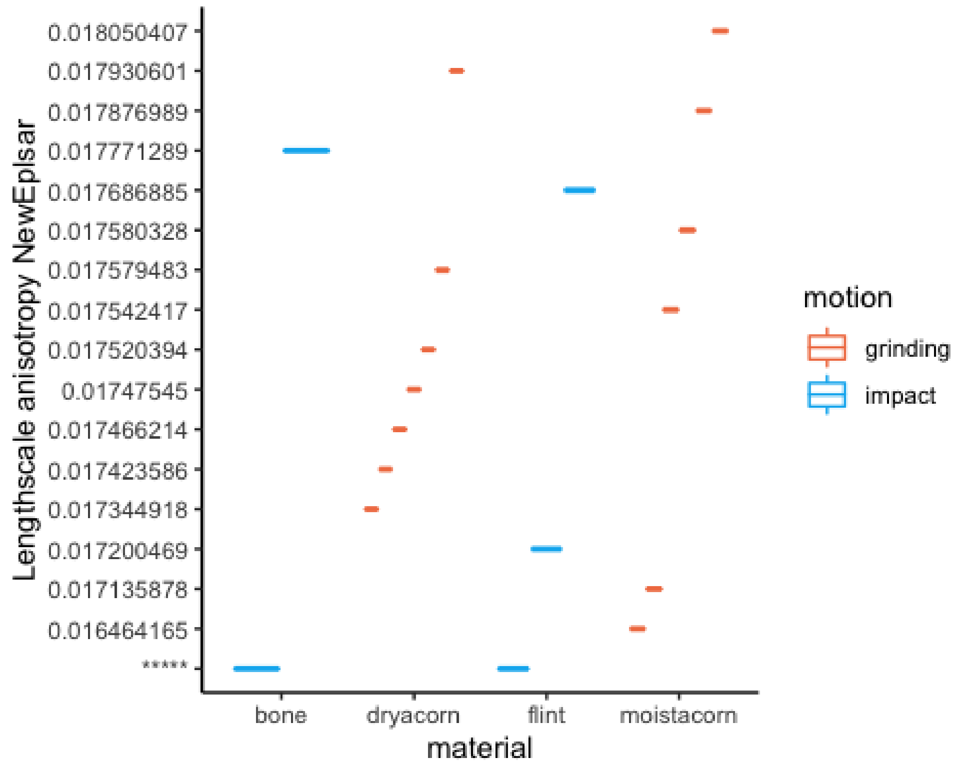

Third direction
150
100
50
0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact



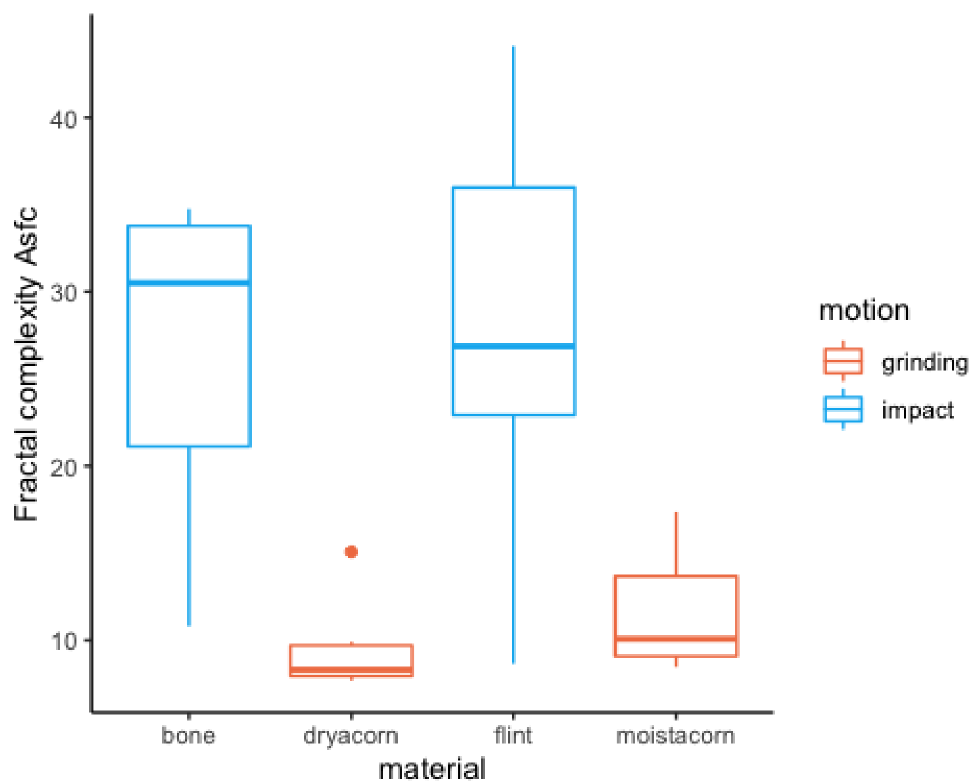
Isotropy
80
60
40
20
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact



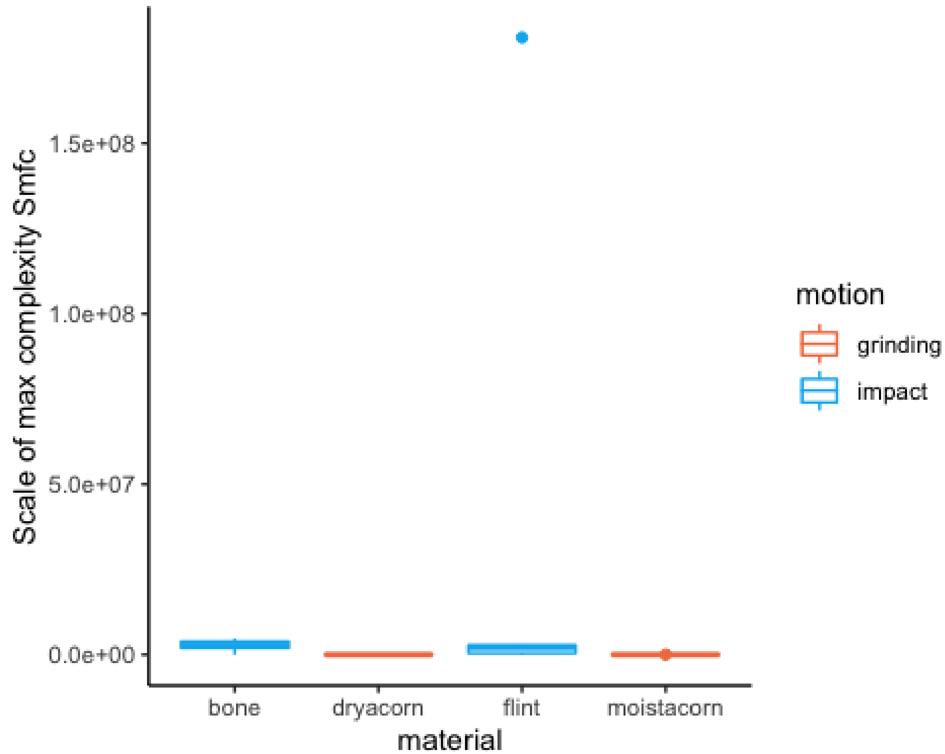
Lengthscale anisotropy Sfrax epLsar
0.003874676
0.003001935
0.002668201
0.001545072
0.001500182
0.001282868
0.00121782
0.001198241
0.001014567
0.000876078
0.000806498
0.000667127
0.00059539
0.000514819
0.000493204
0.000421566
*****
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

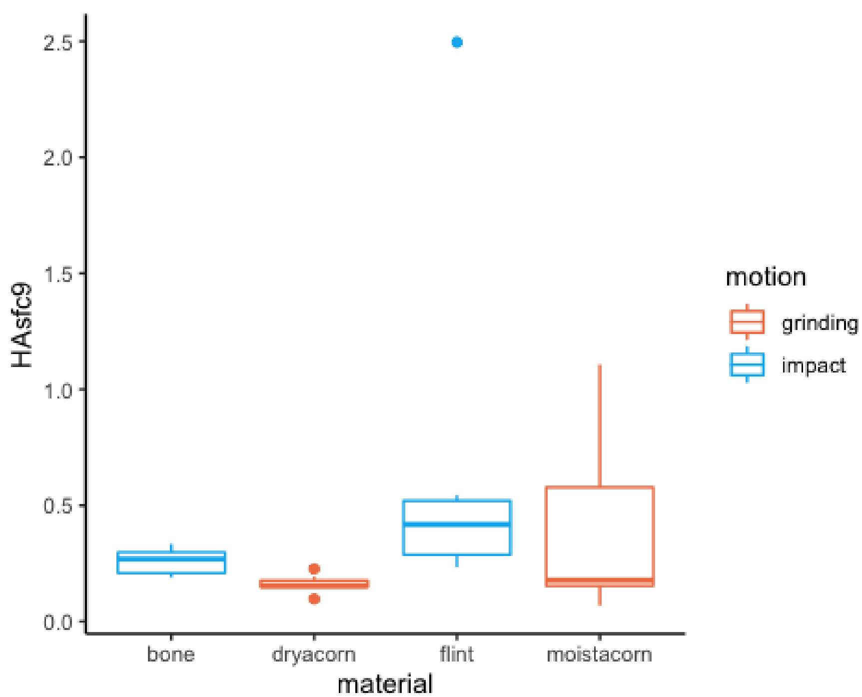


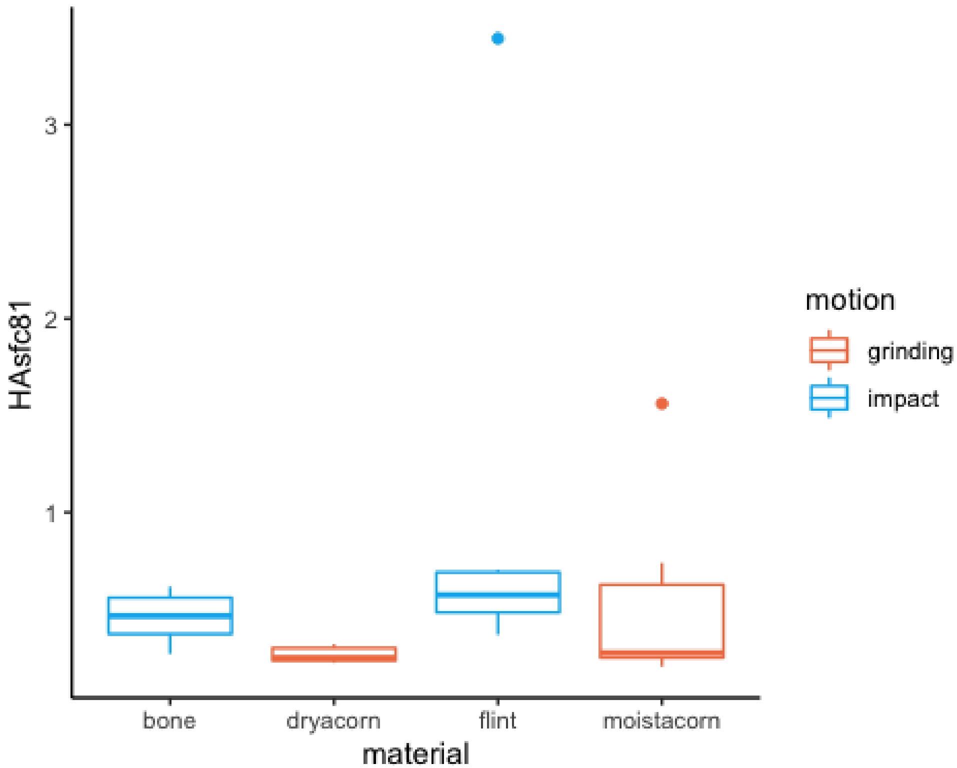
Lengthscale anisotropy NewEplsar
0.018050407
0.017930601
0.017876989
0.017771289
0.017686885
0.017580328
0.017579483
0.017542417
0.017520394
0.01747545
0.017466214
0.017423586
0.017344918
0.017200469
0.017135878
0.016464165
*****
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact



Fractal complexity Asfc
40
30
20
10
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

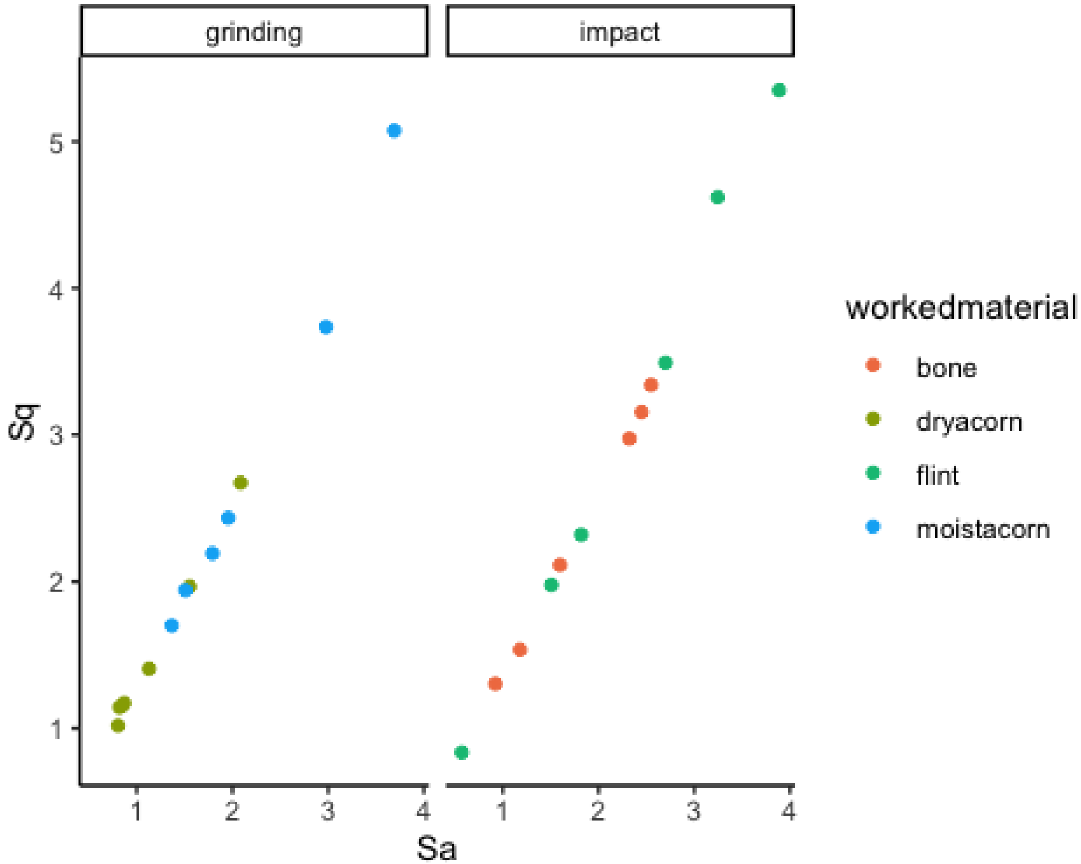

Scale of max complexity Smfc
1.5e+08
1.0e+08
5.0e+07
0.0e+00
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact


HAsfc9
2.5
2.0
1.5
1.0
0.5
0.0
bone
dryacorn
flint
moistacorn
material
motion
grinding
impact

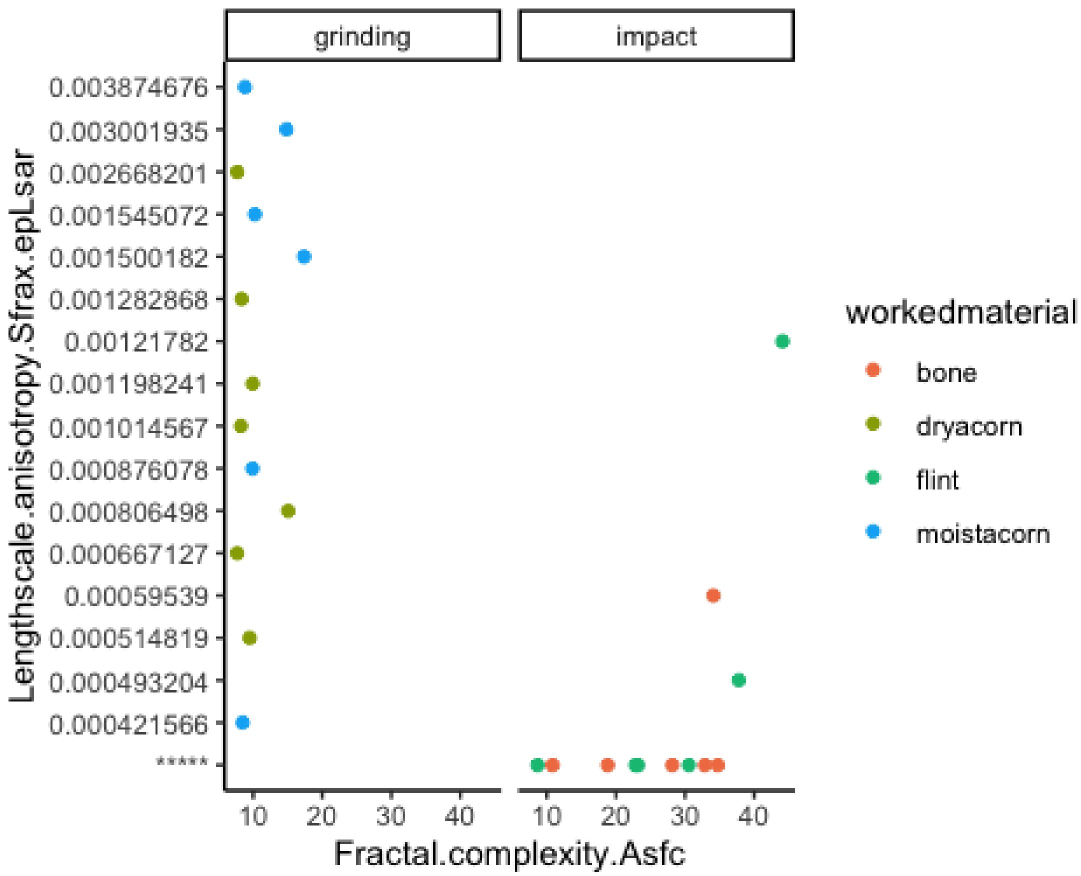


Scatterplots of selected variables combined by “Worked material” and “Motion”

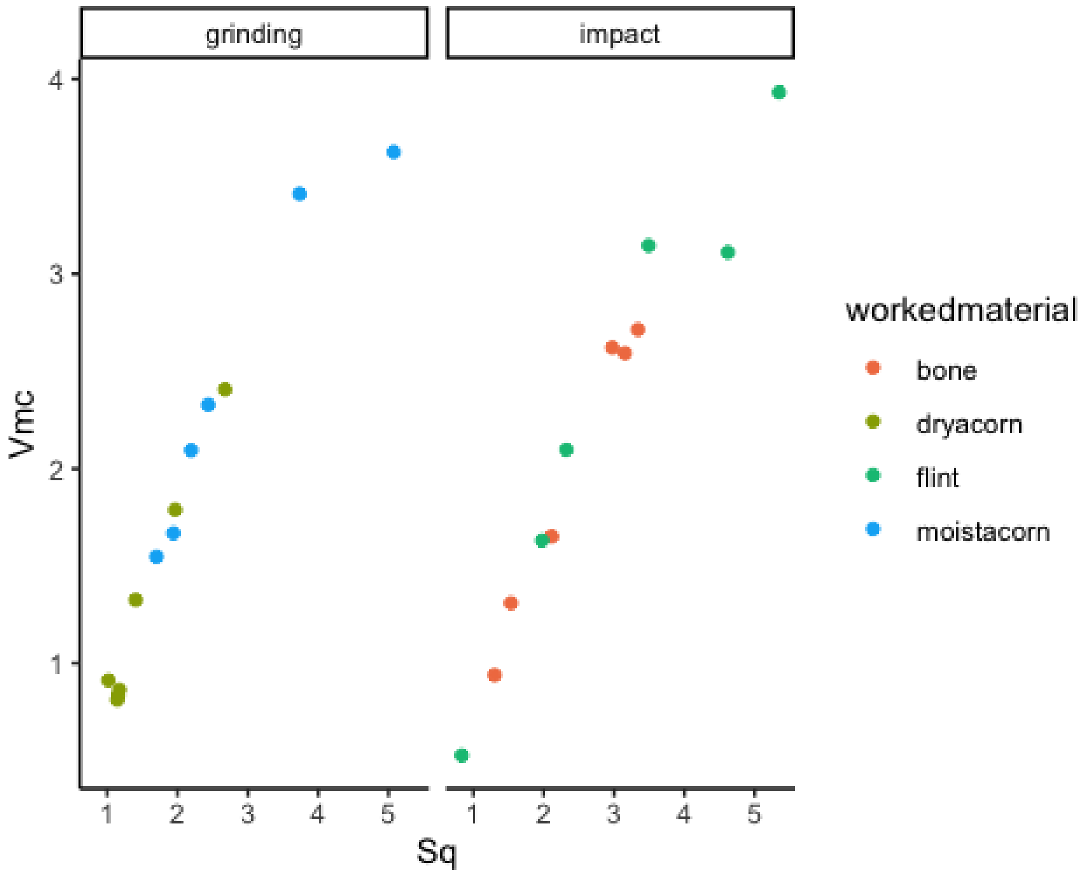
```
# Sa vs. Sq

Sa_Sq <- ggplot(data = confocaldataexp) +
         geom_point(mapping = aes(x = Sa, y = Sq, colour = workedmaterial)) +
         theme_classic() +
         labs(colour = "workedmaterial") +
         facet_wrap(~ motion) +
         scale_colour_hue(h = c(25, 230))
print(Sa_Sq)
```



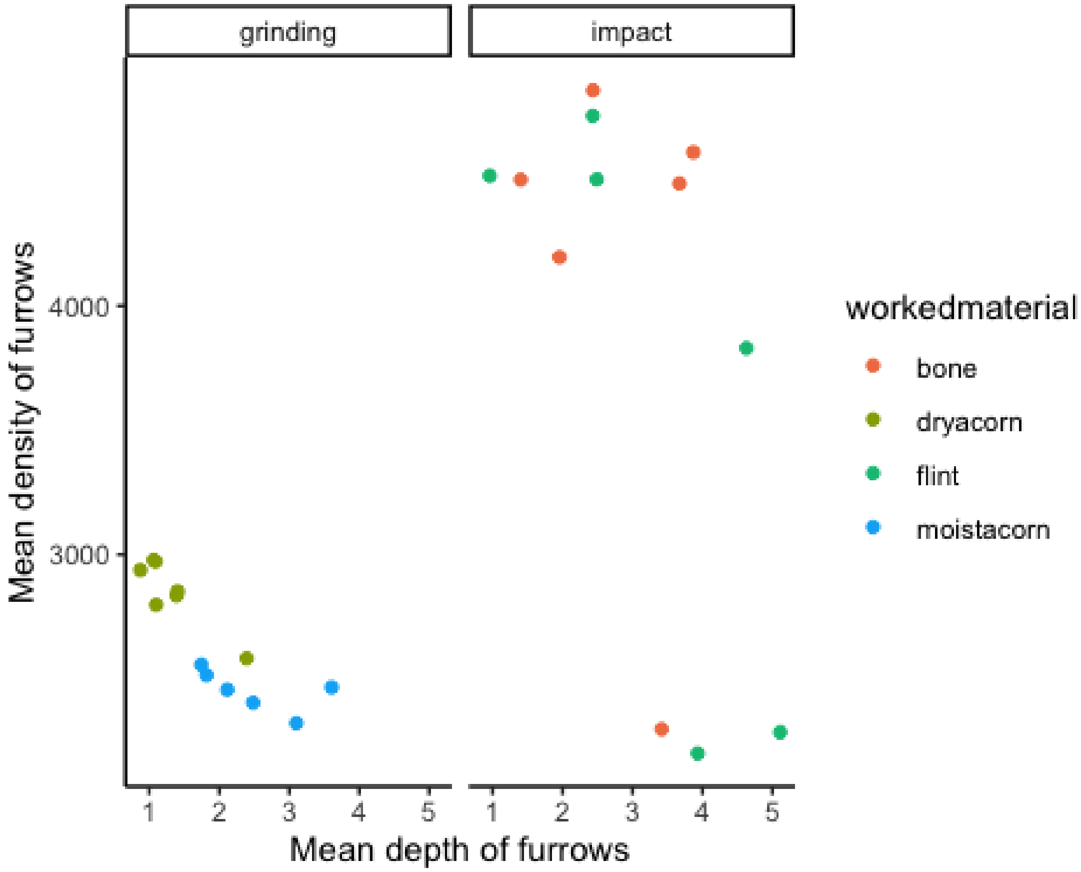

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Sa-Sq", ".pdf")
ggsave(filename = file_out, plot = Sa_Sq, path = "../plots/confocalexp", device = "pdf")

## Saving 5 x 4 in image

# epLsar vs. Asfc

ep_As <- ggplot(data = confocaldataexp) +
         geom_point(mapping = aes(x = Fractal.complexity.Asfc, y = Lengthscale.anisotropy.Sfrax
.epLsar, colour = workedmaterial)) +
         theme_classic() +
         labs(colour = "workedmaterial") +
         facet_wrap(~ motion) +
         scale_colour_hue(h = c(25, 230))
print(ep_As)
```



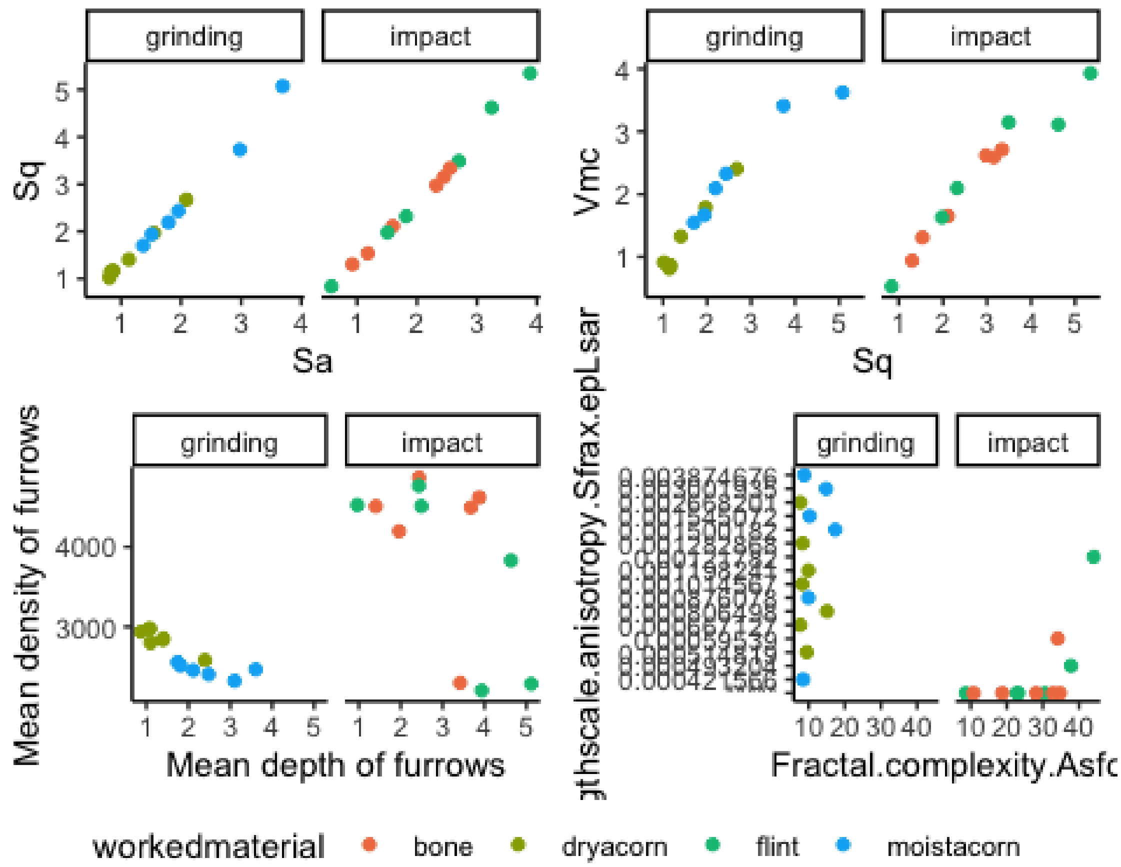

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Asfc-epLsar", ".pdf")
ggsave(filename = file_out, plot = ep_As, path = "../plots/confocalexp", device = "pdf")

## Saving 5 x 4 in image

# Sq vs. Vmc

Sq_Vmc <- ggplot(data = confocaldataexp) +
          geom_point(mapping = aes(x = Sq, y = Vmc, colour = workedmaterial)) +
          theme_classic() +
          labs(colour = "workedmaterial") +
          facet_wrap(~ motion) +
          scale_colour_hue(h = c(25, 230))
print(Sq_Vmc)
```




```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Sq-Vmc", ".pdf")
ggsave(filename = file_out, plot = Sq_Vmc, path = "../plots/confocalexp", device = "pdf")

## Saving 5 x 4 in image

# Mean depth of furrows vs. mean density of furrows

furrows <- ggplot(data = confocaldataexp) +
           geom_point(mapping = aes(x = Mean.depth.of.furrows, y = Mean.density.of.furrows,
                                    colour = workedmaterial)) +
           theme_classic() +
           labs(colour = "workedmaterial", x = "Mean depth of furrows", y = "Mean density of fu
rrows") +
           facet_wrap(~ motion) +
           scale_colour_hue(h = c(25, 230))
print(furrows)
```



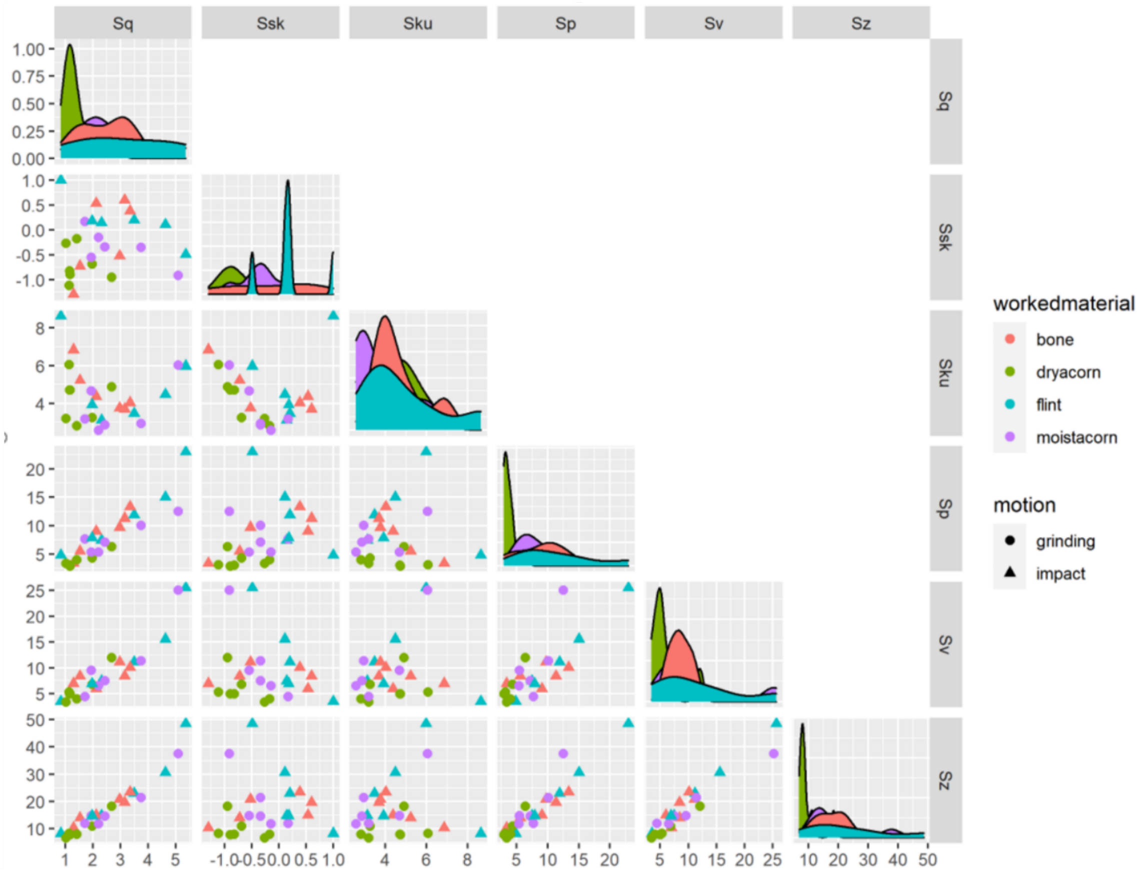

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_furrows", ".pdf")
ggsave(filename = file_out, plot = furrows, path = "../plots/confocalexp", device = "pdf")

## Saving 5 x 4 in image

# combine all in a single image

ggarrange(Sa_Sq, Sq_Vmc, furrows, ep_As, common.legend = TRUE, legend = "bottom")
```



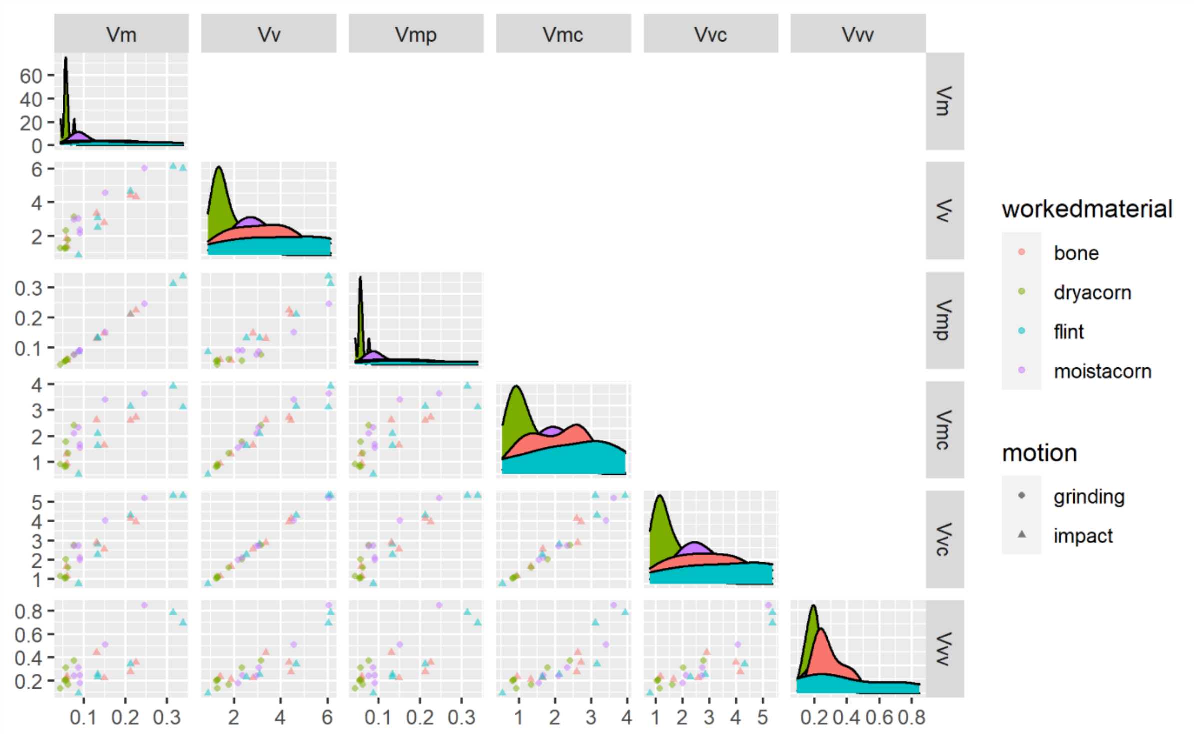

```
ggsave("../plots//confocalexp/confocalscatterplotsexp.png")

## Saving 5 x 4 in image
```

Scatterplot matrix for the ISO 25178 Area scale, Height and volume parameters

```
data(confocaldata, package = "reshape")

## Warning in data(confocaldata, package = "reshape"): data set 'confocaldata' not
## found

# Height parameters

ggpairs(data=confocaldataexp,
        columns = c(21:27),
        cardinality_threshold = 30,
        mapping = ggplot2::aes(color = workedmaterial, shape = motion),
        lower = list(continuous = wrap("points", alpha = 0.5, size = 1)),
        upper = list(continuous = "blank"),
        legend = c(2,1)
        ) +

    theme(legend.position = "right") +
  labs(fill = "Micro polish type")
```




```
ggsave("../plots/confocalexp/confocalexparea_matrix.png")

## Saving 5 x 4 in image

# Volume parameters

ggpairs(data=confocaldataexp,
        columns = c(36:41),
        cardinality_threshold = 30,
        mapping = ggplot2::aes(color = workedmaterial, shape = motion),
        lower = list(continuous = wrap("points", alpha = 0.5, size = 1)),
        upper = list(continuous = "blank"),
        legend = c(2,1)
        ) +

    theme(legend.position = "right") +
  labs(fill = "Micro polish type")
```

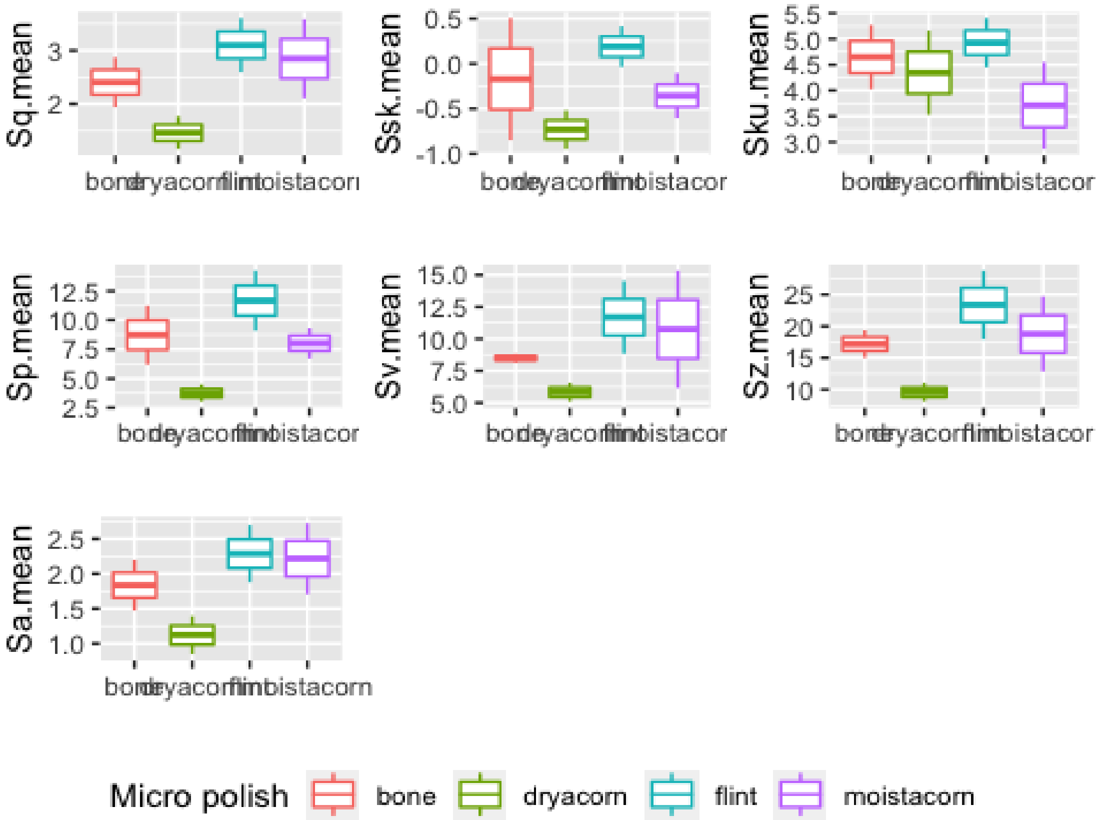



```
ggsave("../plots/confocalexp/confocalexpvolume_matrix.png")

## Saving 5 x 4 in image
```

Plot confostats for the ISO 25178 Area-scale, Height and volume parameters

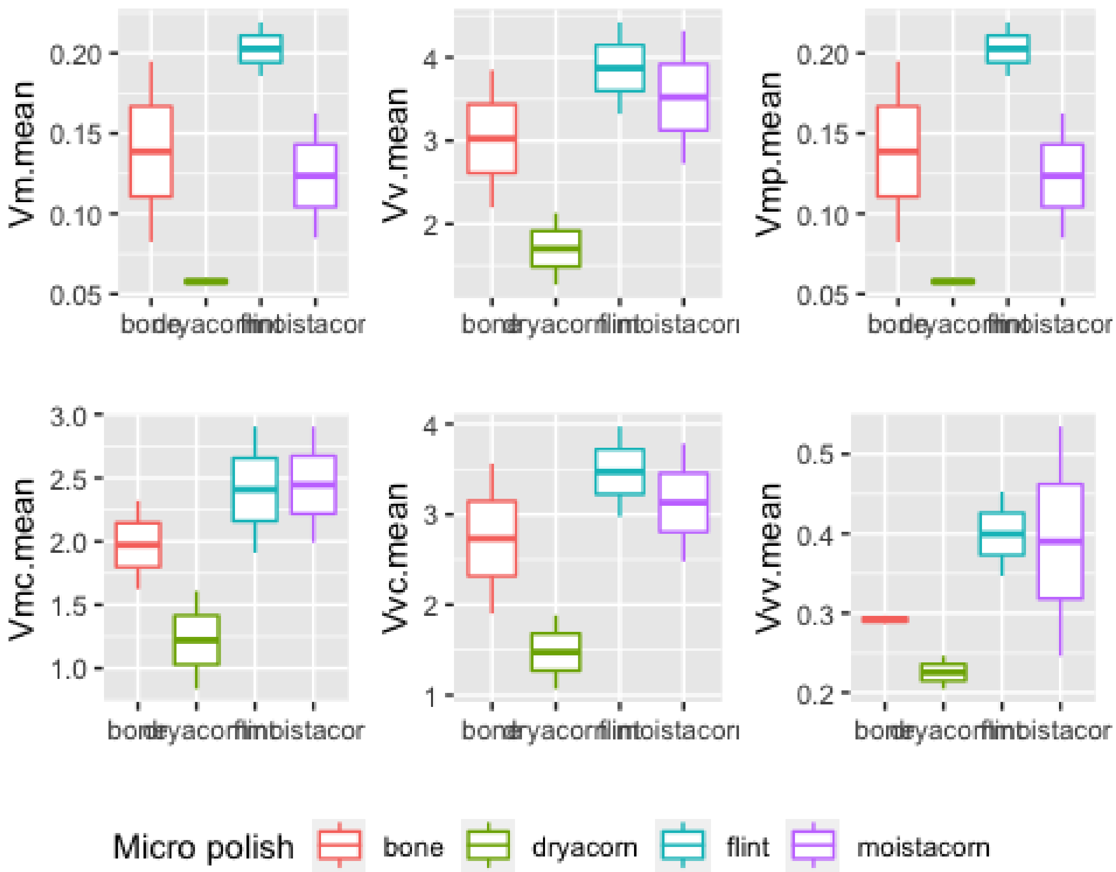
```
# select parameter from dataset

# first Height parameters

heightconfostatsexp <- select(confostatsexp,sample,workedmaterial, Sq.mean,Ssk.mean,Sku.mean,Sp
.mean,Sv.mean,Sz.mean,Sa.mean)

p1 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sq.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p2 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Ssk.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p3 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sku.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p4 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sp.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p5 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p6 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sz.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")
```

```
p7 <- ggplot(heightconfostatsexp, aes(x=workedmaterial, y=Sa.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

ggarrange(p1, p2, p3, p4, p5, p6, p7, common.legend = TRUE, font.label = list(size=8), legend="
bottom")
```




```
ggsave("../plots/confocalexp/confostatsexparea_boxplots.png")

## Saving 5 x 4 in image

# Now, compute Volume parameters

volumeconfostatsexp <- select(confostatsexp,sample,workedmaterial, Vm.mean,Vv.mean,Vmp.mean,Vmc
.mean,Vvc.mean,Vvv.mean)

p8 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vm.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p9 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p10 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vmp.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p11 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vmc.mean, colour=workedmaterial)) +
  geom_boxplot() +
```

```
  labs(x="", colour="Micro polish")

p12 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vvc.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p13 <- ggplot(volumeconfostatsexp, aes(x=workedmaterial, y=Vvv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

ggarrange(p8, p9, p10, p11, p12, p13, common.legend = TRUE, font.label = list(size=8), legend="
bottom")
```




```
ggsave("../plots//confocalexp/confostatexpvolume_boxplots.png")

## Saving 5 x 4 in image
```

End and Session info

```
sessionInfo()

## R version 4.0.0 Patched (2020-05-04 r78358)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Catalina 10.15.7
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
```

```
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] tools     stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] ggpubr_0.4.0    doBy_4.6.8      GGally_2.1.0    janitor_2.1.0
##  [5] knitr_1.31      forcats_0.5.1   stringr_1.4.0   dplyr_1.0.4
##  [9] purrr_0.3.4     readr_1.4.0     tidyr_1.1.2     tibble_3.0.6
## [13] ggplot2_3.3.3   tidyverse_1.3.0
##
## loaded via a namespace (and not attached):
##  [1] httr_1.4.2         jsonlite_1.7.2     carData_3.0-4      modelr_0.1.8
##  [5] assertthat_0.2.1   highr_0.8          cellranger_1.1.0   yaml_2.2.1
##  [9] pillar_1.4.7       backports_1.2.1    lattice_0.20-41    glue_1.4.2
## [13] digest_0.6.27      RColorBrewer_1.1-2 ggsignif_0.6.0     rvest_0.3.6
## [17] snakecase_0.11.0   colorspace_2.0-0   cowplot_1.1.1      htmltools_0.5.1.1
## [21] Matrix_1.3-2       plyr_1.8.6         pkgconfig_2.0.3    broom_0.7.4
## [25] haven_2.3.1        scales_1.1.1       openxlsx_4.2.3     rio_0.5.16
## [29] farver_2.0.3       generics_0.1.0     car_3.0-10         ellipsis_0.3.1
## [33] withr_2.4.1        cli_2.3.0          magrittr_2.0.1     crayon_1.4.0
## [37] readxl_1.3.1       evaluate_0.14      fs_1.5.0           MASS_7.3-53
## [41] rstatix_0.6.0      xml2_1.3.2         foreign_0.8-81     data.table_1.13.6
## [45] hms_1.0.0          lifecycle_0.2.0    munsell_0.5.0      reprex_1.0.0
## [49] zip_2.1.1          Deriv_4.1.2        compiler_4.0.0     rlang_0.4.10
## [53] grid_4.0.0         rstudioapi_0.13    labeling_0.4.2     rmarkdown_2.6
## [57] gtable_0.3.0       abind_1.4-5        DBI_1.1.1          reshape_0.8.8
## [61] curl_4.3           R6_2.5.0           gridExtra_2.3      lubridate_1.7.9.2
## [65] stringi_1.5.3      Rcpp_1.0.6         vctrs_0.3.6        dbplyr_2.1.0
## [69] tidyselect_1.1.0   xfun_0.20
```

```
##  [1] httr_1.4.2         jsonlite_1.7.2     carData_3.0-4      modelr_0.1.8
##  [5] assertthat_0.2.1   highr_0.8          cellranger_1.1.0   yaml_2.2.1
##  [9] pillar_1.4.7       backports_1.2.1    lattice_0.20-41    glue_1.4.2
## [13] digest_0.6.27      RColorBrewer_1.1-2 ggsignif_0.6.0     rvest_0.3.6
## [17] snakecase_0.11.0   colorspace_2.0-0   cowplot_1.1.1      htmltools_0.5.1.1
## [21] Matrix_1.3-2       plyr_1.8.6         pkgconfig_2.0.3    broom_0.7.4
## [25] haven_2.3.1        scales_1.1.1       openxlsx_4.2.3     rio_0.5.16
## [29] farver_2.0.3       generics_0.1.0     car_3.0-10         ellipsis_0.3.1
## [33] withr_2.4.1        cli_2.3.0          magrittr_2.0.1     crayon_1.4.0
## [37] readxl_1.3.1       evaluate_0.14      fs_1.5.0           MASS_7.3-53
## [41] rstatix_0.6.0      xml2_1.3.2         foreign_0.8-81     data.table_1.13.6
## [45] hms_1.0.0          lifecycle_0.2.0    munsell_0.5.0      reprex_1.0.0
## [49] zip_2.1.1          Deriv_4.1.2        compiler_4.0.0     rlang_0.4.10
## [53] grid_4.0.0         rstudioapi_0.13    labeling_0.4.2     rmarkdown_2.6
## [57] gtable_0.3.0       abind_1.4-5        DBI_1.1.1          reshape_0.8.8
## [61] curl_4.3           R6_2.5.0           gridExtra_2.3      lubridate_1.7.9.2
## [65] stringi_1.5.3      Rcpp_1.0.6         vctrs_0.3.6        dbplyr_2.1.0
## [69] tidyselect_1.1.0   xfun_0.20
```

1.4. Confocal surface texture analysis of archaeological samples

Paixão PhD - Confocal surface texture analysis of archaeological samples

EP

2021-02-08 10:39:24

Brief description of the script

This R markdown document reads, summarizes and plots data for the PhD dissertation *Paixão 2021. Groundbreaking technologies in the Middle Paleolithic of the Levant: High resolution and multi-scale functional analysis of Ground Stone Tools*

The document contains:

1. Tables
2. Plots (illustrations of the data analysis)
3. Supplementary material, including extra tables and figures (data analysis)

This R project and respective scripts follow the procedures described by Marwick et al. 2017.

To compile this markdown document do not delete or move files from their original folders. Please note that most of the tables and figures in this file do not match the numbering in the PhD dissertation manuscript.

For any questions, comments and inputs, please contact:

Eduardo Paixão, paixao@rgzm.de

Load data into R project

Imported files are in: '../analysis/raw_data'

Figures are saved in: '../analysis/plots'

Tables are saved in: '../analysis/derived_data'

```
# Load required libraries

library(tidyverse)

## ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──

## ✓ ggplot2 3.3.3     ✓ purrr   0.3.4
## ✓ tibble  3.0.6     ✓ dplyr   1.0.4
## ✓ tidyr   1.1.2     ✓ stringr 1.4.0
## ✓ readr   1.4.0     ✓ forcats 0.5.1

## Warning: package 'ggplot2' was built under R version 4.0.2

## Warning: package 'tibble' was built under R version 4.0.2

## Warning: package 'readr' was built under R version 4.0.2
```

```
## Warning: package 'dplyr' was built under R version 4.0.2

## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(utils)
library(knitr)
library(janitor)

## Warning: package 'janitor' was built under R version 4.0.2

##
## Attaching package: 'janitor'

## The following objects are masked from 'package:stats':
##
##     chisq.test, fisher.test

library(kableExtra)

## Warning: package 'kableExtra' was built under R version 4.0.2

##
## Attaching package: 'kableExtra'

## The following object is masked from 'package:dplyr':
##
##     group_rows

library(GGally)

## Warning: package 'GGally' was built under R version 4.0.2

## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2

library(doBy)

## Warning: package 'doBy' was built under R version 4.0.2

##
## Attaching package: 'doBy'

## The following object is masked from 'package:dplyr':
##
##     order_by

library(ggpubr)

## Warning: package 'ggpubr' was built under R version 4.0.2

library(tools)

# See your WD and update the following paths
# getwd()

# Load data from .csv
confocaldataarch <- read.delim("../raw_data/confocalarch/confocaldataarch.csv", header = T,
";")

data_file <- list.files("../raw_data/confocalarch", pattern = "\\.csv$", full.names = TRUE)
```

```r
md5_in <- md5sum(data_file)
info_in <- data.frame(file = basename(names(md5_in)), checksum = md5_in, row.names = NULL)
```

Confocal micro surface texture data

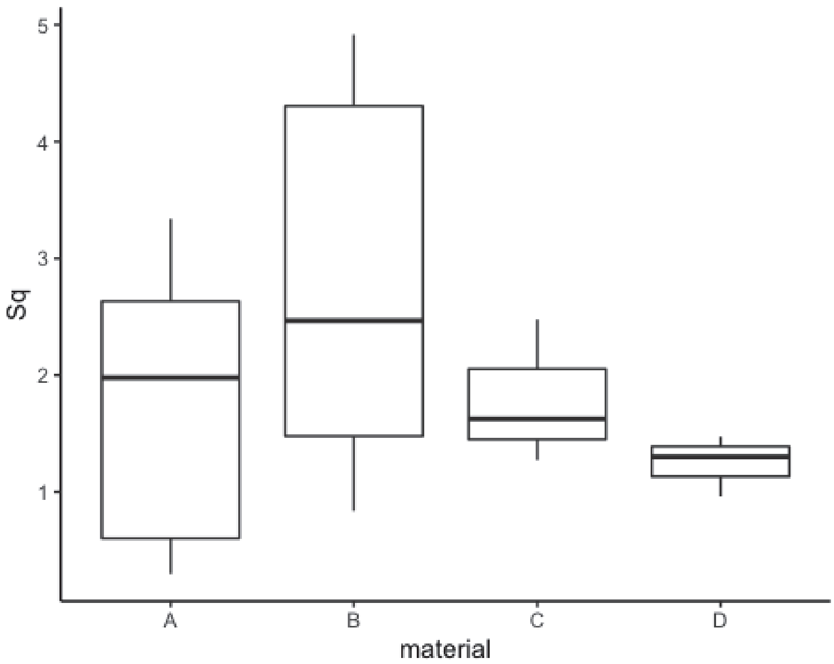
Import and summarize data

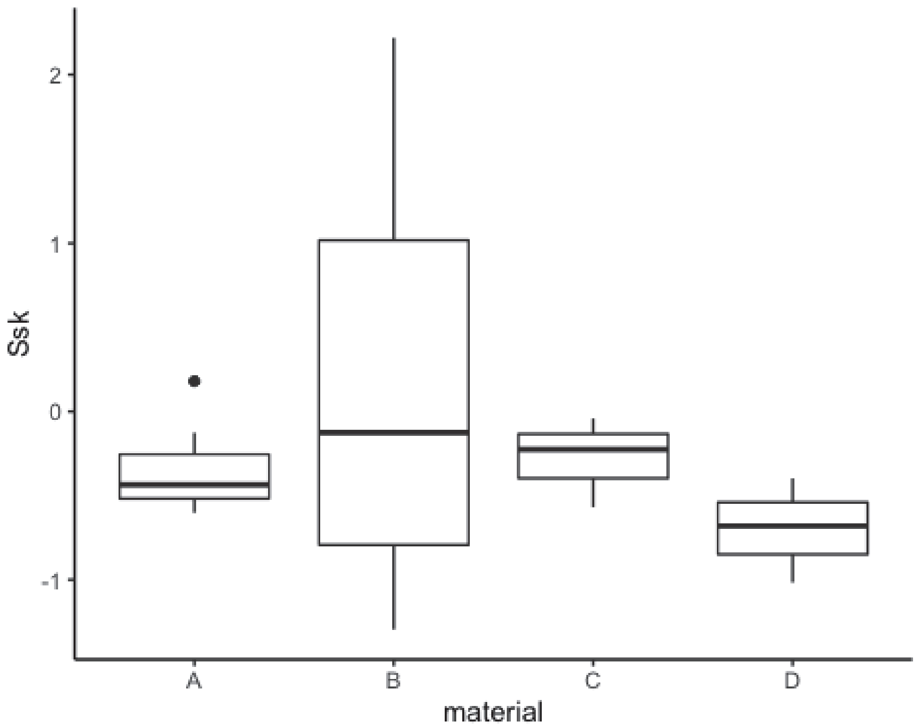
```
# compute descriptive statistics

nminmaxmeanmedsd <- function(x){
    y <- x[!is.na(x)]
    n_test <- length(y)
    min_test <- min(y)
    max_test <- max(y)
    mean_test <- mean(y)
    med_test <- median(y)
    sd_test <- sd(y)
    out <- c(n_test, min_test, max_test, mean_test, med_test, sd_test)
    names(out) <- c("n", "min", "max", "mean", "median", "sd")
    return(out)
}

num.var <- 21:length(confocaldataarch)

confostatsarch <- summaryBy(.~sample + workedmaterial, data=confocaldataarch[c("sample", "w
orkedmaterial", names(confocaldataarch)[num.var])], FUN=nminmaxmeanmedsd)

write_csv(confostatsarch, "../derived_data/confocalstats_arch.csv")
```

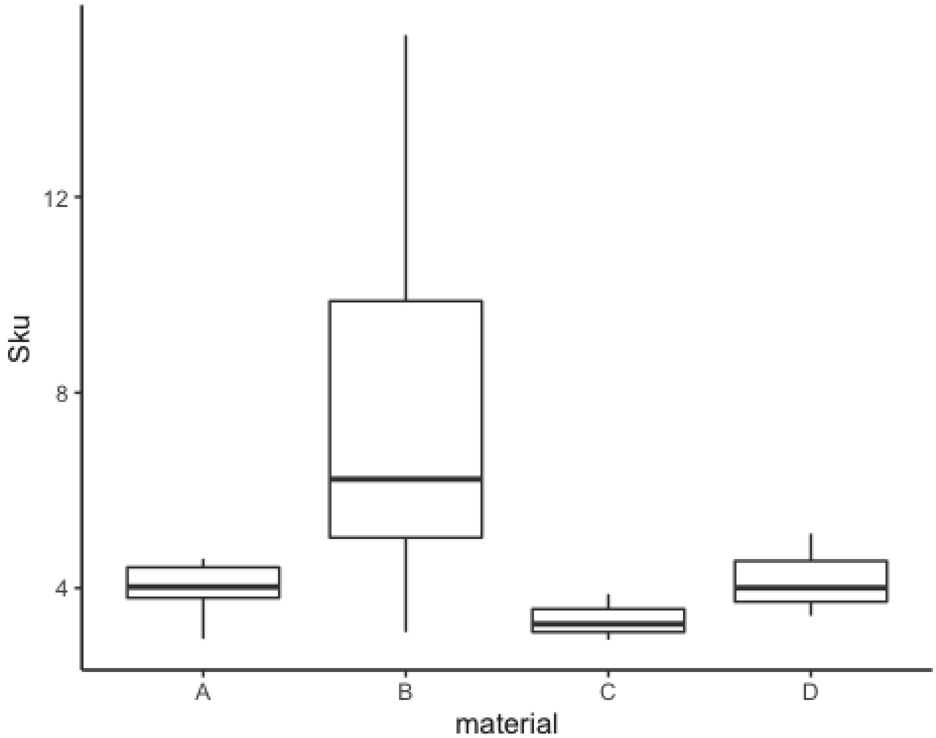
Plot all paramaters

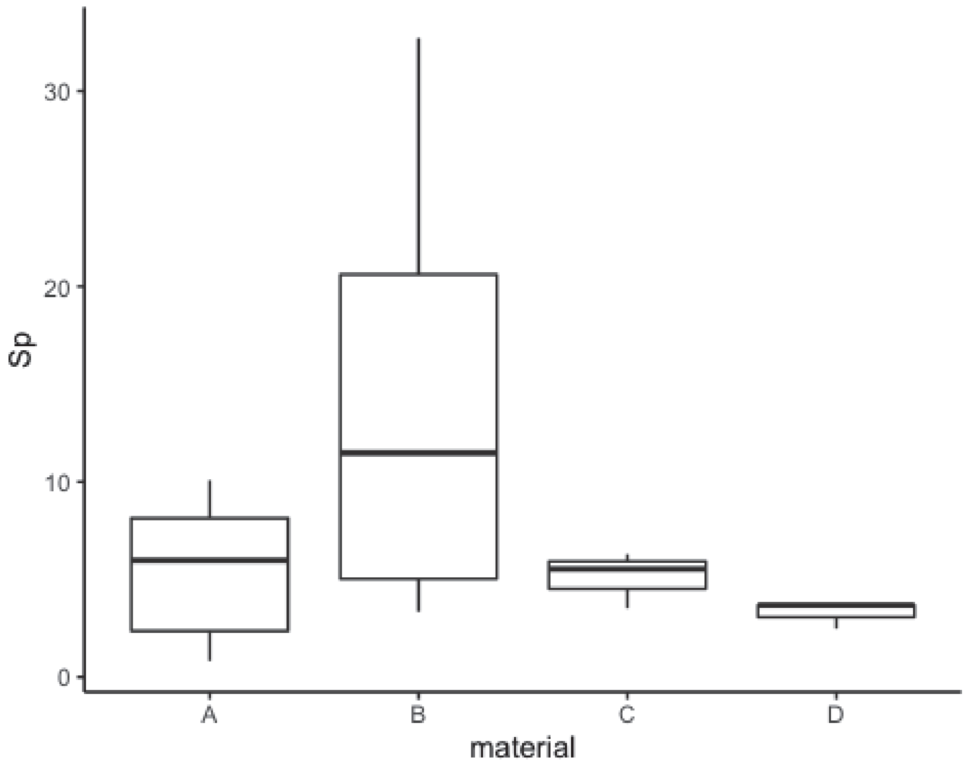
```
# Only experimental tools

confoarch <- filter(confocaldataarch, sample == "archaeological")

# Loop for plotting all surface texture parameters

for (i in num.var) cat("[",i,"] ", names(confoarch)[i], "\n", sep = "")

## [21] Sq
## [22] Ssk
## [23] Sku
## [24] Sp
## [25] Sv
## [26] Sz
## [27] Sa
## [28] Smr
## [29] Smc
## [30] Sxp
## [31] Sal
## [32] Str
## [33] Std
## [34] Sdq
## [35] Sdr
## [36] VM
## [37] Vv
## [38] Vmp
## [39] Vmc
## [40] Vvc
## [41] Vvv..p...80.00..
## [42] Vvv
## [43] Mean.depth.of.furrows
## [44] Mean.density.of.furrows
```

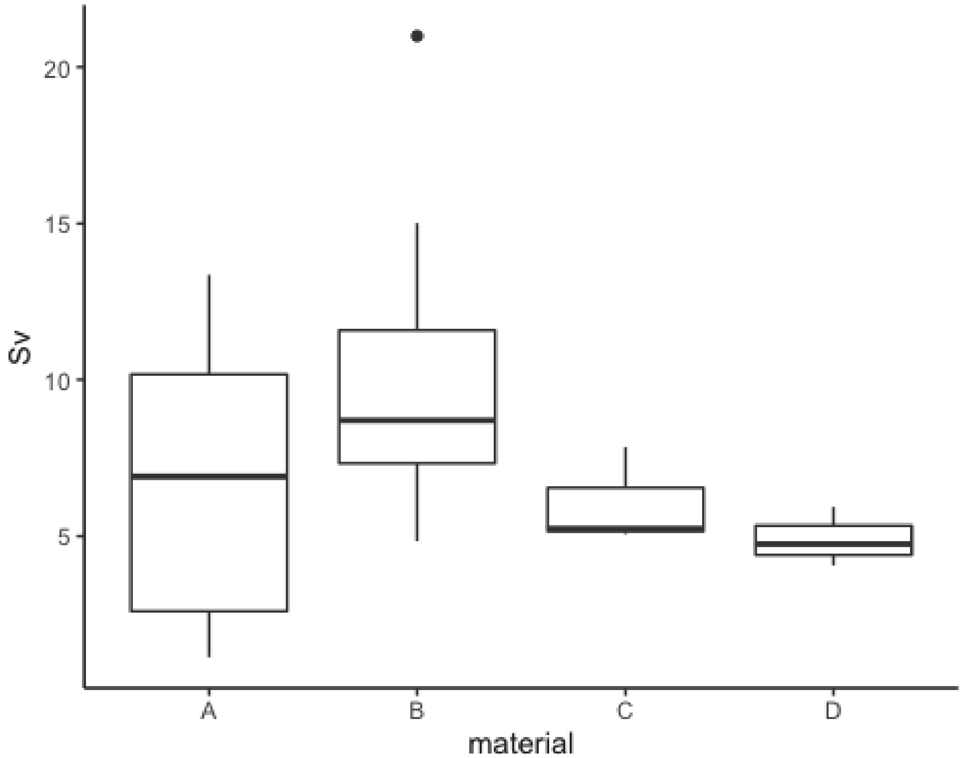
```
## [45] First.direction
## [46] Second.direction
## [47] Third.direction
## [48] Isotropy
## [49] Lengthscale.anisotropy.Sfrax.epLsar
## [50] Length.scale.anisotropy..NewEplsar.
## [51] Fractal.complexity.Asfc
## [52] Smfc
## [53] HAsfc9
## [54] HAsfc81

for (i in num.var) {
  p <- ggplot(data = confocaldataarch, aes_string(x = "workedmaterial", y = names(confoarch
)[i])) +
         geom_boxplot() +
         # geom_line(aes(group = motion)) +
         theme_classic() +
         # facet_wrap(~ sample) +
         labs(x = "material", y = gsub("\\.", " ", names(confoarch)[i])) +
         scale_colour_hue(h = c(25,225))
  print(p)

  # saves the plots
  file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_plot_",
                     names(confoarch)[i], ".pdf")
    ggsave(filename = file_out, plot = p, path = "../plots/confocalarch", device = "pdf", w
idth = 26,
           height = 21, units = "cm" )
}
```


Sq
5
4
3
2
1
A
B
C
D
material

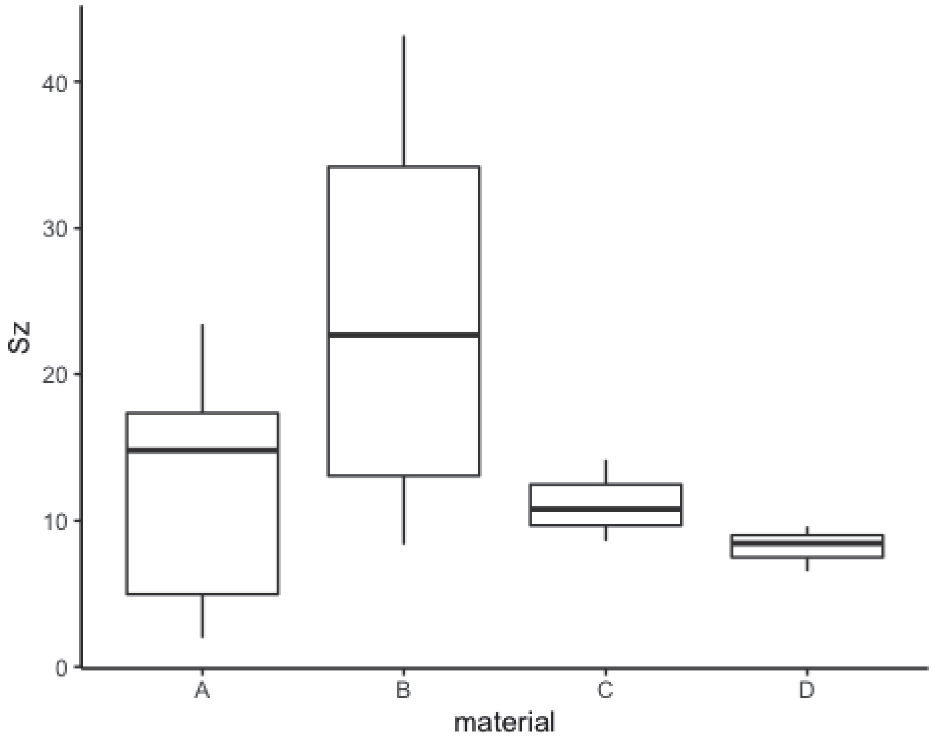

Ssk
2
1
0
-1
A
B
C
D
material


Sku
12
8
4
A
B
C
D
material

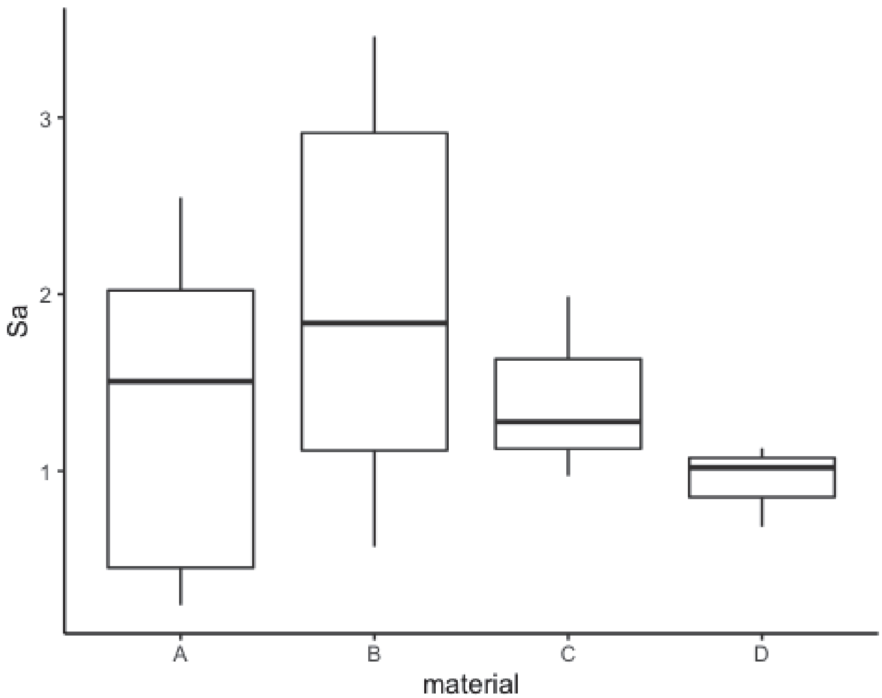

Sp
30
20
10
0
A
B
C
D
material

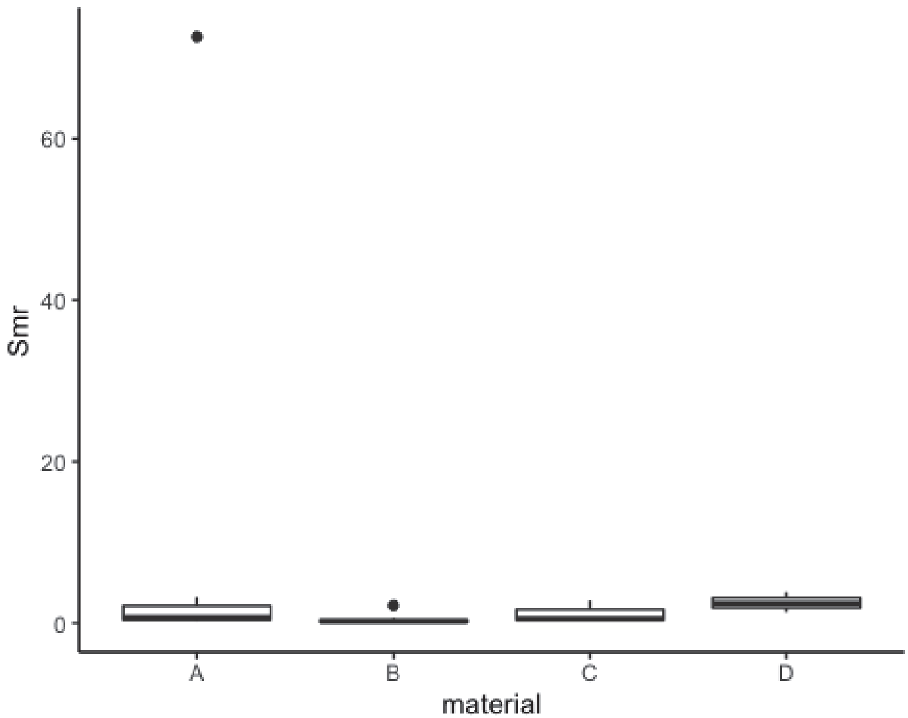


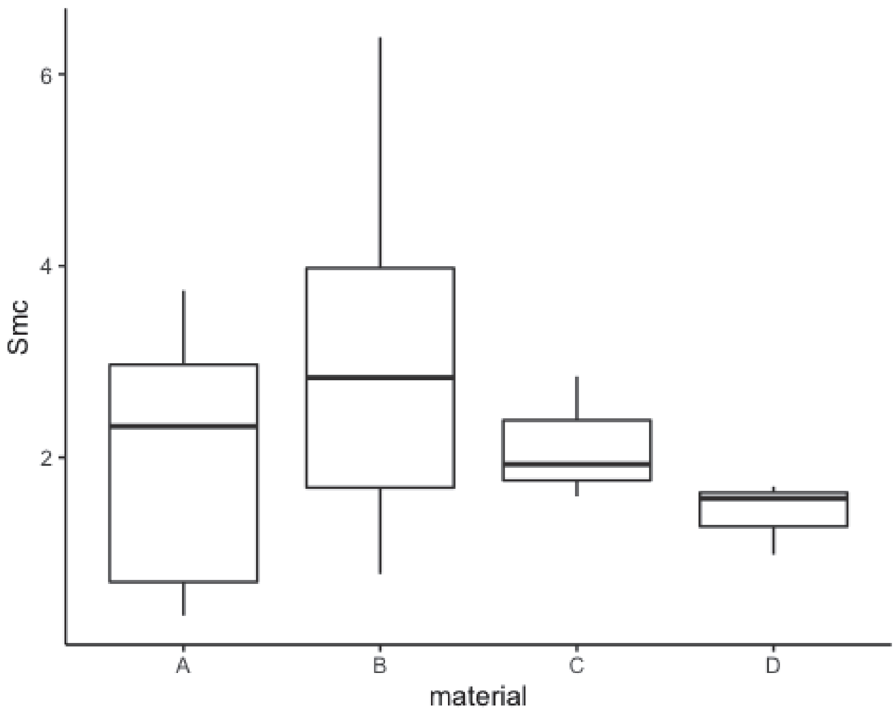
20
15
10
5
Sv
A
B
C
D
material



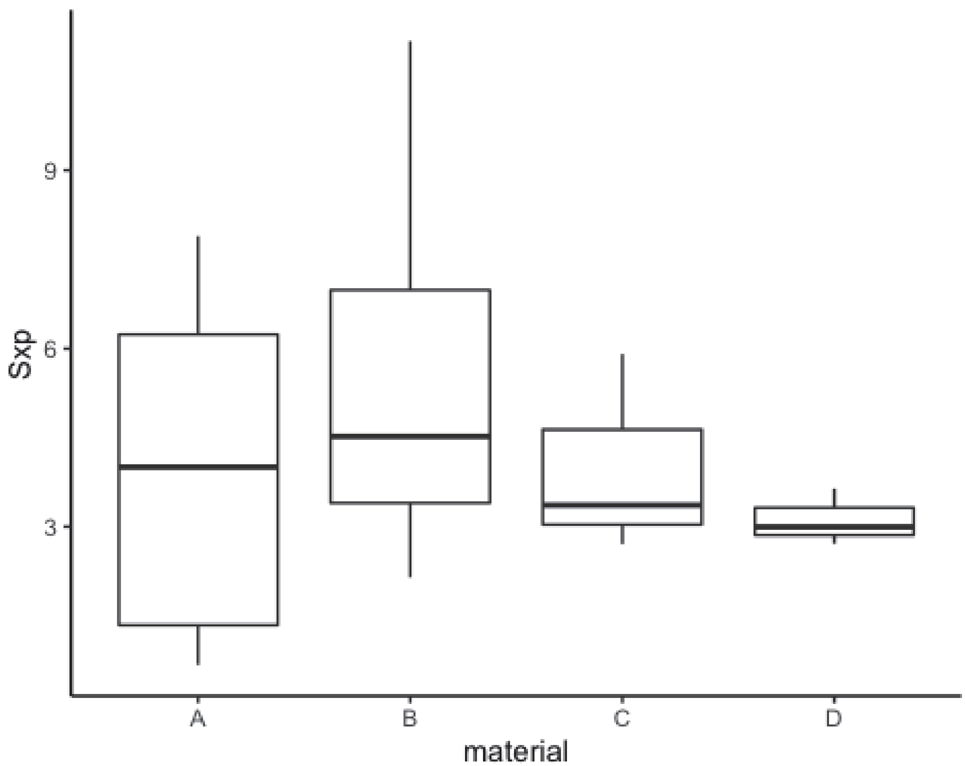
40
30
20
10
0
Sz
A
B
C
D
material


Sa
3
2
1
A
B
C
D
material

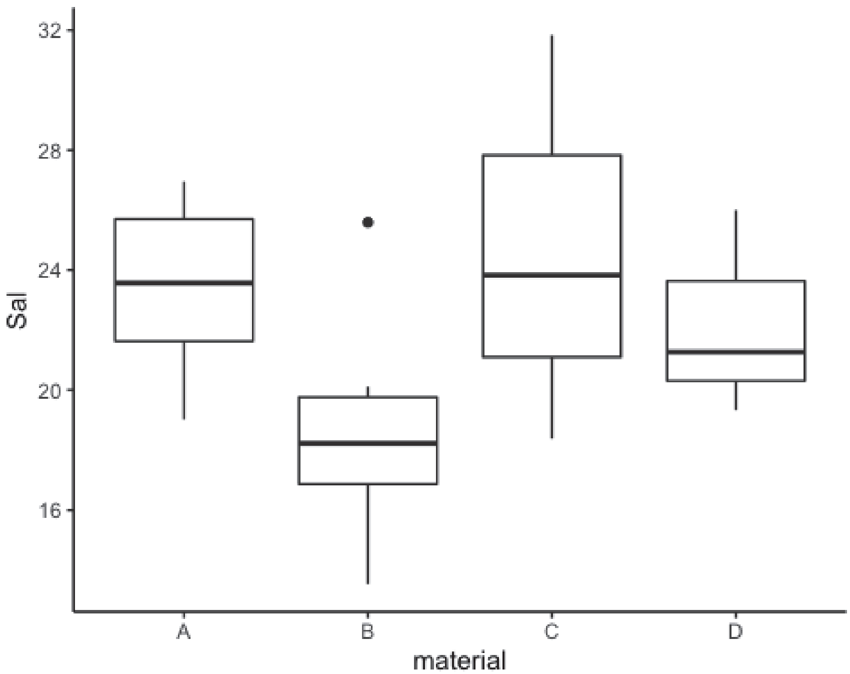

Smr
60
40
20
0
A
B
C
D
material



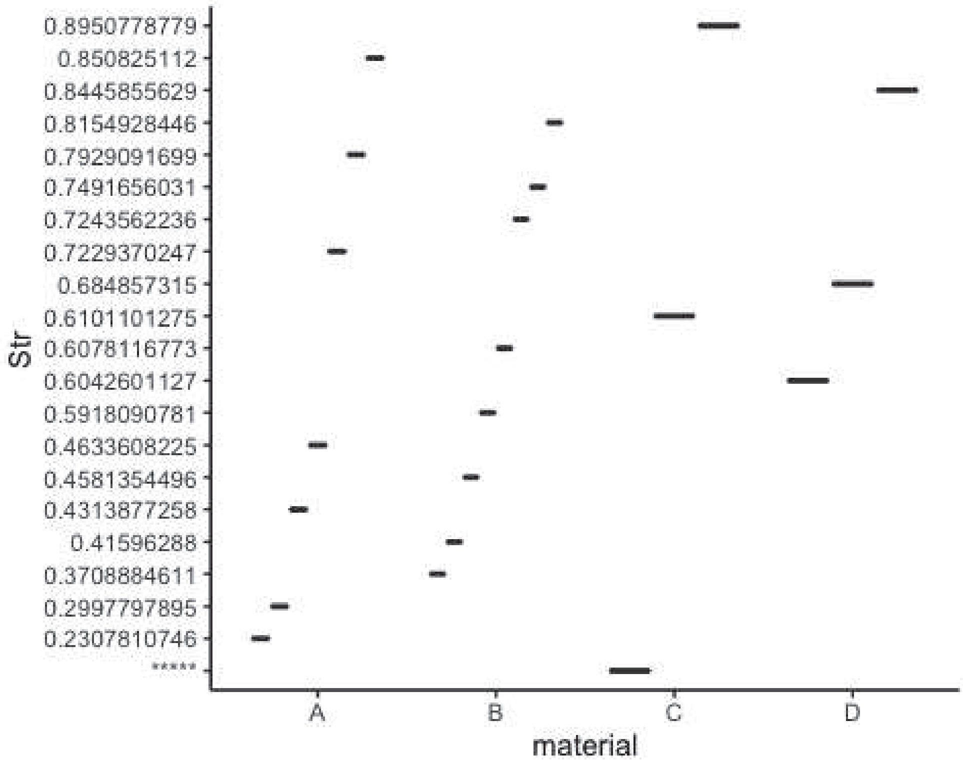
Smc
6
4
2
A
B
C
D
material



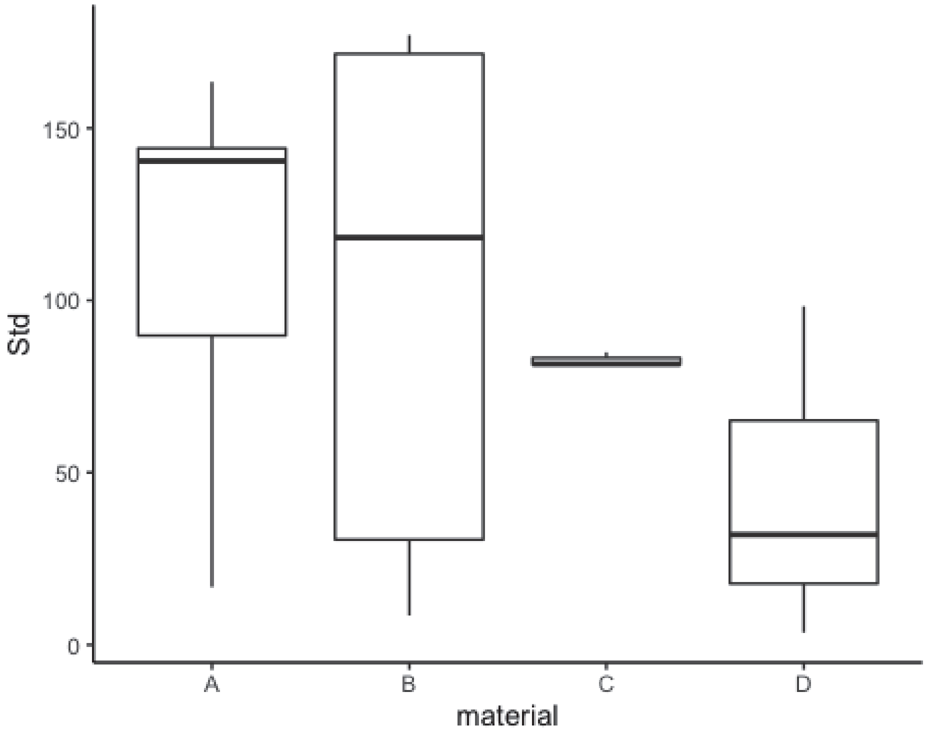
Sxp
9
6
3
A
B
C
D
material



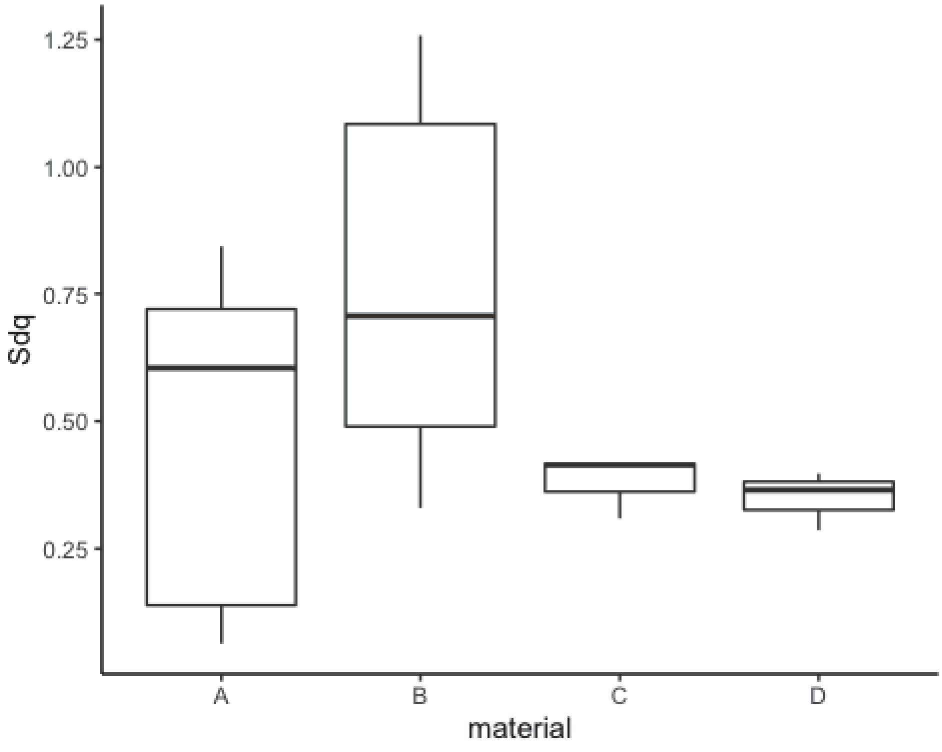
32
28
24
20
16
Sal
A
B
C
D
material



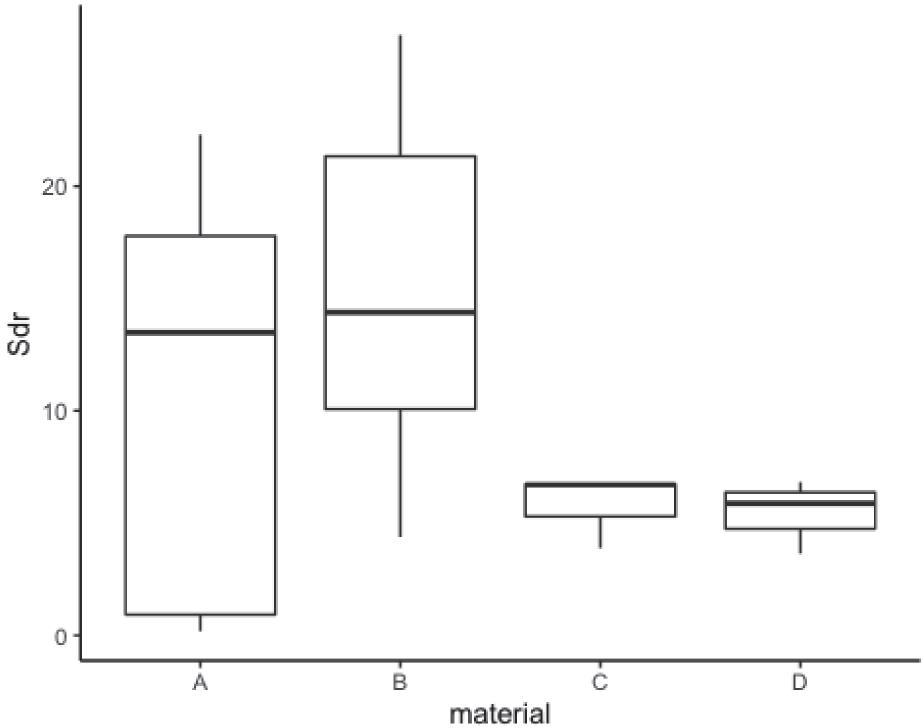
0.8950778779
0.850825112
0.8445855629
0.8154928446
0.7929091699
0.7491656031
0.7243562236
0.7229370247
0.684857315
0.6101101275
0.6078116773
0.6042601127
0.5918090781
0.4633608225
0.4581354496
0.4313877258
0.41596288
0.3708884611
0.2997797895
0.2307810746
*****
Str
A
B
C
D
material



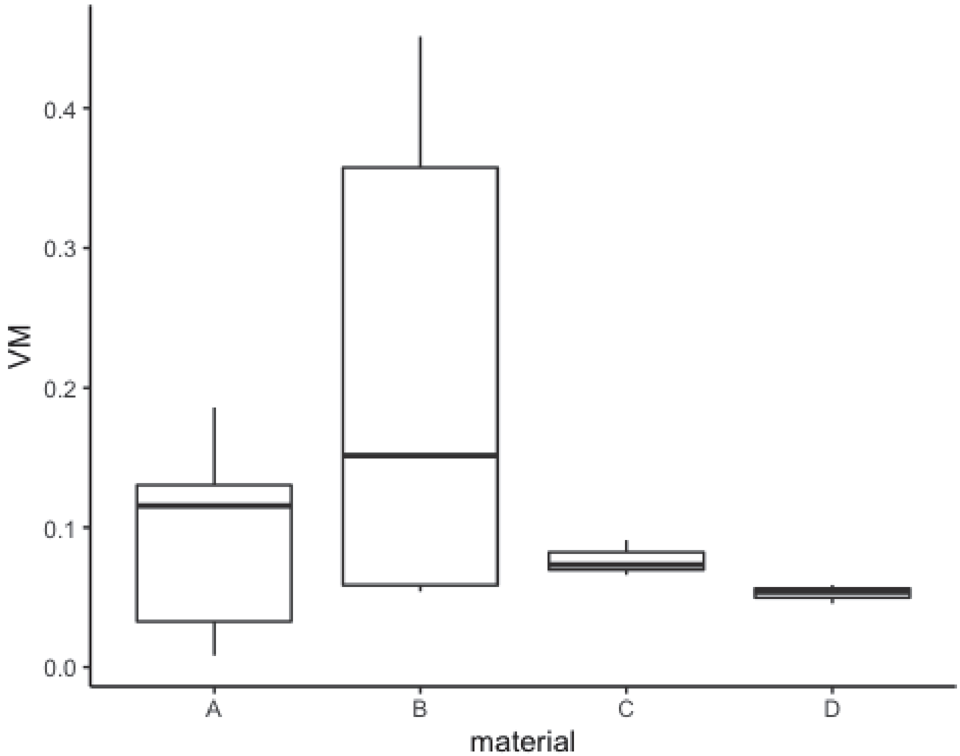
Std
150
100
50
0
A
B
C
D
material



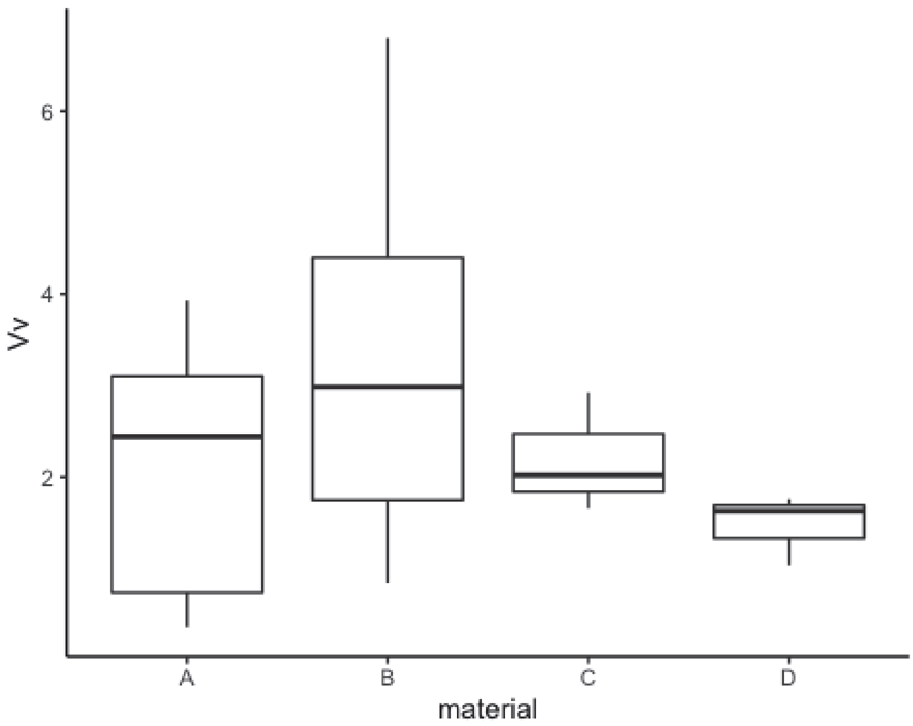
Sdq
1.25
1.00
0.75
0.50
0.25
A
B
C
D
material



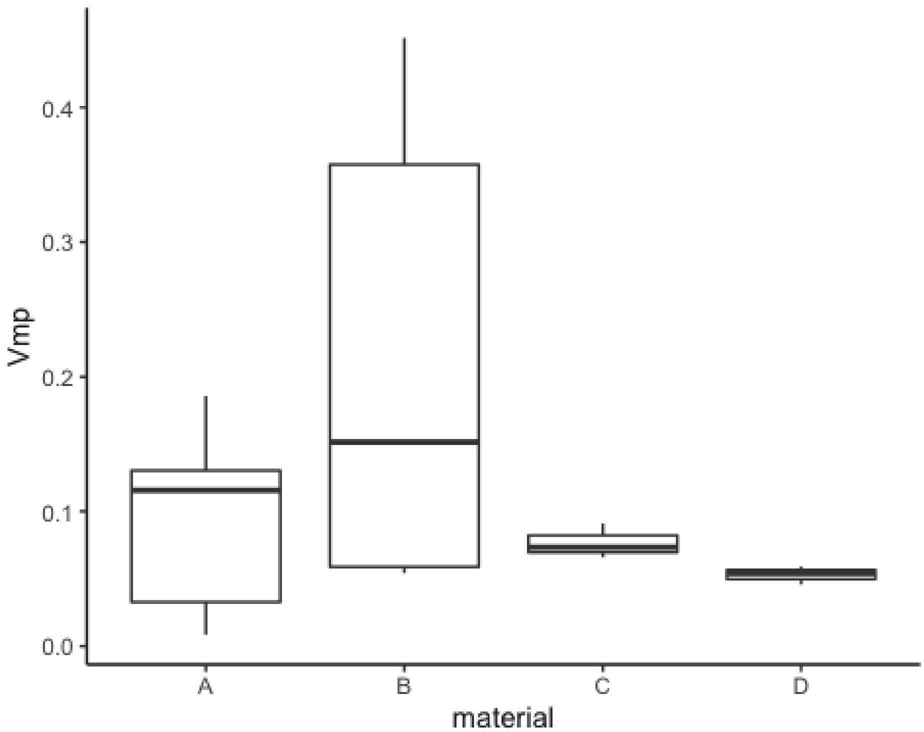
Sdr
20
10
0
A
B
C
D
material



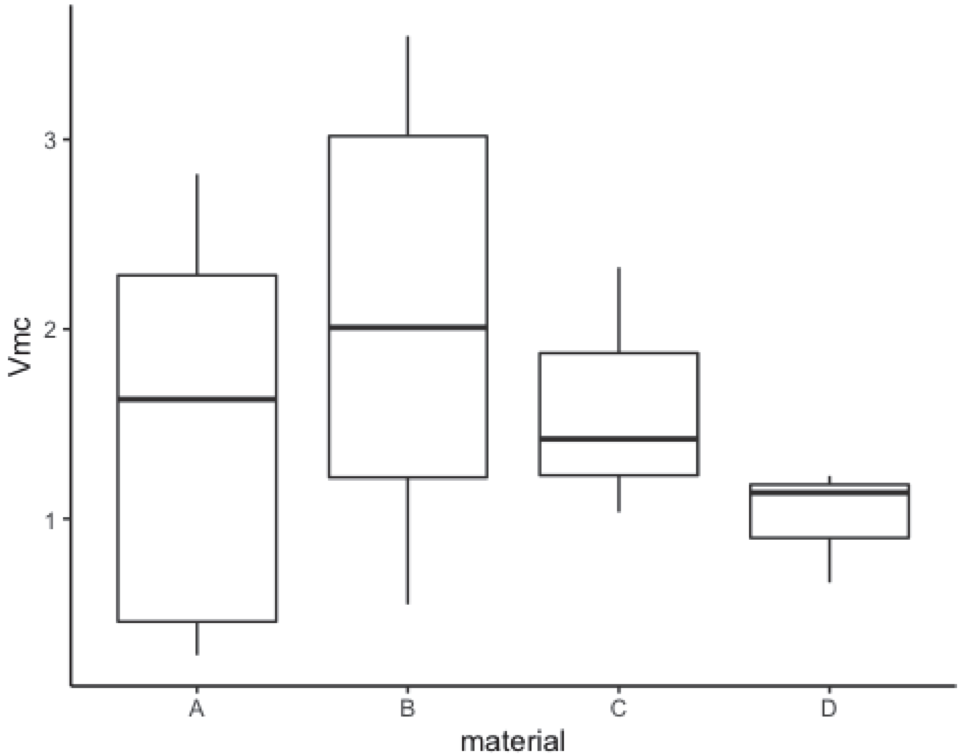
VM
0.4
0.3
0.2
0.1
0.0
A
B
C
D
material



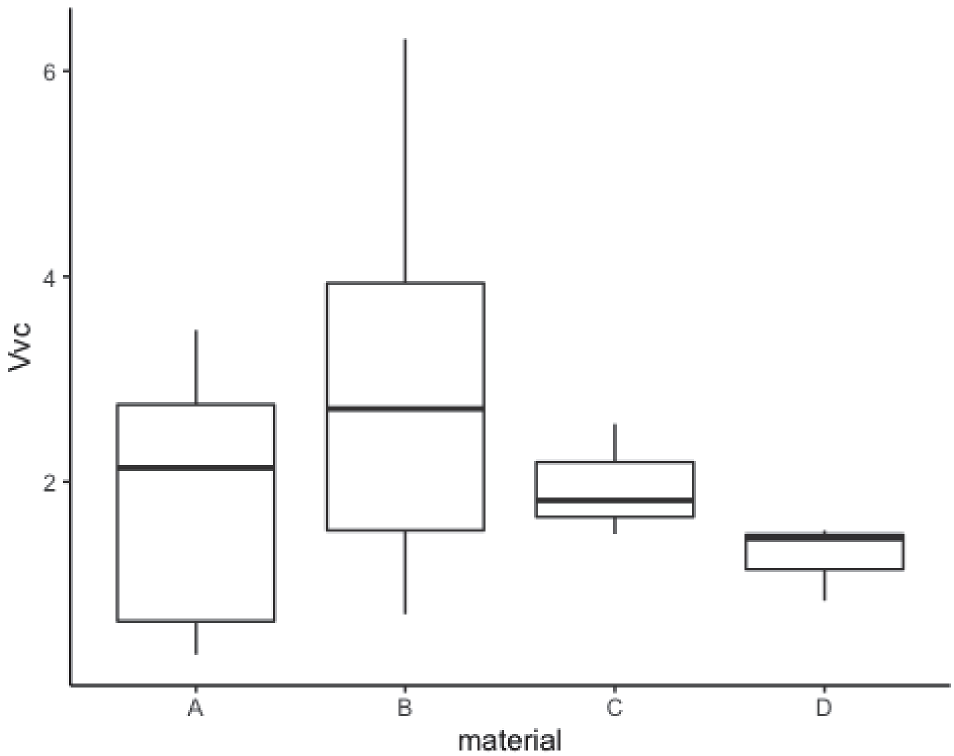
6
4
2
Vv
A
B
C
D
material



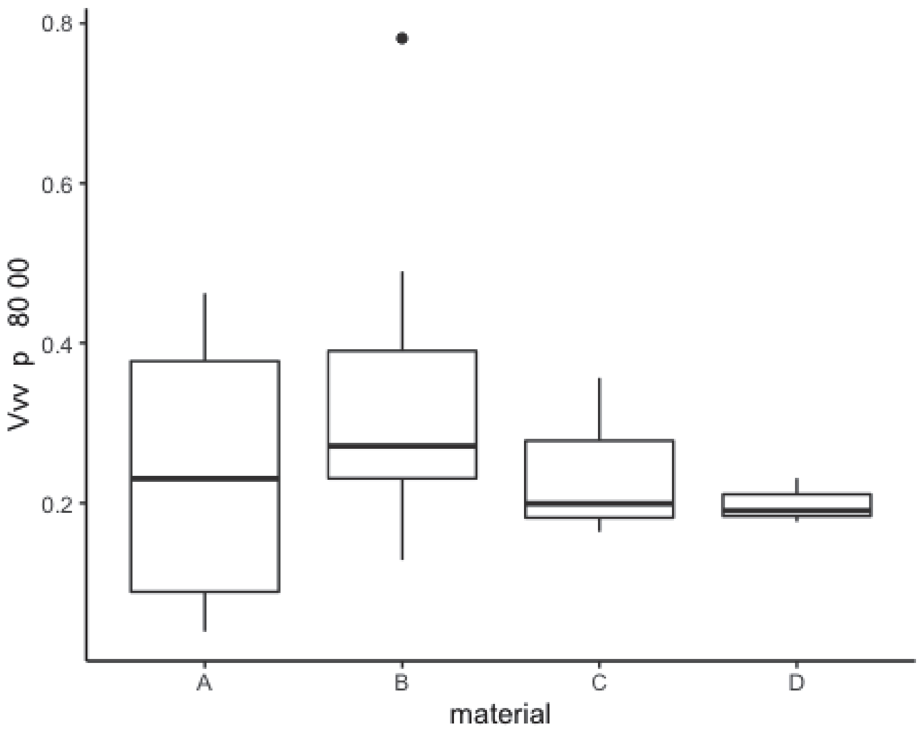
0.4
0.3
0.2
0.1
0.0
Vmp
A
B
C
D
material

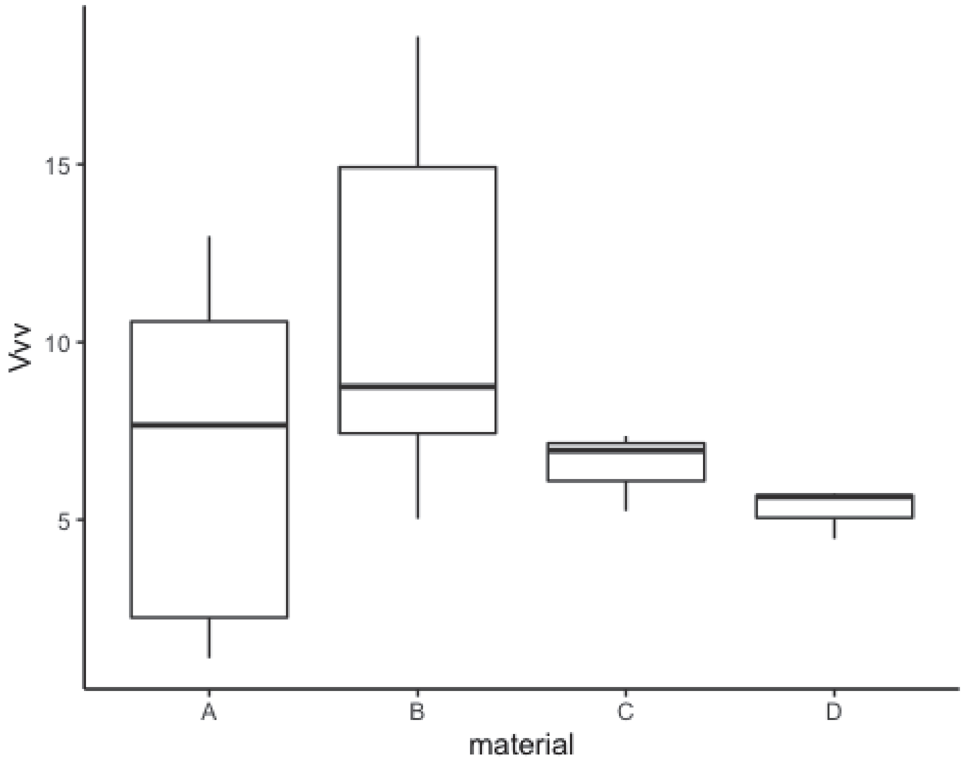


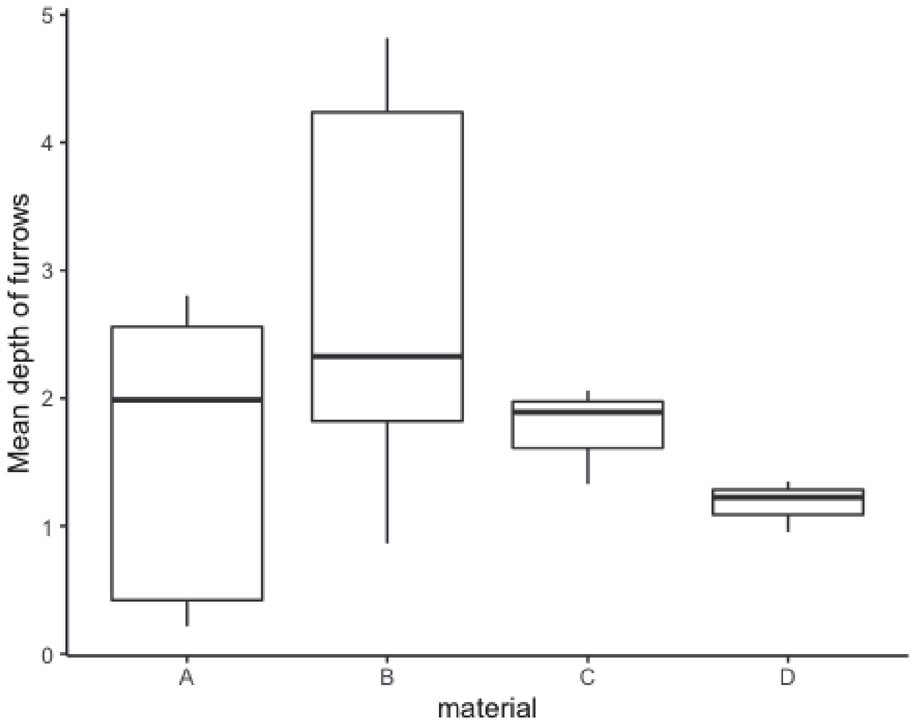
3
2
1
Vmc
A
B
C
D
material



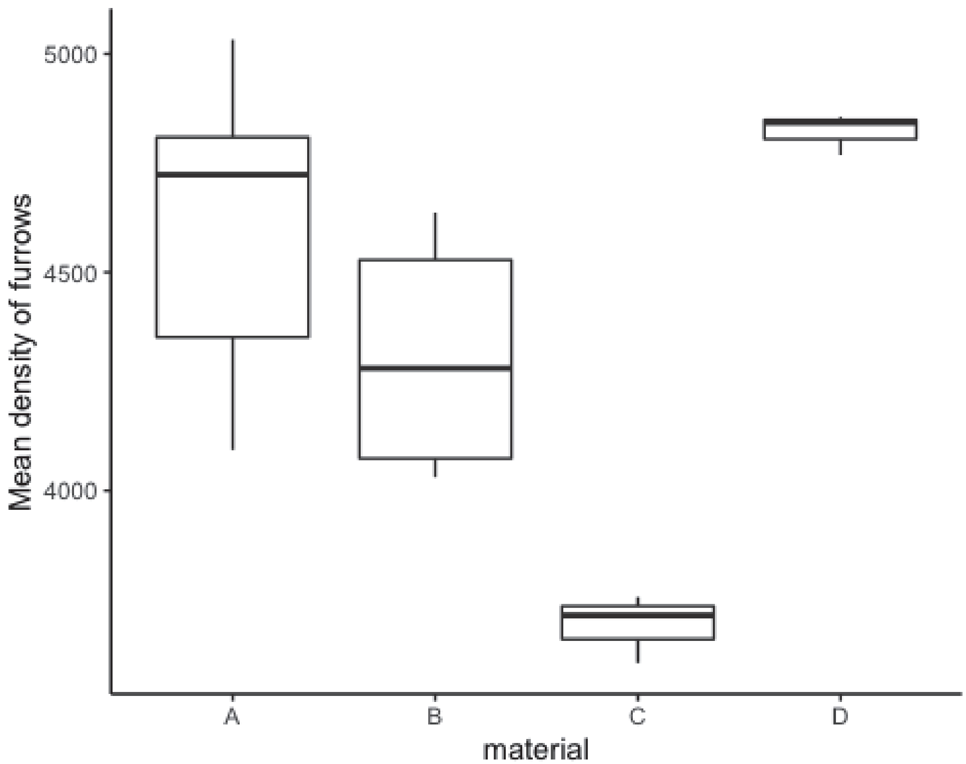
6
4
2
Vvc
A
B
C
D
material


0.8
0.6
0.4
0.2
Vvv p 80 00
A
B
C
D
material

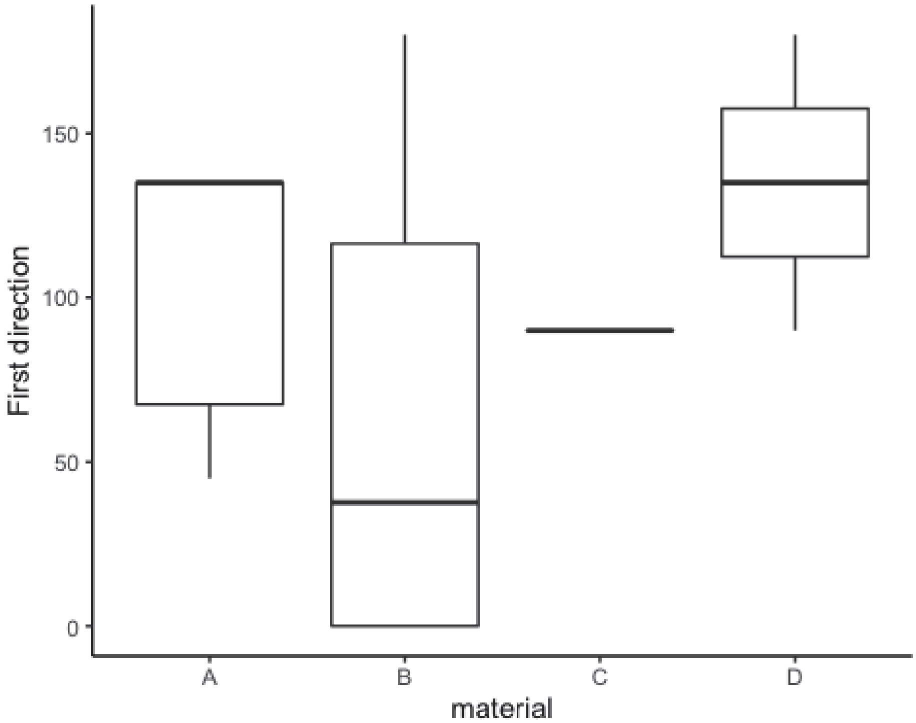

15
10
5
Vvv
A
B
C
D
material

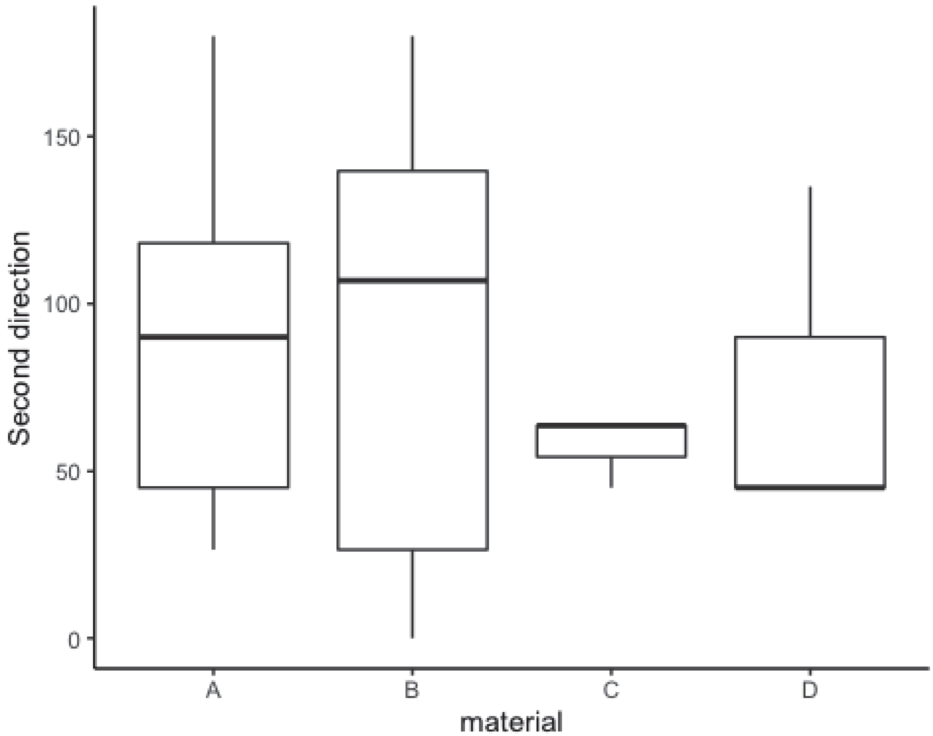


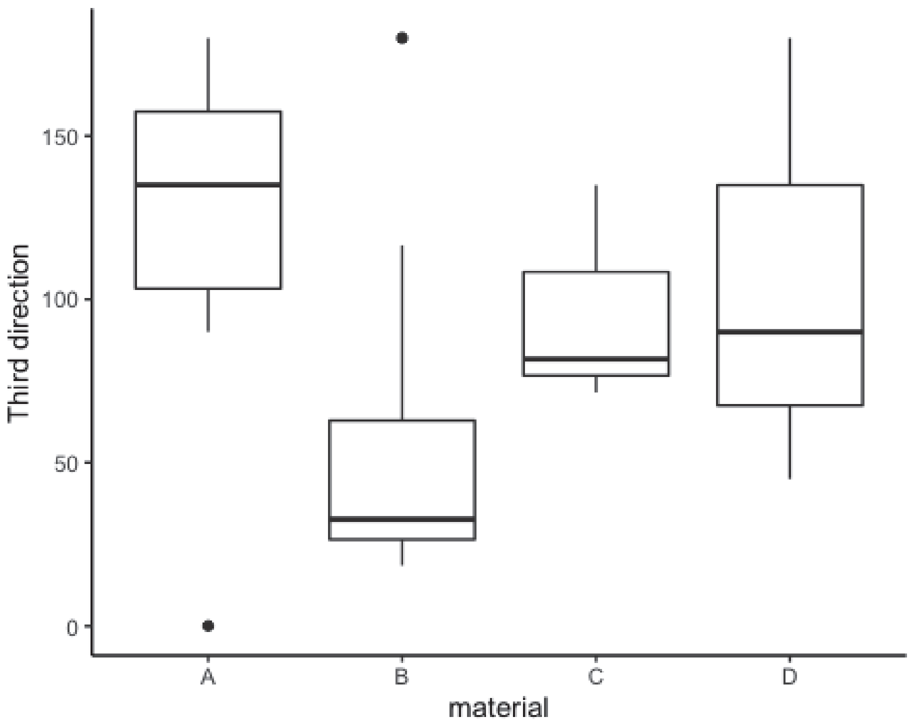
5
4
3
2
1
0
Mean depth of furrows
A
B
C
D
material

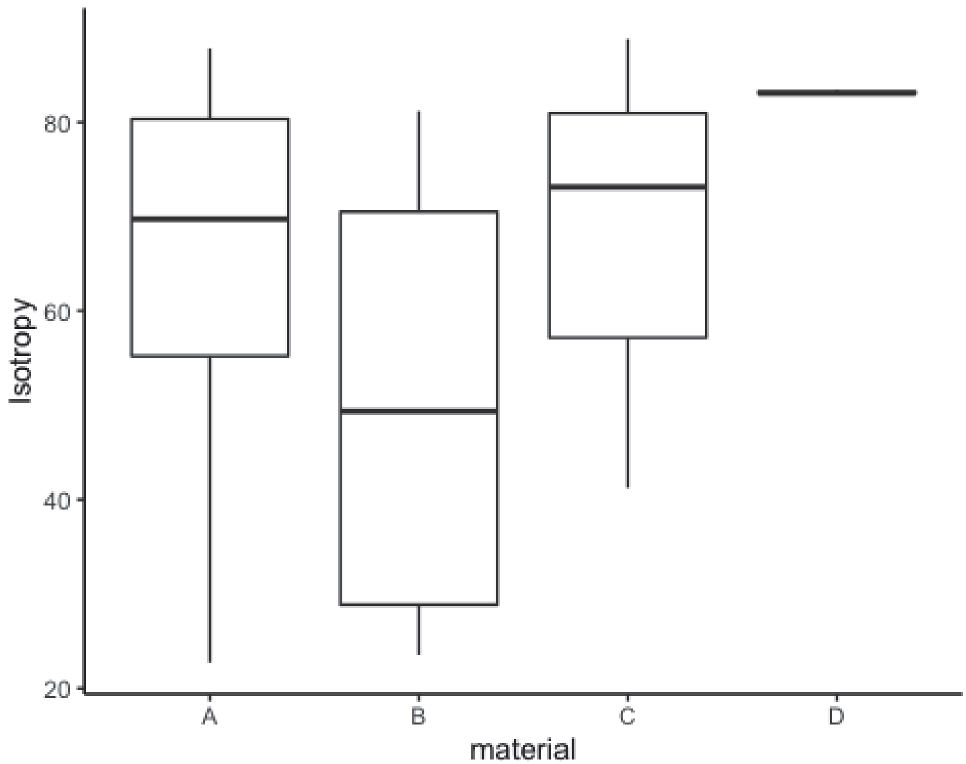


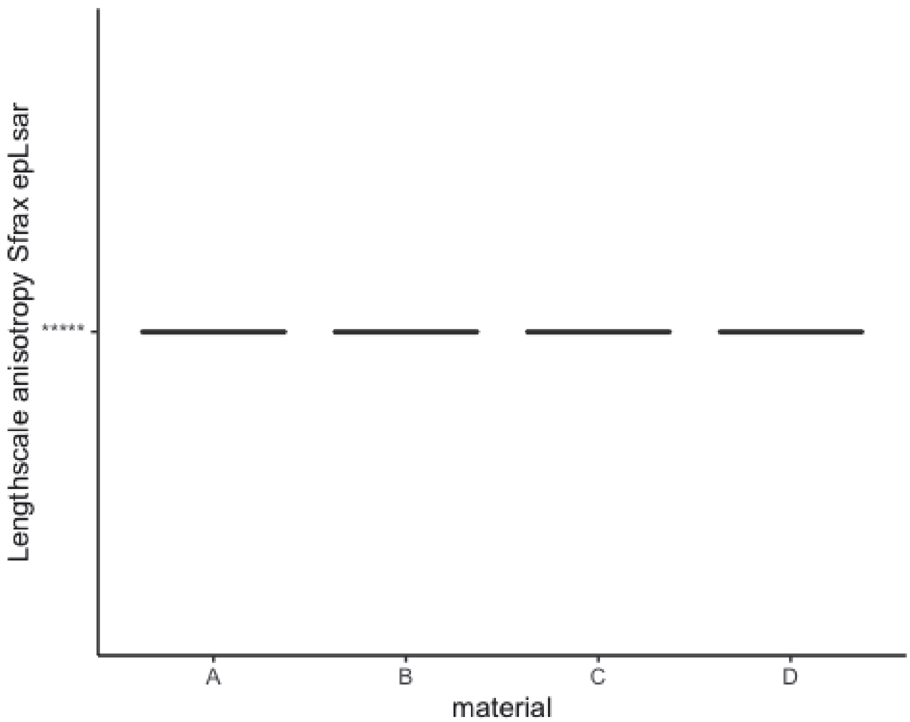
5000
4500
4000
Mean density of furrows
A
B
C
D
material

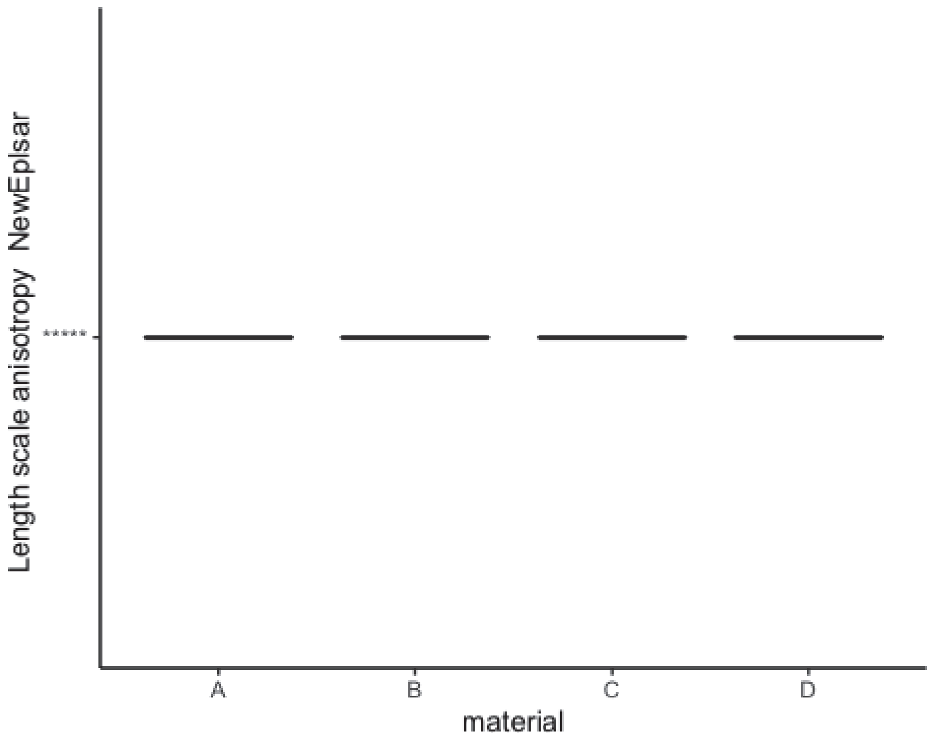

First direction
150
100
50
0
A
B
C
D
material

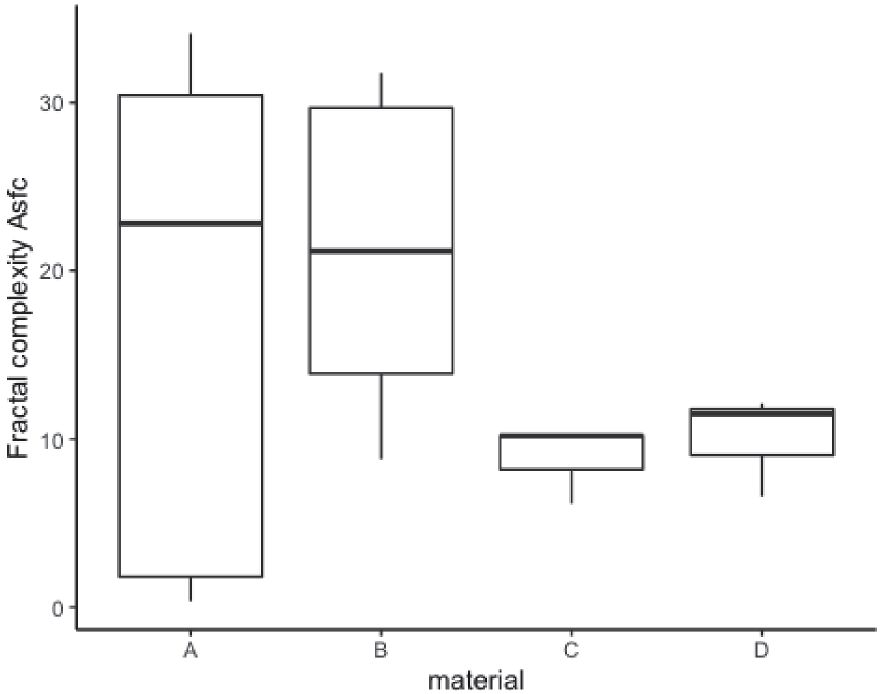

Second direction
150
100
50
0
A
B
C
D
material

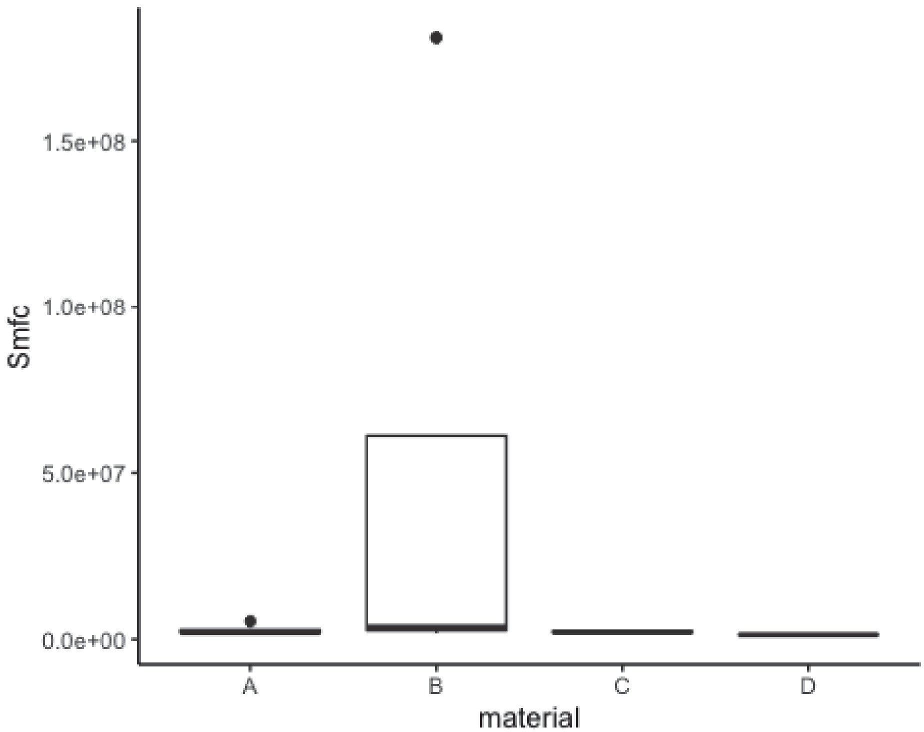

Third direction
150
100
50
0
A
B
C
D
material

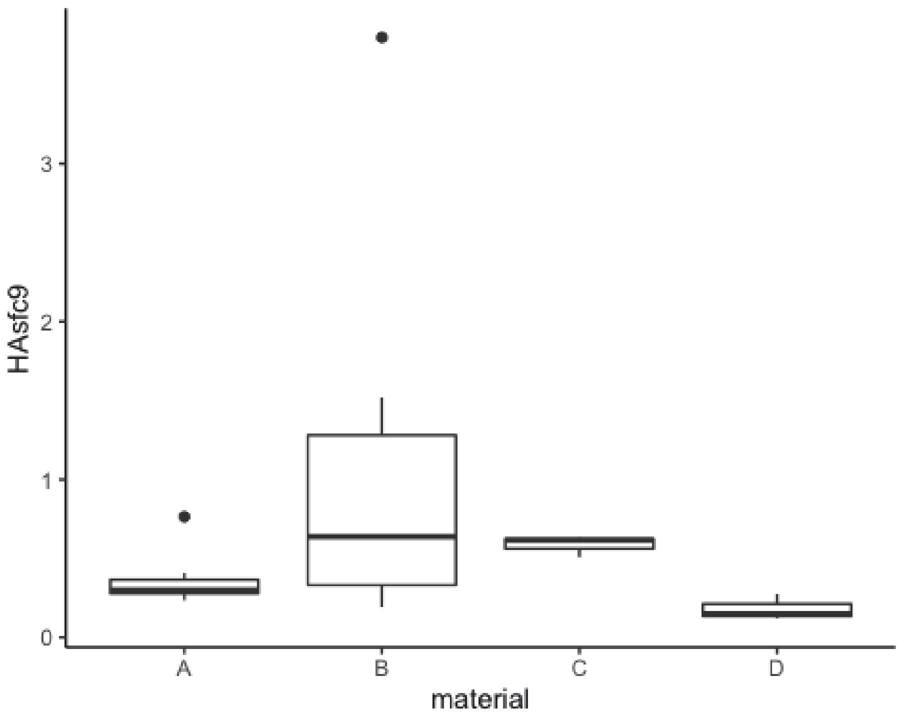

Isotropy
80
60
40
20
A
B
C
D
material

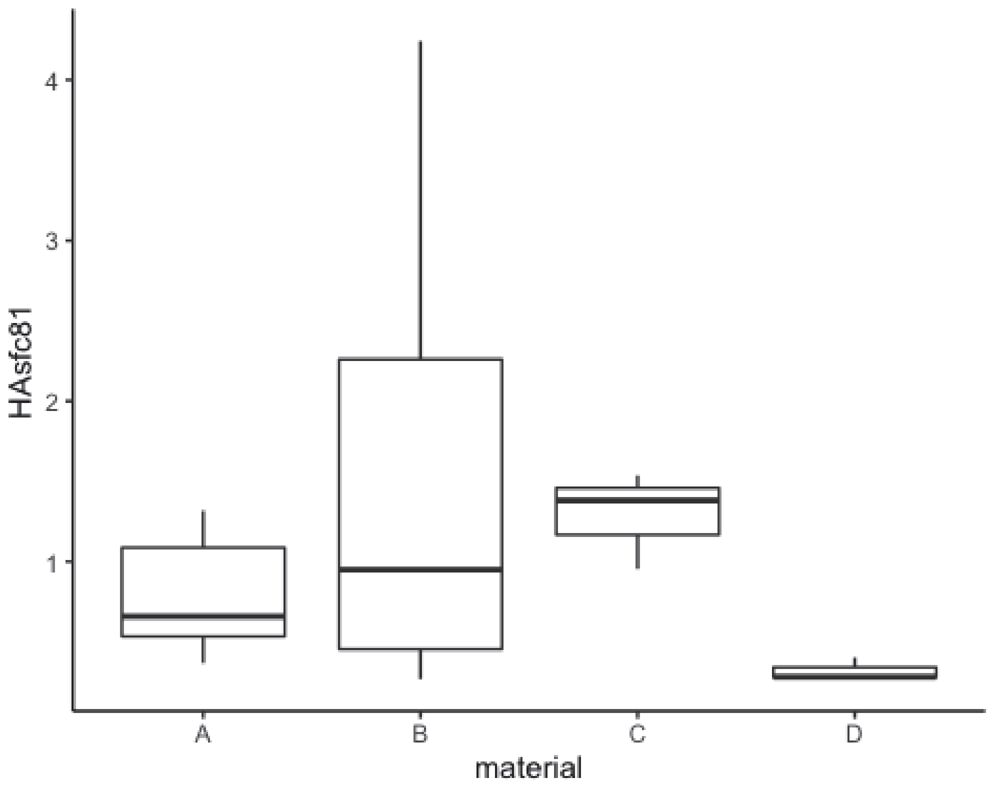

Lengthscale anisotropy Sfrax epLsar
*****
A
B
C
D
material


Length scale anisotropy NewEplsar
*****
A
B
C
D
material


Fractal complexity Asfc
30
20
10
0
A
B
C
D
material


Smfc
1.5e+08
1.0e+08
5.0e+07
0.0e+00
A
B
C
D
material

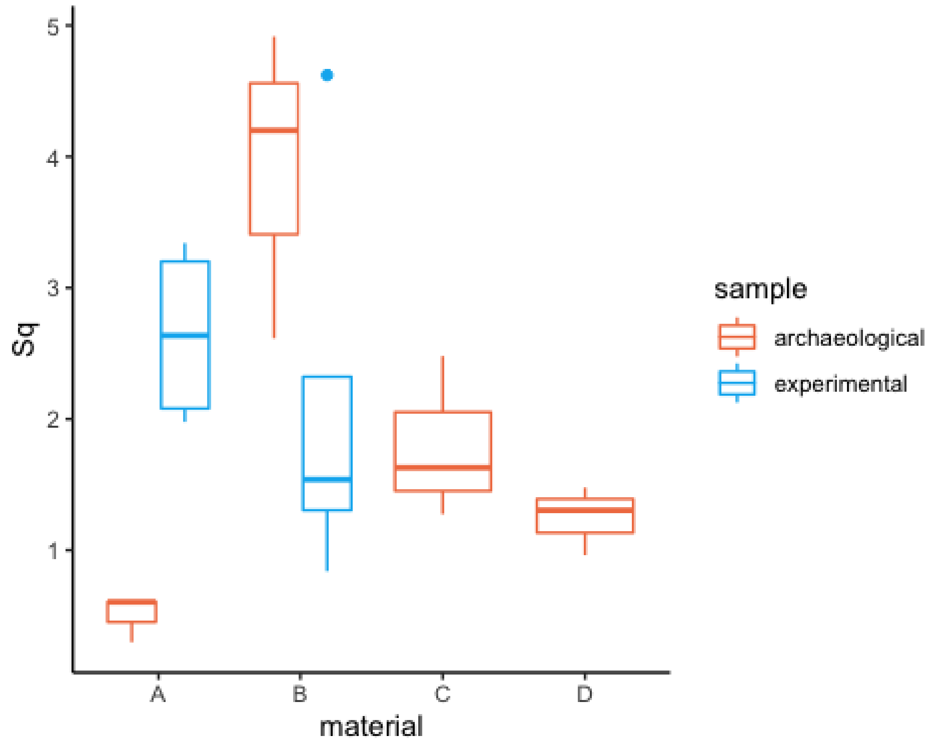


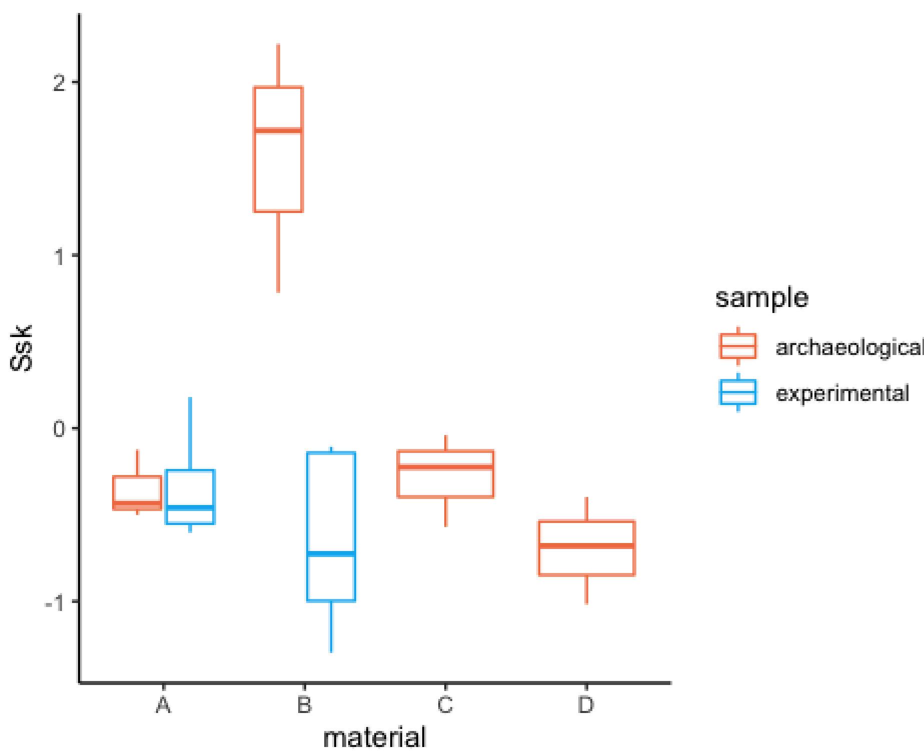


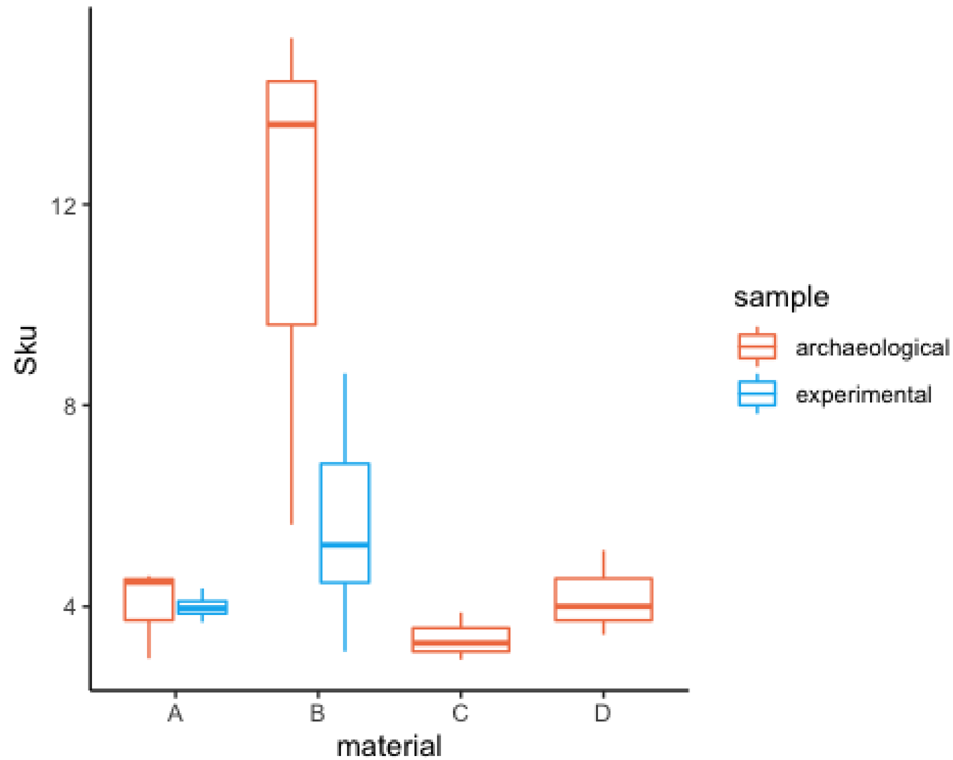

```
# Comparing archaeological and experimental

# Loop for plotting all surface texture parameters

for (i in num.var) cat("[",i,"] ", names(confocaldataarch)[i], "\n", sep = "")
```

```
## [21] Sq
## [22] Ssk
## [23] Sku
## [24] Sp
## [25] Sv
## [26] Sz
## [27] Sa
## [28] Smr
## [29] Smc
## [30] Sxp
## [31] Sal
## [32] Str
## [33] Std
## [34] Sdq
## [35] Sdr
## [36] VM
## [37] Vv
## [38] Vmp
## [39] Vmc
## [40] Vvc
## [41] Vvv..p...80.00..
## [42] Vvv
## [43] Mean.depth.of.furrows
## [44] Mean.density.of.furrows
## [45] First.direction
## [46] Second.direction
## [47] Third.direction
## [48] Isotropy
## [49] Lengthscale.anisotropy.Sfrax.epLsar
## [50] Length.scale.anisotropy..NewEplsar.
## [51] Fractal.complexity.Asfc
## [52] Smfc
## [53] HAsfc9
## [54] HAsfc81
```

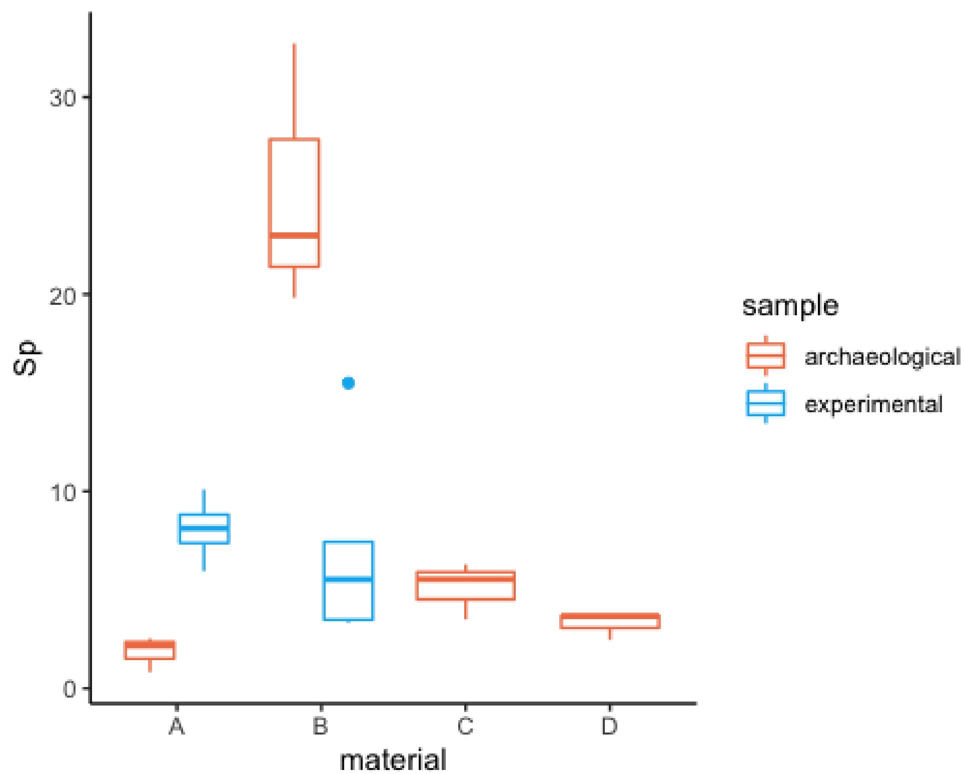
```
for (i in num.var) {
  p <- ggplot(data = confocaldataarch, aes_string(x = "workedmaterial", y = names(confocaldataa
rch)[i],
                                                  colour = "sample")) +
         geom_boxplot() +
         # geom_line(aes(group = motion)) +
         theme_classic() +
         labs(colour = "sample") +
         # facet_wrap(~ sample) +
         labs(x = "material", y = gsub("\\.", " ", names(confocaldataarch)[i])) +
         scale_colour_hue(h = c(25,225), limits = levels(confocaldataarch[["sample"]]))
  print(p)

  # saves the plots
  file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_plot_",
                     names(confocaldataarch)[i], ".pdf")
    ggsave(filename = file_out, plot = p, path = "../plots/confocalarch&exp", device = "pdf", w
idth = 26,
           height = 21, units = "cm" )
}
```


5
4
3
2
1
Sq
A
B
C
D
material
sample
archaeological
experimental

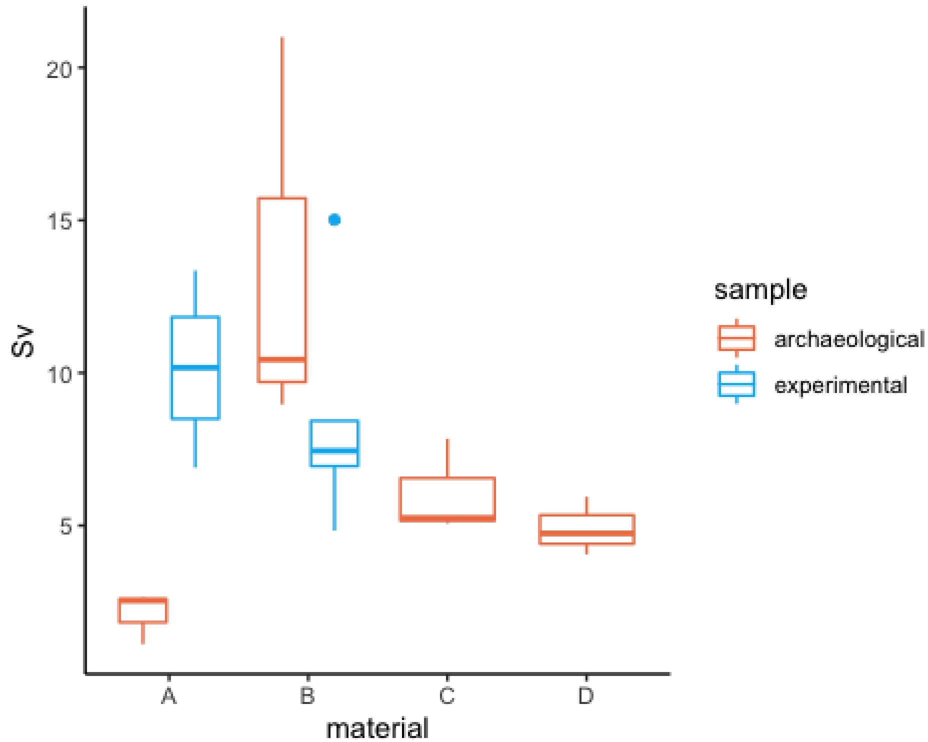

2
1
0
-1
Ssk
A
B
C
D
material
sample
archaeological
experimental

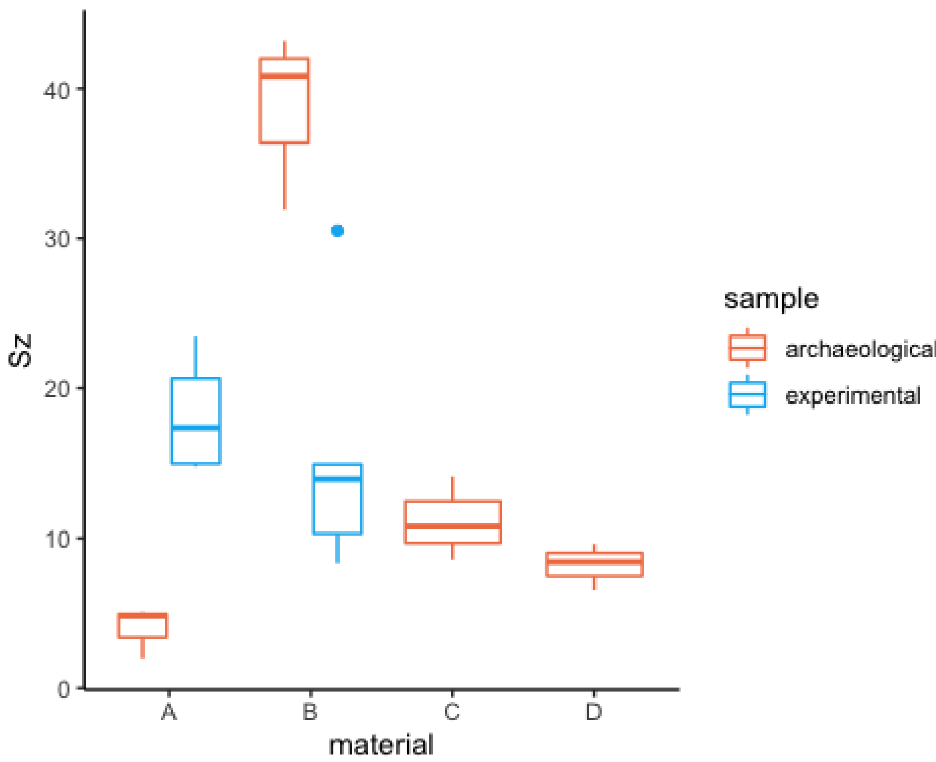


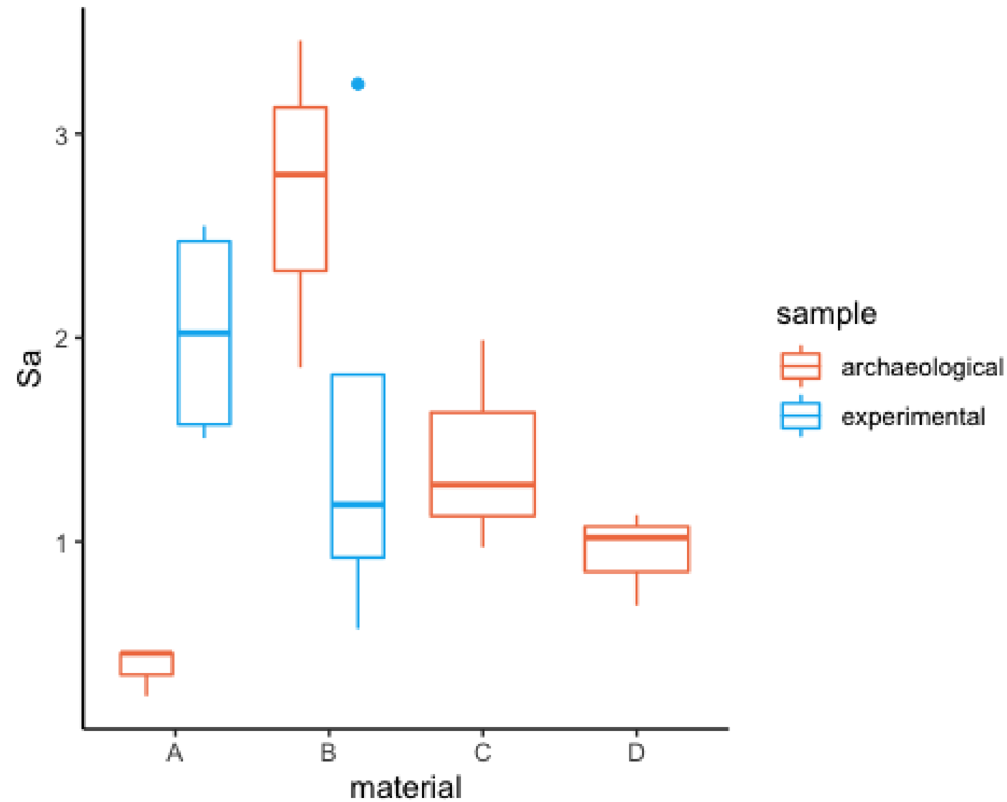
Sku
12
8
4
A
B
C
D
material
sample
archaeological
experimental

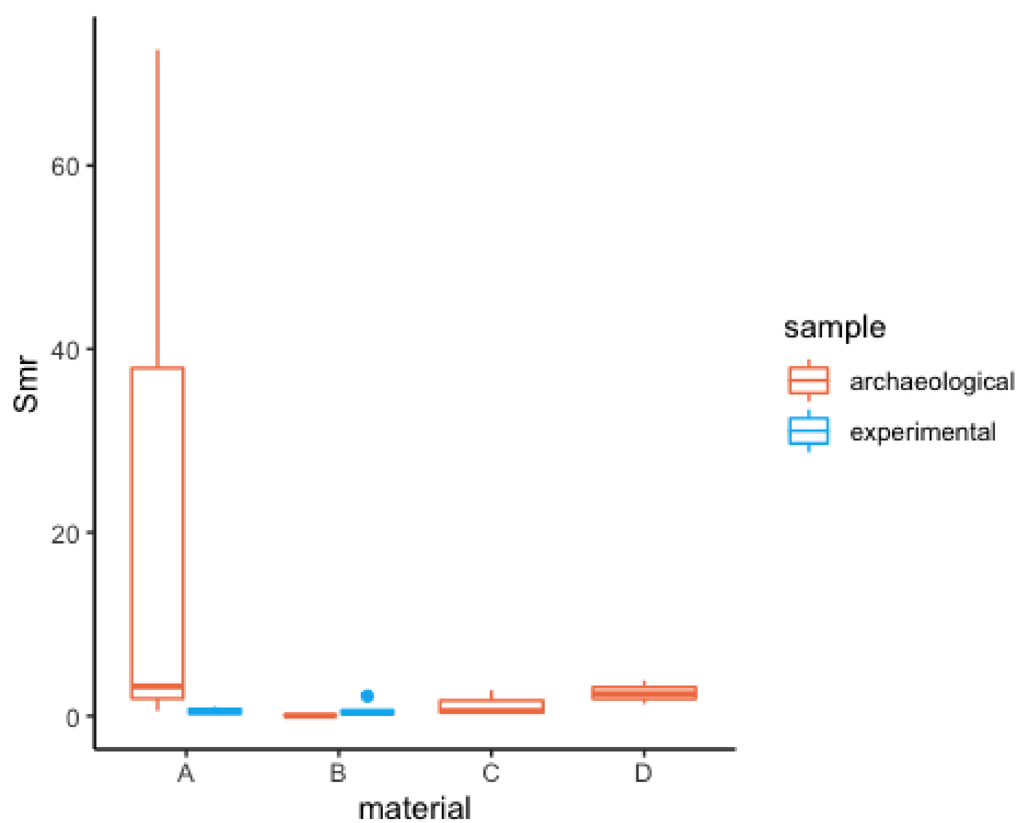


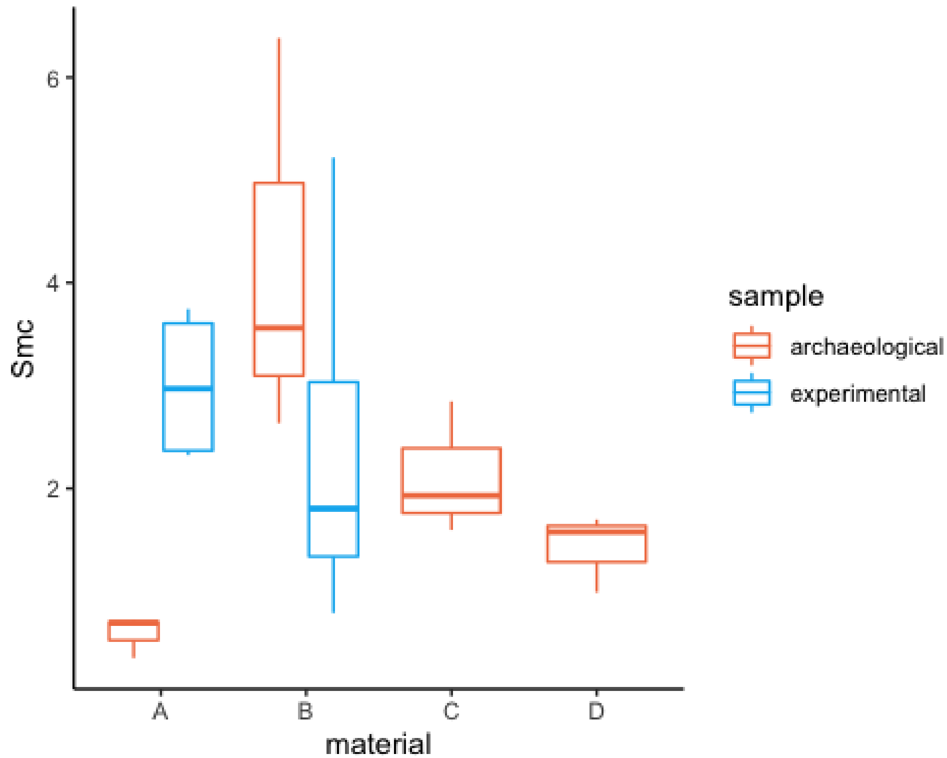
Sp
30
20
10
0
A
B
C
D
material
sample
archaeological
experimental


Sv
20
15
10
5
A
B
C
D
material
sample
archaeological
experimental

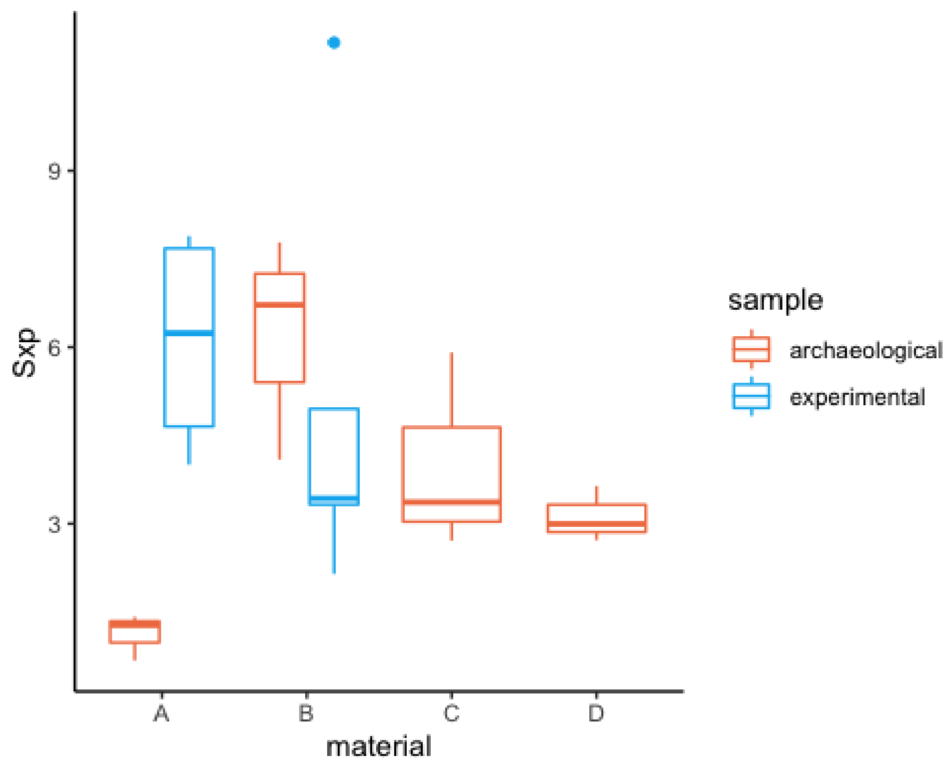

Sz
40
30
20
10
0
A
B
C
D
material
sample
archaeological
experimental


Sa
3
2
1
A
B
C
D
material
sample
archaeological
experimental

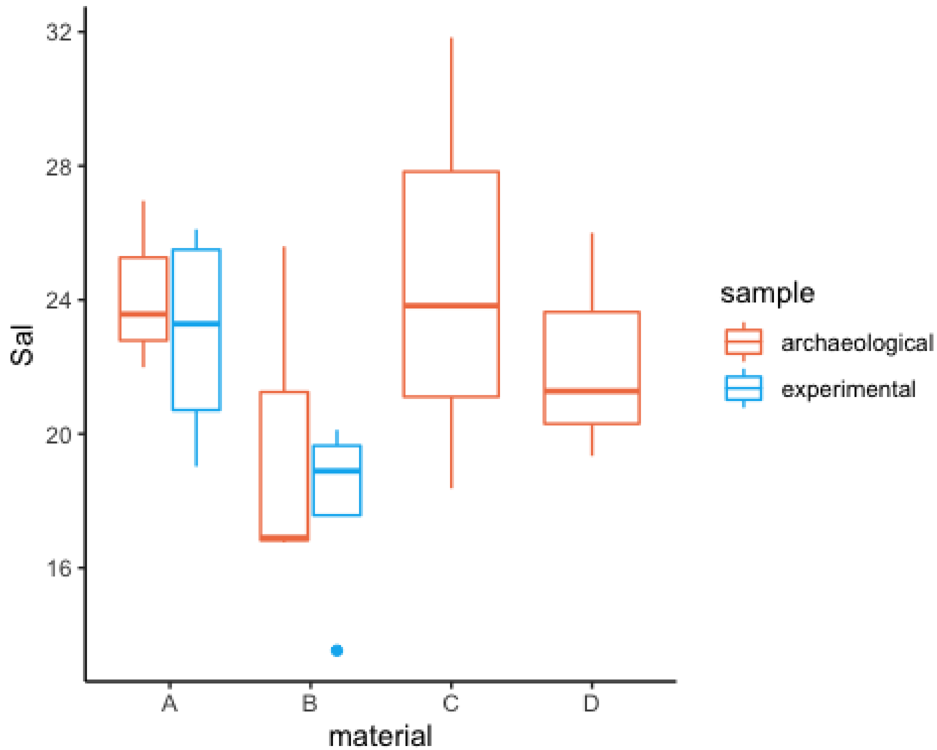

Smr
60
40
20
0
A
B
C
D
material
sample
archaeological
experimental

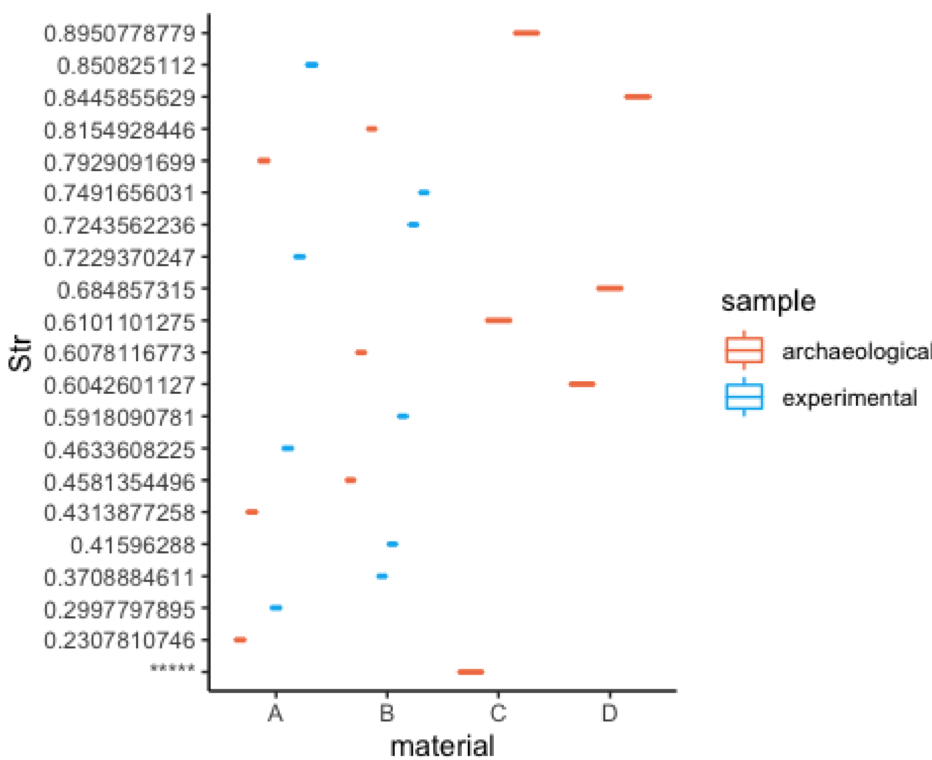


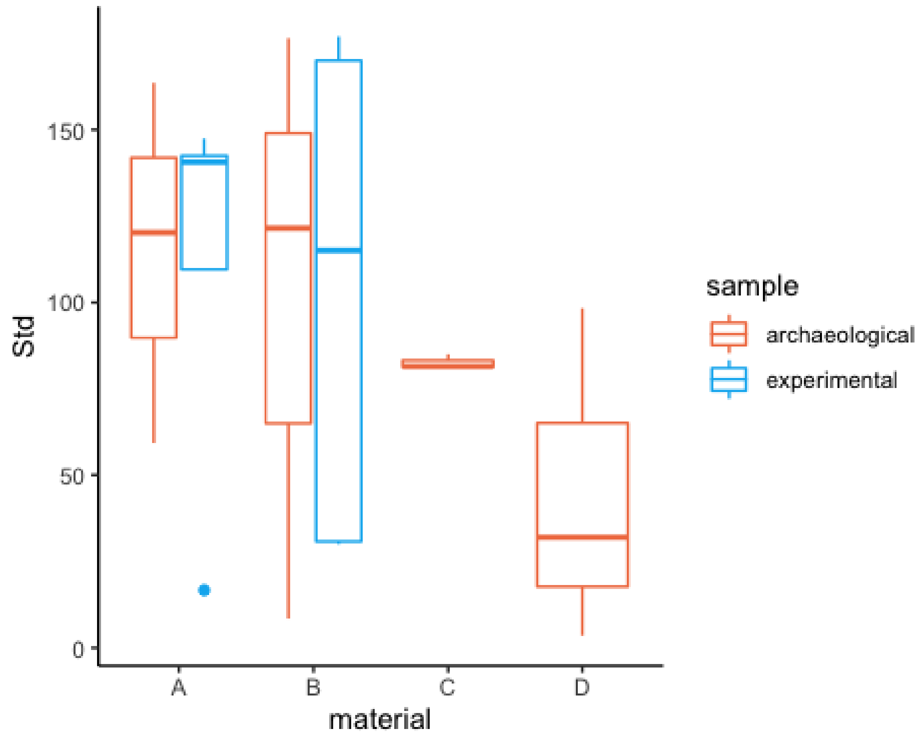
6
4
2
Smc
A
B
C
D
material
sample
archaeological
experimental

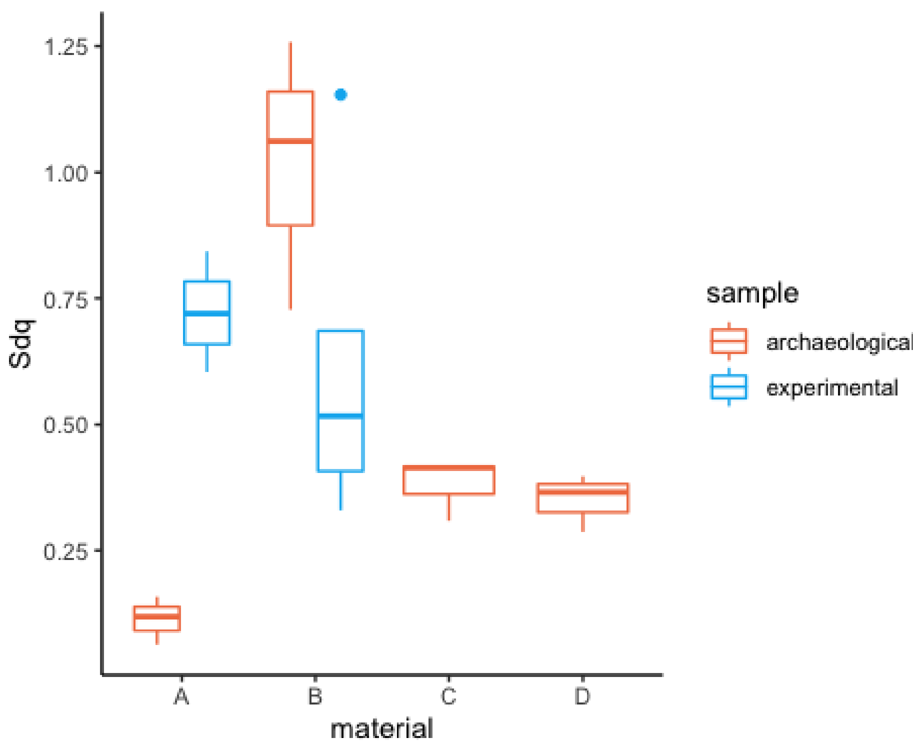


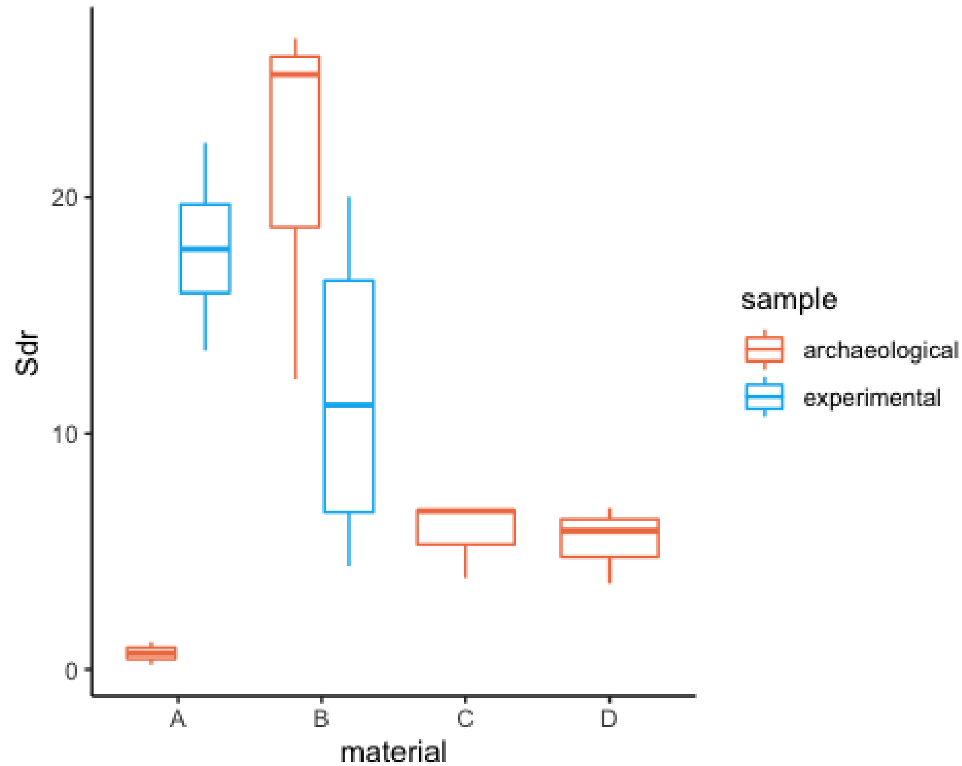
9
6
3
Sxp
A
B
C
D
material
sample
archaeological
experimental

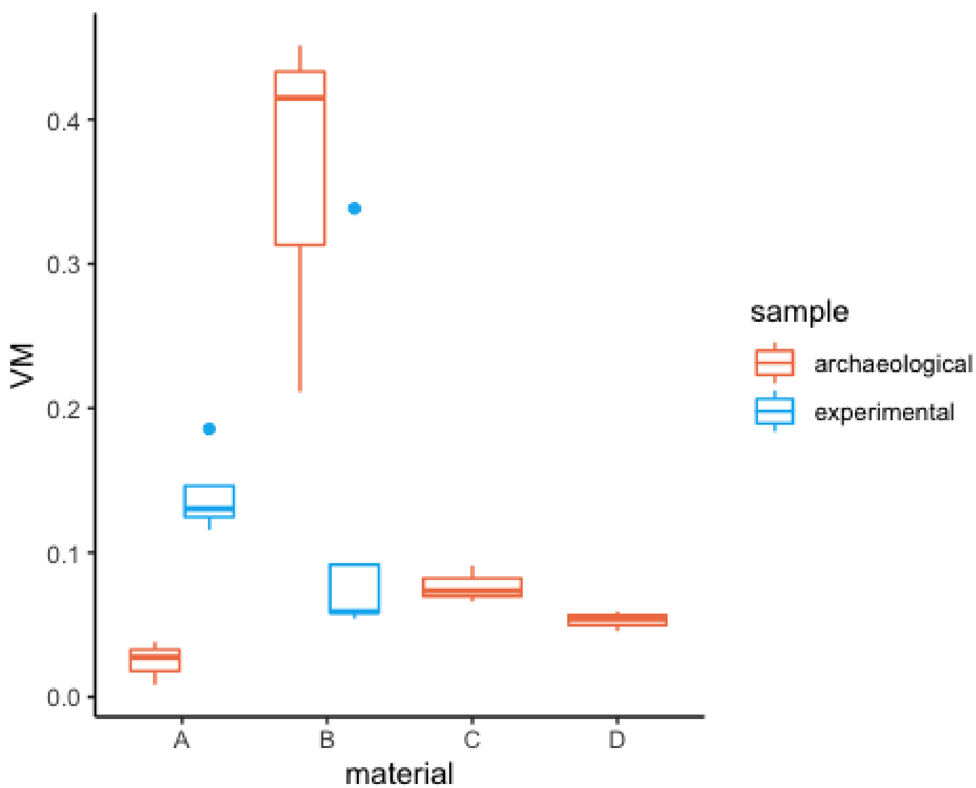

32
28
24
20
16
Sal
A
B
C
D
material
sample
archaeological
experimental

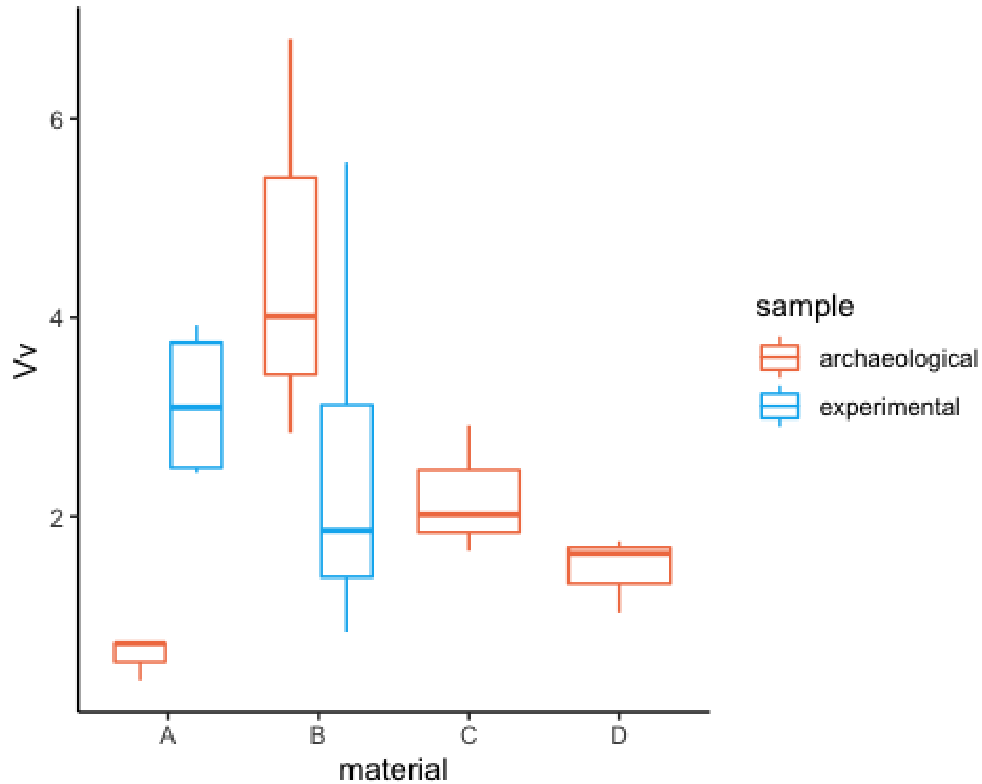

0.8950778779
0.850825112
0.8445855629
0.8154928446
0.7929091699
0.7491656031
0.7243562236
0.7229370247
0.684857315
0.6101101275
0.6078116773
0.6042601127
0.5918090781
0.4633608225
0.4581354496
0.4313877258
0.41596288
0.3708884611
0.2997797895
0.2307810746
*****
Str
A
B
C
D
material
sample
archaeological
experimental

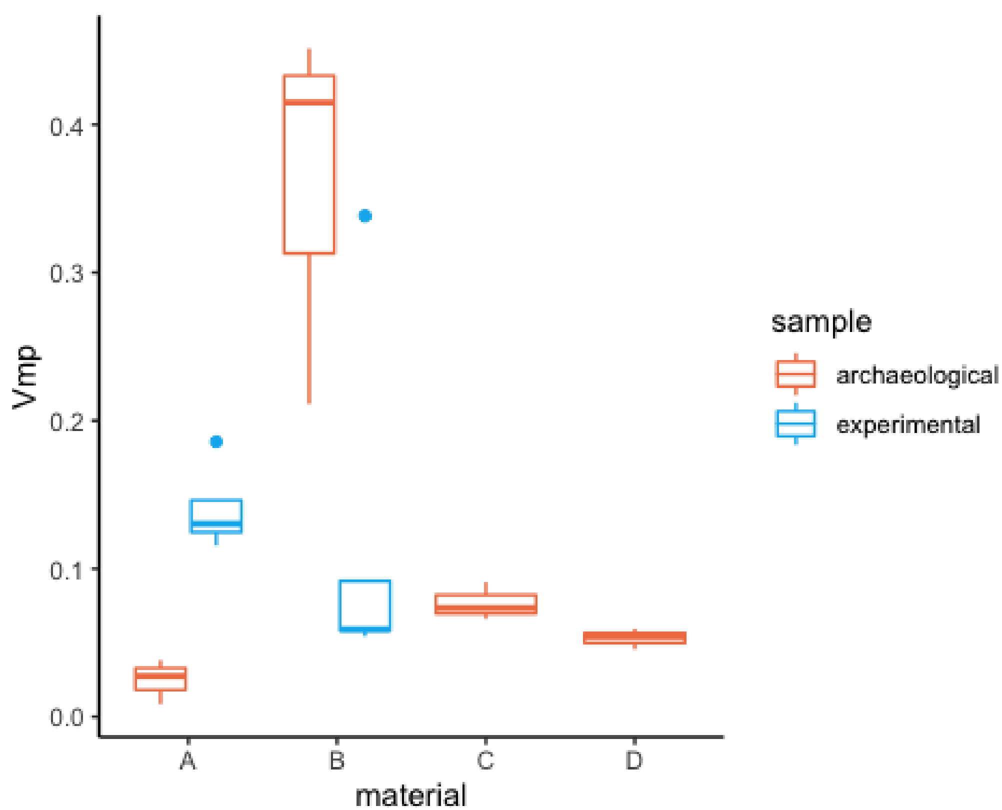

Std
150
100
50
0
A
B
C
D
material
sample
archaeological
experimental

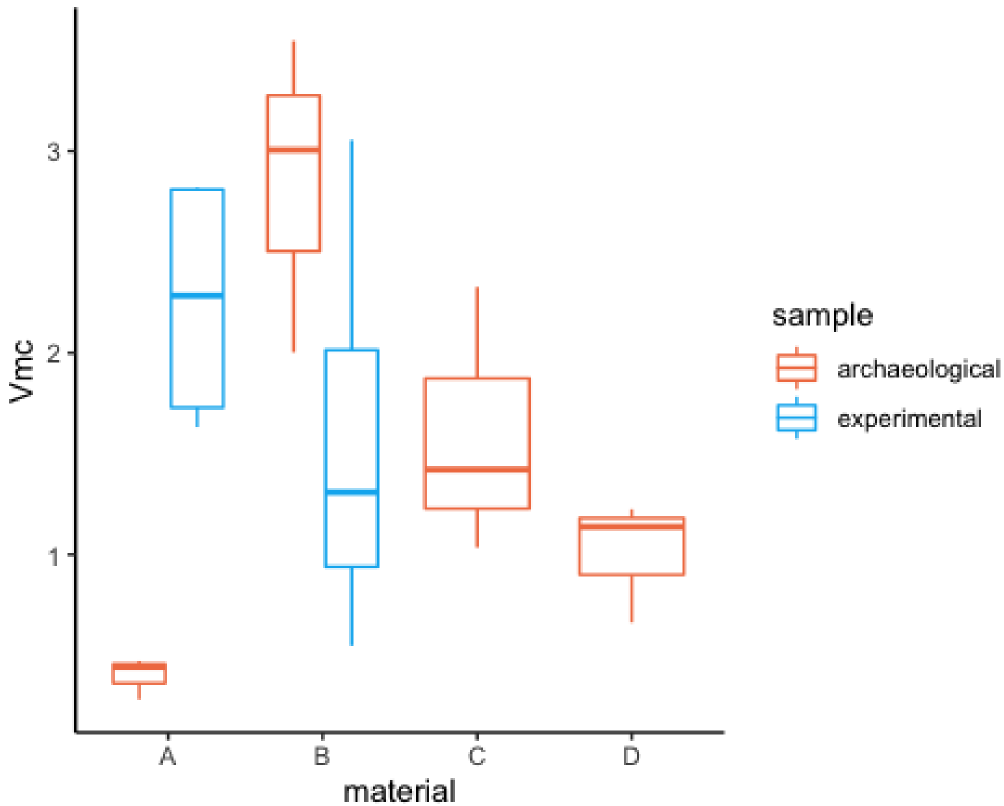

Sdq
1.25
1.00
0.75
0.50
0.25
A
B
C
D
material
sample
archaeological
experimental

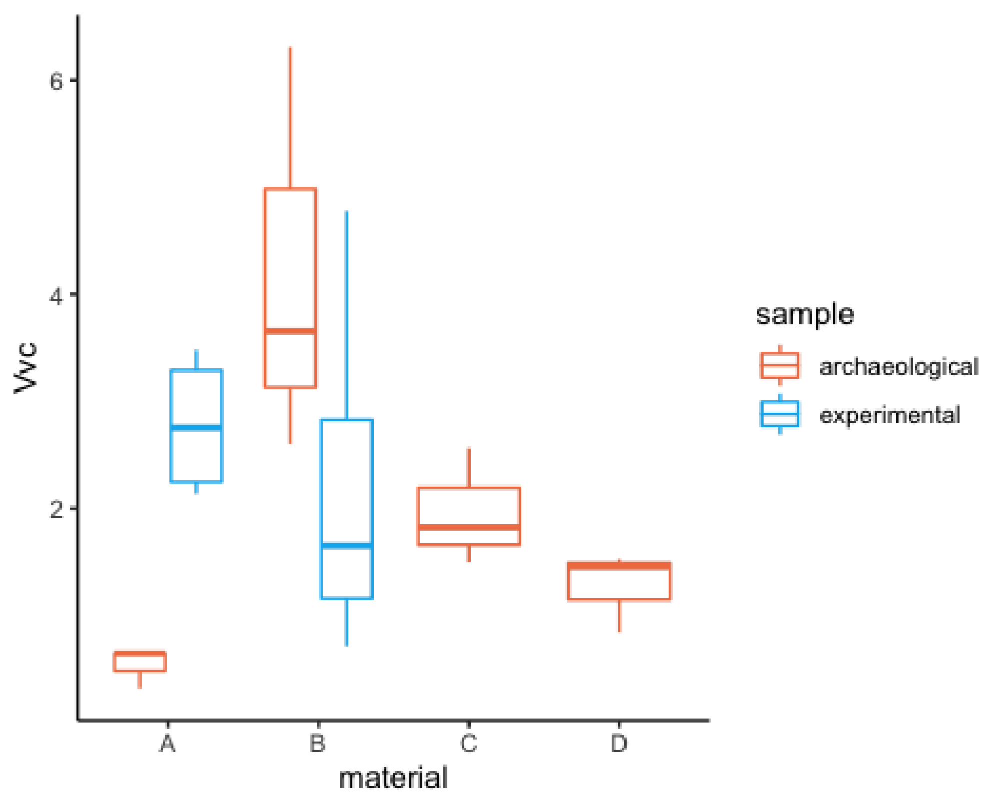

Sdr
20
10
0
A
B
C
D
material
sample
archaeological
experimental

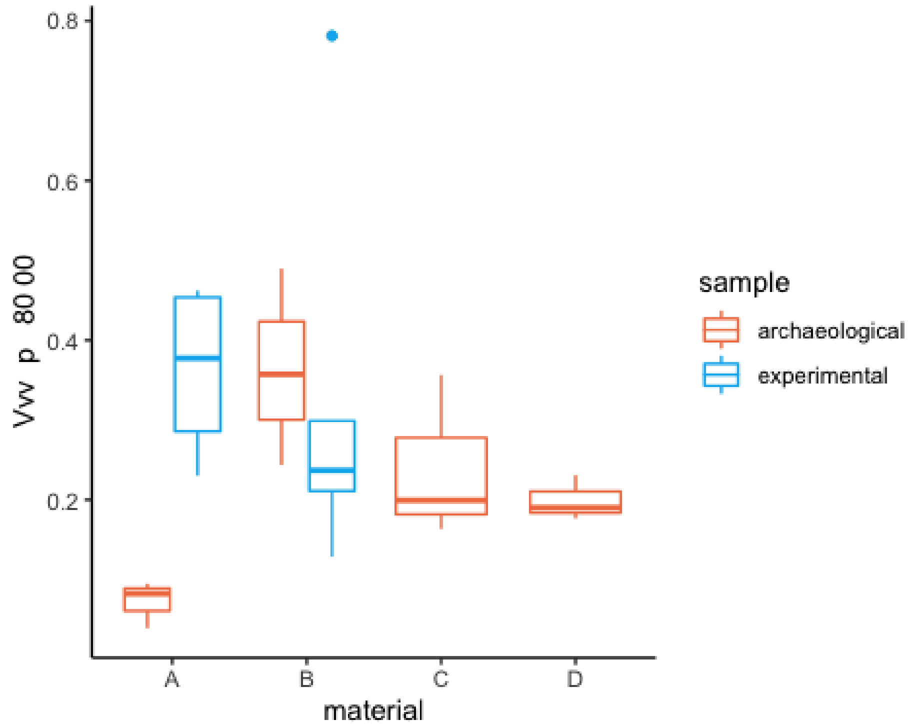

VM
0.4
0.3
0.2
0.1
0.0
A
B
C
D
material
sample
archaeological
experimental

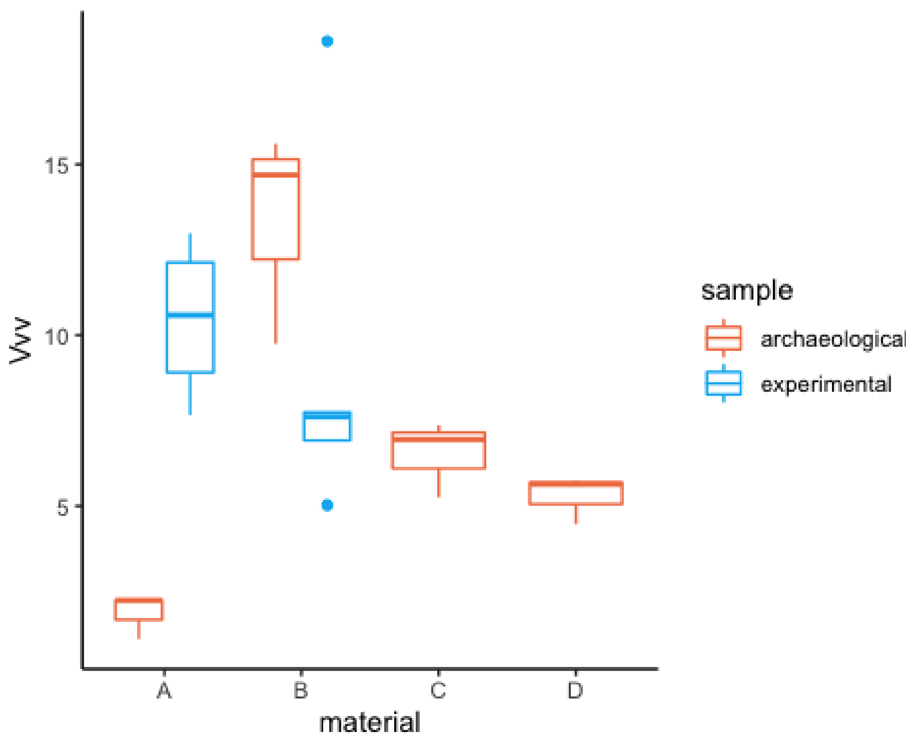

Vv
6
4
2
A
B
C
D
material
sample
archaeological
experimental

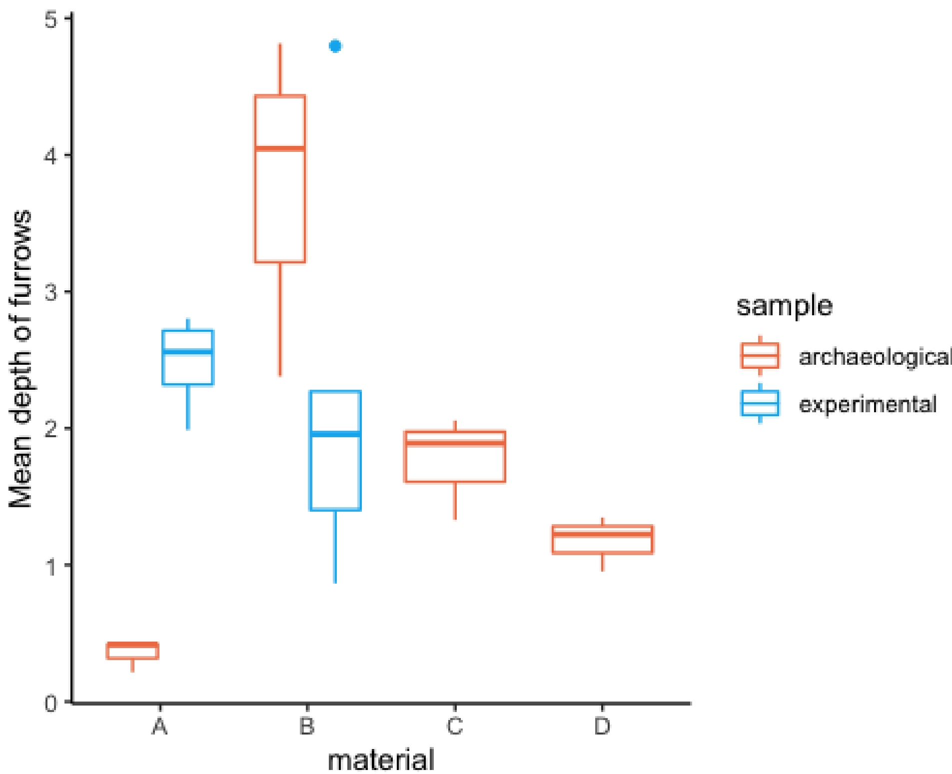

Vmp
0.4
0.3
0.2
0.1
0.0
A
B
C
D
material
sample
archaeological
experimental

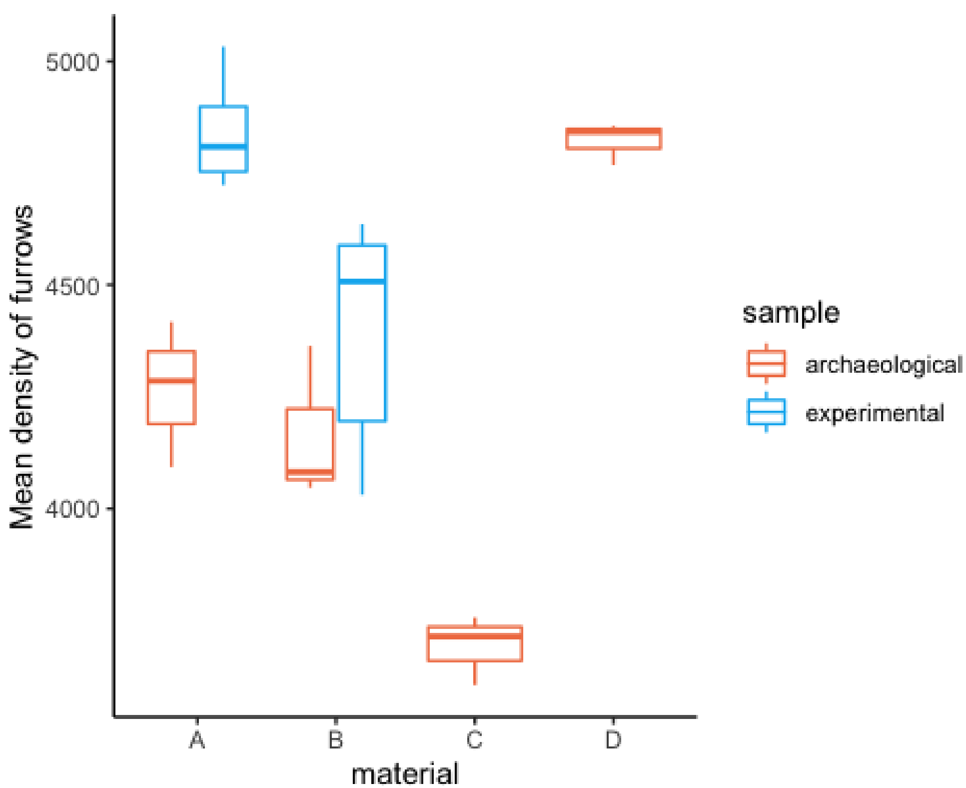

Vmc
3
2
1
A
B
C
D
material
sample
archaeological
experimental

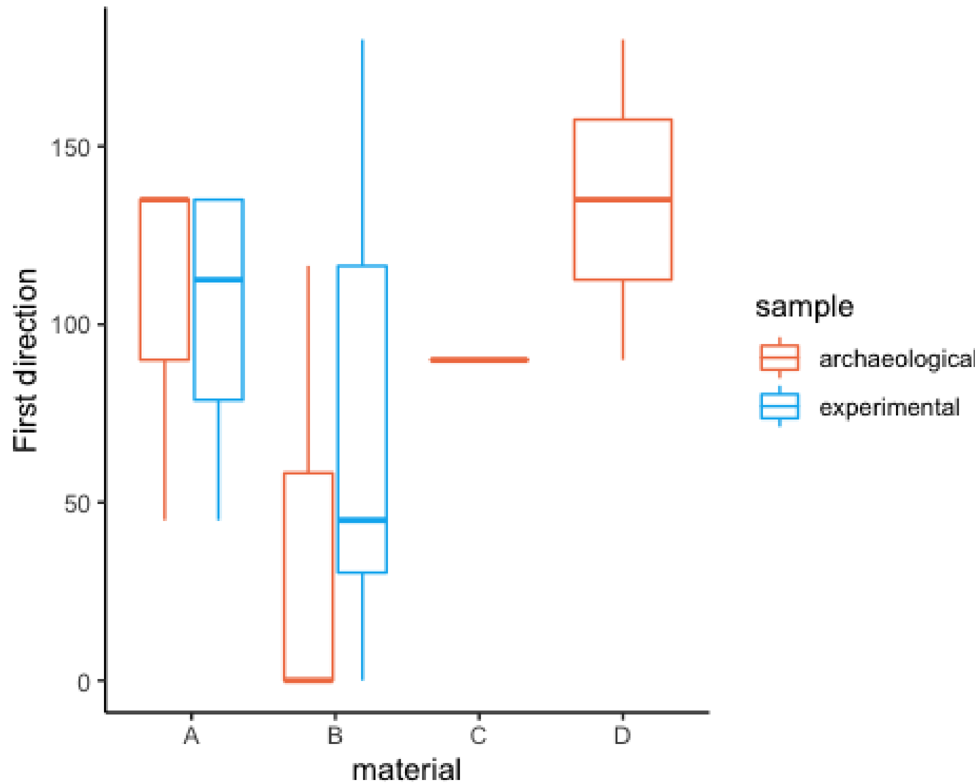

Vvc
6
4
2
A
B
C
D
material
sample
archaeological
experimental

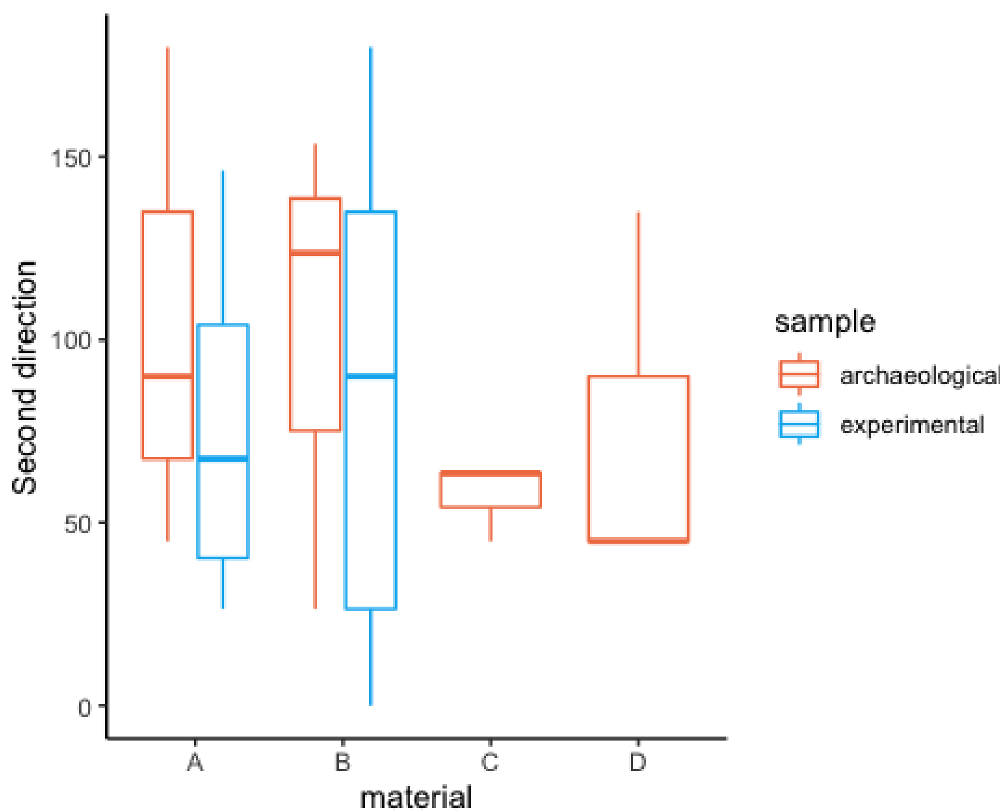

Vvv_p_80 00
0.8
0.6
0.4
0.2
A
B
C
D
material
sample
archaeological
experimental

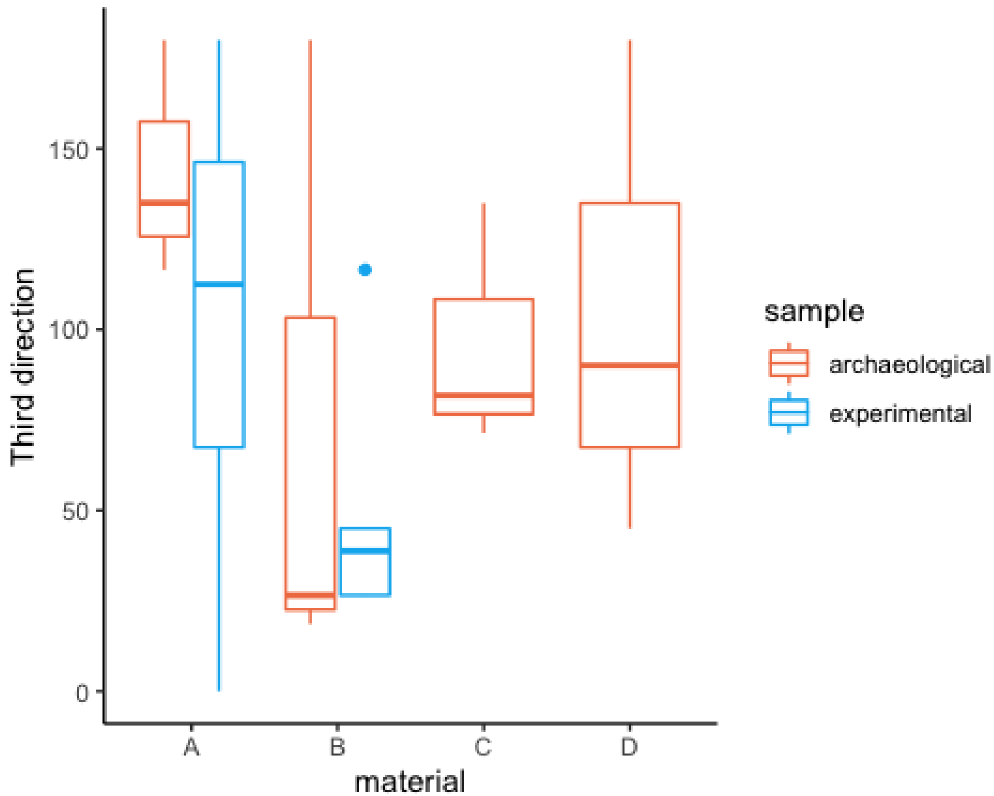

Vvv
15
10
5
A
B
C
D
material
sample
archaeological
experimental

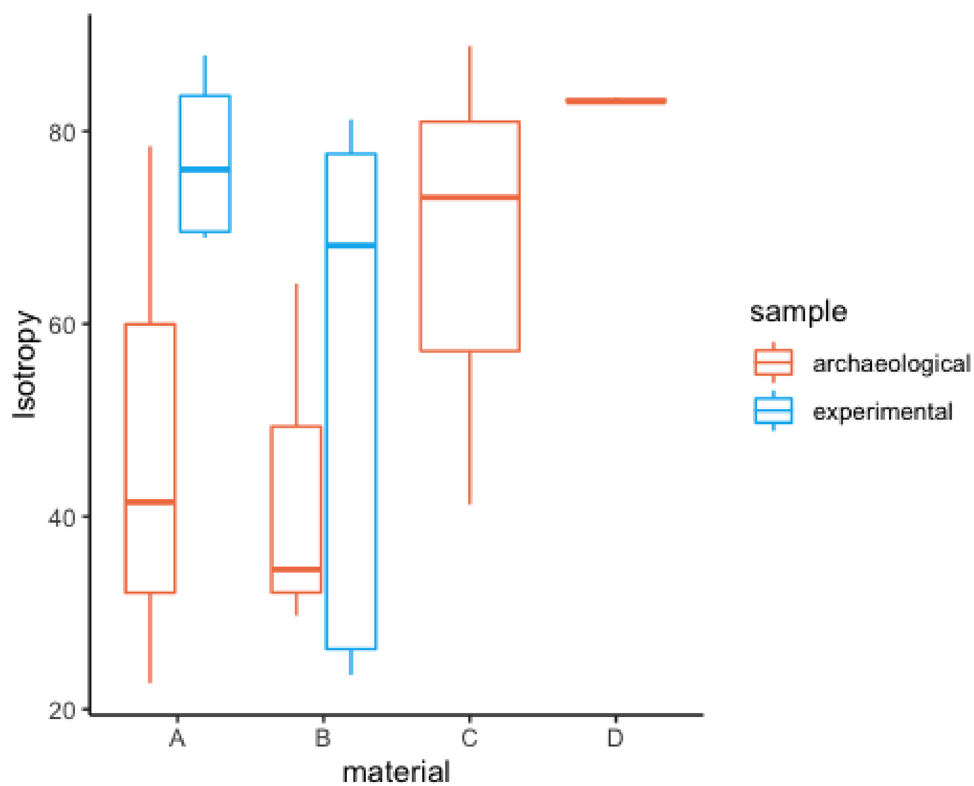

Mean depth of furrows
5
4
3
2
1
0
A
B
C
D
material
sample
archaeological
experimental

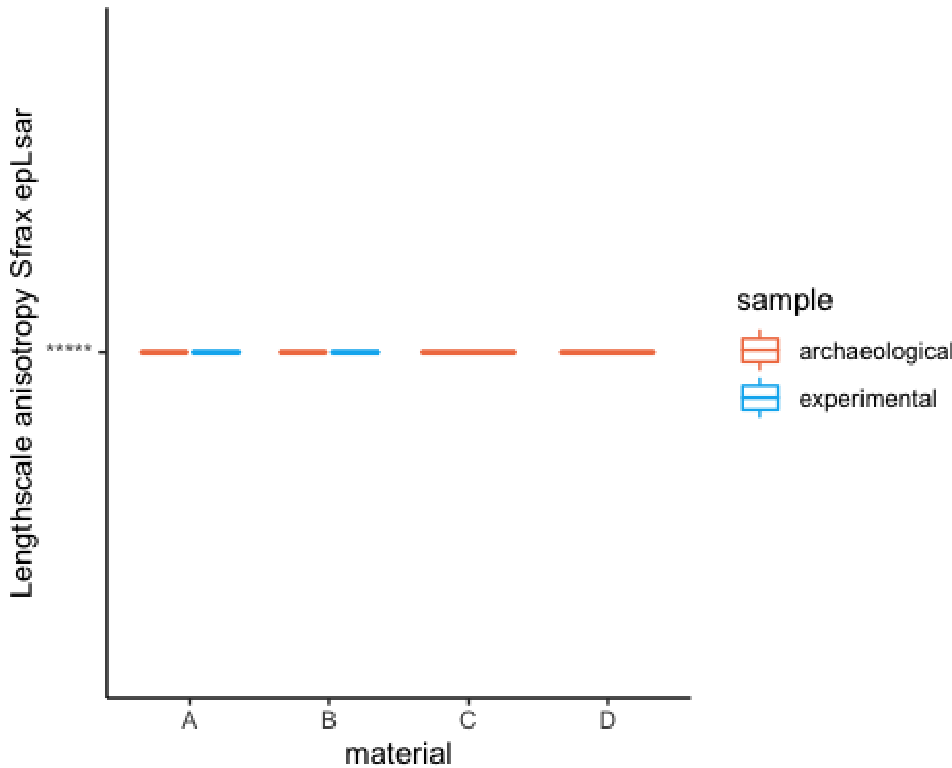

Mean density of furrows
5000
4500
4000
A
B
C
D
material
sample
archaeological
experimental

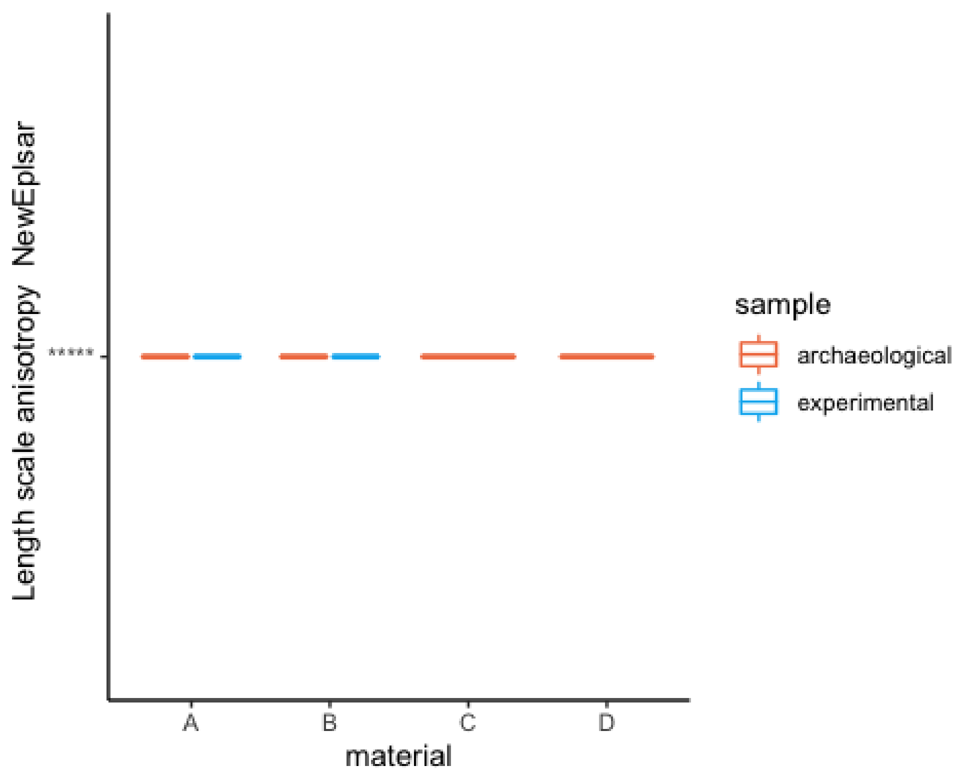

First direction
150
100
50
0
A
B
C
D
material
sample
archaeological
experimental

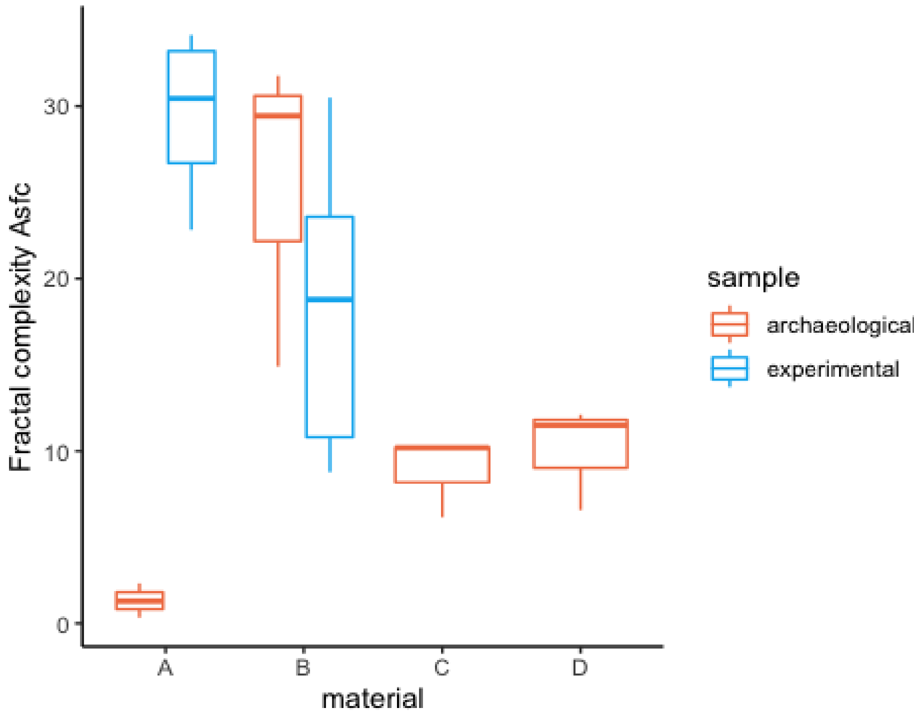

Second direction
150
100
50
0
A
B
C
D
material
sample
archaeological
experimental

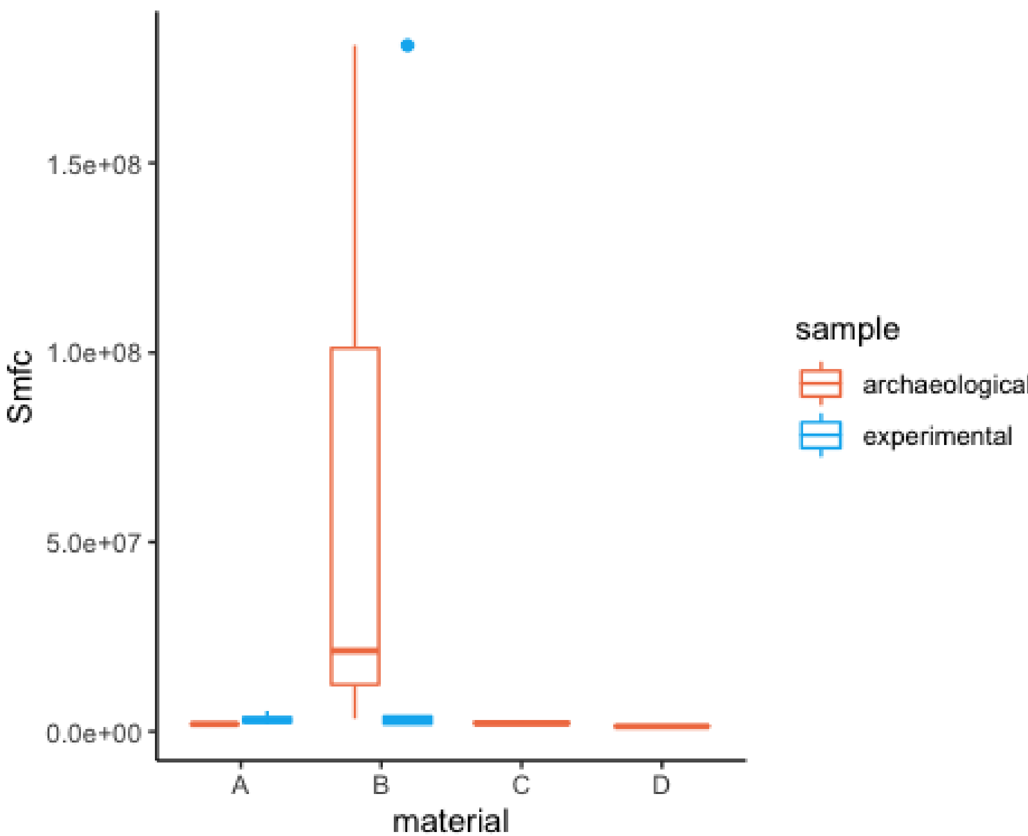

Third direction
150
100
50
0
A
B
C
D
material
sample
archaeological
experimental

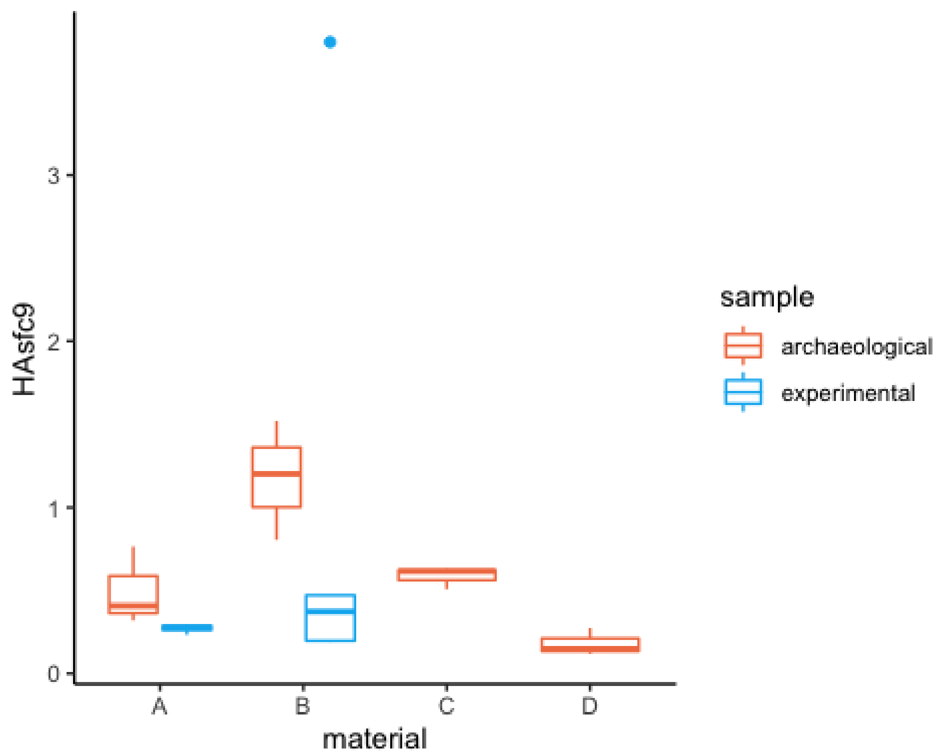

Isotropy
80
60
40
20
A
B
C
D
material
sample
archaeological
experimental

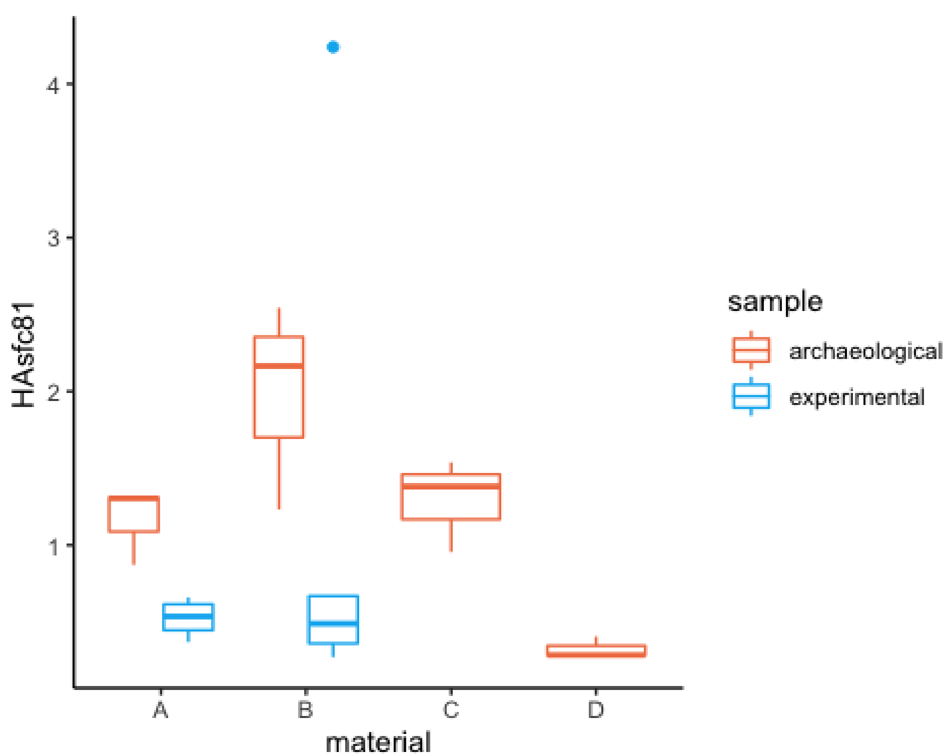

Lengthscale anisotropy Sfrax epLsar
*****
A
B
C
D
material
sample
archaeological
experimental


Length scale anisotropy NewEplsar
*****
A
B
C
D
material
sample
archaeological
experimental


Fractal complexity Asfc
30
20
10
0
A
B
C
D
material
sample
archaeological
experimental


Smfc
1.5e+08
1.0e+08
5.0e+07
0.0e+00
A
B
C
D
material
sample
archaeological
experimental

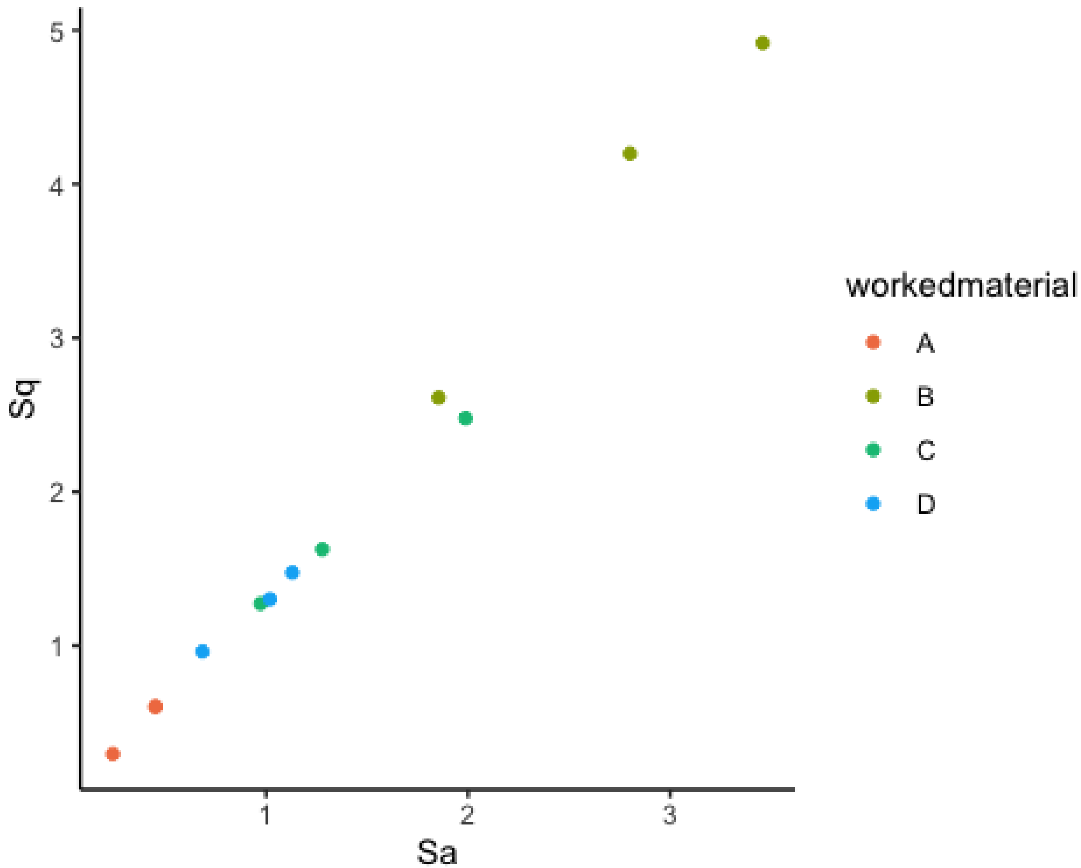




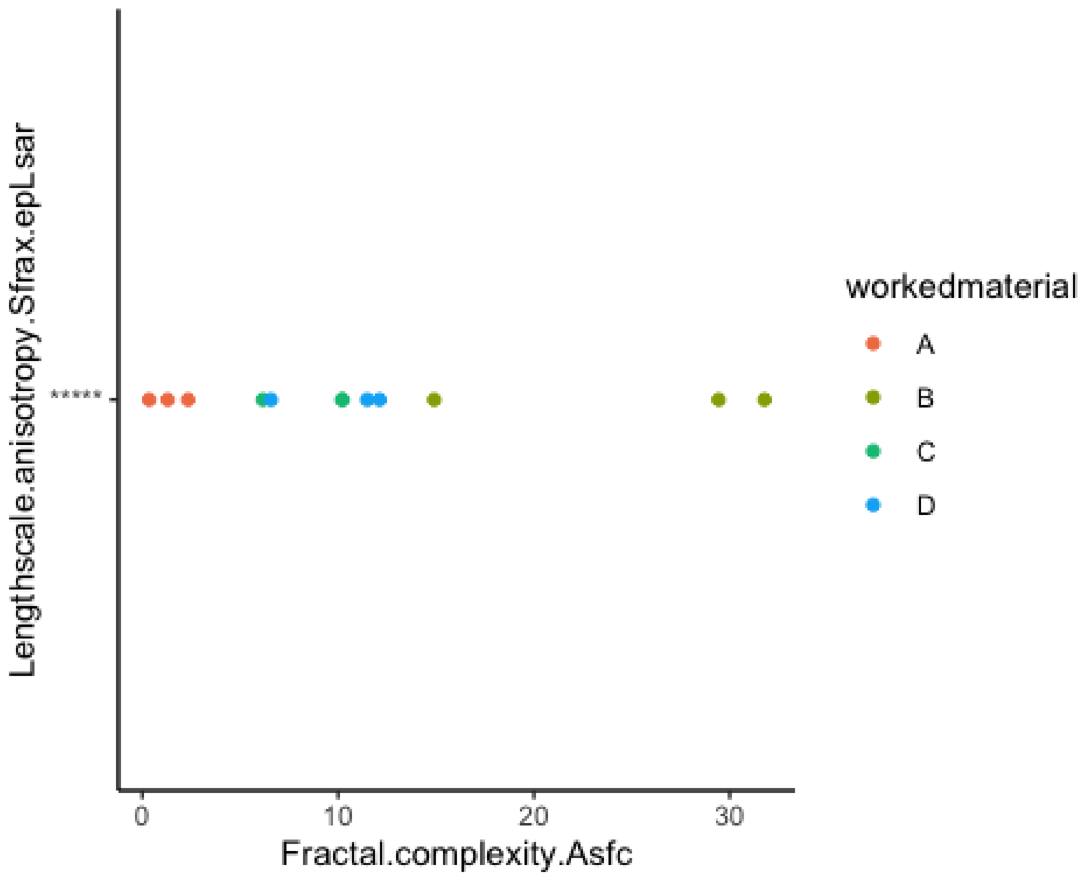
Scatterplots of selected variables combined by “Worked material” and “Motion”

```
# Only archaeological
# Sa vs. Sq
```

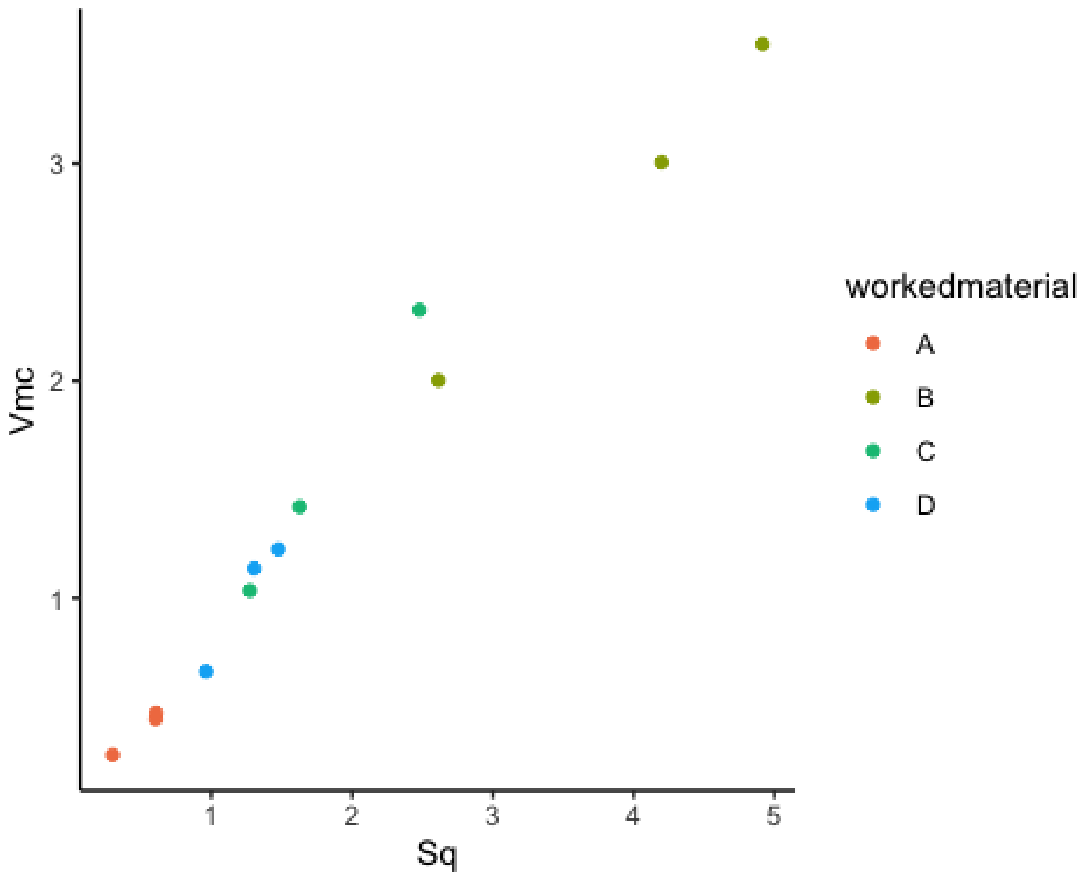
```
Sa_Sq <- ggplot(data = confoarch) +
         geom_point(mapping = aes(x = Sa, y = Sq, colour = workedmaterial)) +
         theme_classic() +
         labs(colour = "workedmaterial") +
          scale_colour_hue(h = c(25, 230))
print(Sa_Sq)
```



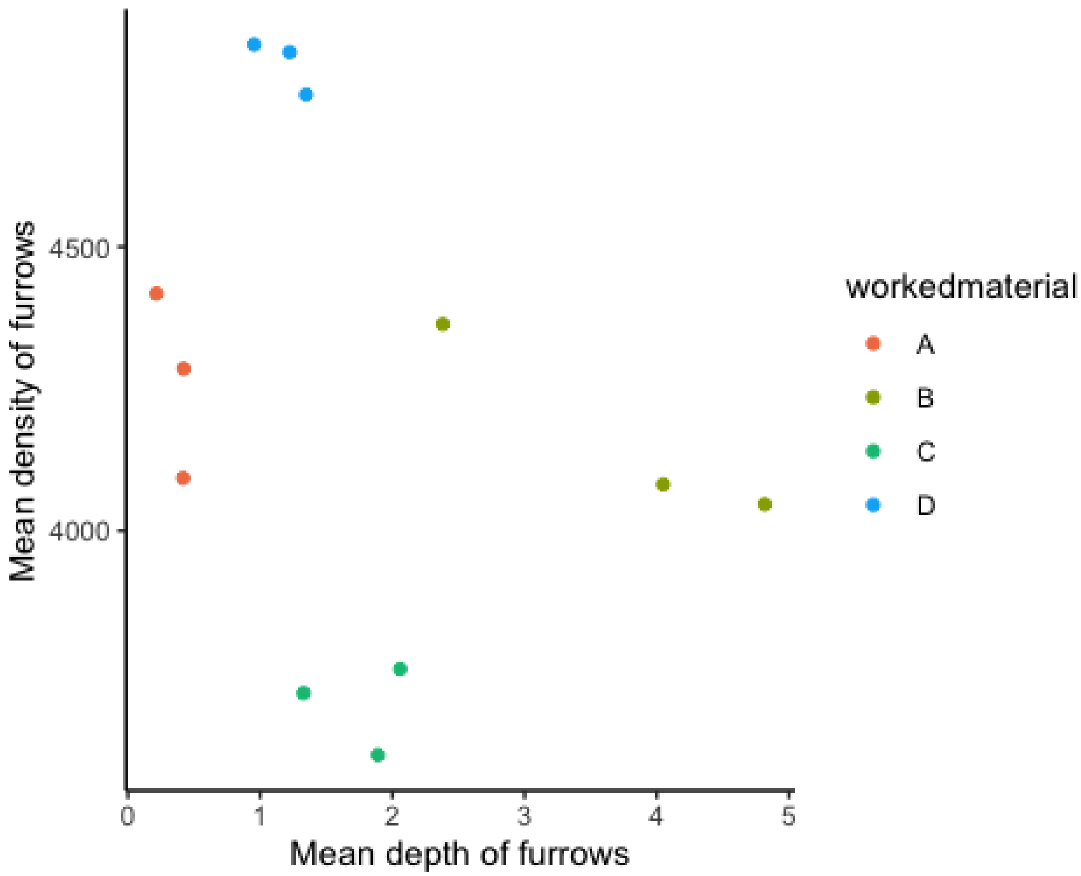

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Sa-Sq", ".pdf")
ggsave(filename = file_out, plot = Sa_Sq, path = "../plots/confocalarch", device = "pdf")

## Saving 5 x 4 in image

# epLsar vs. Asfc

ep_As <- ggplot(data = confoarch) +
         geom_point(mapping = aes(x = Fractal.complexity.Asfc, y = Lengthscale.anisotropy.Sfrax
.epLsar, colour = workedmaterial)) +
         theme_classic() +
         labs(colour = "workedmaterial") +
         scale_colour_hue(h = c(25, 230))
print(ep_As)
```



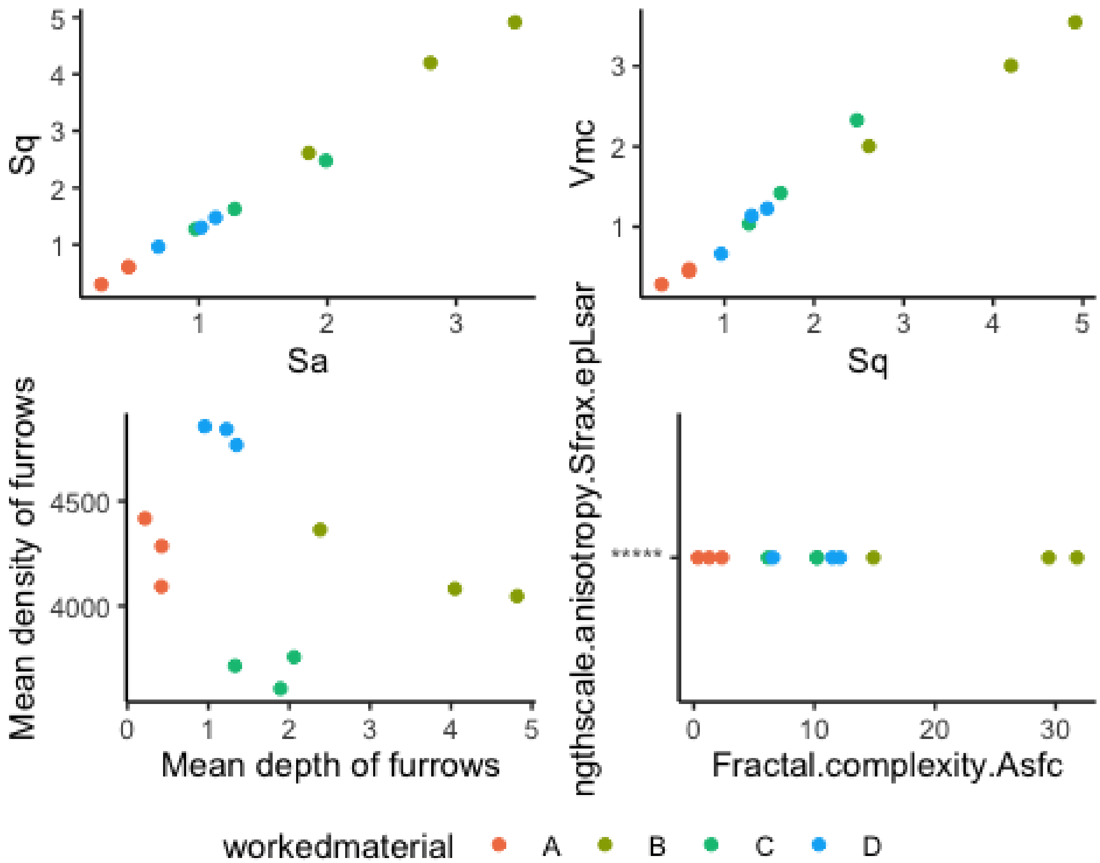

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Asfc-epLsar", ".pdf")
ggsave(filename = file_out, plot = ep_As, path = "../plots/confocalarch", device = "pdf")

## Saving 5 x 4 in image

# Sq vs. Vmc

Sq_Vmc <- ggplot(data = confoarch) +
          geom_point(mapping = aes(x = Sq, y = Vmc, colour = workedmaterial)) +
          theme_classic() +
          labs(colour = "workedmaterial") +
          scale_colour_hue(h = c(25, 230))
print(Sq_Vmc)
```



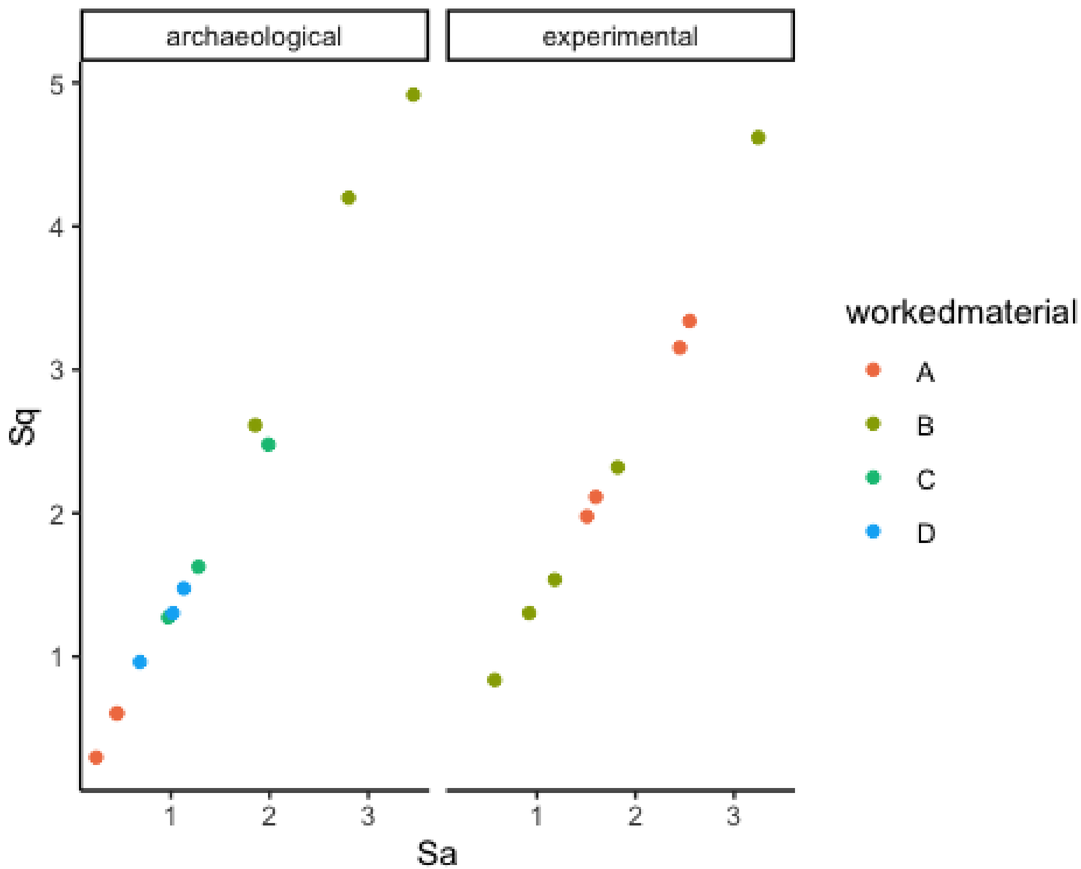

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Sq-Vmc", ".pdf")
ggsave(filename = file_out, plot = Sq_Vmc, path = "../plots/confocalarch", device = "pdf")

## Saving 5 x 4 in image

# Mean depth of furrows vs. mean density of furrows

furrows <- ggplot(data = confoarch) +
           geom_point(mapping = aes(x = Mean.depth.of.furrows, y = Mean.density.of.furrows,
                                    colour = workedmaterial)) +
           theme_classic() +
           labs(colour = "workedmaterial", x = "Mean depth of furrows", y = "Mean density of fu
rrows") +
           scale_colour_hue(h = c(25, 230))
print(furrows)
```



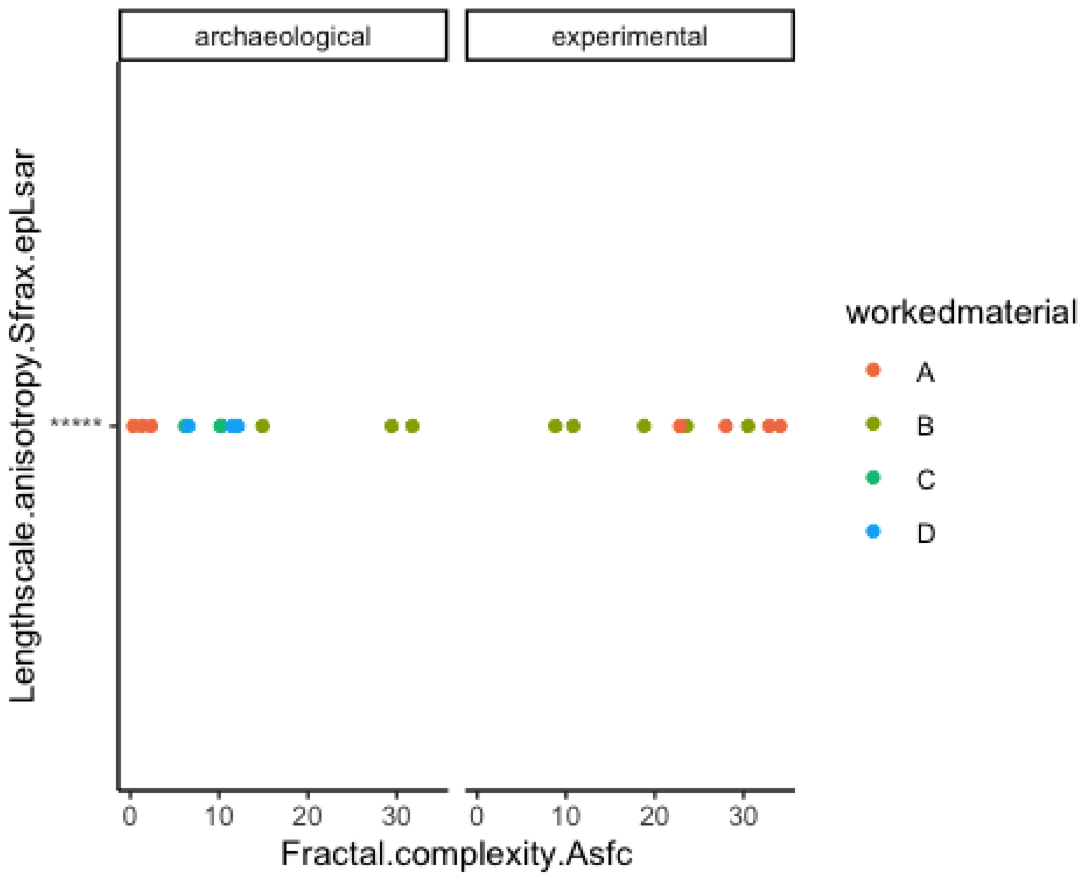

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_furrows", ".pdf")
ggsave(filename = file_out, plot = furrows, path = "../plots/confocalarch", device = "pdf")

## Saving 5 x 4 in image

# combine all in a single image

ggarrange(Sa_Sq, Sq_Vmc, furrows, ep_As, common.legend = TRUE, legend = "bottom")
```



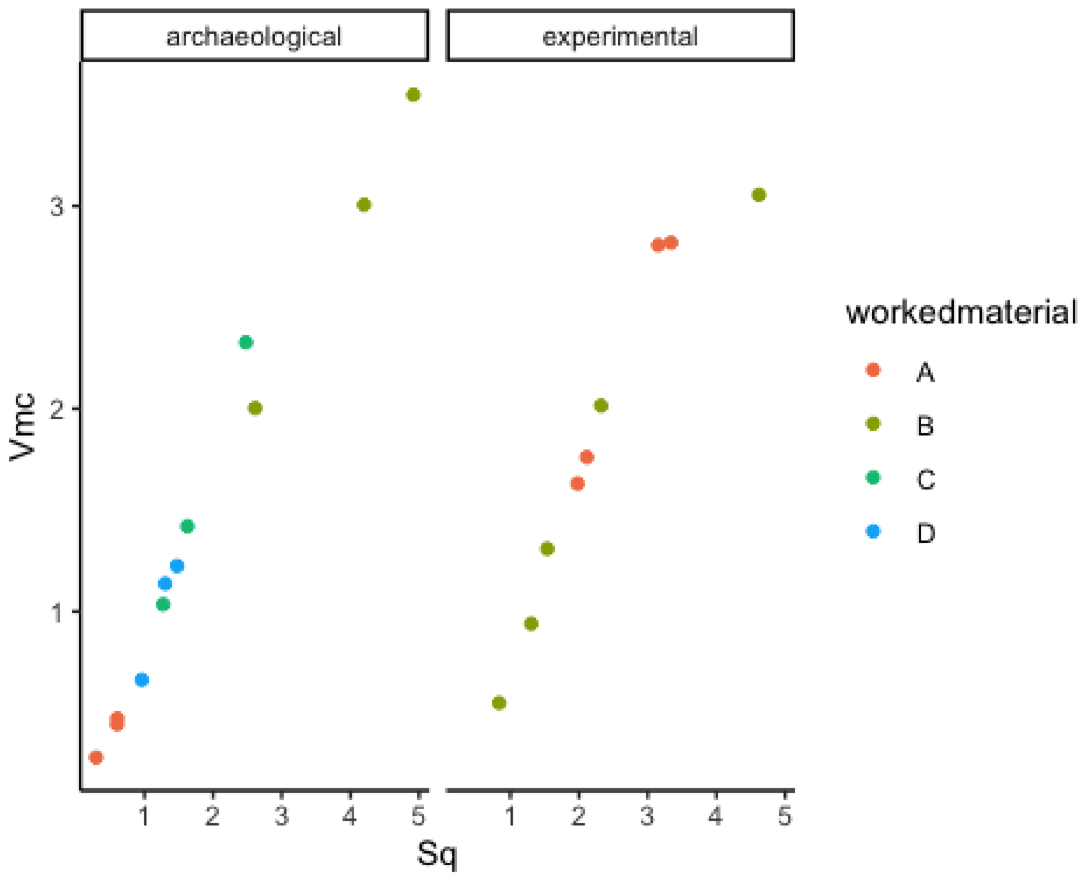

```
ggsave("../plots/confocalarch/scatterplots.png")

## Saving 5 x 4 in image

# Comparing archaeological and experimental

# Sa vs. Sq

Sa_Sq <- ggplot(data = confocaldataarch) +
         geom_point(mapping = aes(x = Sa, y = Sq, colour = workedmaterial)) +
         theme_classic() +
         labs(colour = "workedmaterial") +
         facet_wrap(~ sample) +
         scale_colour_hue(h = c(25, 230))
print(Sa_Sq)
```



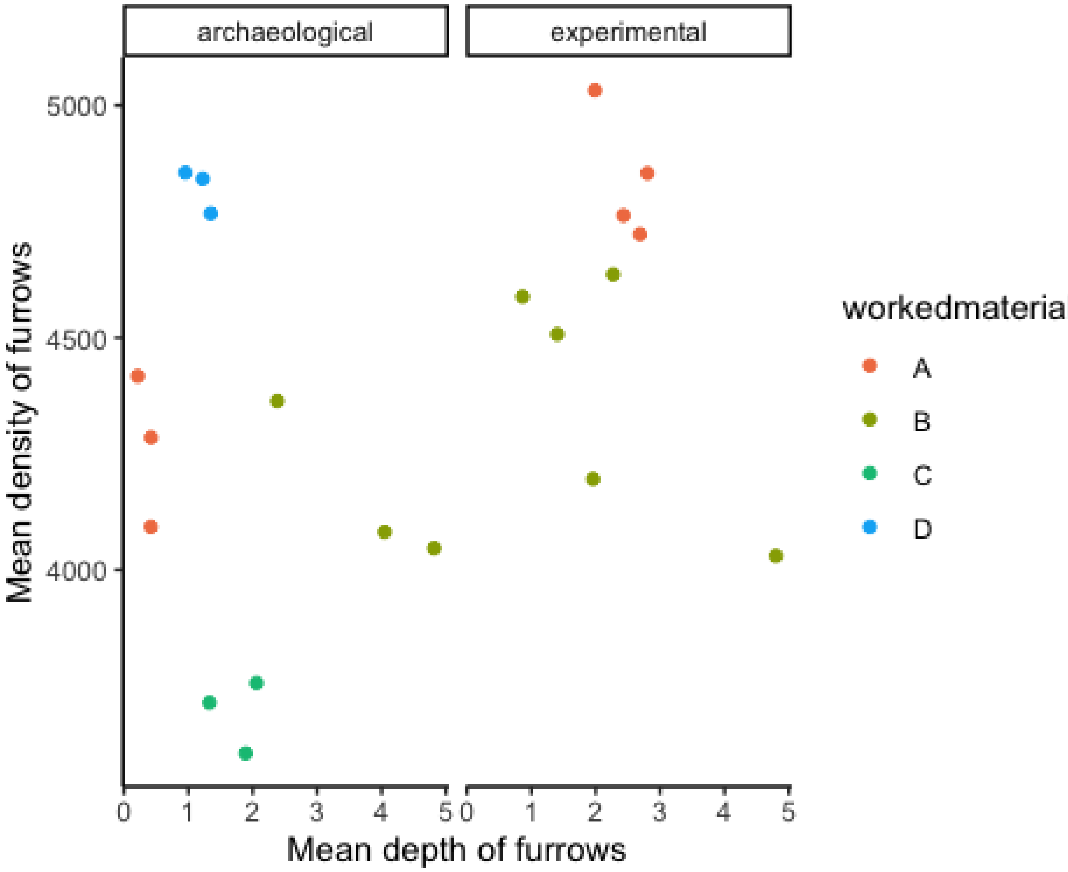

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Sa-Sq", ".pdf")
ggsave(filename = file_out, plot = Sa_Sq, path = "../plots/confocalarch&exp", device = "pdf")

## Saving 5 x 4 in image

# epLsar vs. Asfc

ep_As <- ggplot(data = confocaldataarch) +
         geom_point(mapping = aes(x = Fractal.complexity.Asfc, y = Lengthscale.anisotropy.Sfrax
.epLsar, colour = workedmaterial)) +
         theme_classic() +
         labs(colour = "workedmaterial") +
         facet_wrap(~ sample) +
         scale_colour_hue(h = c(25, 230))
print(ep_As)
```



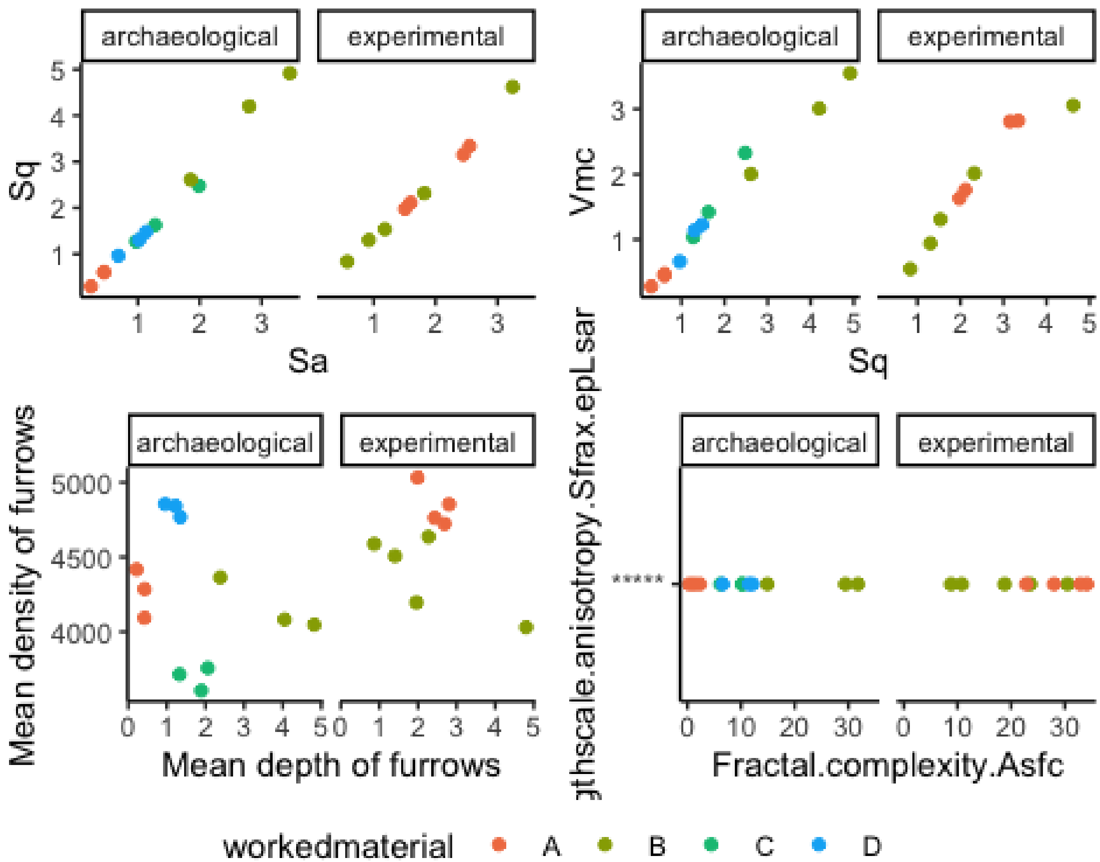

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Asfc-epLsar", ".pdf")
ggsave(filename = file_out, plot = ep_As, path = "../plots/confocalarch&exp", device = "pdf")

## Saving 5 x 4 in image

# Sq vs. Vmc

Sq_Vmc <- ggplot(data = confocaldataarch) +
          geom_point(mapping = aes(x = Sq, y = Vmc, colour = workedmaterial)) +
          theme_classic() +
          labs(colour = "workedmaterial") +
          facet_wrap(~ sample) +
          scale_colour_hue(h = c(25, 230))
print(Sq_Vmc)
```




```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_Sq-Vmc", ".pdf")
ggsave(filename = file_out, plot = Sq_Vmc, path = "../plots/confocalarch&exp", device = "pdf")

## Saving 5 x 4 in image

# Mean depth of furrows vs. mean density of furrows

furrows <- ggplot(data = confocaldataarch) +
           geom_point(mapping = aes(x = Mean.depth.of.furrows, y = Mean.density.of.furrows,
                                    colour = workedmaterial)) +
           theme_classic() +
           labs(colour = "workedmaterial", x = "Mean depth of furrows", y = "Mean density of fu
rrows") +
           facet_wrap(~ sample) +
           scale_colour_hue(h = c(25, 230))
print(furrows)
```



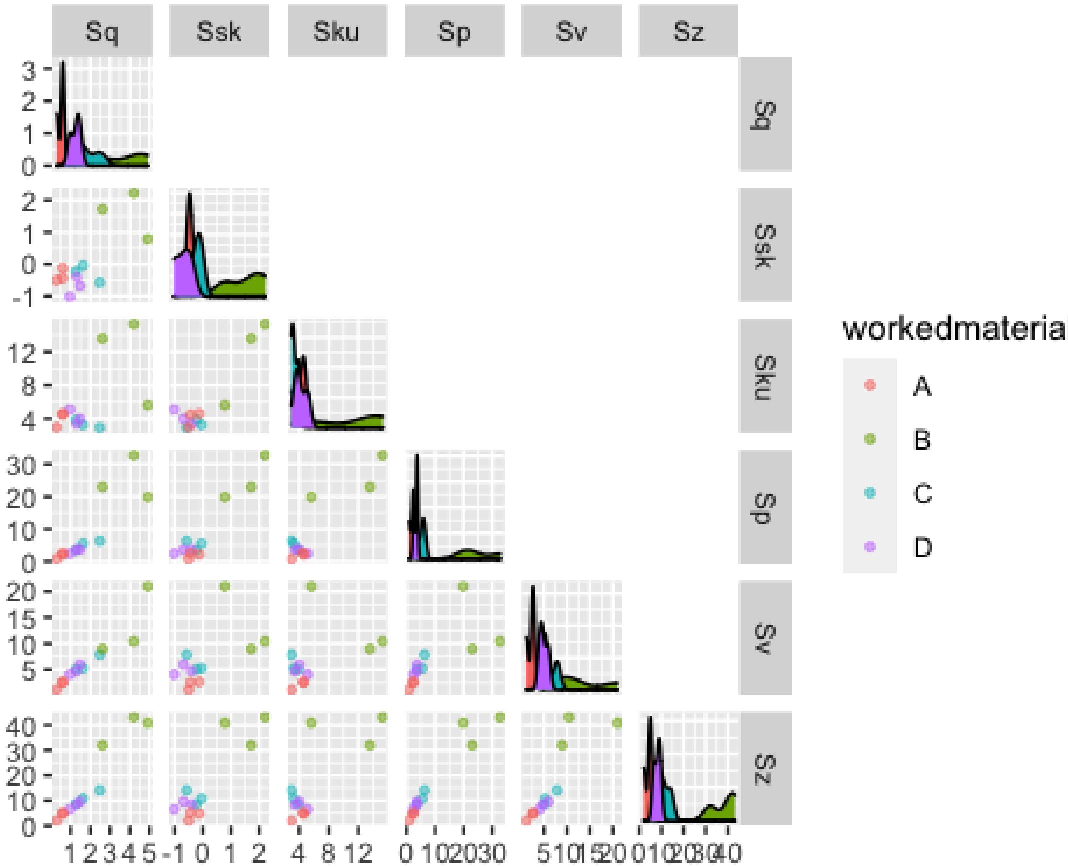

```
file_out <- paste0(file_path_sans_ext(info_in[["file"]]), "_scatterplot_furrows", ".pdf")
ggsave(filename = file_out, plot = furrows, path = "../plots/confocalarch&exp", device = "pdf")

## Saving 5 x 4 in image

# combine all in a single image

ggarrange(Sa_Sq, Sq_Vmc, furrows, ep_As, common.legend = TRUE, legend = "bottom")
```



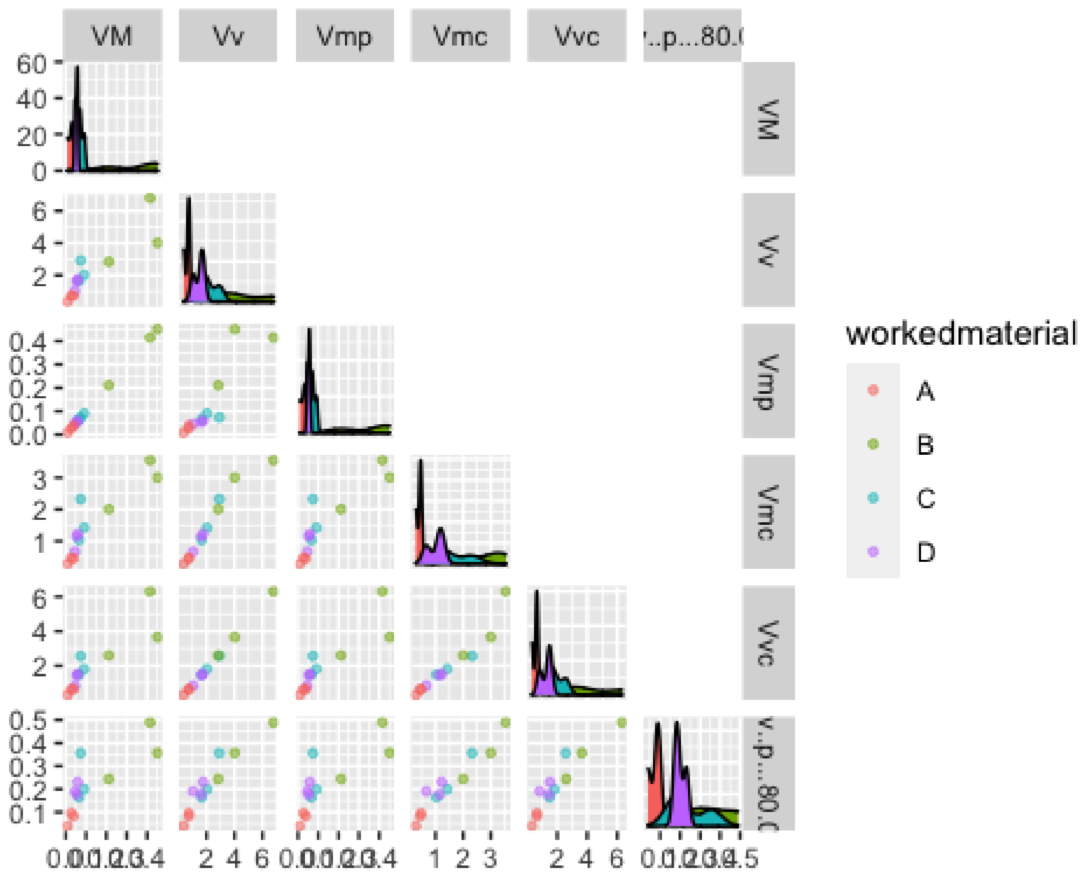

```
ggsave("../plots/confocalarch&exp/scatterplots.png")

## Saving 5 x 4 in image
```

Scatterplot matrix for the ISO 25178 Area scale, Height and volume parameters

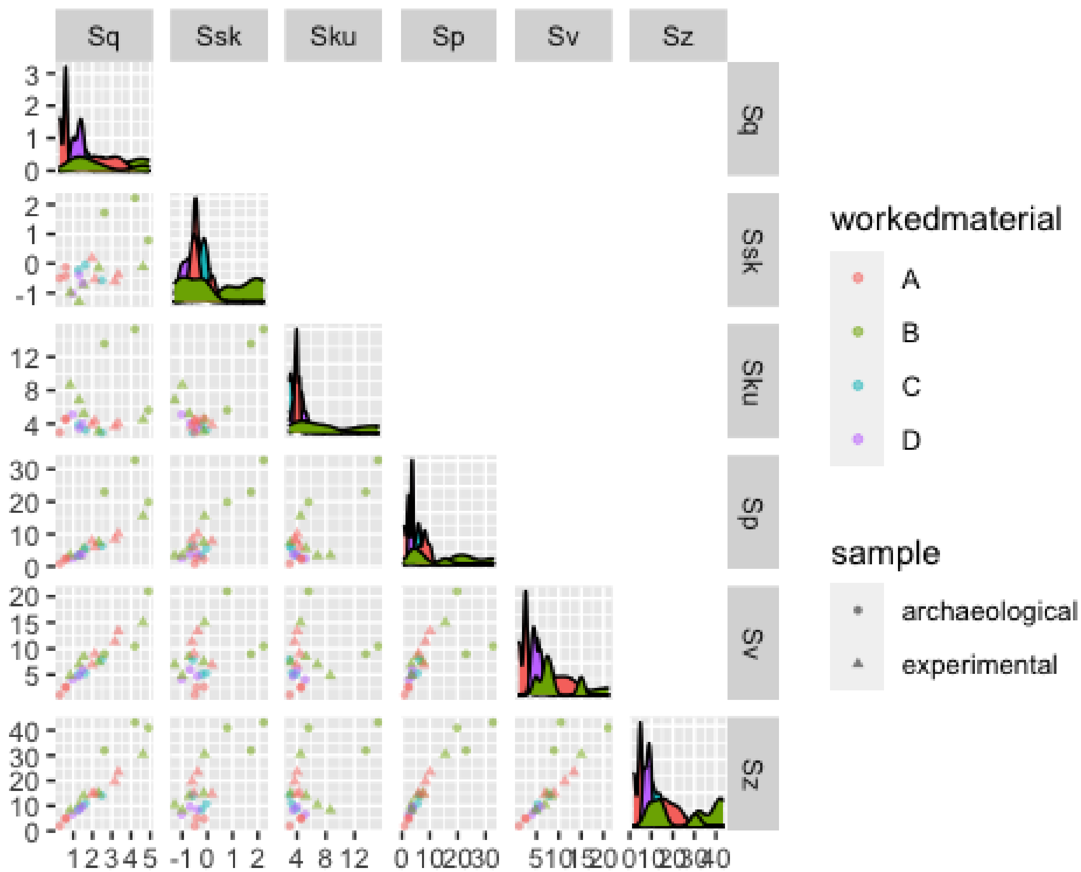
```
data(confocaldataarch, package = "reshape")

## Warning in data(confocaldataarch, package = "reshape"): data set
## 'confocaldataarch' not found

data(confoarch, package = "reshape")

## Warning in data(confoarch, package = "reshape"): data set 'confoarch' not found

# Only archaeological
# Height parameters

ggpairs(data=confoarch,
        columns = c(21:26),
        cardinality_threshold = 30,
        mapping = ggplot2::aes(color = workedmaterial),
        lower = list(continuous = wrap("points", alpha = 0.5, size = 1)),
        upper = list(continuous = "blank"),
        legend = c(2,1)
        ) +

    theme(legend.position = "right") +
  labs(fill = "Micro polish type")
```



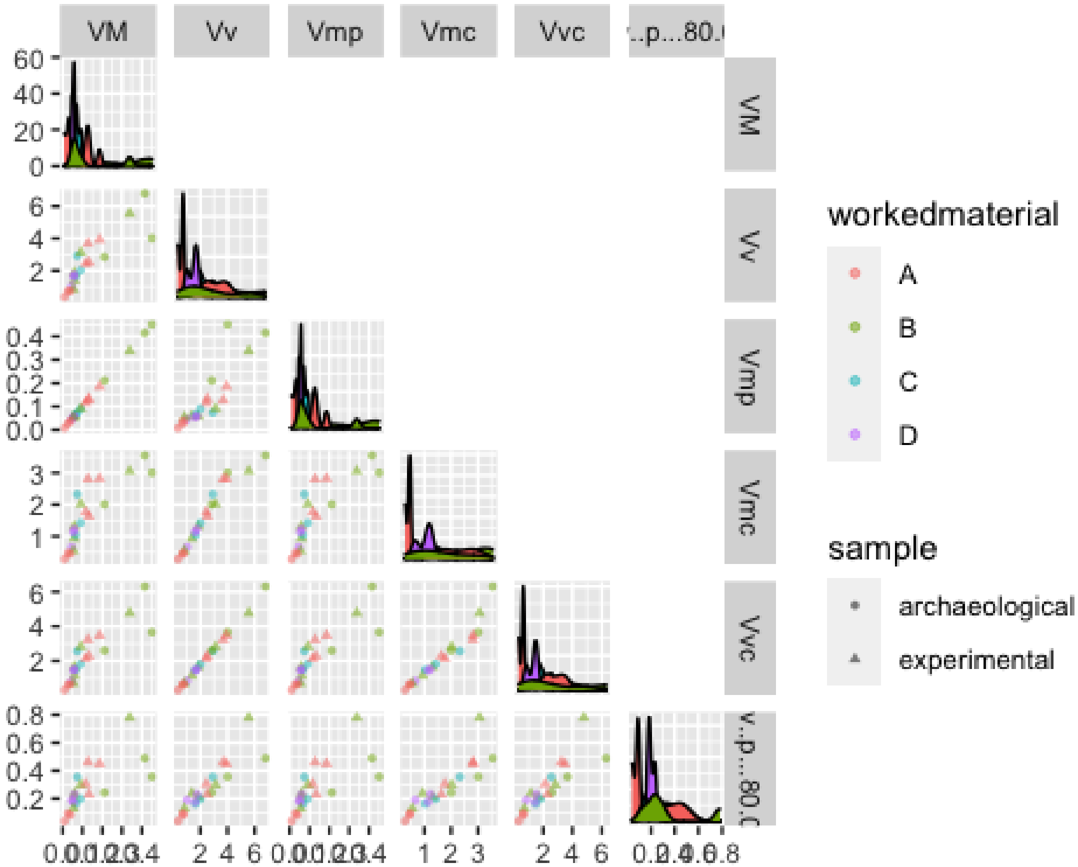

```
ggsave("../plots/confocalarch/confocalarcharea_matrix.png")

## Saving 5 x 4 in image

# Volume parameters

ggpairs(data=confoarch,
        columns = c(36:41),
        cardinality_threshold = 30,
        mapping = ggplot2::aes(color = workedmaterial),
        lower = list(continuous = wrap("points", alpha = 0.5, size = 1)),
        upper = list(continuous = "blank"),
        legend = c(2,1)
        ) +

    theme(legend.position = "right") +
  labs(fill = "Micro polish type")
```




```
ggsave("../plots/confocalarch/confocalarchvolume_matrix.png")

## Saving 5 x 4 in image

# Comparing archaeological and experimental

# Height parameters

ggpairs(data=confocaldataarch,
        columns = c(21:26),
        cardinality_threshold = 30,
        mapping = ggplot2::aes(color = workedmaterial, shape = sample),
        lower = list(continuous = wrap("points", alpha = 0.5, size = 1)),
        upper = list(continuous = "blank"),
        legend = c(2,1)
        ) +

    theme(legend.position = "right") +
  labs(fill = "Micro polish type")
```




```
ggsave("../plots/confocalarch&exp/confocalarcharea_matrix.png")

## Saving 5 x 4 in image

# Volume parameters

ggpairs(data=confocaldataarch,
        columns = c(36:41),
        cardinality_threshold = 30,
        mapping = ggplot2::aes(color = workedmaterial, shape = sample),
        lower = list(continuous = wrap("points", alpha = 0.5, size = 1)),
        upper = list(continuous = "blank"),
        legend = c(2,1)
        ) +

    theme(legend.position = "right") +
  labs(fill = "Micro polish type")
```

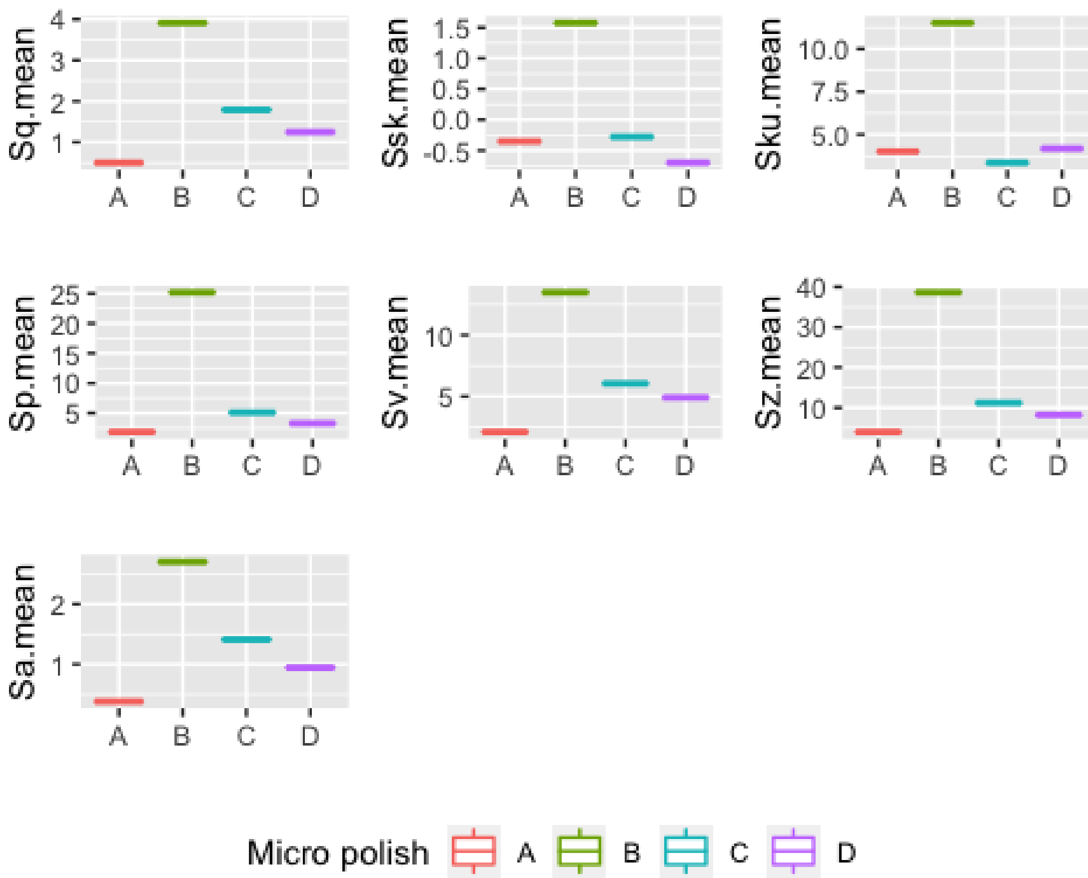



```
ggsave("../plots/confocalarch&exp/confocalarchvolume_matrix.png")

## Saving 5 x 4 in image
```

Plot confostats for the ISO 25178 Area-scale, Height and volume parameters

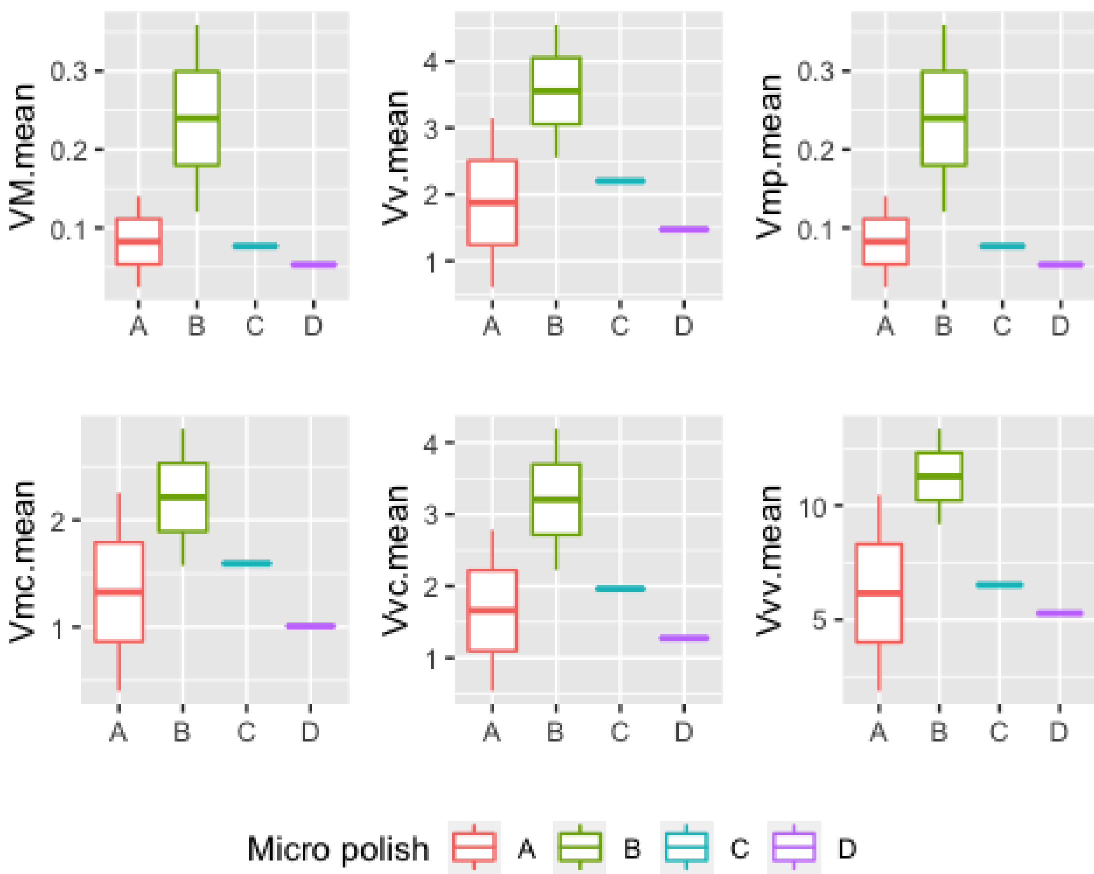
```
# select parameter from dataset

# Only archaeological

confostatsarch2 <- filter(confostatsarch, sample == "archaeological")


heightconfostats <- select(confostatsarch2,workedmaterial, Sq.mean,Ssk.mean,Sku.mean,Sp.mean,Sv
.mean,Sz.mean,Sa.mean)

p1 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sq.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p2 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Ssk.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p3 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sku.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p4 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sp.mean, colour=workedmaterial)) +
  geom_boxplot() +
```

```
  labs(x="", colour="Micro polish")

p5 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p6 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sz.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p7 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sa.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

ggarrange(p1, p2, p3, p4, p5, p6, p7, common.legend = TRUE, font.label = list(size=8), legend="
bottom")
```



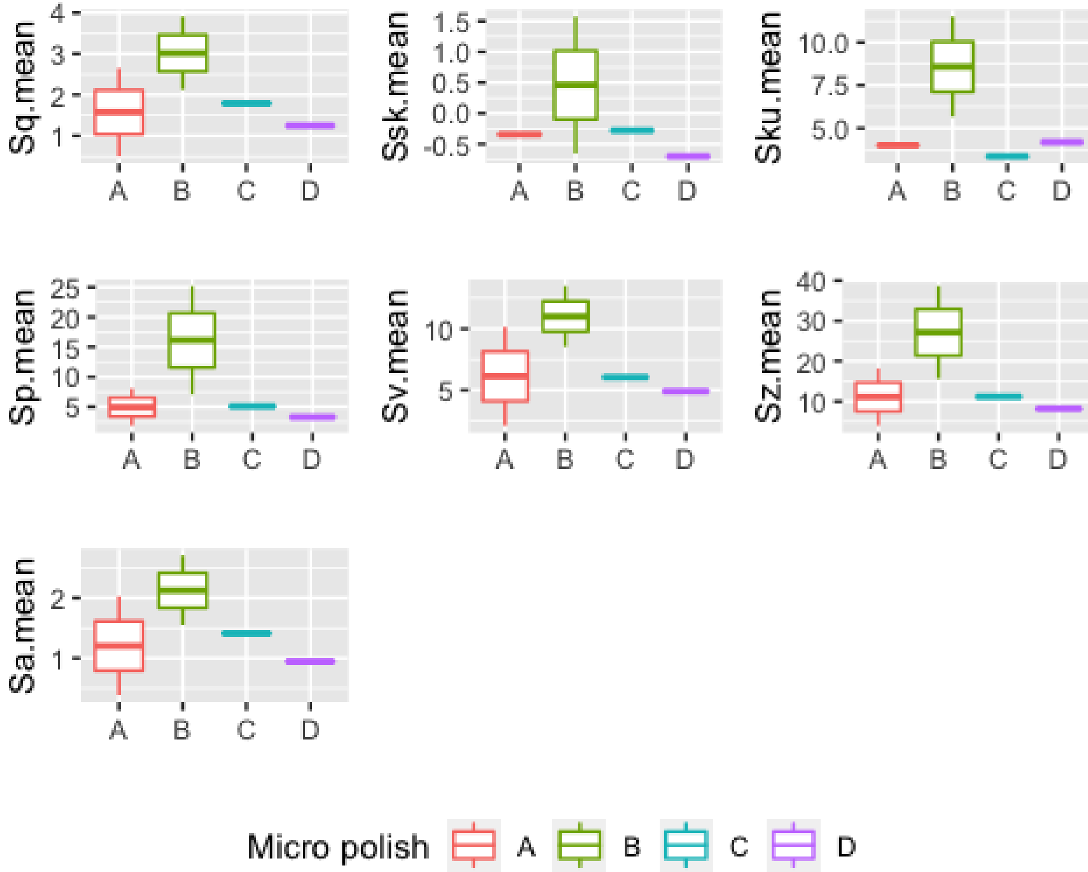

```
ggsave("../plots/confocalarch/confostatsarcharea_boxplots.png")

## Saving 5 x 4 in image

# Now Volume parameters

volumeconfostats <- select(confostatsarch,sample,workedmaterial, VM.mean,Vv.mean,Vmp.mean,Vmc.m
ean,Vvc.mean,Vvv.mean)

p8 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=VM.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")
```

```r
p9 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p10 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vmp.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p11 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vmc.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p12 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vvc.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p13 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vvv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

ggarrange(p8, p9, p10, p11, p12, p13, common.legend = TRUE, font.label = list(size=8), legend="
bottom")
```



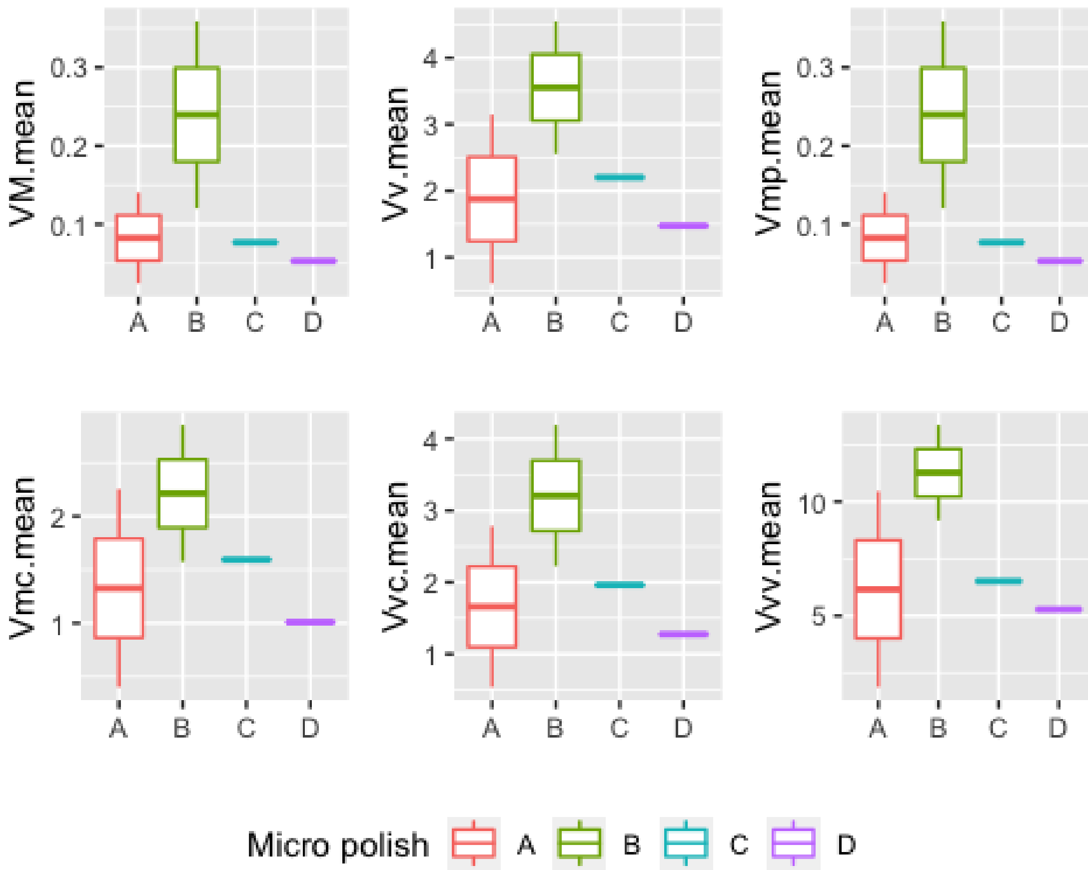

```r
ggsave("../plots/confocalarch/confostatarchvolume_boxplots.png")

## Saving 5 x 4 in image
```

```r
# Comparing archaeological and experimental

# first Height parameters

heightconfostats <- select(confostatsarch,sample,workedmaterial, Sq.mean,Ssk.mean,Sku.mean,Sp.mean,Sv.mean,Sz.mean,Sa.mean)

p1 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sq.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p2 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Ssk.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p3 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sku.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p4 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sp.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p5 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p6 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sz.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p7 <- ggplot(heightconfostats, aes(x=workedmaterial, y=Sa.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

ggarrange(p1, p2, p3, p4, p5, p6, p7, common.legend = TRUE, font.label = list(size=8), legend="bottom")
```




```
ggsave("../plots/confocalarch&exp/confostatsarcharea_boxplots.png")

## Saving 5 x 4 in image

# Now Volume parameters

volumeconfostats <- select(confostatsarch,sample,workedmaterial, VM.mean,Vv.mean,Vmp.mean,Vmc.m
ean,Vvc.mean,Vvv.mean)

p8 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=VM.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p9 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p10 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vmp.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p11 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vmc.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

p12 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vvc.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")
```

```
p13 <- ggplot(volumeconfostats, aes(x=workedmaterial, y=Vvv.mean, colour=workedmaterial)) +
  geom_boxplot() +
  labs(x="", colour="Micro polish")

ggarrange(p8, p9, p10, p11, p12, p13, common.legend = TRUE, font.label = list(size=8), legend="
bottom")
```




```
ggsave("../plots/confocalarch&exp/confostatarchvolume_boxplots.png")

## Saving 5 x 4 in image
```

End and Session info

```
sessionInfo()

## R version 4.0.0 Patched (2020-05-04 r78358)
## Platform: x86_64-apple-darwin17.0 (64-bit)
## Running under: macOS Catalina 10.15.7
##
## Matrix products: default
## BLAS:   /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.dylib
## LAPACK: /Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
##
## locale:
## [1] en_US.UTF-8/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
##
## attached base packages:
## [1] tools     stats     graphics  grDevices utils     datasets  methods
## [8] base
```

```
##
## other attached packages:
##  [1] ggpubr_0.4.0     doBy_4.6.8       GGally_2.1.0     kableExtra_1.3.1
##  [5] janitor_2.1.0    knitr_1.31       forcats_0.5.1    stringr_1.4.0
##  [9] dplyr_1.0.4      purrr_0.3.4      readr_1.4.0      tidyr_1.1.2
## [13] tibble_3.0.6     ggplot2_3.3.3    tidyverse_1.3.0
##
## loaded via a namespace (and not attached):
##  [1] httr_1.4.2         jsonlite_1.7.2     viridisLite_0.3.0  carData_3.0-4
##  [5] modelr_0.1.8       assertthat_0.2.1   highr_0.8          cellranger_1.1.0
##  [9] yaml_2.2.1         pillar_1.4.7       backports_1.2.1    lattice_0.20-41
## [13] glue_1.4.2         digest_0.6.27      RColorBrewer_1.1-2 ggsignif_0.6.0
## [17] rvest_0.3.6        snakecase_0.11.0   colorspace_2.0-0   cowplot_1.1.1
## [21] htmltools_0.5.1.1  Matrix_1.3-2       plyr_1.8.6         pkgconfig_2.0.3
## [25] broom_0.7.4        haven_2.3.1        scales_1.1.1       webshot_0.5.2
## [29] openxlsx_4.2.3     rio_0.5.16         farver_2.0.3       generics_0.1.0
## [33] car_3.0-10         ellipsis_0.3.1     withr_2.4.1        cli_2.3.0
## [37] magrittr_2.0.1     crayon_1.4.0       readxl_1.3.1       evaluate_0.14
## [41] fs_1.5.0           MASS_7.3-53        rstatix_0.6.0      xml2_1.3.2
## [45] foreign_0.8-81     data.table_1.13.6  hms_1.0.0          lifecycle_0.2.0
## [49] munsell_0.5.0      reprex_1.0.0       zip_2.1.1          Deriv_4.1.2
## [53] compiler_4.0.0     rlang_0.4.10       grid_4.0.0         rstudioapi_0.13
## [57] labeling_0.4.2     rmarkdown_2.6      gtable_0.3.0       abind_1.4-5
## [61] DBI_1.1.1          reshape_0.8.8      curl_4.3           R6_2.5.0
## [65] gridExtra_2.3      lubridate_1.7.9.2  stringi_1.5.3      Rcpp_1.0.6
## [69] vctrs_0.3.6        dbplyr_2.1.0       tidyselect_1.1.0   xfun_0.20
```

1.5. Archaeological GIS data analysis

Paixão PhD - archaeological GIS data analysis

EP

2021-02-03 10:09:54

Brief description of the script

This R markdown document reads, summarizes and plots data for the PhD dissertation *Paixão 2021. Groundbreaking technologies in the Middle Paleolithic of the Levant: High resolution and multi-scale functional analysis of Ground Stone Tools*

The document contains:

1. Tables
2. Plots (illustrations of the data analysis)
3. Supplementary material, including extra tables and figures (data analysis)

This R project and respective scripts follow the procedures described by Marwick et al. 2017.

To compile this markdown document do not delete or move files from their original folders. Please note that most of the tables and figures in this file do not match the numbering in the Phd dissertation manuscript.

For any questions, comments and inputs, please contact:

Eduardo Paixão, paixao@rgzm.de

Load data into R project

Imported files are in: '../analysis/raw_data'

Figures are saved in: '../analysis/plots'

Tables are saved in: '../analysis/derived_data'

Load libraries

```
# Load required libraries

library(tidyverse)

## -- Attaching packages --------------------------------------- tidyverse 1.3.0 --

## v ggplot2 3.3.3     v purrr   0.3.4
## v tibble  3.0.5     v dplyr   1.0.3
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.0

## Warning: package 'ggplot2' was built under R version 4.0.3

## Warning: package 'readr' was built under R version 4.0.3
```

```
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(utils)
library(knitr)
library(janitor)

## Warning: package 'janitor' was built under R version 4.0.3

##
## Attaching package: 'janitor'

## The following objects are masked from 'package:stats':
##
##     chisq.test, fisher.test

library(kableExtra)

## Warning: package 'kableExtra' was built under R version 4.0.3

##
## Attaching package: 'kableExtra'

## The following object is masked from 'package:dplyr':
##
##     group_rows

library(GGally)

## Warning: package 'GGally' was built under R version 4.0.3

## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2

library(doBy)

## Warning: package 'doBy' was built under R version 4.0.3

##
## Attaching package: 'doBy'

## The following object is masked from 'package:dplyr':
##
##     order_by

library(ggpubr)
library(ggfortify)

## Warning: package 'ggfortify' was built under R version 4.0.3

library(tools)

# See your WD and update the following paths
# getwd()

# Load data from .csv

db1 <- read.delim("../raw_data/gisdataarch.csv", sep = ",")

data_file <- list.files("../raw_data/", pattern = "\\.csv$", full.names = TRUE)
```

```
# filter general datasets by site

# Fa'rah II
db1fr <- filter(db1, site == "FARAII")
# Ein Qashish
db1eq <- filter(db1, site == "EIN_QUASHISH")
# Nesher Ramla
db1nr <- filter(db1, site  == "NESHER_RAMLA")
```

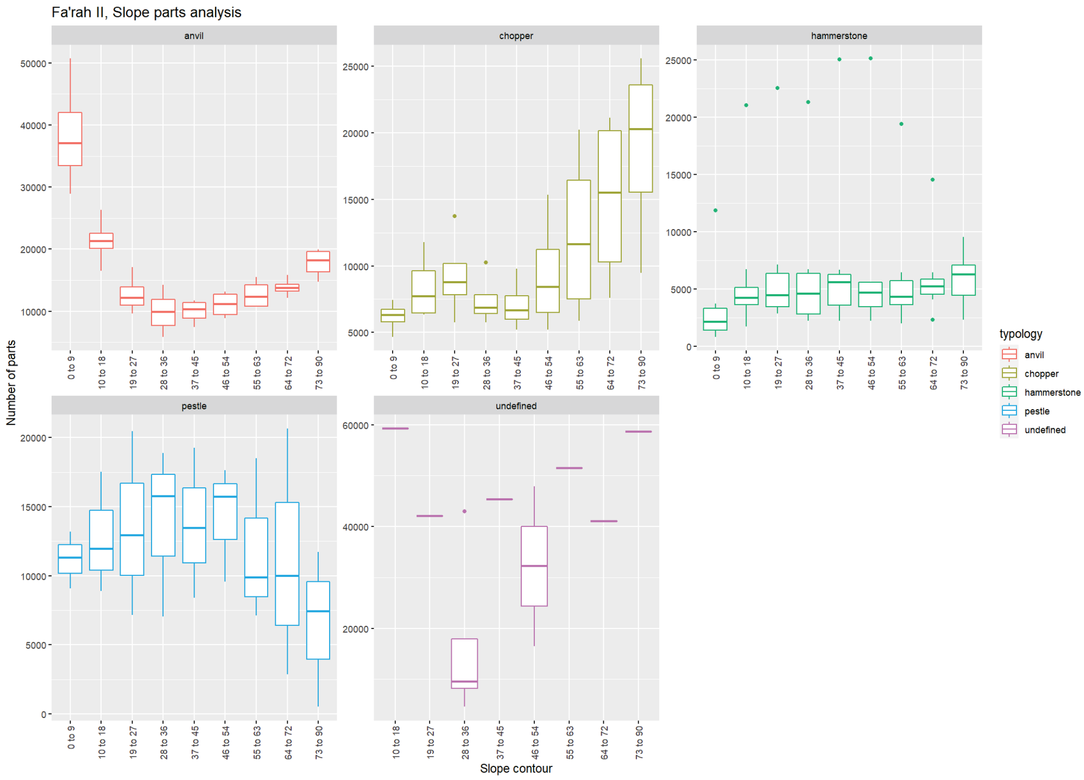
GIS analysis, Terrain analysis for Slope and TRI based on the 3D surface point clouds

Slope

Complete surfaces

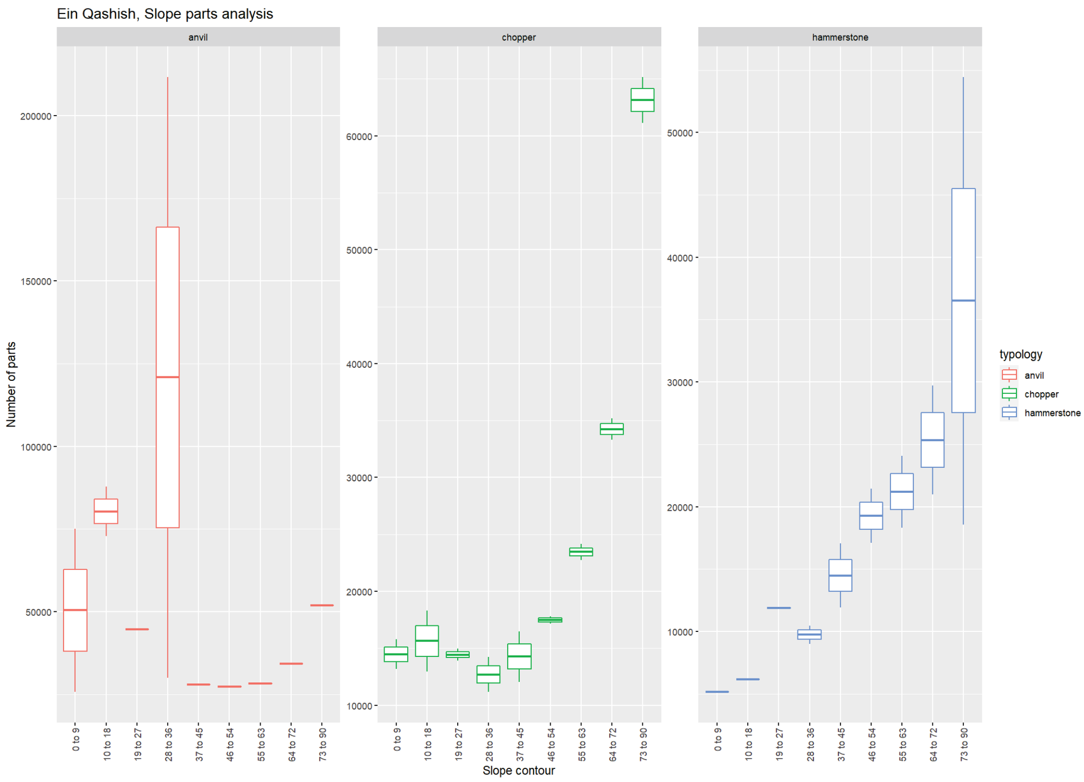
```
# Filter

slopefr <- filter(db1fr, parameter == "slope" & samplearea == "complete")
slopeeq <- filter(db1eq, parameter == "slope" & samplearea == "complete")
slopenr <- filter(db1nr, parameter == "slope" & samplearea == "complete")

# calculate proportions (percentages %)
slopefr <- slopefr %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

slopeeq <- slopeeq %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

slopenr <- slopenr %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

# Bind new datasets

newslope <- do.call("rbind", list(slopefr, slopeeq, slopenr))

# save outputs

write_csv(newslope,"../derived_data/newslope_arch_complete.csv")

# Plot data (sort by site)´

# Fa'rah II
newslopefr <- filter(newslope, site == "FARAII")
# Ein Qashish
newslopeeq <- filter(newslope, site == "EIN_QUASHISH")
# Nesher Ramla
newslopenr <- filter(newslope, site  == "NESHER_RAMLA")

# Number of parts
```

```
# Fa'rah
newslopefr$contourelev <- factor(newslopefr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopeparts_fr <- ggplot(newslopefr, aes(x = contourelev, y = nparts, colour = typology)) +
  geom_boxplot() +
  ggtitle("Fa'rah II, Slope parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopeparts_fr
```

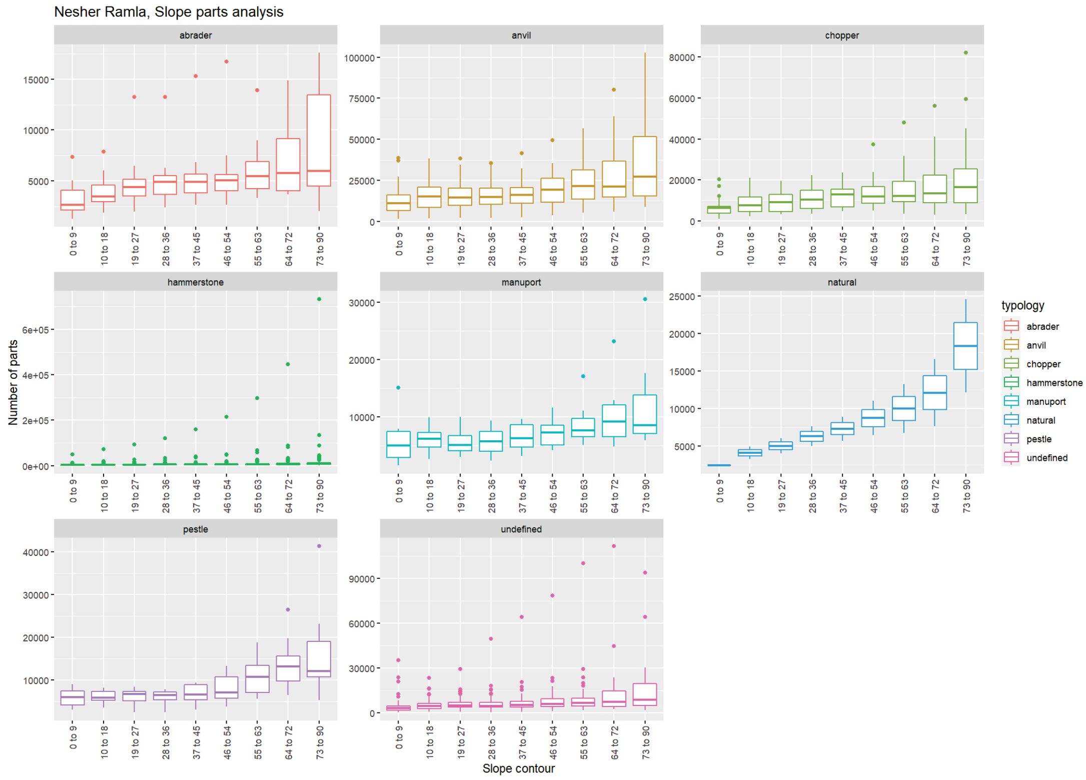



```
ggsave("../plots/slopeparts_fr_complete.png")

## Saving 14 x 10 in image

# Ein Qashish
newslopeeq$contourelev <- factor(newslopeeq$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopeparts_eq <- ggplot(newslopeeq, aes(x = contourelev, y = nparts, colour = typology)) +
  geom_boxplot() +
  ggtitle("Ein Qashish, Slope parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
```

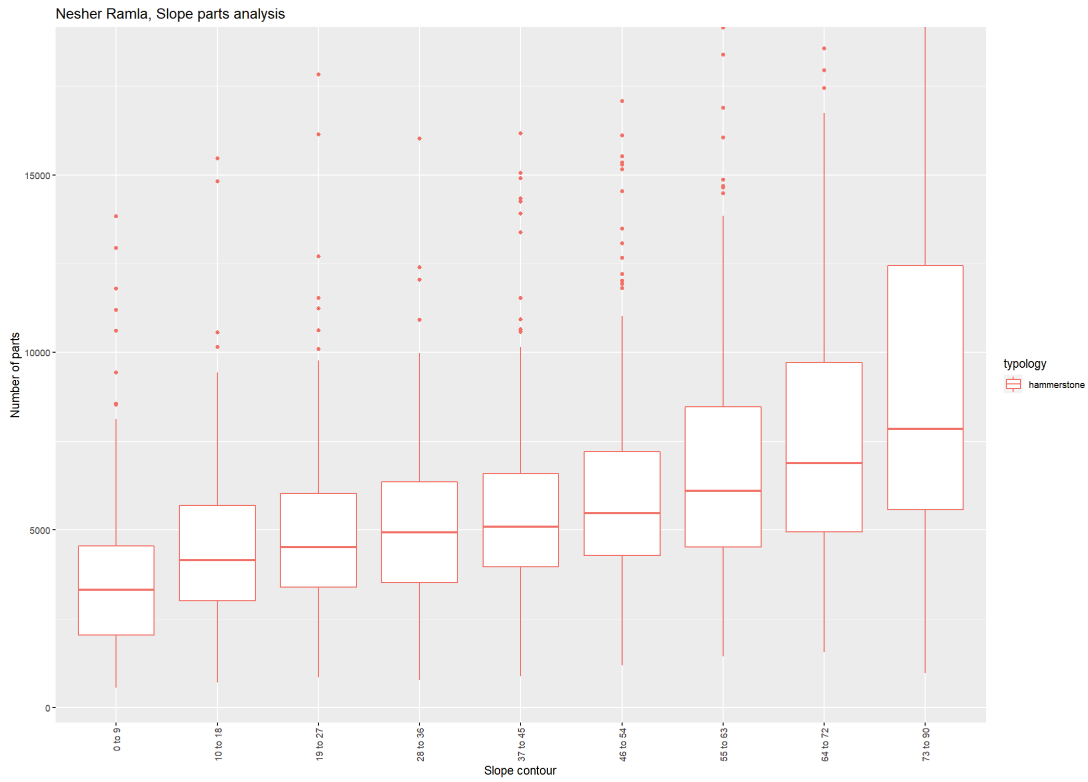
```
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopeparts_eq
```



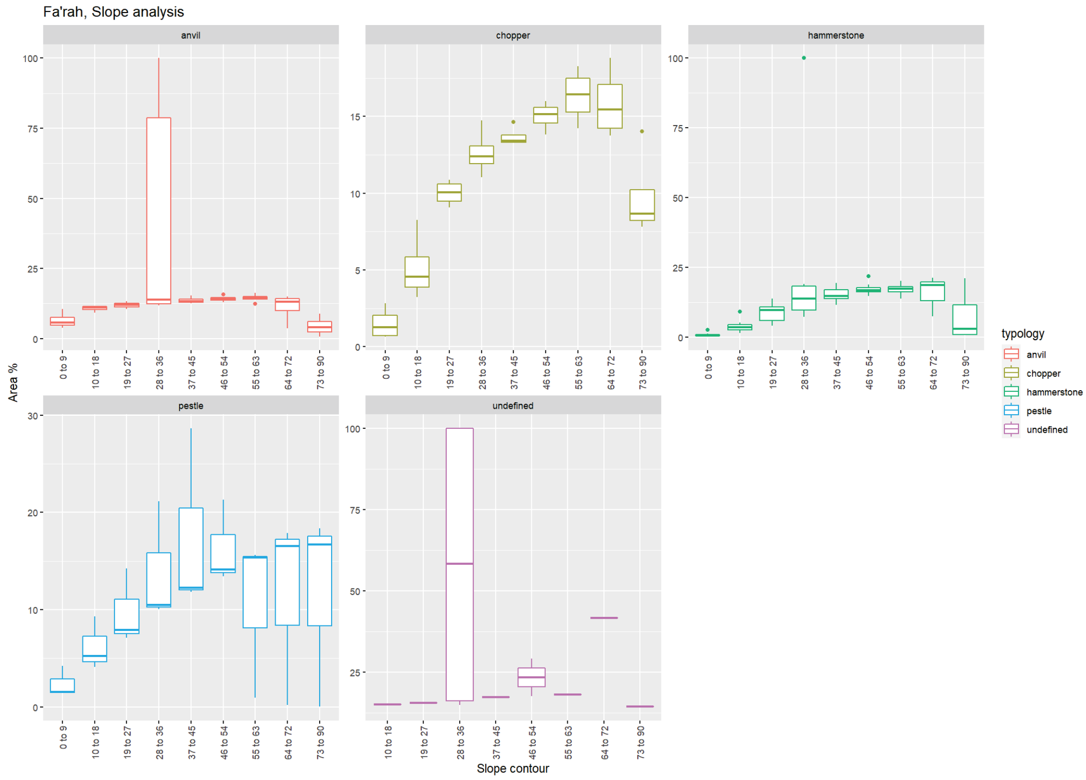

```
ggsave("../plots/slopeparts_eq_complete.png")

## Saving 14 x 10 in image

# Nesher Ramla

newslopenr$contourelev <- factor(newslopenr$contourelev, levels=c("0 to 9",
                                                                   "10 to 18",
                                                                   "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopeparts_nr <- ggplot(newslopenr, aes(x = contourelev, y = nparts, colour = typology)) +
  geom_boxplot() +
  ggtitle("Nesher Ramla, Slope parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopeparts_nr
```



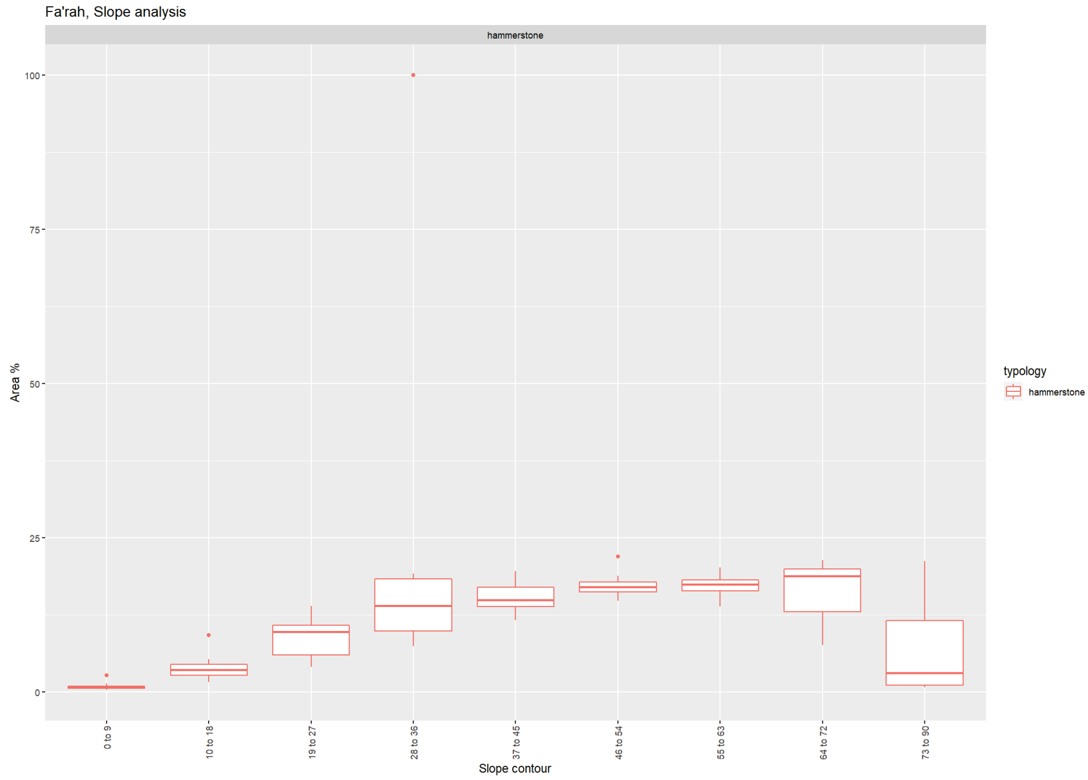

```
ggsave("../plots/slopeparts_nr_complete.png")

## Saving 14 x 10 in image

# Now just hammerstones from Nesher Ramla

slopepartsham <- filter(newslopenr, typology == "hammerstone") # dealing with outliers
ylim1 = boxplot.stats(newslopenr$nparts)$stats[c(1,5)]

slopepartsham$contourelev <- factor(slopepartsham$contourelev, levels=c("0 to 9",
                                                                        "10 to 18",
                                                                        "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopeparts_nr_hammer <- ggplot(slopepartsham, aes(x = contourelev, y = nparts, colour = typ
ology)) +
  geom_boxplot() +
  ggtitle("Nesher Ramla, Slope parts analysis") +
  ylab("Number of parts") +
  xlab("Slope contour") +
  coord_cartesian(ylim = ylim1*1.05) +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopeparts_nr_hammer
```



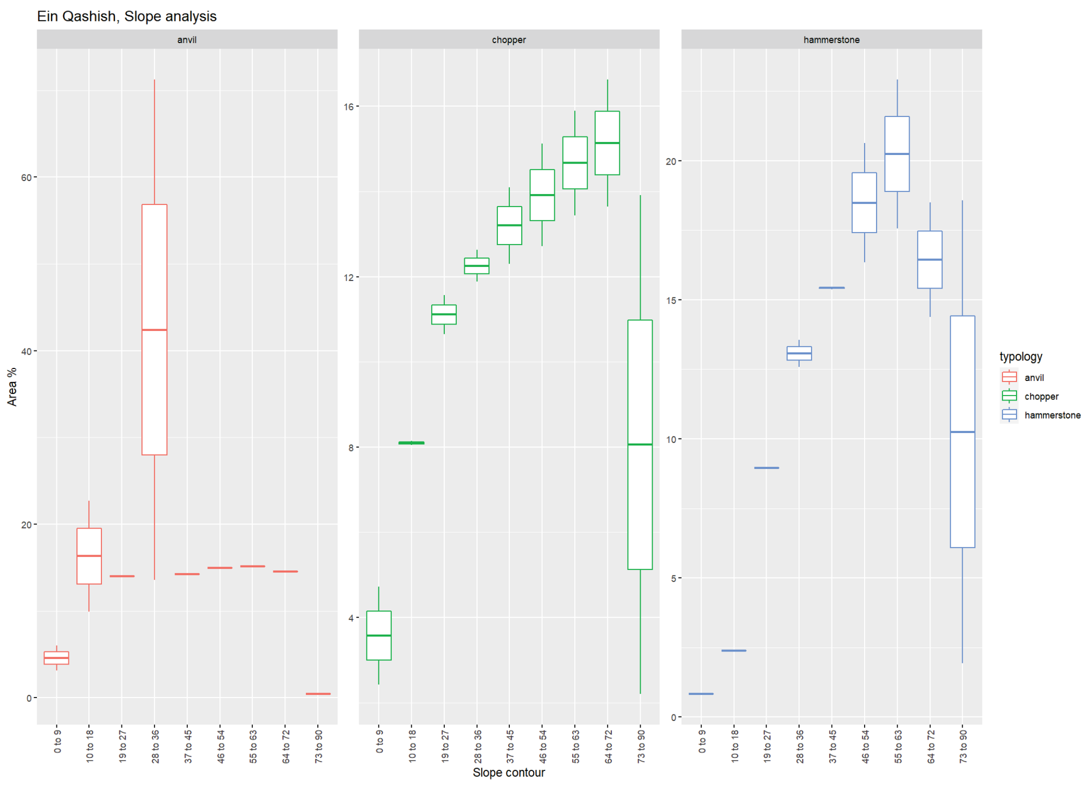

```
ggsave("../plots/slopeparts_nr_hammer_complete_noout.png")

## Saving 14 x 10 in image

# Area %, per site

# Fa'rah
newslopefr$contourelev <- factor(newslopefr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopetypology_fr <- ggplot(newslopefr, aes(x = contourelev, y = areaperc, colour = typology
)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Fa'rah, Slope analysis") +
  ylab("Area %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopetypology_fr
```



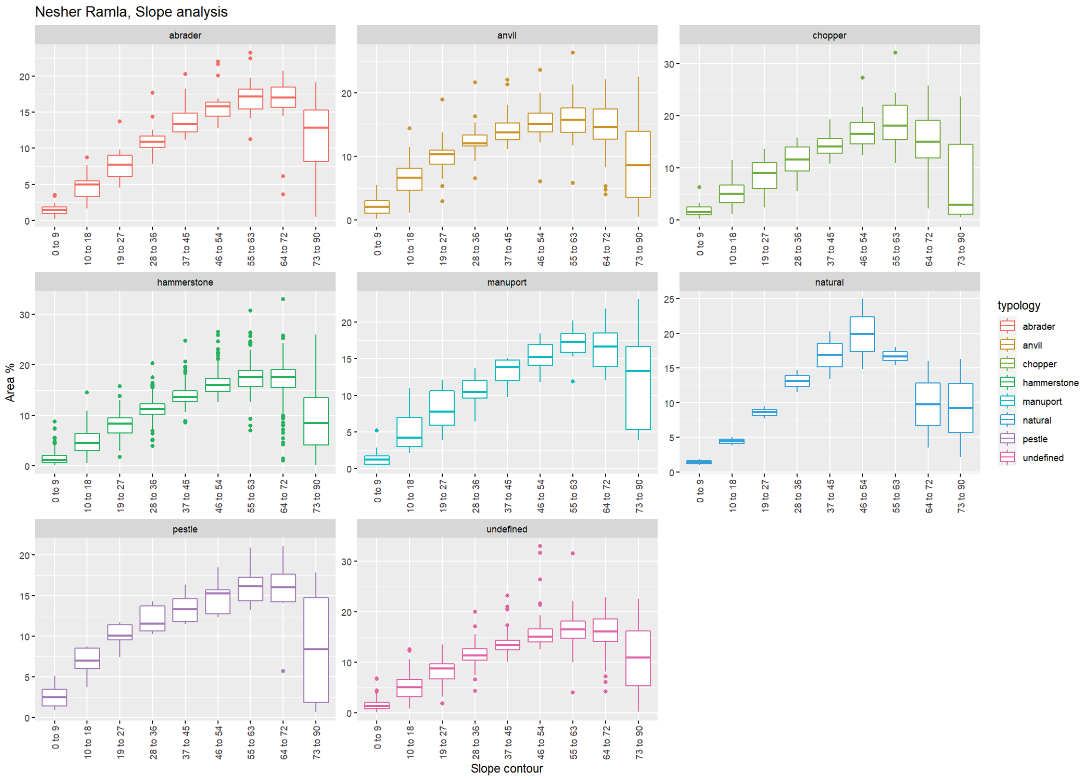

```
ggsave("../plots/slopetypology_fr_complete.png")

## Saving 14 x 10 in image

# Now just hammerstones from Fa'rah

slopepartsham <- filter(newslopefr, typology == "hammerstone") # dealing with outliers
ylim1 = boxplot.stats(newslopefr$nparts)$stats[c(1,5)]

newslopefr$contourelev <- factor(newslopefr$contourelev, levels=c("0 to 9",
                                                                    "10 to 18",
                                                                    "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopetypology_fr <- ggplot(slopepartsham, aes(x = contourelev, y = areaperc, colour = typol
ogy)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Fa'rah, Slope analysis") +
  ylab("Area %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopetypology_fr
```



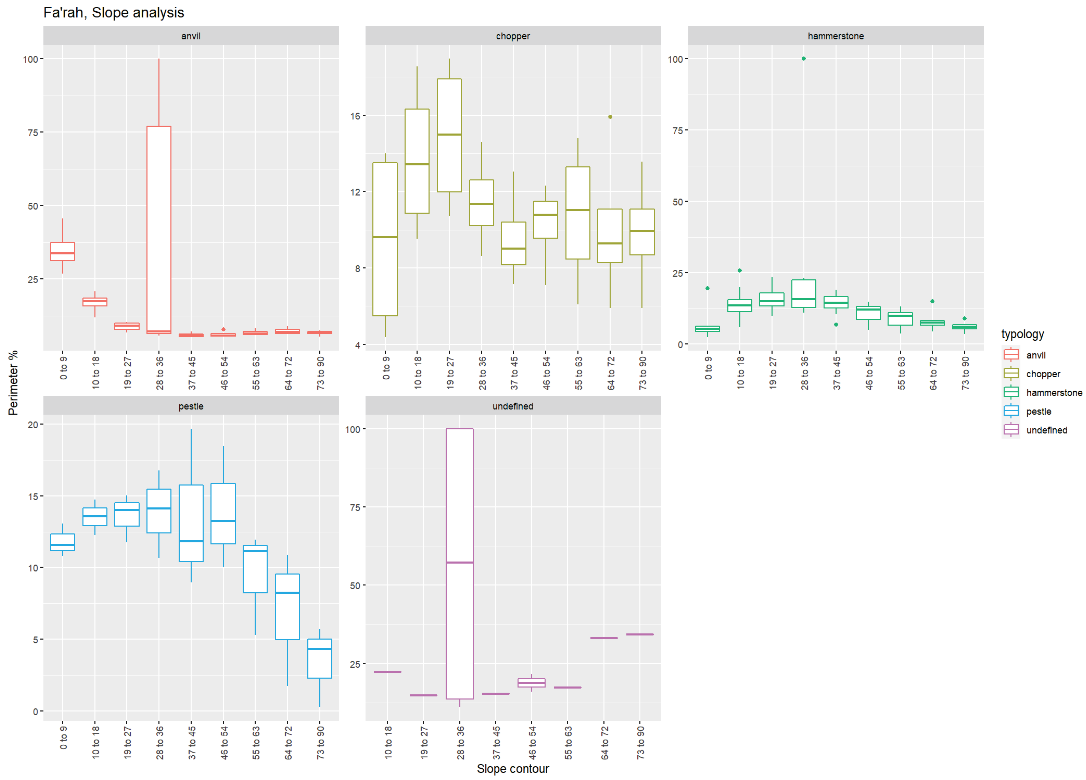

```
ggsave("../plots/slopetypology_fr_complete_noout.png")

## Saving 14 x 10 in image

# Ein Qashish
newslopeeq$contourelev <- factor(newslopeeq$contourelev, levels=c("0 to 9",
                                                    "10 to 18",
                                                    "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopetypology_eq <- ggplot(newslopeeq, aes(x = contourelev, y = areaperc, colour = typology
)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Ein Qashish, Slope analysis") +
  ylab("Area %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopetypology_eq
```



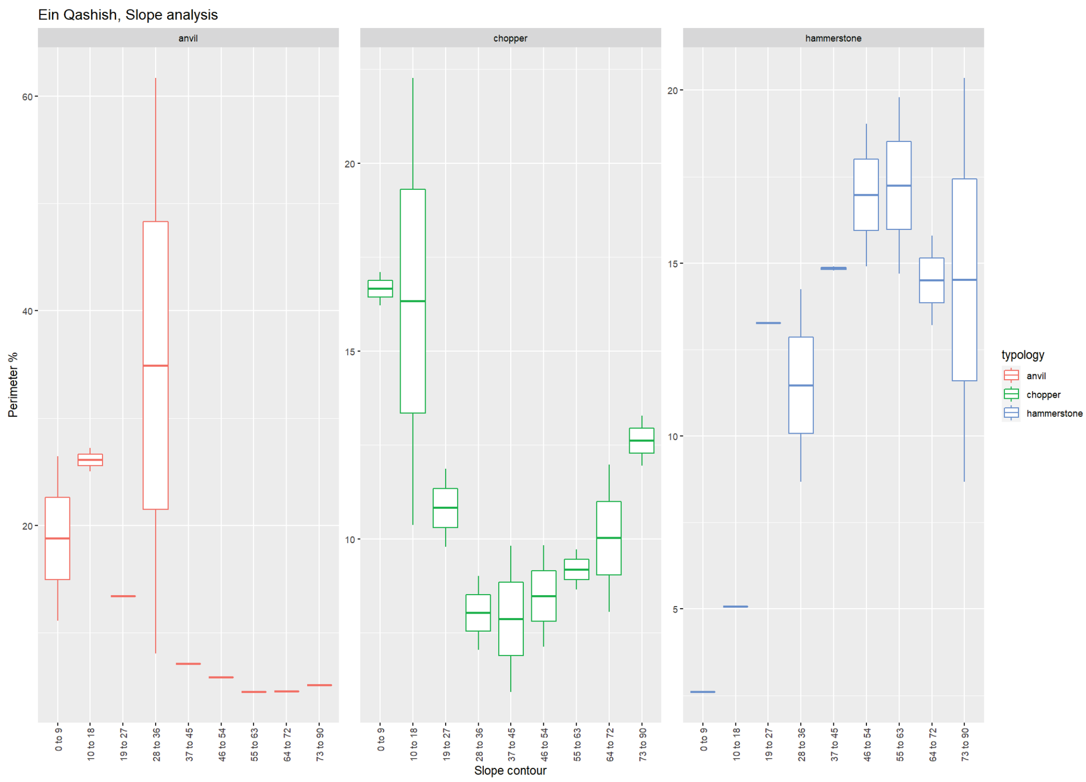

```
ggsave("../plots/slopetypology_eq_complete.png")

## Saving 14 x 10 in image

# Nesher Ramla

newslopenr$contourelev <- factor(newslopenr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopetypology_nr <- ggplot(newslopenr, aes(x = contourelev, y = areaperc, colour = typology
)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Nesher Ramla, Slope analysis") +
  ylab("Area %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopetypology_nr
```



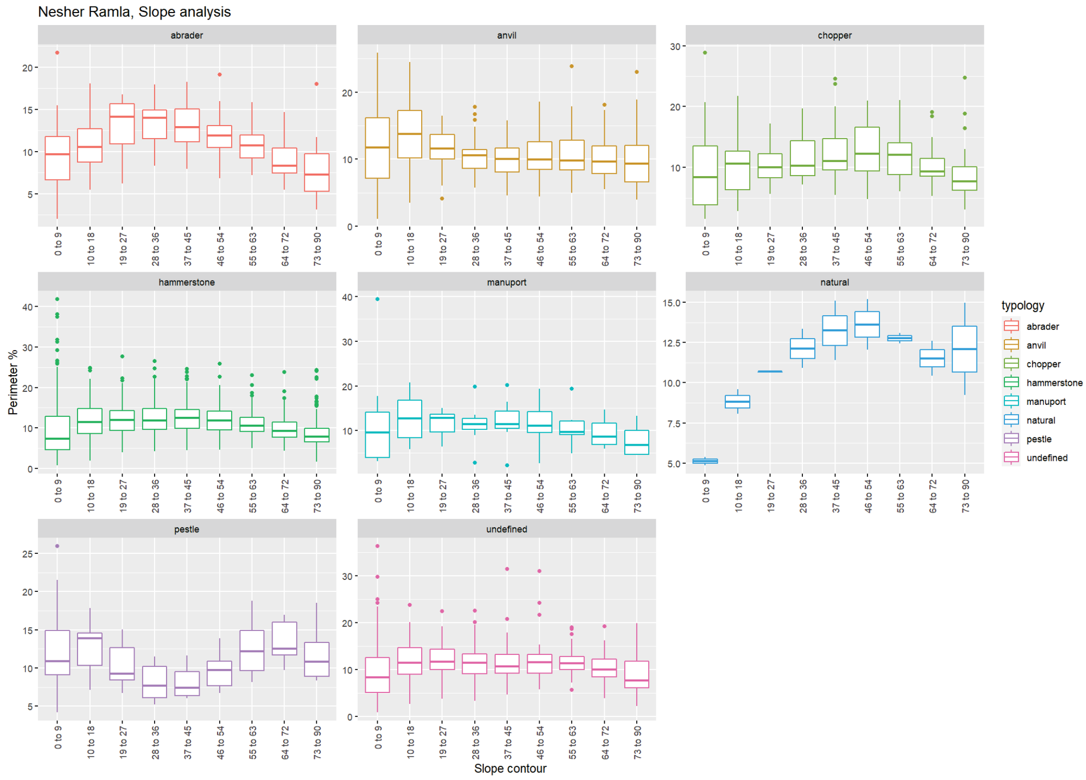

```
ggsave("../plots/slopetypology_nr_complete.png")

## Saving 14 x 10 in image

# Perimeter %

# Fa'rah
newslopefr$contourelev <- factor(newslopefr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))
slope_perim_typology_fr <- ggplot(newslopefr, aes(x = contourelev, y = perimperc, colour =
typology)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Fa'rah, Slope analysis") +
  ylab("Perimeter %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slope_perim_typology_fr
```




```r
ggsave("../plots/slope_perim_typology_fr_complete.png")

## Saving 14 x 10 in image

# Ein Qashish

newslopeeq$contourelev <- factor(newslopeeq$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slope_perim_typology_eq <- ggplot(newslopeeq, aes(x = contourelev, y = perimperc, colour =
typology)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Ein Qashish, Slope analysis") +
  ylab("Perimeter %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slope_perim_typology_eq
```




```
ggsave("../plots/slope_perim_typology_eq_complete.png")

## Saving 14 x 10 in image

# Nesher Ramla
newslopenr$contourelev <- factor(newslopenr$contourelev, levels=c("0 to 9",
                                                                 "10 to 18",
                                                                 "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slope_perim_typology_nr <- ggplot(newslopenr, aes(x = contourelev, y = perimperc, colour =
typology)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Nesher Ramla, Slope analysis") +
  ylab("Perimeter %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slope_perim_typology_nr
```

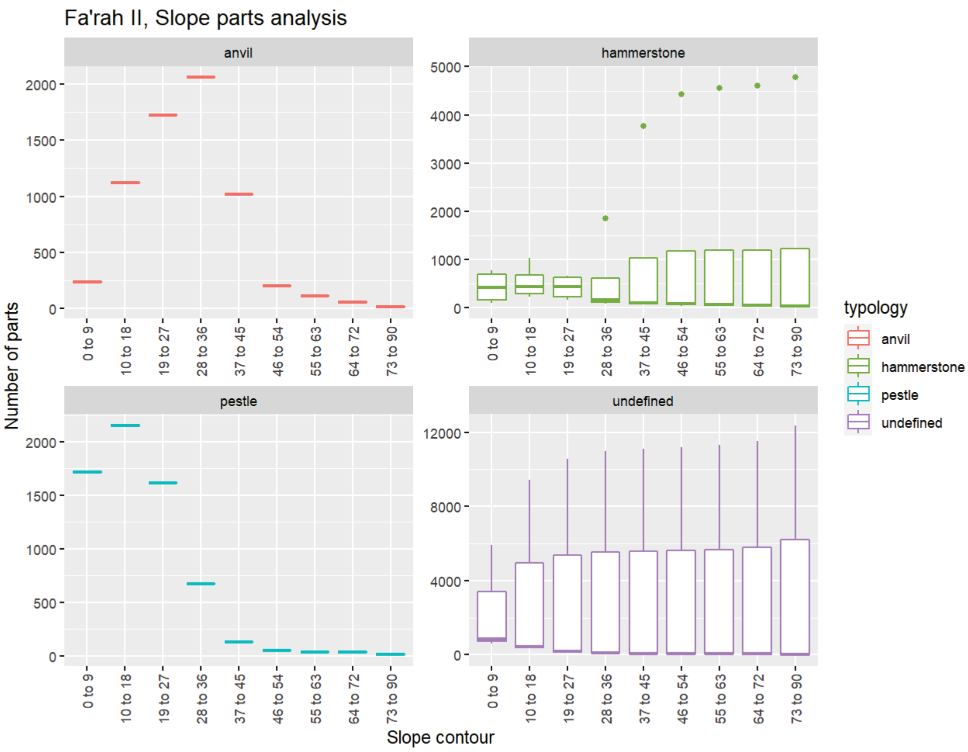



```r
ggsave("../plots/slope_perim_typology_nr_complete.png")

## Saving 14 x 10 in image
```

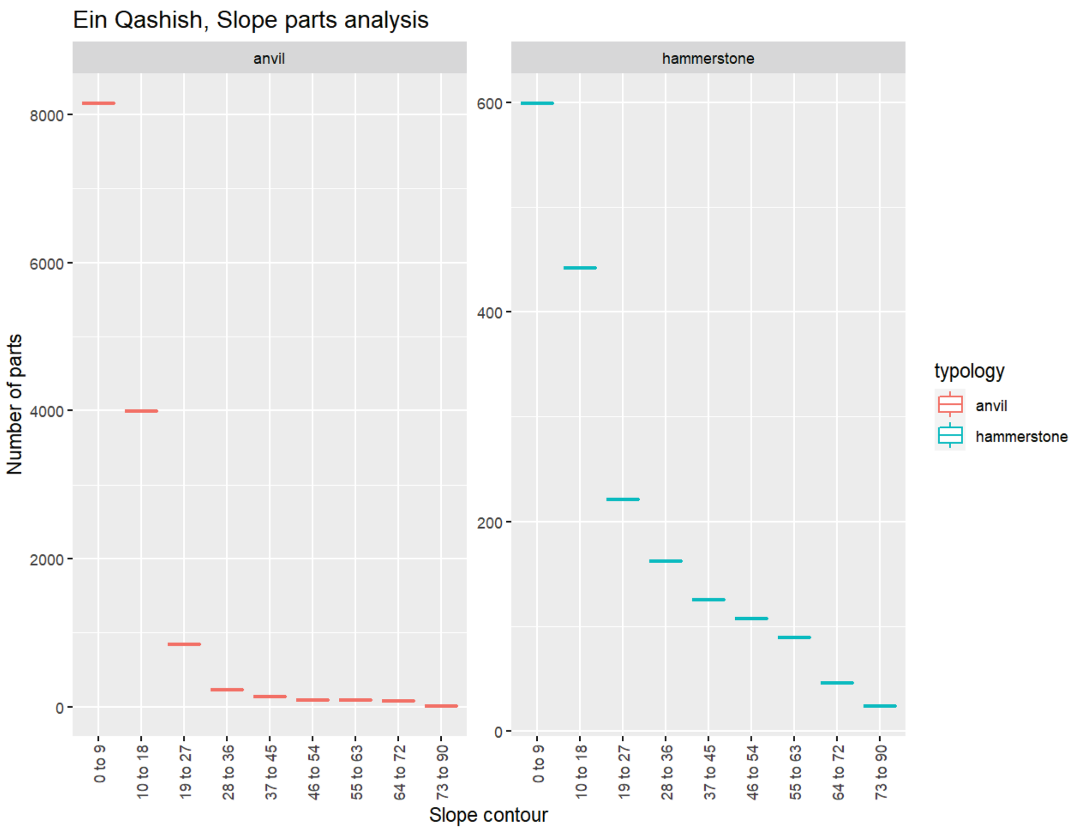
Cutted surfaces

```r
# Filter

slopefr <- filter(db1fr, parameter == "slope" & samplearea == "cutted")
slopeeq <- filter(db1eq, parameter == "slope" & samplearea == "cutted")
slopenr <- filter(db1nr, parameter == "slope" & samplearea == "cutted")

# calculate proportions (percentages %)
slopefr <- slopefr %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

slopeeq <- slopeeq %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

slopenr <- slopenr %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

# Bind new datasets
```

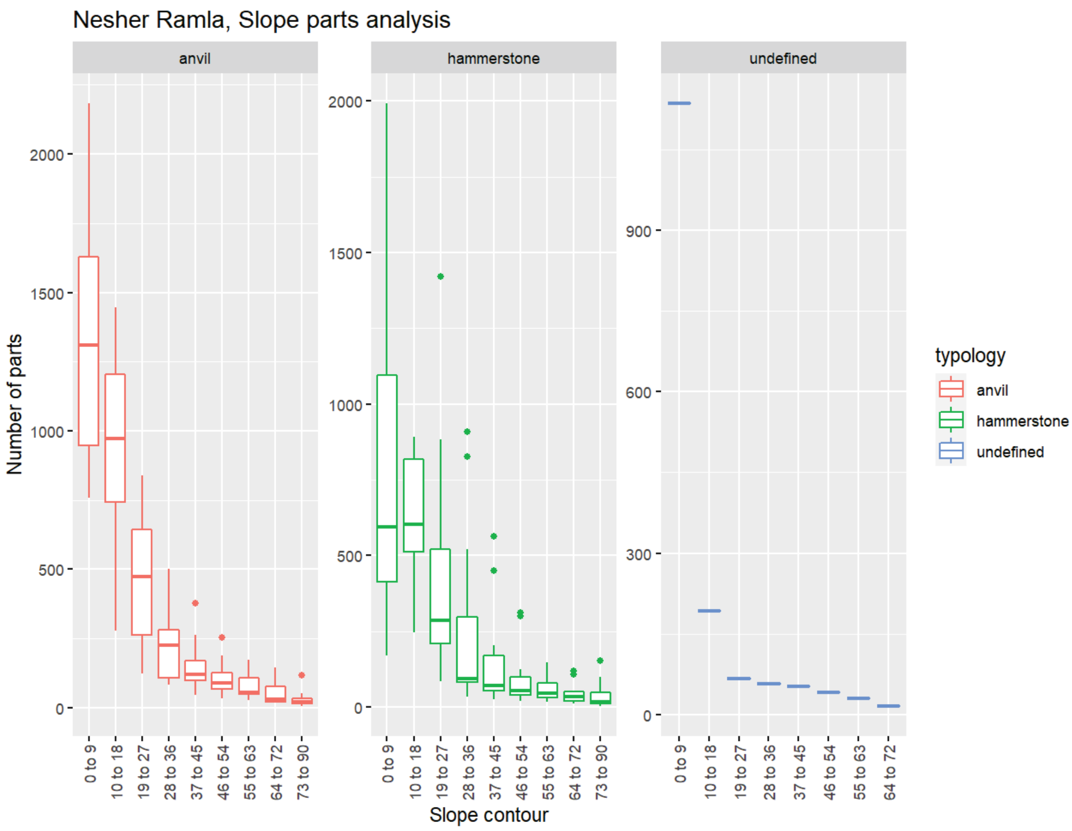
```r
newslope <- do.call("rbind", list(slopefr, slopeeq, slopenr))

# save outputs

write_csv(newslope,"../derived_data/newslope_arch.csv")

# Plot data (sort by site)´

# Fa'rah II
newslopefr <- filter(newslope, site == "FARAII")
# Ein Qashish
newslopeeq <- filter(newslope, site == "EIN_QUASHISH")
# Nesher Ramla
newslopenr <- filter(newslope, site  == "NESHER_RAMLA")

# Number of parts

# Fa'rah
newslopefr$contourelev <- factor(newslopefr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopeparts_fr <- ggplot(newslopefr, aes(x = contourelev, y = nparts, colour = typology)) +
  geom_boxplot() +
  ggtitle("Fa'rah II, Slope parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopeparts_fr
```



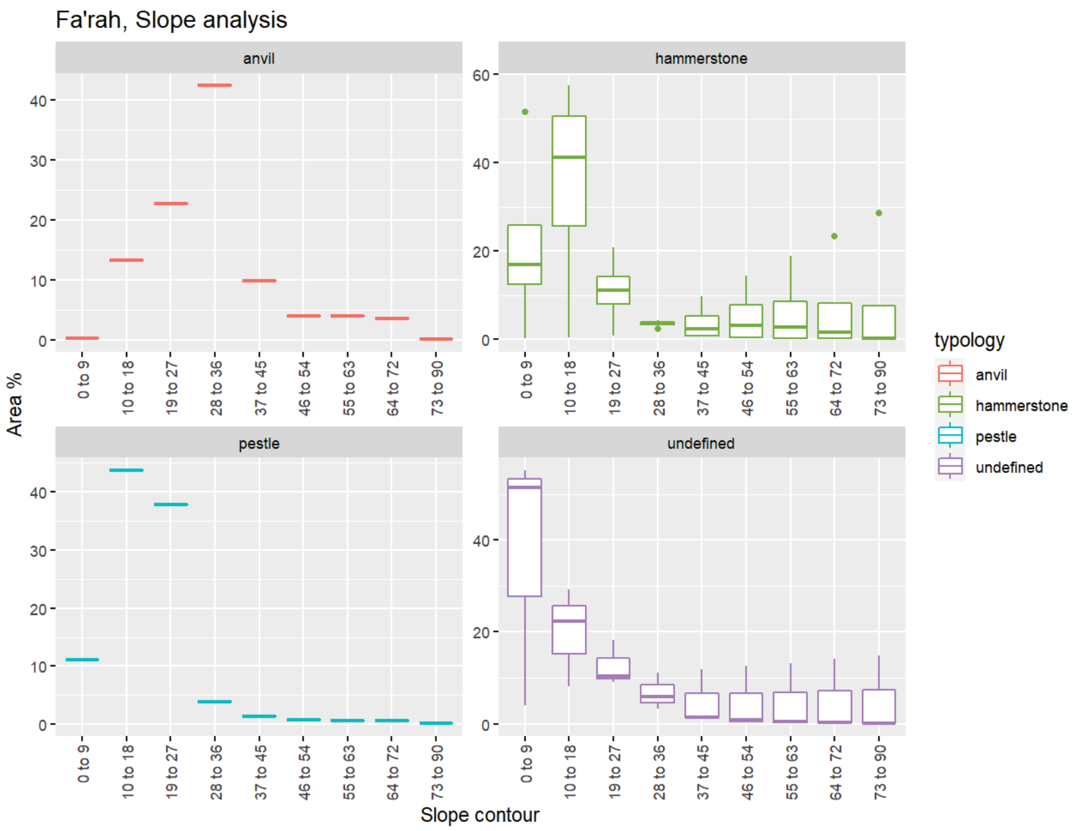

```
ggsave("../plots/slopeparts_fr.png")

## Saving 8.5 x 6.5 in image

# Ein Qashish
newslopeeq$contourelev <- factor(newslopeeq$contourelev, levels=c("0 to 9",
                                                                   "10 to 18",
                                                                   "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopeparts_eq <- ggplot(newslopeeq, aes(x = contourelev, y = nparts, colour = typology)) +
  geom_boxplot() +
  ggtitle("Ein Qashish, Slope parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopeparts_eq
```



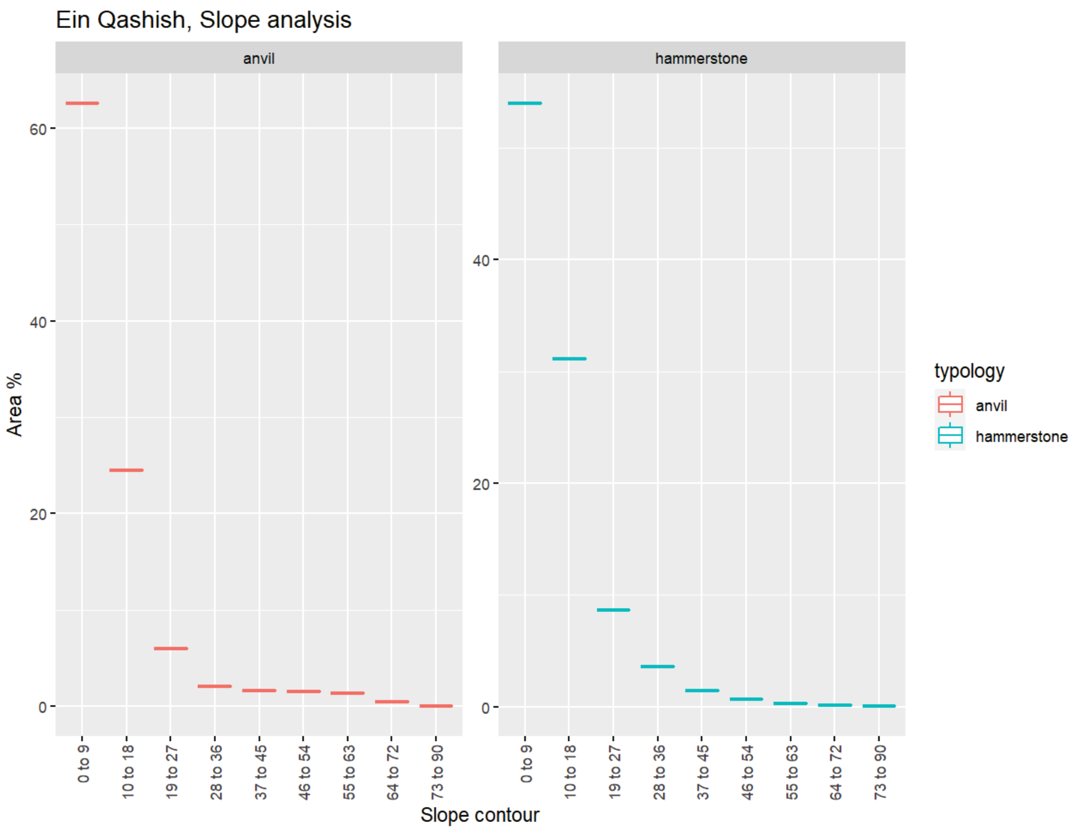

```
ggsave("../plots/slopeparts_eq.png")

## Saving 8.5 x 6.5 in image

# Nesher Ramla

newslopenr$contourelev <- factor(newslopenr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopeparts_nr <- ggplot(newslopenr, aes(x = contourelev, y = nparts, colour = typology)) +
  geom_boxplot() +
  ggtitle("Nesher Ramla, Slope parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopeparts_nr
```



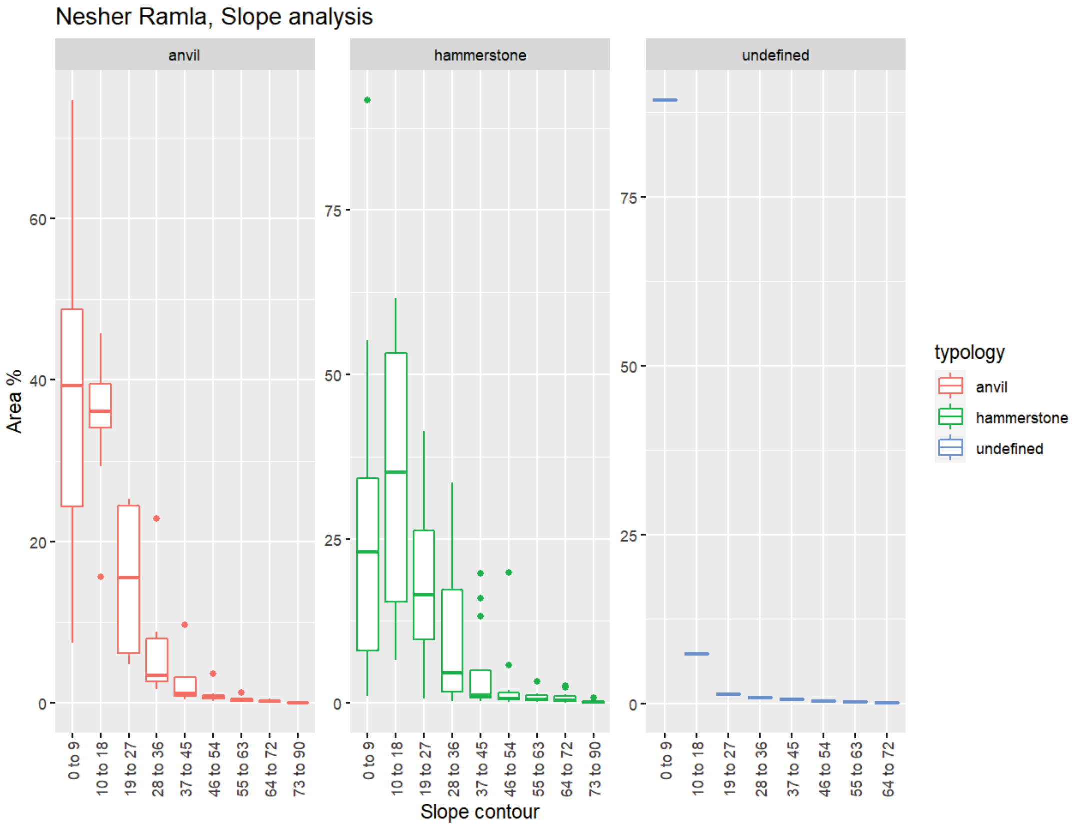

```
ggsave("../plots/slopeparts_nr.png")

## Saving 8.5 x 6.5 in image

# Area %, per site

# Fa'rah
newslopefr$contourelev <- factor(newslopefr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopetypology_fr <- ggplot(newslopefr, aes(x = contourelev, y = areaperc, colour = typology
)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Fa'rah, Slope analysis") +
  ylab("Area %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopetypology_fr
```



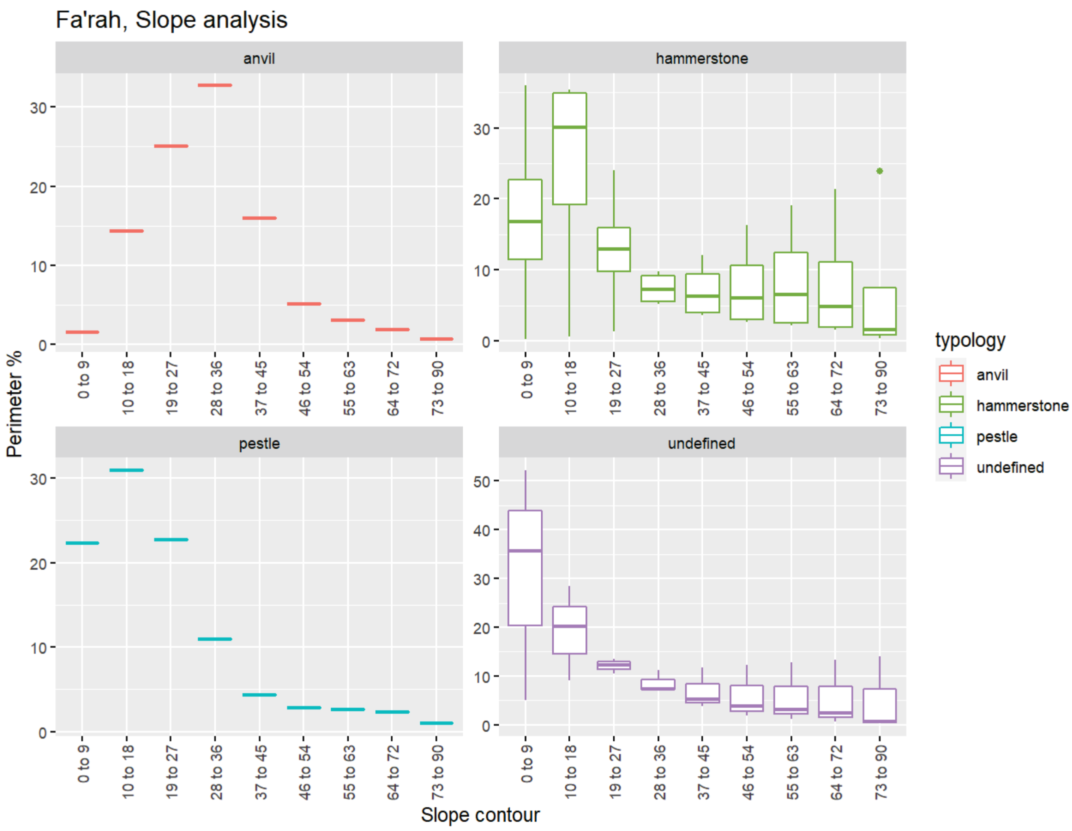

```r
ggsave("../plots/slopetypology_fr.png")

## Saving 8.5 x 6.5 in image

# Ein Qashish
newslopeeq$contourelev <- factor(newslopeeq$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopetypology_eq <- ggplot(newslopeeq, aes(x = contourelev, y = areaperc, colour = typology
)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Ein Qashish, Slope analysis") +
  ylab("Area %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopetypology_eq
```



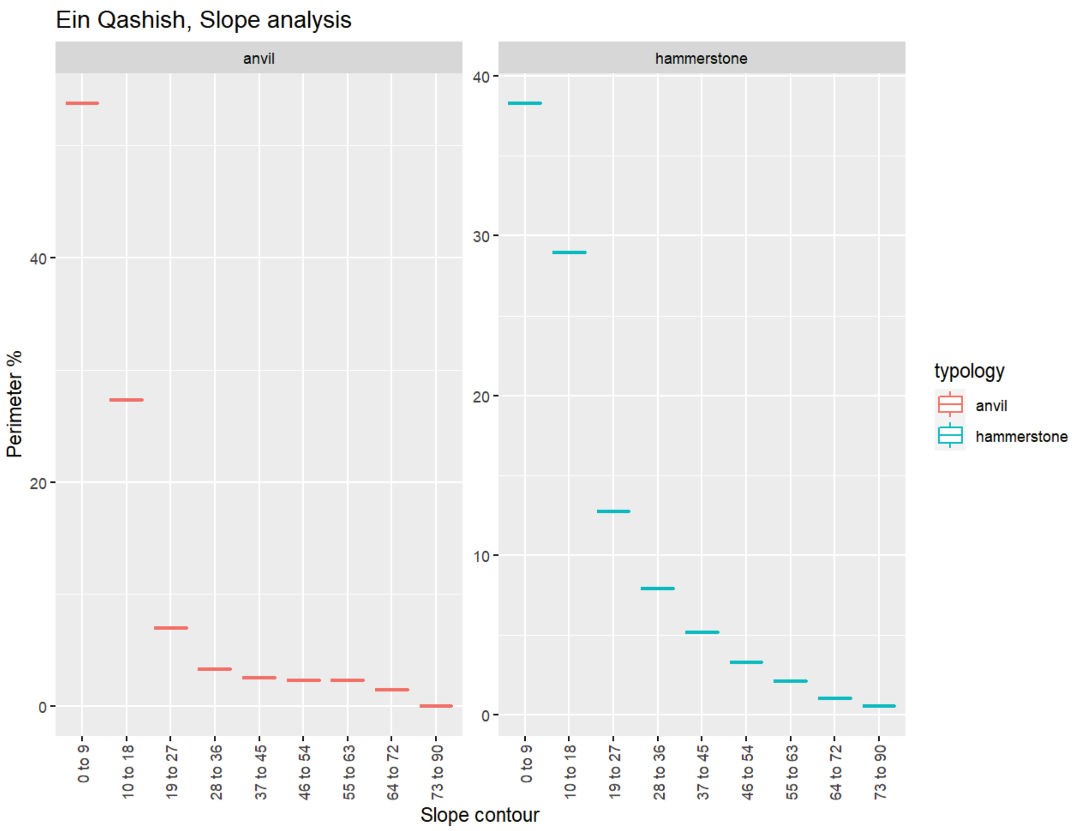

```
ggsave("../plots/slopetypology_eq.png")

## Saving 8.5 x 6.5 in image

# Nesher Ramla

newslopenr$contourelev <- factor(newslopenr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slopetypology_nr <- ggplot(newslopenr, aes(x = contourelev, y = areaperc, colour = typology
)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Nesher Ramla, Slope analysis") +
  ylab("Area %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slopetypology_nr
```



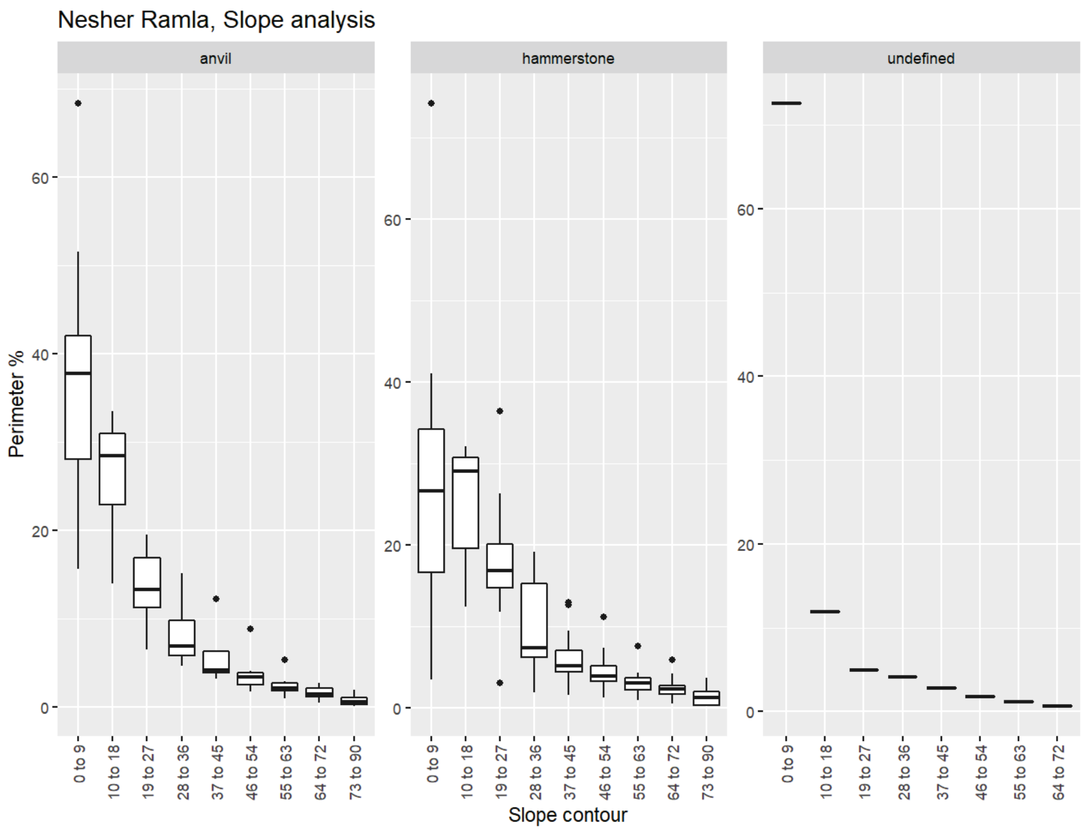

```r
ggsave("../plots/slopetypology_nr.png")

## Saving 8.5 x 6.5 in image

# Perimeter %

# Fa'rah
newslopefr$contourelev <- factor(newslopefr$contourelev, levels=c("0 to 9",
                                                                   "10 to 18",
                                                                   "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))
slope_perim_typology_fr <- ggplot(newslopefr, aes(x = contourelev, y = perimperc, colour =
typology)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Fa'rah, Slope analysis") +
  ylab("Perimeter %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slope_perim_typology_fr
```




```
ggsave("../plots/slope_perim_typology_fr.png")

## Saving 8.5 x 6.5 in image

# Ein Qashish, only two observations
newslopeeq$contourelev <- factor(newslopeeq$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slope_perim_typology_eq <- ggplot(newslopeeq, aes(x = contourelev, y = perimperc, colour =
typology)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Ein Qashish, Slope analysis") +
  ylab("Perimeter %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slope_perim_typology_eq
```




```
ggsave("../plots/slope_perim_typology_eq.png")

## Saving 8.5 x 6.5 in image

# Nesher Ramla, only tree observations
newslopenr$contourelev <- factor(newslopenr$contourelev, levels=c("0 to 9",
                                                                  "10 to 18",
                                                                  "19 to 27", "28 to 36", "
37 to 45", "46 to 54", "55 to 63", "64 to 72", "73 to 90"))

slope_perim_typology_nr <- ggplot(newslopenr, aes(x = contourelev, y = perimperc)) +
  geom_boxplot() +
  facet_wrap(~typology, scale = "free") +
  ggtitle("Nesher Ramla, Slope analysis") +
  ylab("Perimeter %") +
  xlab("Slope contour") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

slope_perim_typology_nr
```

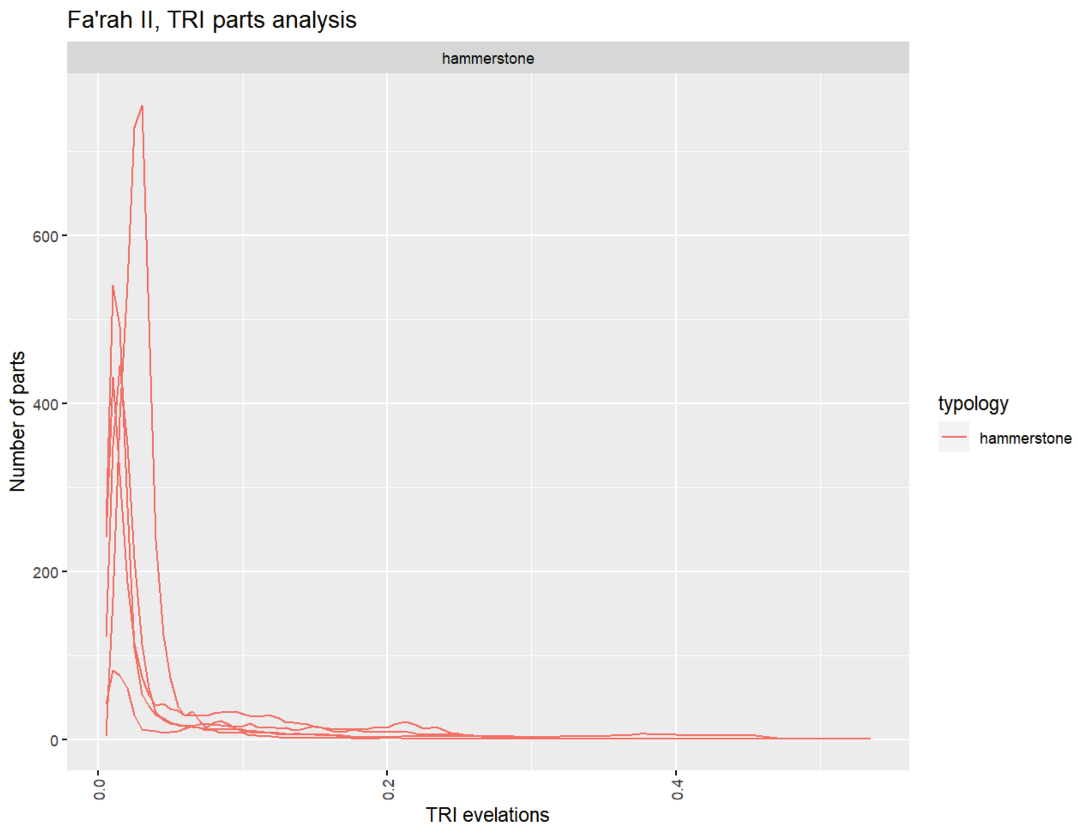



```r
ggsave("../plots/slope_perim_typology_nr.png")

## Saving 8.5 x 6.5 in image
```

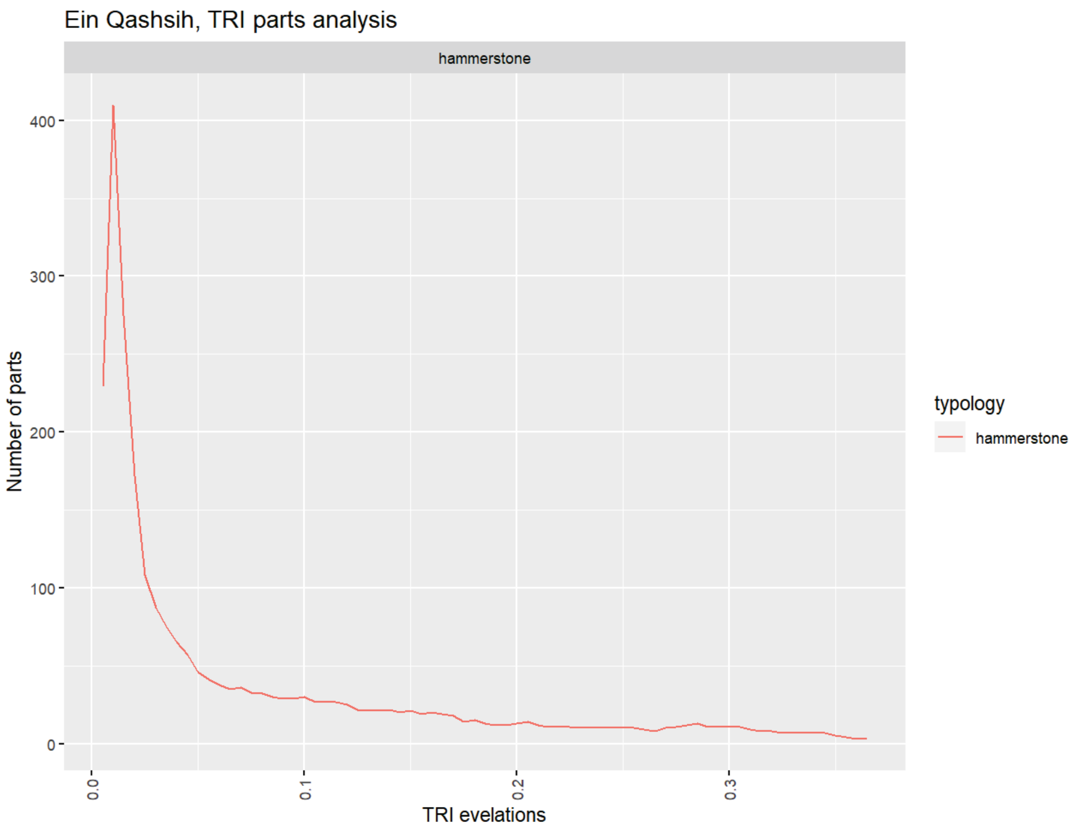
TRI (Terrain roughness index)

```r
# filter

trifr <- filter(db1fr, parameter == "tri")
trieq <- filter(db1eq, parameter == "tri")
trinr <- filter(db1nr, parameter == "tri")

# calculate proportions (percentages %)

trifr <- trifr %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

trieq <- trieq %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

trinr <- trinr %>%
  group_by(sampleid) %>%
  mutate(
    areaperc = area / sum(area) * 100,
```

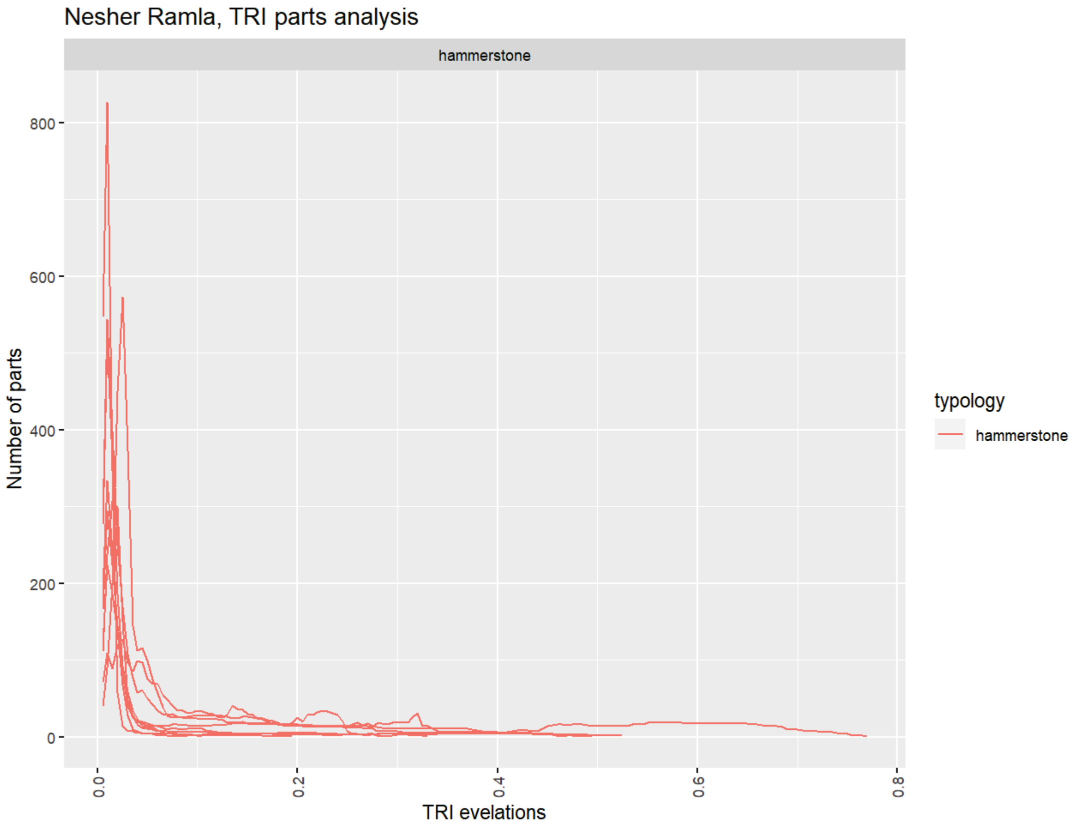
```r
    perimperc = perimeter / sum(perimeter) * 100)

# Bind new datasets

newtri <- do.call("rbind", list(trifr, trieq, trinr))

# save outputs

write_csv(newtri,"../derived_data/newtri_arch.csv")

# Plot data

# Fa'rah II
newtrifr <- filter(newtri, site == "FARAII")
# Ein Qashish
newtrieq <- filter(newtri, site == "EIN_QUASHISH")
# Nesher Ramla
newtrinr <- filter(newtri, site  == "NESHER_RAMLA")

# Number of parts

# Fa'rah
triparts_fr <- ggplot(newtrifr, aes(x = elev_max, y = nparts, colour = typology)) +
  geom_line(aes(group = sampleid)) +
  ggtitle("Fa'rah II, TRI parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
  xlab("TRI evelations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

triparts_fr
```



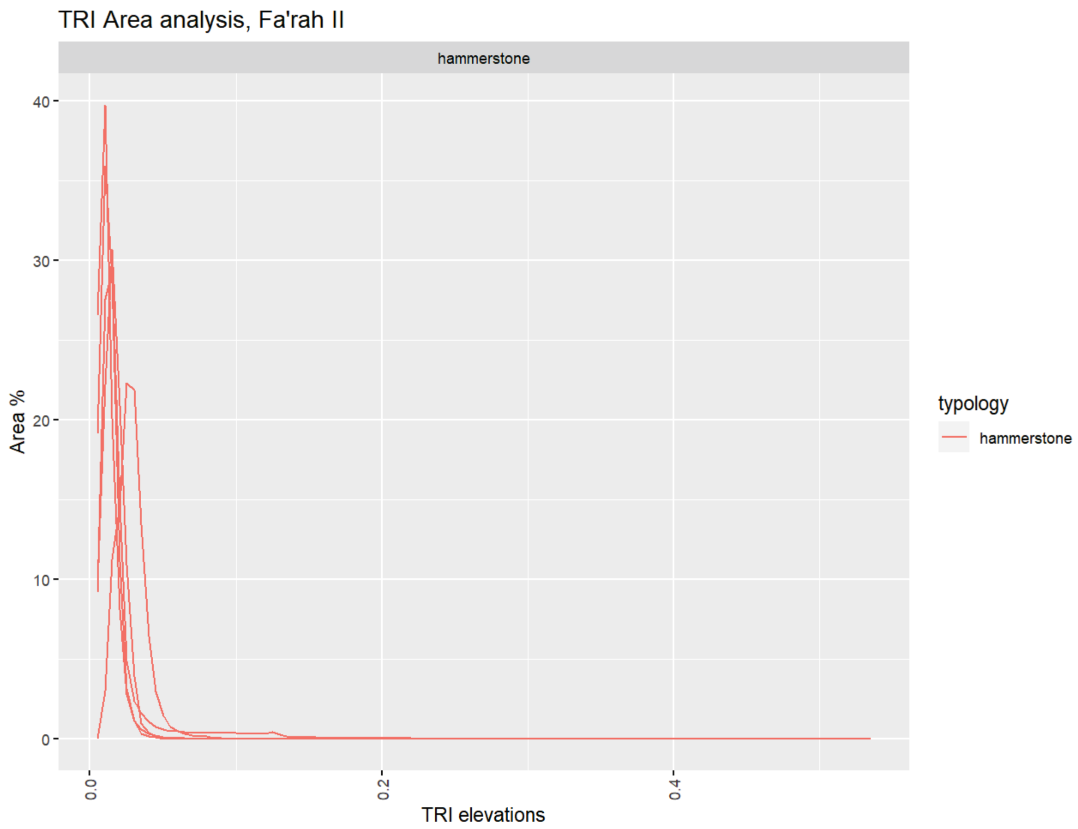

```r
ggsave("../plots/triparts_fr.png")

## Saving 8.5 x 6.5 in image

# Ein Qashish
triparts_eq <- ggplot(newtrieq, aes(x = elev_max, y = nparts, colour = typology)) +
  geom_line(aes(group = sampleid)) +
  ggtitle("Ein Qashsih, TRI parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
  xlab("TRI evelations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

triparts_eq
```



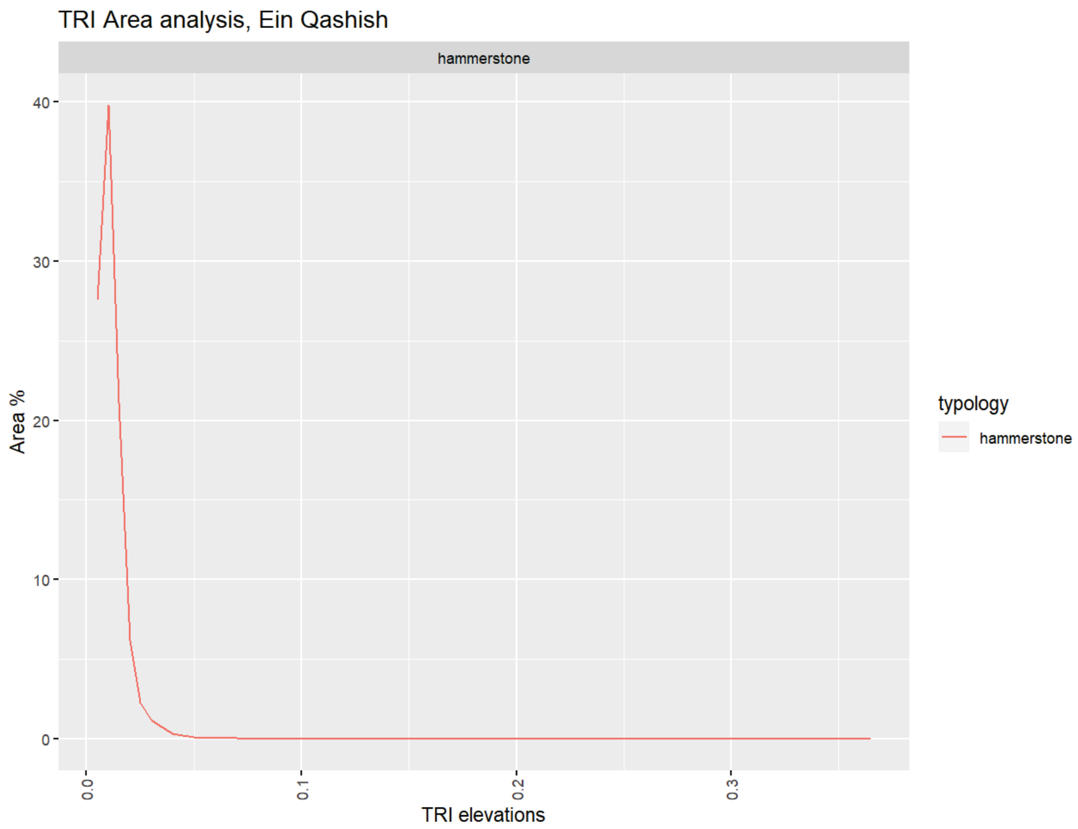

```r
ggsave("../plots/triparts_eq.png")

## Saving 8.5 x 6.5 in image

# Nesher Ramla
triparts_nr <- ggplot(newtrinr, aes(x = elev_max, y = nparts, colour = typology)) +
  geom_line(aes(group = sampleid)) +
  ggtitle("Nesher Ramla, TRI parts analysis") +
  facet_wrap(~typology, scale = "free") +
  ylab("Number of parts") +
  xlab("TRI evelations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

triparts_nr
```



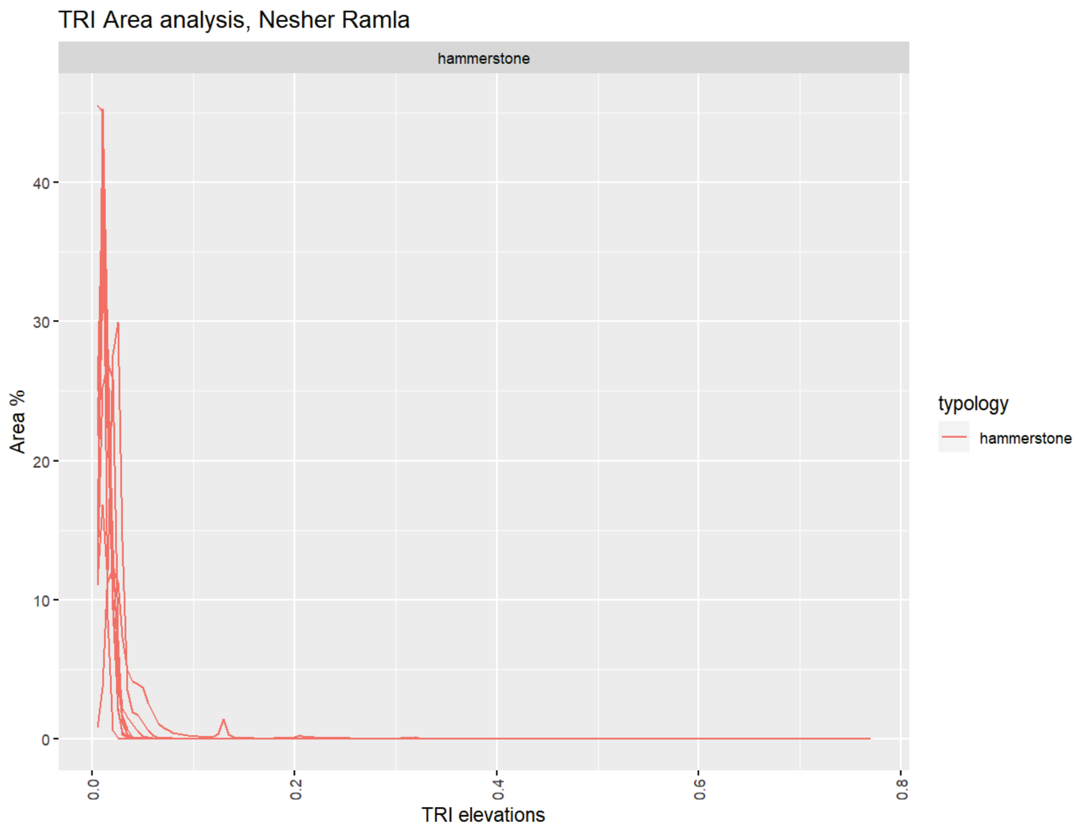

```
ggsave("../plots/triparts_nr.png")

## Saving 8.5 x 6.5 in image

# Area %, per site

# Fa'rah
tritypology_fr <- ggplot(newtrifr, aes(x = elev_max, y = areaperc, colour = typology)) +
  geom_line(aes(group = sampleid)) +
  ggtitle("TRI Area analysis, Fa'rah II") +
  facet_wrap(~typology, scale = "free") +
  ylab("Area %") +
  xlab("TRI elevations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

tritypology_fr
```



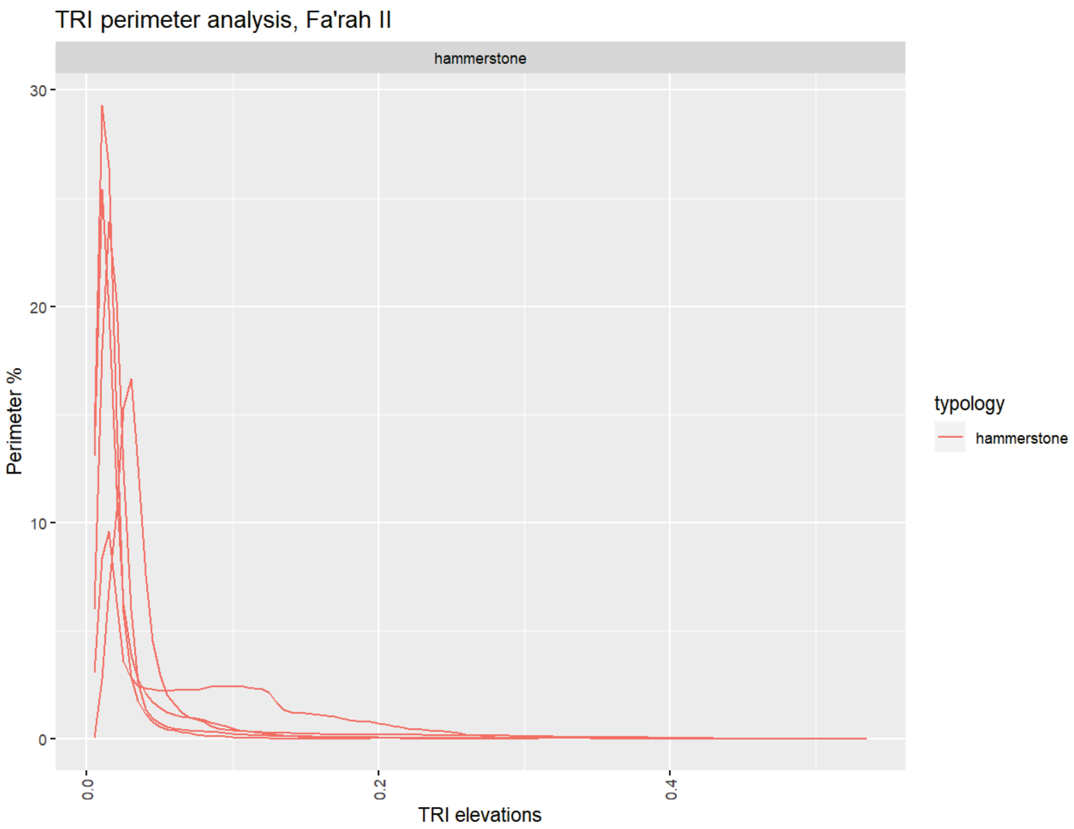

```r
ggsave("../plots/tritypology_fr.png")

## Saving 8.5 x 6.5 in image

# Ein Qashish
tritypology_eq <- ggplot(newtrieq, aes(x = elev_max, y = areaperc, colour = typology)) +
  geom_line(aes(group = sampleid)) +
  ggtitle("TRI Area analysis, Ein Qashish") +
  facet_wrap(~typology, scale = "free") +
  ylab("Area %") +
  xlab("TRI elevations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

tritypology_eq
```



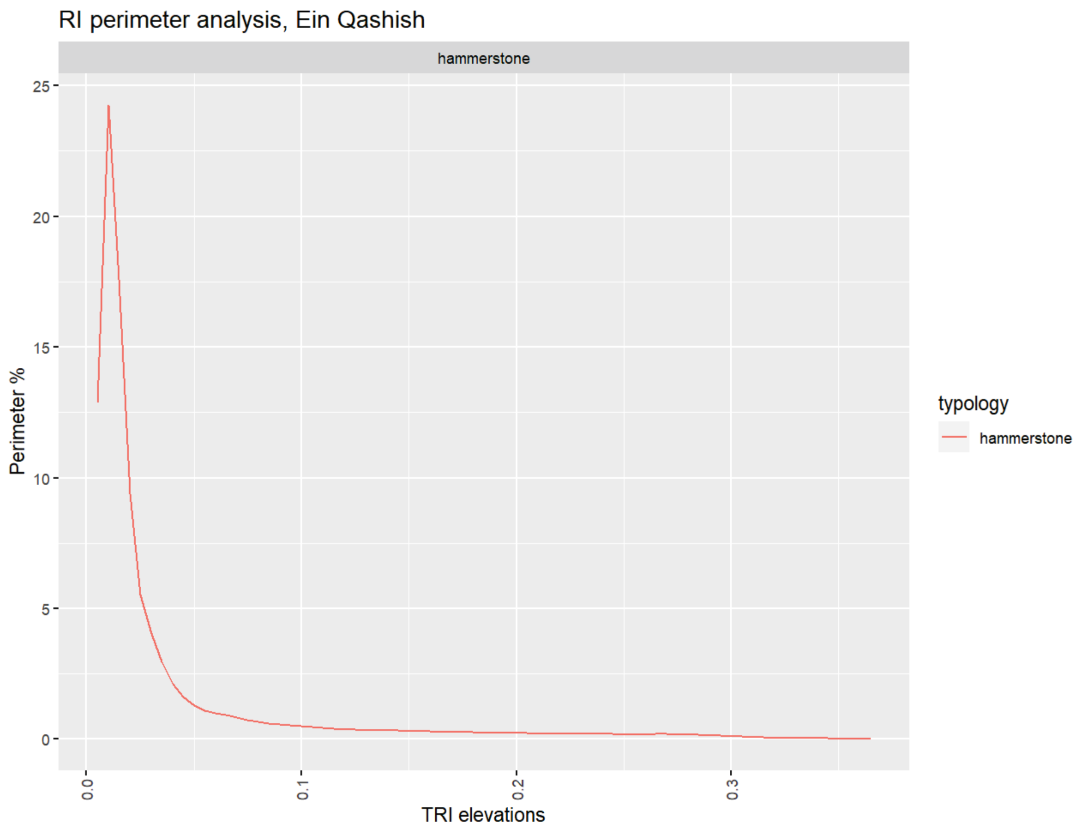

```
ggsave("../plots/tritypology_eq.png")

## Saving 8.5 x 6.5 in image

# Nesher Ramla
tritypology_nr <- ggplot(newtrinr, aes(x = elev_max, y = areaperc, colour = typology)) +
  geom_line(aes(group = sampleid)) +
  ggtitle("TRI Area analysis, Nesher Ramla") +
  facet_wrap(~typology, scale = "free") +
  ylab("Area %") +
  xlab("TRI elevations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

tritypology_nr
```



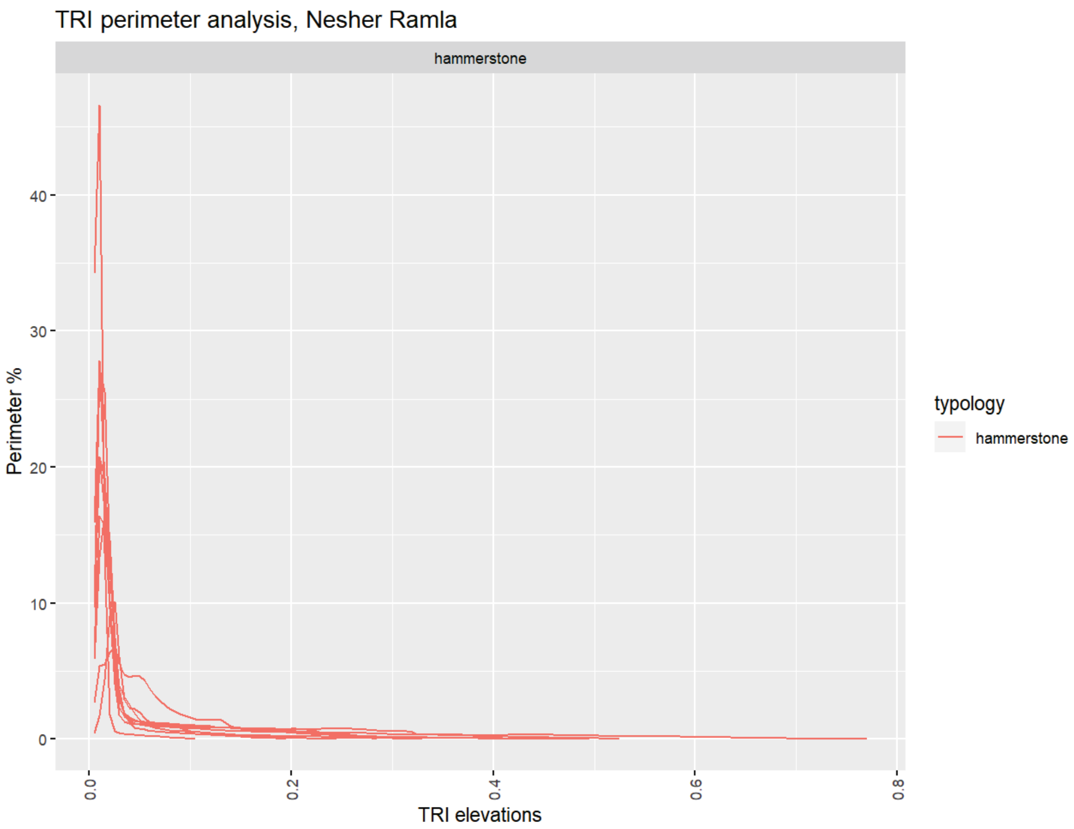

```r
ggsave("../plots/tritypology_nr.png")

## Saving 8.5 x 6.5 in image

# Perimeter %

# Fa'rah II
tri_perim_typology_fr <- ggplot(newtrifr, aes(x = elev_max, y = perimperc, colour = typolog
y)) +
  geom_line(aes(group = sampleid)) +
  facet_wrap(~typology, scale = "free") +
  ggtitle("TRI perimeter analysis, Fa'rah II") +
  facet_wrap(~typology, scale = "free") +
  ylab("Perimeter %") +
  xlab("TRI elevations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

tri_perim_typology_fr
```




```
ggsave("../plots/tri_perim_typology_fr.png")

## Saving 8.5 x 6.5 in image

# Ein Qashish
tri_perim_typology_eq <- ggplot(newtrieq, aes(x = elev_max, y = perimperc, colour = typolog
y)) +
  geom_line(aes(group = sampleid)) +
  ggtitle("RI perimeter analysis, Ein Qashish") +
  facet_wrap(~typology, scale = "free") +
  ylab("Perimeter %") +
  xlab("TRI elevations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

tri_perim_typology_eq
```




```
ggsave("../plots/tri_perim_typology_eq.png")

## Saving 8.5 x 6.5 in image

# Nesher Ramla
tri_perim_typology_nr <- ggplot(newtrinr, aes(x = elev_max, y = perimperc, colour = typolog
y)) +
  geom_line(aes(group = sampleid)) +
  ggtitle("TRI perimeter analysis, Nesher Ramla") +
  facet_wrap(~typology, scale = "free") +
  ylab("Perimeter %") +
  xlab("TRI elevations") +
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))

tri_perim_typology_nr
```




```r
ggsave("../plots/tri_perim_typology_nr.png")

## Saving 8.5 x 6.5 in image
```

End and Session info

```r
sessionInfo()

## R version 4.0.2 (2020-06-22)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 10 x64 (build 18362)
##
## Matrix products: default
##
## locale:
## [1] LC_COLLATE=English_United Kingdom.1252
## [2] LC_CTYPE=English_United Kingdom.1252
## [3] LC_MONETARY=English_United Kingdom.1252
## [4] LC_NUMERIC=C
## [5] LC_TIME=English_United Kingdom.1252
##
## attached base packages:
## [1] tools     stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] ggfortify_0.4.11 ggpubr_0.4.0     doBy_4.6.8       GGally_2.1.0
##  [5] kableExtra_1.3.1 janitor_2.1.0    knitr_1.30       forcats_0.5.0
##  [9] stringr_1.4.0    dplyr_1.0.3      purrr_0.3.4      readr_1.4.0
## [13] tidyr_1.1.2      tibble_3.0.5     ggplot2_3.3.3    tidyverse_1.3.0
##
```

```
## loaded via a namespace (and not attached):
##  [1] httr_1.4.2          jsonlite_1.7.2     viridisLite_0.3.0  carData_3.0-4
##  [5] modelr_0.1.8        assertthat_0.2.1   cellranger_1.1.0   yaml_2.2.1
##  [9] pillar_1.4.7        backports_1.2.1    lattice_0.20-41    glue_1.4.2
## [13] digest_0.6.27       RColorBrewer_1.1-2 ggsignif_0.6.0     rvest_0.3.6
## [17] snakecase_0.11.0    colorspace_2.0-0   htmltools_0.5.1    Matrix_1.2-18
## [21] plyr_1.8.6          pkgconfig_2.0.3    broom_0.7.3        haven_2.3.1
## [25] scales_1.1.1        webshot_0.5.2      openxlsx_4.2.3     rio_0.5.16
## [29] farver_2.0.3        generics_0.1.0     car_3.0-10         ellipsis_0.3.1
## [33] withr_2.4.0         cli_2.2.0          magrittr_2.0.1     crayon_1.3.4
## [37] readxl_1.3.1        evaluate_0.14      fs_1.5.0           fansi_0.4.2
## [41] MASS_7.3-53         rstatix_0.6.0      xml2_1.3.2         foreign_0.8-80
## [45] data.table_1.13.6  hms_1.0.0          lifecycle_0.2.0    munsell_0.5.0
## [49] reprex_0.3.0        zip_2.1.1          Deriv_4.1.2        compiler_4.0.2
## [53] rlang_0.4.10        grid_4.0.2         rstudioapi_0.13    labeling_0.4.2
## [57] rmarkdown_2.6       gtable_0.3.0       abind_1.4-5        DBI_1.1.1
## [61] reshape_0.8.8       curl_4.3           R6_2.5.0           gridExtra_2.3
## [65] lubridate_1.7.9.2  stringi_1.5.3      Rcpp_1.0.6         vctrs_0.3.6
## [69] dbplyr_2.0.0        tidyselect_1.1.0   xfun_0.20
```

1.6. Experiments GIS data analysis

Paixão PhD - experiments GIS data analysis

EP

2021-02-03 09:29:08

Brief description of the script

This R markdown document reads, summarizes and plots data for the PhD dissertation *Paixão 2021. Groundbreaking technologies in the Middle Paleolithic of the Levant: High resolution functional analysis of Ground Stone Tools*

The document contains:

1. Tables
2. Plots (illustrations of the data analysis)
3. Supplementary material, including extra tables and figures (data analysis)

This R project and respective scripts follow the procedures described by Marwick et al. 2017.

To compile this markdown document do not delete or move files from their original folders. Please note that most of the tables and figures in this file do not match the numbering in the PhD dissertation manuscript.

For any questions, comments and inputs, please contact:

Eduardo Paixão, paixao@rgzm.de

Load data into R project

Imported files are in: '../analysis/raw_data'

Figures are saved in: '../analysis/plots'

Tables are saved in: '../analysis/derived_data'

Load libraries

```
library(tidyverse)

## -- Attaching packages --------------------------------------- tidyverse 1.3.0 --

## v ggplot2 3.3.3     v purrr   0.3.4
## v tibble  3.0.5     v dplyr   1.0.3
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.0

## Warning: package 'ggplot2' was built under R version 4.0.3

## Warning: package 'readr' was built under R version 4.0.3

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(utils)
library(knitr)
library(janitor)

## Warning: package 'janitor' was built under R version 4.0.3

##
## Attaching package: 'janitor'

## The following objects are masked from 'package:stats':
##
##     chisq.test, fisher.test

library(kableExtra)

## Warning: package 'kableExtra' was built under R version 4.0.3

##
## Attaching package: 'kableExtra'

## The following object is masked from 'package:dplyr':
##
##     group_rows

library(GGally)

## Warning: package 'GGally' was built under R version 4.0.3

## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2

library(doBy)

## Warning: package 'doBy' was built under R version 4.0.3

##
## Attaching package: 'doBy'

## The following object is masked from 'package:dplyr':
##
##     order_by

library(ggpubr)
library(ggfortify)

## Warning: package 'ggfortify' was built under R version 4.0.3

library(tools)
```

Import datasets

```
gisdata <- read.delim("../raw_data/gisdata.csv", sep = ",")
data_file <- list.files("../raw_data/", pattern = "\\.csv$", full.names = TRUE)
```

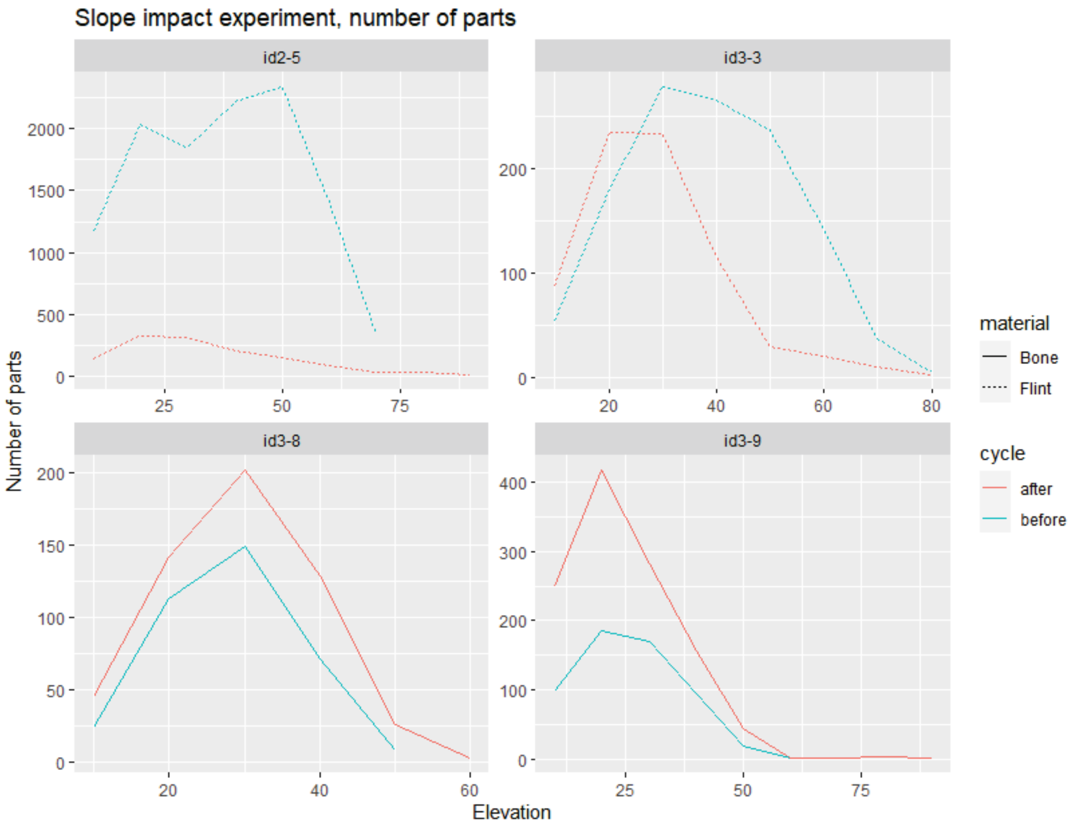
GIS analysis, Terrain analysis for Slope and TRI based on the 3D surface point clouds

Slope

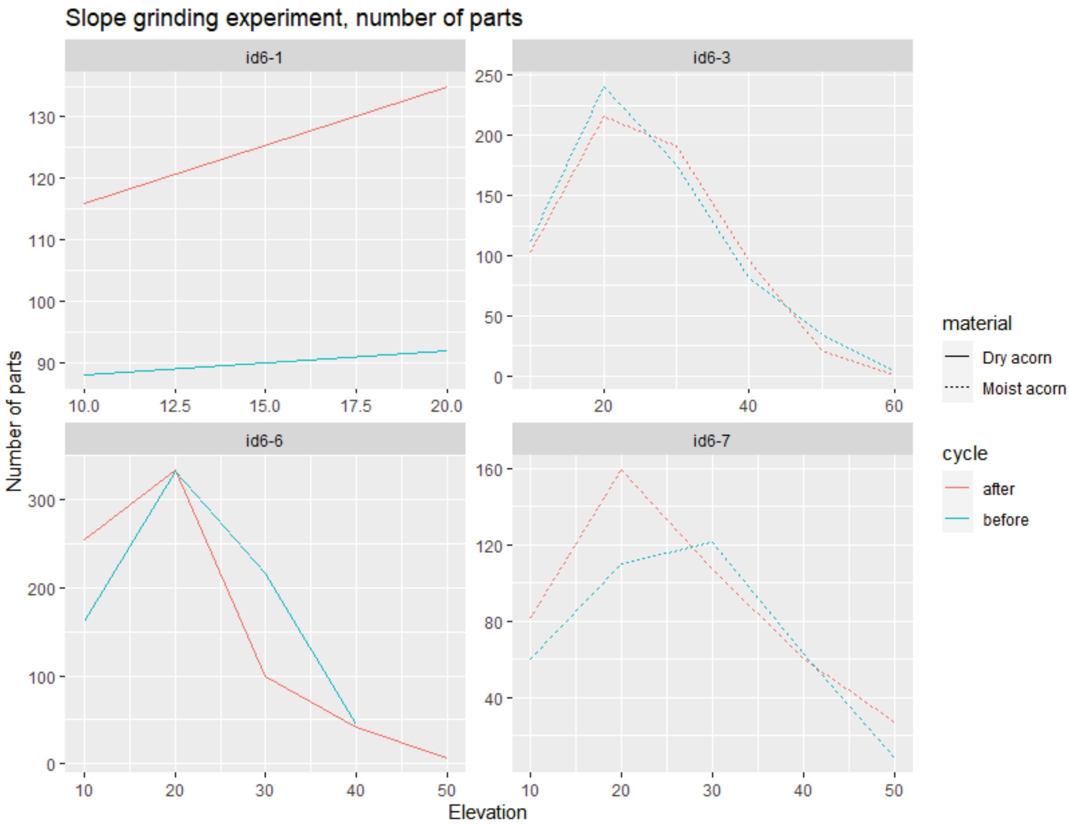
```
# Compute proportions for perimeter and area grouped by sample and GIS parameter

slope <- filter(gisdata, parameter == "slope")
slopebefore <- filter(slope, cycle == "before")
slopeafter <-  filter(slope, cycle == "after")

# before experimental cycles (i.e. natural surfaces)

id2.5before <- filter(slopebefore, sample == "id2-5")
id3.3before <- filter(slopebefore, sample == "id3-3")
id3.8before <- filter(slopebefore, sample == "id3-8")
id3.9before <- filter(slopebefore, sample == "id3-9")
id6.1before <- filter(slopebefore, sample == "id6-1")
id6.3before <- filter(slopebefore, sample == "id6-3")
id6.6before <- filter(slopebefore, sample == "id6-6")
id6.7before <- filter(slopebefore, sample == "id6-7")

id2.5before <- id2.5before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.3before <- id3.3before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.8before <- id3.8before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.9before <- id3.9before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.1before <- id6.1before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.3before <- id6.3before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.6before <- id6.6before %>%
  group_by(sample) %>%
  mutate(
```

```
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.7before <- id6.7before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

# after experimental cycles

id2.5after <- filter(slopeafter, sample == "id2-5")
id3.3after <- filter(slopeafter, sample == "id3-3")
id3.8after <- filter(slopeafter, sample == "id3-8")
id3.9after <- filter(slopeafter, sample == "id3-9")
id6.1after <- filter(slopeafter, sample == "id6-1")
id6.3after <- filter(slopeafter, sample == "id6-3")
id6.6after <- filter(slopeafter, sample == "id6-6")
id6.7after <- filter(slopeafter, sample == "id6-7")

id2.5after <- id2.5after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.3after <- id3.3after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.8after <- id3.8after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.9after <- id3.9after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.1after <- id6.1after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.3after <- id6.3after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.6after <- id6.6after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
```

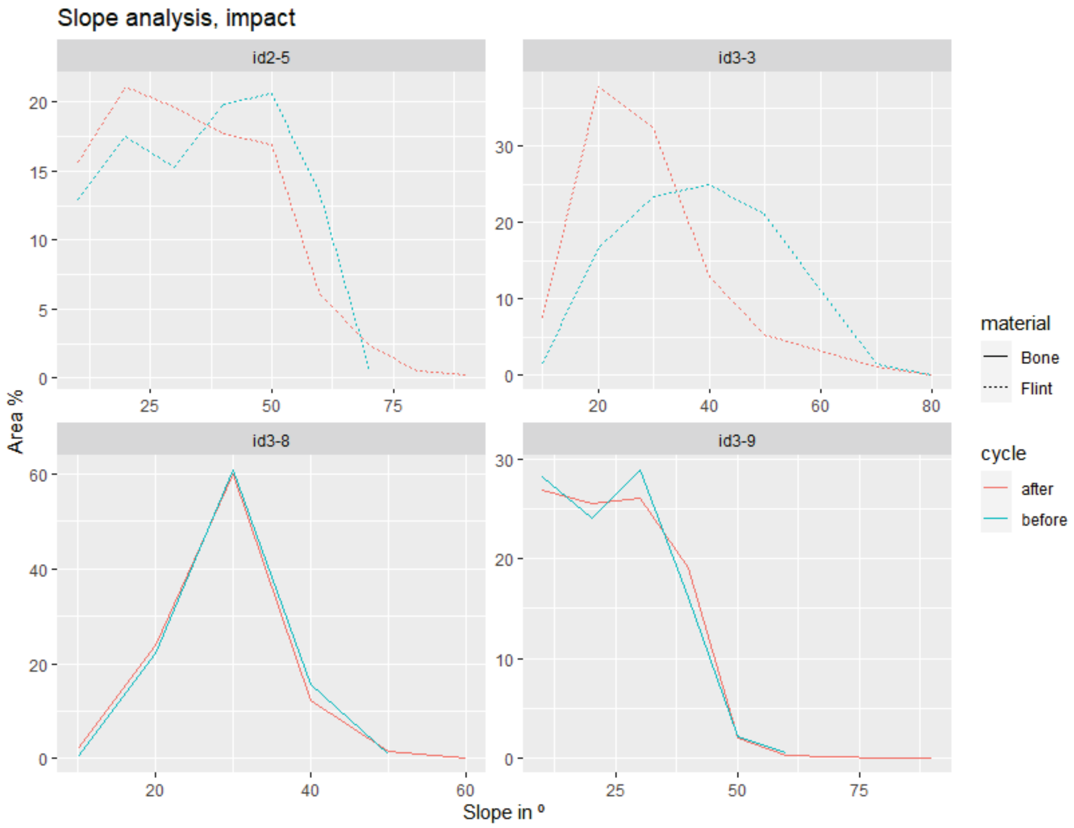
```
    perimperc = perimeter / sum(perimeter) * 100)

id6.7after <- id6.7after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)


newslope <- do.call("rbind", list(id2.5before, id3.3before, id3.8before, id3.9before, id6.1
before, id6.3before, id6.6before, id6.7before, id2.5after, id3.3after, id3.8after, id3.9aft
er, id6.1after, id6.3after, id6.6after, id6.7after))

# save outputs

write_csv(newslope,"../derived_data/newslope.csv")

# Plot data

# Number of parts

impactdf <- filter(newslope, motion == "Impact")
grinding <- filter(newslope, motion == "Grinding")

slopepartsexp_impac <- ggplot(impactdf, aes(x = elev_max, y = nparts, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope impact experiment, number of parts") +
    ylab("Number of parts") +
  xlab("Elevation")

slopepartsexp_impac
```



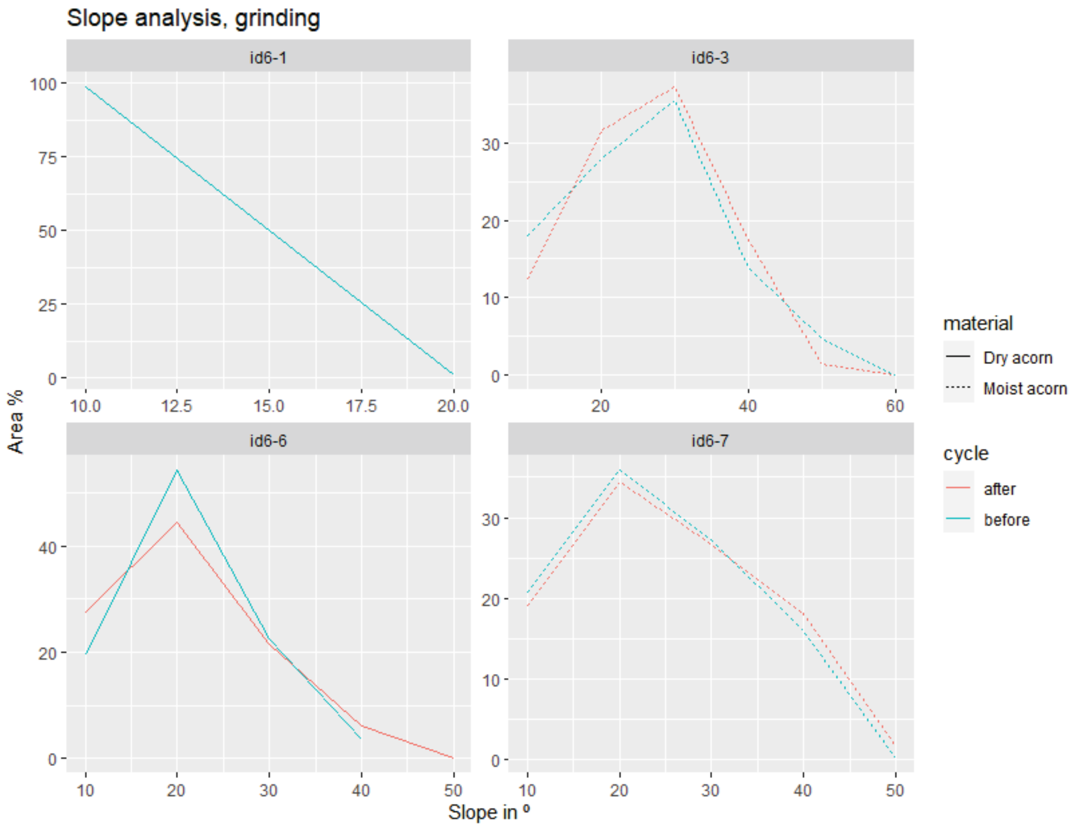

```
ggsave("../plots/slopepartsexp_impac.png")

## Saving 8.5 x 6.5 in image

slopepartsexp_grind <- ggplot(grinding, aes(x = elev_max, y = nparts, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope grinding experiment, number of parts") +
    ylab("Number of parts") +
  xlab("Elevation")

slopepartsexp_grind
```



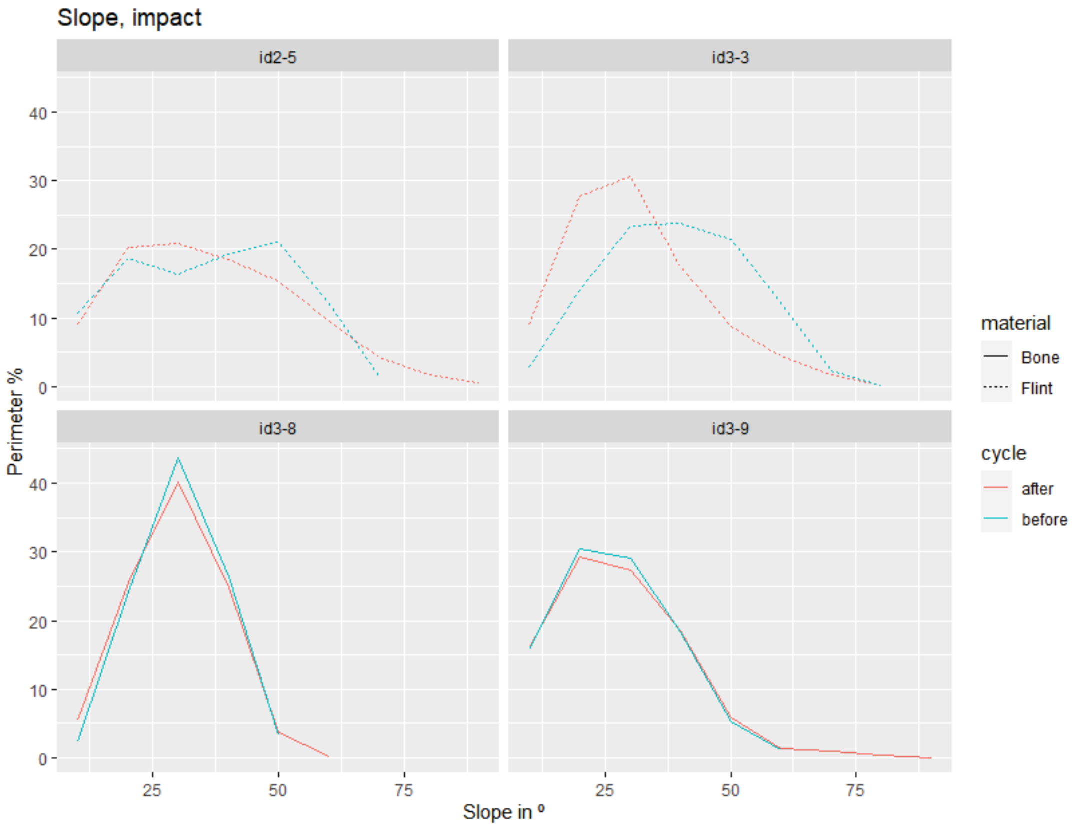

```
ggsave("../plots/slopepartsexp_grind.png")

## Saving 8.5 x 6.5 in image

# Area %

impactdf <- filter(newslope, motion == "Impact")
grinding <- filter(newslope, motion == "Grinding")


areaimpact <- ggplot(impactdf, aes(x = elev_max, y = areaperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope analysis, impact") +
  ylab("Area %") +
  xlab("Slope in º")

areaimpact
```



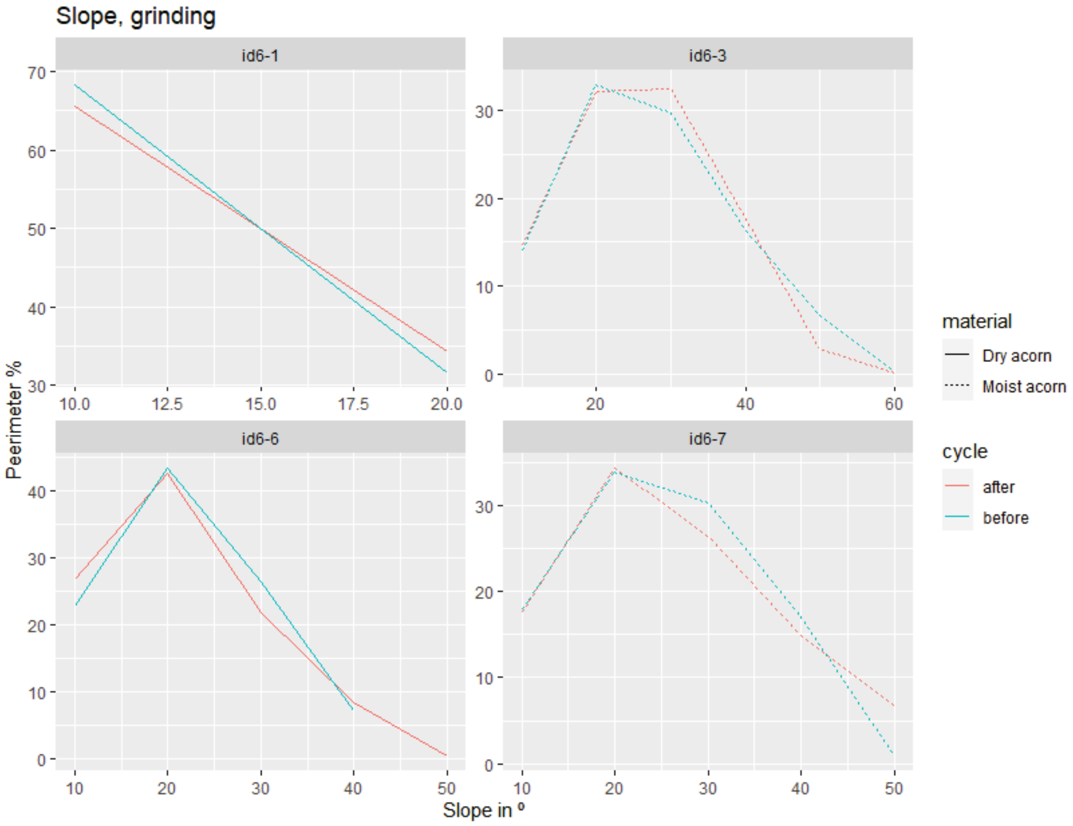

```r
ggsave("../plots/slopeareaimpact.png")

## Saving 8.5 x 6.5 in image

areagrinding <- ggplot(grinding, aes(x = elev_max, y = areaperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope analysis, grinding") +
  ylab("Area %") +
  xlab("Slope in º")

areagrinding
```




```r
ggsave("../plots/slopeareagrinding.png")

## Saving 8.5 x 6.5 in image

# Perimeter %

perimimpact <- ggplot(impactdf, aes(x = elev_max, y = perimperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample) +
  ggtitle("Slope, impact") +
  ylab("Perimeter %") +
  xlab("Slope in º")

perimimpact
```




```r
ggsave("../plots/slopeperimimpact.png")

## Saving 8.5 x 6.5 in image

perimgrinding <- ggplot(grinding, aes(x = elev_max, y = perimperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("Slope, grinding") +
  ylab("Peerimeter %") +
  xlab("Slope in º")

perimgrinding
```




```
ggsave("../plots/slopeperimgrinding.png")

## Saving 8.5 x 6.5 in image
```

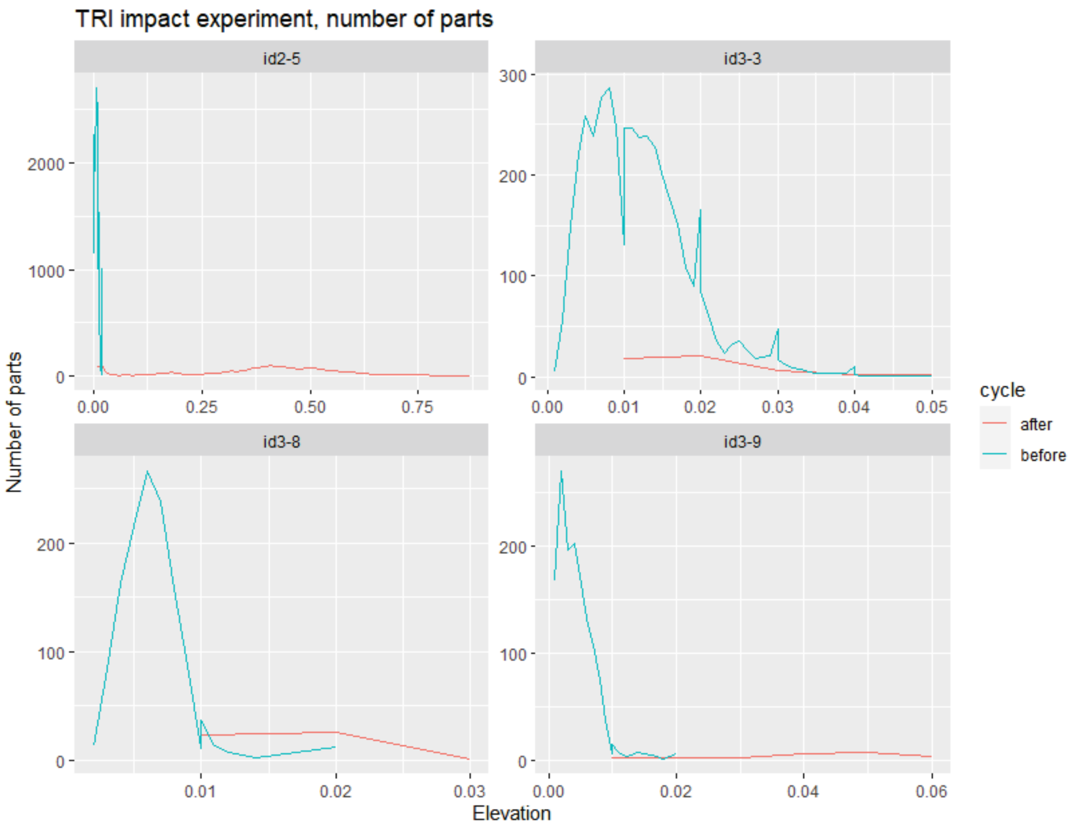
TRI (Terrain roughness index)

```
tri <- filter(gisdata, parameter == "tri")
tribefore <- filter(tri, cycle == "before")
triafter <- filter(tri, cycle =="after")


# before experimental cycles (i.e. natural surfaces)

id2.5before <- filter(tribefore, sample == "id2-5")
id3.3before <- filter(tribefore, sample == "id3-3")
id3.8before <- filter(tribefore, sample == "id3-8")
id3.9before <- filter(tribefore, sample == "id3-9")
id6.1before <- filter(tribefore, sample == "id6-1")
id6.3before <- filter(tribefore, sample == "id6-3")
id6.6before <- filter(tribefore, sample == "id6-6")
id6.7before <- filter(tribefore, sample == "id6-7")

id2.5before <- id2.5before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.3before <- id3.3before %>%
  group_by(sample) %>%
```

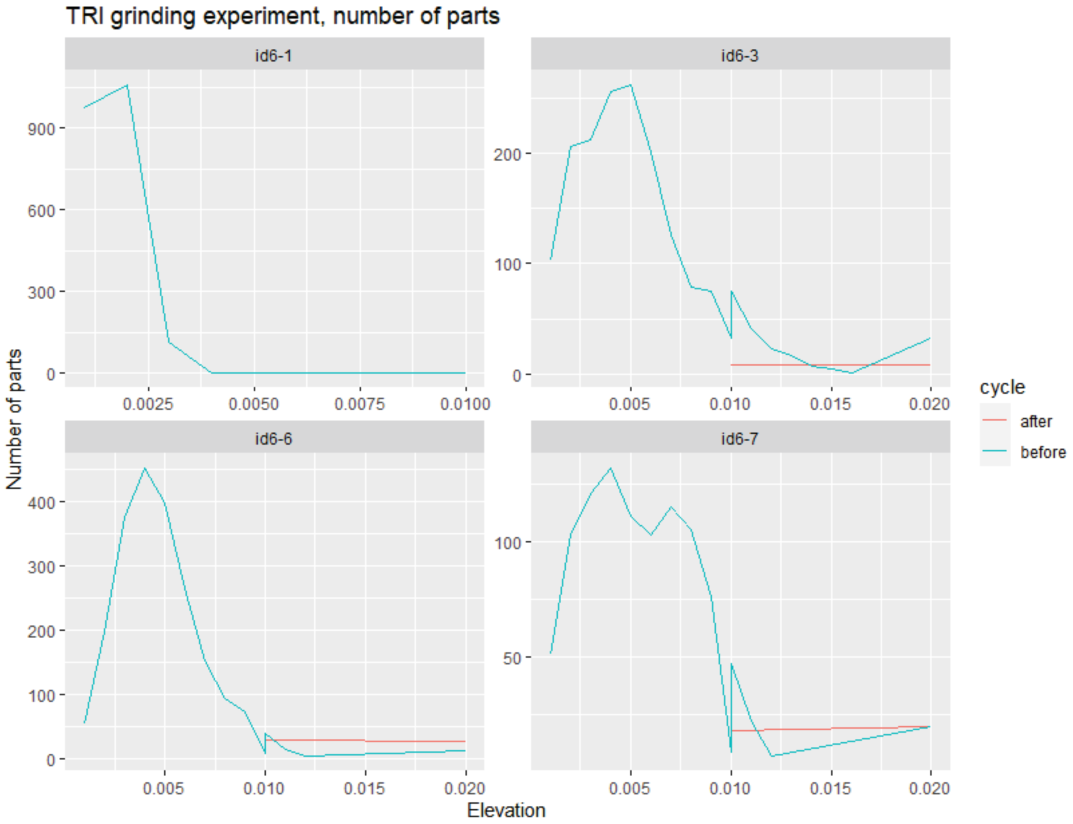
```r
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.8before <- id3.8before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.9before <- id3.9before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.1before <- id6.1before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.3before <- id6.3before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.6before <- id6.6before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.7before <- id6.7before %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)


# after experimental cycles

id2.5after <- filter(triafter, sample == "id2-5")
id3.3after <- filter(triafter, sample == "id3-3")
id3.8after <- filter(triafter, sample == "id3-8")
id3.9after <- filter(triafter, sample == "id3-9")
id6.1after <- filter(triafter, sample == "id6-1")
id6.3after <- filter(triafter, sample == "id6-3")
id6.6after <- filter(triafter, sample == "id6-6")
id6.7after <- filter(triafter, sample == "id6-7")

id2.5after <- id2.5after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.3after <- id3.3after %>%
  group_by(sample) %>%
```

```
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.8after <- id3.8after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id3.9after <- id3.9after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.1after <- id6.1after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.3after <- id6.3after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.6after <- id6.6after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)

id6.7after <- id6.7after %>%
  group_by(sample) %>%
  mutate(
    areaperc = area / sum(area) * 100,
    perimperc = perimeter / sum(perimeter) * 100)


newtri <- do.call("rbind", list(id2.5before, id3.3before, id3.8before, id3.9before, id6.1be
fore, id6.3before, id6.6before, id6.7before, id2.5after, id3.3after, id3.8after, id3.9after
, id6.1after, id6.3after, id6.6after, id6.7after))

# save outputs

write_csv(newtri,"../derived_data/newtri.csv")

# Plot data

# Number of parts

# Motion
impactdf <- filter(newtri, motion == "Impact")
grinding <- filter(newtri, motion == "Grinding")

imapact_parts <- ggplot(impactdf, aes(x = elev_max, y = nparts, colour = cycle)) +
  geom_line() +
```

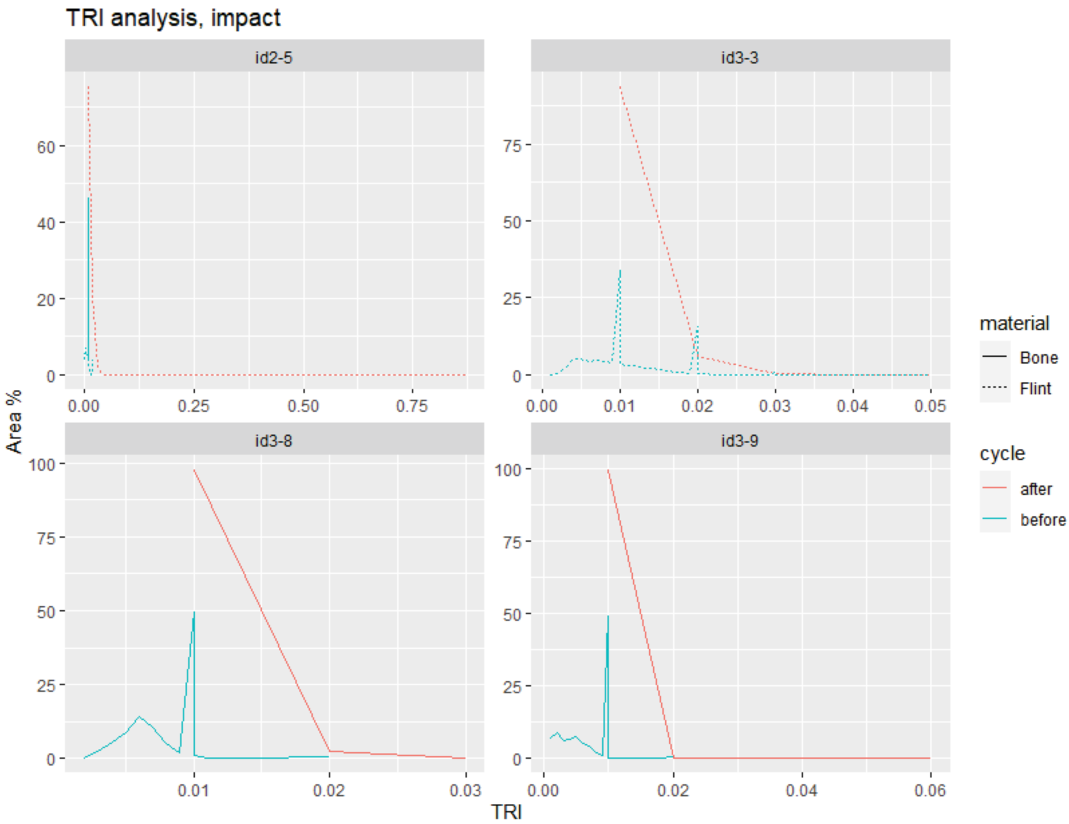
```
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI impact experiment, number of parts") +
    ylab("Number of parts") +
  xlab("Elevation")

imapact_parts
```



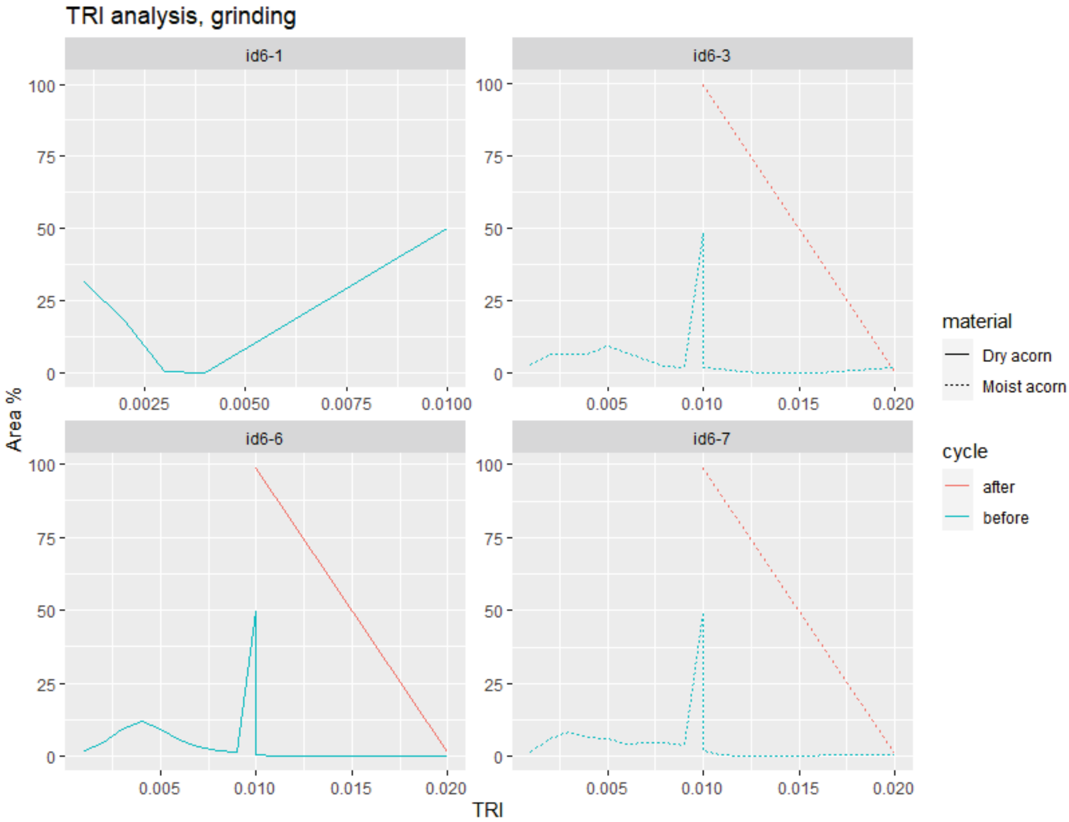

```
ggsave("../plots/tripartsexp_impac.png")

## Saving 8.5 x 6.5 in image

grinding_parts <- ggplot(grinding, aes(x = elev_max, y = nparts, colour = cycle)) +
  geom_line() +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI grinding experiment, number of parts") +
    ylab("Number of parts") +
  xlab("Elevation")

grinding_parts
```



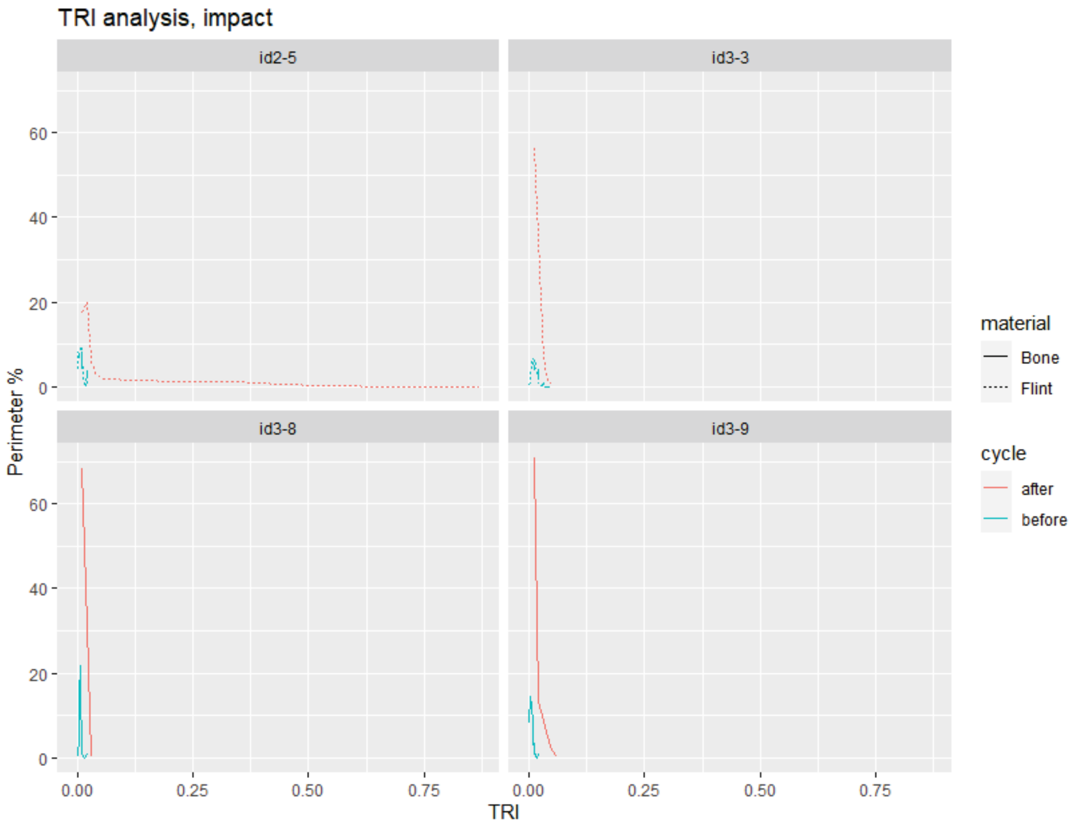

```r
ggsave("../plots/tripartsexp_grind.png")

## Saving 8.5 x 6.5 in image

# Area %

areaimpact <- ggplot(impactdf, aes(x = elev_max, y = areaperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI analysis, impact") +
  ylab("Area %") +
  xlab("TRI")

areaimpact
```



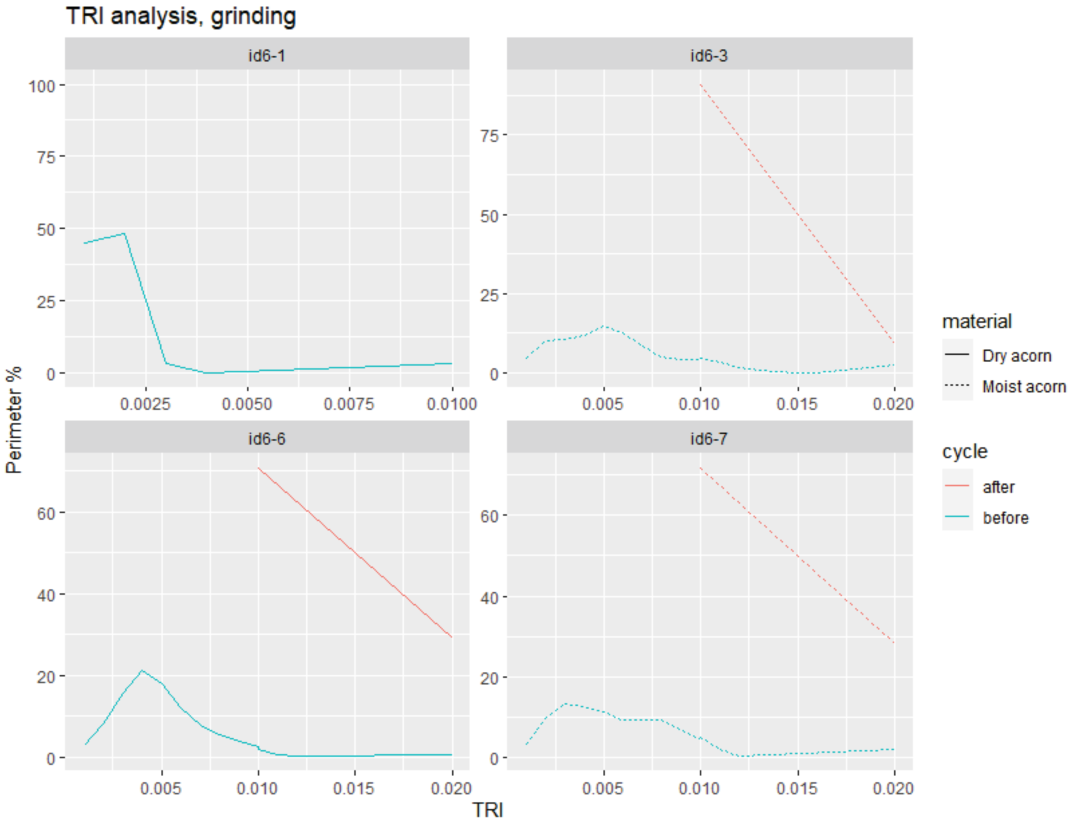

```r
ggsave("../plots/triareaimpact.png")

## Saving 8.5 x 6.5 in image

areagrinding <- ggplot(grinding, aes(x = elev_max, y = areaperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI analysis, grinding") +
  ylab("Area %") +
  xlab("TRI")

areagrinding
```




```r
ggsave("../plots/triareagrinding.png")

## Saving 8.5 x 6.5 in image

# Perimeter %

perimimpact <- ggplot(impactdf, aes(x = elev_max, y = perimperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample) +
  ggtitle("TRI analysis, impact") +
  ylab("Perimeter %") +
  xlab("TRI")

perimimpact
```




```r
ggsave("../plots/triperimimpact.png")

## Saving 8.5 x 6.5 in image

perimgrinding <- ggplot(grinding, aes(x = elev_max, y = perimperc, colour = cycle)) +
  geom_line(aes(linetype = material)) +
  facet_wrap(~sample, scale = "free") +
  ggtitle("TRI analysis, grinding") +
  ylab("Perimeter %") +
  xlab("TRI")

perimgrinding
```




```r
ggsave("../plots/triperimgrinding.png")

## Saving 8.5 x 6.5 in image
```

End and Session info

```r
sessionInfo()

## R version 4.0.2 (2020-06-22)
## Platform: x86_64-w64-mingw32/x64 (64-bit)
## Running under: Windows 10 x64 (build 18362)
##
## Matrix products: default
##
## locale:
## [1] LC_COLLATE=English_United Kingdom.1252
## [2] LC_CTYPE=English_United Kingdom.1252
## [3] LC_MONETARY=English_United Kingdom.1252
## [4] LC_NUMERIC=C
## [5] LC_TIME=English_United Kingdom.1252
##
## attached base packages:
## [1] tools     stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] ggfortify_0.4.11 ggpubr_0.4.0     doBy_4.6.8       GGally_2.1.0
##  [5] kableExtra_1.3.1 janitor_2.1.0    knitr_1.30       forcats_0.5.0
##  [9] stringr_1.4.0    dplyr_1.0.3      purrr_0.3.4      readr_1.4.0
## [13] tidyr_1.1.2      tibble_3.0.5     ggplot2_3.3.3    tidyverse_1.3.0
##
```

```
## loaded via a namespace (and not attached):
##  [1] httr_1.4.2         jsonlite_1.7.2     viridisLite_0.3.0  carData_3.0-4
##  [5] modelr_0.1.8       assertthat_0.2.1   cellranger_1.1.0   yaml_2.2.1
##  [9] pillar_1.4.7       backports_1.2.1    lattice_0.20-41    glue_1.4.2
## [13] digest_0.6.27      RColorBrewer_1.1-2 ggsignif_0.6.0     rvest_0.3.6
## [17] snakecase_0.11.0   colorspace_2.0-0   htmltools_0.5.1    Matrix_1.2-18
## [21] plyr_1.8.6         pkgconfig_2.0.3    broom_0.7.3        haven_2.3.1
## [25] scales_1.1.1       webshot_0.5.2      openxlsx_4.2.3     rio_0.5.16
## [29] farver_2.0.3       generics_0.1.0     car_3.0-10         ellipsis_0.3.1
## [33] withr_2.4.0        cli_2.2.0          magrittr_2.0.1     crayon_1.3.4
## [37] readxl_1.3.1       evaluate_0.14      fs_1.5.0           fansi_0.4.2
## [41] MASS_7.3-53        rstatix_0.6.0      xml2_1.3.2         foreign_0.8-80
## [45] data.table_1.13.6  hms_1.0.0          lifecycle_0.2.0    munsell_0.5.0
## [49] reprex_0.3.0       zip_2.1.1          Deriv_4.1.2        compiler_4.0.2
## [53] rlang_0.4.10       grid_4.0.2         rstudioapi_0.13    labeling_0.4.2
## [57] rmarkdown_2.6      gtable_0.3.0       abind_1.4-5        DBI_1.1.1
## [61] reshape_0.8.8      curl_4.3           R6_2.5.0           gridExtra_2.3
## [65] lubridate_1.7.9.2  stringi_1.5.3      Rcpp_1.0.6         vctrs_0.3.6
## [69] dbplyr_2.0.0       tidyselect_1.1.0   xfun_0.20
```

2. Python scripts for automated GIS analyses

Report on workflow (Script by Geoff Carver)

The following outlines the steps involved in “automatically” processing data from 3D scans. Since processing over 400 scans manually would have been too time-consuming and prone to errors, the work was automated using scripts written in the Python programming language. Python is useful in that it is *relatively* easy for humans to read, open-source, and relatively well documented (although the documentation is often very difficult for anyone without a strong background in computing to comprehend). It is therefore the scripting language used for such open-source software as QGIS, GIMP, etc.

The scripts detailed below all present variations on a theme: a folder is identified, a script file is created, a set of instructions are written to the script file in a specific format for each file that fulfills the identifying criteria, and then the script file is saved (to be run using the appropriate software).

The first step in each script was to loop through all the relevant files and either process them directly (**File conversion**), or write file names into secondary scripts consisting of commands for one of the GIS processing languages, depending on the specific tool being utilised: .json scripts for use with batch processing in QGIS itself, or .bat files running commands for the SAGA tools package.

This may seem complicated, but it basically just involved repeatedly writing strings of text with minor variations: the kind of repetitive task computers were initially designed to do without error.

File conversion

The data in the scan files first had to be reformatted before processing by QGIS. This conversion simply involved rewriting the files as “point clouds” by substituting tabs for commas. This was performed using the following Python script:

```
import os
import glob
import string

# change folder address as necessary
inputFolder = "u:\\eduardo\\input"
outputFolder = "u:\\eduardo\\output"

for path, dir, files in os.walk(inputFolder):
    head, tail = os.path.splitdrive(path)
    for file in files:
        fileNameNoExt, end = os.path.splitext(file)
        if glob.fnmatch.fnmatch(file, "*.txt"):

            InputFile = os.path.join(path + os.sep + fileNameNoExt + ".txt")

            if not os.path.exists(outputFolder + os.sep + fileNameNoExt):
                os.makedirs(outputFolder + os.sep + fileNameNoExt)
```

```
            OutputFile = os.path.join(outputFolder + os.sep + fileNameNoExt + 
os.sep + fileNameNoExt + ".txt")

            with open(InputFile, "r") as coordinates:

                fileOutput = open(OutputFile, "a+")

                for line in coordinates:
                    X,Y,Z = line.split(",")
                    fileOutput.write(X + "\t" + Y + "\t" + Z)
                fileOutput.close()
```

The first three lines import packages necessary for the processing. The input and output folders are identified, and then a loop is defined, which allows the process to be performed on all the files inside the input folder which fulfill a given criterion (i.e. ".txt" files). Output files were then created, named after their source files, and written with tabs ("\t") substituted for commas.

Triangulation and slope

The following script cycles through all the files in a given folder, and writes the commands necessary for creating "TIN" (Triangulated Irregular Network) surfaces from the points in a point cloud file, calculates the "slope" (steepness of the fall from one point to the next) and "aspect" (direction of the fall from one point to the next), then TRI (Terrain Roughness Index) and finally TPI (Topographic Position Index) from the TIN.

```
import os
import glob
import string

# change folder address as necessary
inputFolder = "U:\\output"
outputFolder = "U:\\output"
fileOutput = open("u:\\eduardo-experiments\\SAGA_BAT-generator.bat", "w")
fileOutput.write("@ECHO OFF\n\n")

for path, dir, files in os.walk(inputFolder):
    head, tail = os.path.splitdrive(path)
    for file in files:
        fileNameNoExt, end = os.path.splitext(file)
        if glob.fnmatch.fnmatch(file, "*.txt"):
            inputFile = "u:" + tail + os.sep + file

            head1, tail1 = os.path.split(path)
            head2, tail2 = os.path.splitdrive(path)

            SHP_file = os.path.join(outputFolder + os.sep + fileNameNoExt + 
os.sep + fileNameNoExt + ".shp")
            gridfile = os.path.join(outputFolder + os.sep + fileNameNoExt + 
os.sep + fileNameNoExt + ".sgrd")
            triangle_grid = os.path.join(outputFolder + os.sep + fileNameNoExt 
+ os.sep + fileNameNoExt + "_triangle.tif")
            slope_file = os.path.join(outputFolder + os.sep + fileNameNoExt + 
os.sep + fileNameNoExt + "_slope.tif")
```

```
            aspect_file = os.path.join(outputFolder + os.sep + fileNameNoExt +
os.sep + fileNameNoExt + "_aspect.tif")
            TRI_file = os.path.join(outputFolder + os.sep + fileNameNoExt +
os.sep + fileNameNoExt + "_TRI.tif")
            TPI_file = os.path.join(outputFolder + os.sep + fileNameNoExt +
os.sep + fileNameNoExt + "_TPI.tif")

#triangulation
            triangle = "saga_cmd grid_gridding 5 -POINTS=" + SHP_file + " -
FIELD=3 -TARGET_DEFINITION=0 -TARGET_TEMPLATE=" + gridfile + " -
TARGET_OUT_GRID:" + triangle_grid + "\n"

#slope + aspect
            slope_aspect = "saga_cmd ta_morphometry 0 -ELEVATION=" +
triangle_grid + " -SLOPE=" + slope_file + " -ASPECT=" + aspect_file + "\n"
#TRI_file
            TRI = "saga_cmd ta_morphometry 16 -DEM=" + triangle_grid + " -
TRI=" + TRI_file + "\n"
#TPI_file
            TPI = "saga_cmd ta_morphometry 18 -DEM=" + triangle_grid + " -
TPI=" + TPI_file + "\n"

            fileOutput.write(triangle)
            fileOutput.write(slope_aspect + "\n")
            fileOutput.write(TRI)
            fileOutput.write(TPI + "\n")

fileOutput.write("PAUSE")
fileOutput.close()
```

The program loops through all the selected point cloud files, and then writes the commands for processing these files using the SAGA GIS toolbox to a.bat file. The .bat file can be run – in Windows – simply by double-clicking.

The initial triangulation was the most time-consuming stage, and many files were too large for at least two of the three computers used for processing.

Contour polygons

According to the original plan, the next step was to employ the GDAL “contour polygons” command. This is a relatively new command, intended to skip a few steps in a common process. Specifically: contour lines generated from TIN images would be and converted to (closed) polygons, from which relevant data (“polygon properties”) could be extracted. This command did not work, however, on the larger sized TINs, not even with the most powerful computers we had available. The process therefore had to be broken into two steps, first creating contour lines, then converting these from standard vectors to (closed) polygons.

The original script simply looped through all the relevant files and wrote an extra line to the SAGA command-line script used to generate TINs, slope, aspect, etc., as described in the previous sections:

```
import os
import glob
import string
```

```
# change folder address as necessary
inputFolder = "u:\\eduardo\\experimental\\output"
outputFolder = "u:\\eduardo\\experimental\\output"
fo = open("u:\\eduardo\\SAGA_20201125-experimental.bat", "w")
fo.write("@ECHO OFF\n\n")
fo.write("REM SET SAGA_MLB=C:\SAGA\Modules\n")
fo.write("REM SET PATH=%PATH%;C:\SAGA\n\n")

for path, dir, files in os.walk(inputFolder):
    head, tail = os.path.splitdrive(path)
    for file in files:
        fileNameNoExt, end = os.path.splitext(file)
        if glob.fnmatch.fnmatch(file, "*.txt"):
            inputFile = "u:" + tail + os.sep + file

            head1, tail1 = os.path.split(path)
            head2, tail2 = os.path.splitdrive(path)

            output_table = os.path.join("u:" + tail2 + os.sep + fileNameNoExt
+ "_OUT.txt")
            SHP_file = os.path.join("u:" + tail2 + os.sep + fileNameNoExt +
".shp")
            pCloud = os.path.join("u:" + tail2 + os.sep + fileNameNoExt +
".sg-pts-z")
            gridfile = os.path.join("u:" + tail2 + os.sep + fileNameNoExt +
".sgrd")
            triangle_grid = os.path.join("u:" + tail2 + os.sep + fileNameNoExt
+ "_triangle.tif")

            aspect_file = os.path.join("u:" + tail2 + os.sep + fileNameNoExt +
"_aspect.tif")

            slope_file = os.path.join("u:" + tail2 + os.sep + fileNameNoExt +
"_slope.tif")
            slope_contour_file = os.path.join("u:" + tail2 + os.sep +
fileNameNoExt + "_slope_contour.shp")
            slope_contour_polygons_file = os.path.join("u:" + tail2 + os.sep +
fileNameNoExt + "_slope_contour_polygons.shp")
            slope_properties_file = os.path.join("u:" + tail2 + os.sep +
fileNameNoExt + "_slope_contour_properties.shp")

#contours
            slope_contours = "saga_cmd shapes_grid 5 -GRID=" + slope_file + "
-CONTOUR=" + slope_contour_file + " -POLYGONS=" + slope_contour_polygons_file
+ " -VERTEX=1 -ZSTEP=9\n"

#slope contour properties
            slope_contour_properties = "saga_cmd shapes_polygons 2 -POLYGONS="
+ slope_contour_polygons_file + " -OUTPUT=" + slope_properties_file + " -
BPARTS=1 -BPOINTS=1 -BLENGTH=1 -BAREA=1\n"

            fo.write(slope_contours)
            fo.write(slope_contour_properties + "\n")

fo.write("PAUSE")
fo.close()
```

This was rewritten to write a series of `.json` scripts for use in batch processing in QGIS, executing GDAL commands, first to create contours:

```
import os
import glob
import string

# change folder address as necessary
inputFolder = "u:\\input"
outputFolder = "u:\\input"
fileOutput = open("u:\\eduardo\\GDALcontour-20201030.json", "w")
fileOutput.write("[")

for path, dir, files in os.walk(inputFolder):
    head, tail = os.path.splitdrive(path)
    for file in files:
        fileNameNoExt, end = os.path.splitext(file)
        if glob.fnmatch.fnmatch(file, "*_slope.tif"):
            inputFile = "u:" + tail + os.sep + file

            head1, tail1 = os.path.split(path)
            head2, tail2 = os.path.splitdrive(path)

            slope_file = os.path.join("u:" + tail2 + os.sep + fileNameNoExt +
"_slope.tif")
            slope_contour = os.path.join("u:" + tail2 + os.sep + fileNameNoExt
+ "_contour.shp")

            json_line = "{\"PARAMETERS\": {\"INPUT\": \"'" + inputFile +
"\'\", \"BAND\": \"1\", \"INTERVAL\": \"10\", \"FIELD_NAME\": \"'ELEV'\",
\"CREATE_3D\": \"False\", \"IGNORE_NODATA\": \"False\", \"NODATA\": \"None\",
\"OFFSET\": \"0\", \"EXTRA\": \"''\", \"OPTIONS\": \"''\"}, \"OUTPUTS\":
{\"OUTPUT\": \"" + slope_contour + "\"}},\n"

            fileOutput.write(json_line + "\n")

fileOutput.write("]\n")

fileOutput.close()
```

N.B.: the second last line of each `.json` script includes a concluding comma that must be removed manually.

What might not be immediately clear is the fact that this process converts raster data (the TINs) to vector data ("shape" or `.shp` files). The designation "shape" is something of a misnomer, given that the resulting "file" actually consists of a `.shp` file, a `.shx` file, a `.prj` file, an `.mshp` and – most important for our purposes – a `.dbf` file. `.shp` is a standard file format in GIS; `.dbf` is a now largely obsolete database file standard that is still useful for cross-platform applications, and can be read using most spread-sheet software (LibreOffice Calc, Excel, etc.).

It is not immediately clear how the contour lines are generated, but it is assumed that the process ultimately employs a nearest neighbour algorithm similar to those used in "edge detection" in standard imaging programs (GIMP, PhotoShop, etc.); that is: a value for neighbouring points is compared, and if the cut-off value lies between them, then a line is drawn, separating or dividing them. The resulting polygons exhibited some evidence of the way these algorithms function, occasionally creating “artifacts” most evident as straight lines crossing a diagram as a result of closing polygons.

In understanding this problem, it is helpful to understand the underlying geometry (epistemology and/or ontology). Whatever graphics and/or GIS programs have rendered on a screen, the basic data consists of lists of points with 3 coordinates (X, Y and Z; some laser scanners and other devices include R, G and B for colours). A line is created by linking any two points, and nearest neighbour analysis consists of linking any given point only with its nearest neighbours (i.e. ignoring potential links to more distant points). A polyline links up any number of individual line segments, and a polygon is a geometric figure where the beginning and end points coincide.

After this, we need to consider “attributes” or “properties” relating to the various line segments. A line is, by definition, straight, but can be curved, in which case it becomes an “arc” (which may or may not be the source for the name ArcGIS). A line may also have a direction, from one point to another, in which case it becomes a “vector.” Similarly, a polygon may have the attribute of being “open” or “closed,” and simply closing a polyline when the starting and closing point do not coincide results in the kind of artifacts produced by this process.

This is mostly a boundary issue: a long contour drawn around a perimeter will often encounter a value which acts like a barrier and, instead of going around that point, simply “close.” This kind of error is most common along the edges of datasets (point clouds, maps, etc.), because the number of potential “nearest neighbours” is limited; therefore “closing” a polygon means linking the beginning and end points, despite the fact that those extremities may lie in close proximity to the ends of other polylines with the same value, separated only by an aberrant point.

The “fix geometry” process seems to have corrected some of these errors, but each image would have to be examined in order to determine whether all had been.

This is the script to “fix geometry”:

```
import os
import glob
import string

# change folder address as necessary
inputFolder = "u:\\output"
outputFolder = "u:\\output"
fileOutput = open("u:\\output\\GDAL-fix_geometry.json", "w")
fileOutput.write("[")

for path, dir, files in os.walk(inputFolder):
    head, tail = os.path.splitdrive(path)

    head1, tail1 = os.path.split(path)
    head2, tail2 = os.path.splitdrive(path)

    for file in files:
        fileNameNoExt, end = os.path.splitext(file)
```

```
        if glob.fnmatch.fnmatch(file, "*_09.dbf"):
            inputFile = "u:" + tail + os.sep + file
            outputSHP = "u:" + tail + os.sep + tail1 + "_09_fix.shp"
            geometry_fix = "{\"PARAMETERS\": {\"INPUT\": \"'" + inputFile +
"'\"}, \"OUTPUTS\": {\"OUTPUT\": \"" + outputSHP + "\"}},"
            fileOutput.write(geometry_fix + "\n")

        if glob.fnmatch.fnmatch(file, "*_18.dbf"):
            inputFile = "u:" + tail + os.sep + file
            outputSHP = "u:" + tail + os.sep + tail1 + "_18_fix.shp"
            geometry_fix = "{\"PARAMETERS\": {\"INPUT\": \"'" + inputFile +
"'\"}, \"OUTPUTS\": {\"OUTPUT\": \"" + outputSHP + "\"}},"
            fileOutput.write(geometry_fix + "\n")
```

[This string is repeated for every increment of 9 degrees]

```
        if glob.fnmatch.fnmatch(file, "*_81.dbf"):
            inputFile = "u:" + tail + os.sep + file
            outputSHP = "u:" + tail + os.sep + tail1 + "_81_fix.shp"
            geometry_fix = "{\"PARAMETERS\": {\"INPUT\": \"'" + inputFile +
"'\"}, \"OUTPUTS\": {\"OUTPUT\": \"" + outputSHP + "\"}},"
            fileOutput.write(geometry_fix + "\n")

fileOutput.write("]\n")

fileOutput.close()
```

Polygon properties

Once repaired, relevant data ("properties": number of parts, number of points, area and perimeter of each polygon) for each of the polygons in the contour file could be extracted using the following Python script:

```
import os
import glob
import string

# change folder address as necessary
inputFolder = "u:\\output-cut"
outputFolder = "u:\\output-cut"
fileOutput = open("u:\\output-cut\\GDAL_cut-polygon-properties.json", "w")
fileOutput.write("[\n\n")

for path, dir, files in os.walk(inputFolder):
    head, tail = os.path.splitdrive(path)
    for file in files:
        fileNameNoExt, end = os.path.splitext(file)
        if glob.fnmatch.fnmatch(file, "*_slope_contour_polygon.shp"):
            inputFile = "u:" + tail + os.sep + file

            head1, tail1 = os.path.split(path)
            head2, tail2 = os.path.splitdrive(path)

            slope_contour_polygons = os.path.join("u:" + tail2 + os.sep +
fileNameNoExt + "_properties.shp")
```

```
            slope_polygon_properties = "{\"PARAMETERS\": {\"POLYGONS\": \"'" +
inputFile + "'\", \"BPARTS        \": \"True\", \"BPOINTS       \": \"True\",
\"BLENGTH       \": \"True\", \"BAREA         \": \"True\"}, \"OUTPUTS\":
{\"OUTPUT\": \"" + slope_contour_polygons + "\"}},\n\n"

            fileOutput.write(slope_polygon_properties)

fileOutput.write("]\n")
fileOutput.close()
```

This script imports the necessary Python packages, then begins looping through all the relevant files and writing the relevant data to command strings in a script written in .json format (used for batch commands in QGIS). When run in QGIS, this .json script converted each .shp file into a summary of the "properties" for each contour line.

N.B.: the second last line of the .json script includes a concluding comma that must be removed manually.

Aggregating data

Once repaired, relevant data ("properties": number of parts, number of points, area and perimeter of each polygon) for each of the polygons in the contour file could be extracted using the following Python script:

```
import os
import glob
import string

# change folder address as necessary
inputFolder = "u:\\output"
outputFolder = "u:\\output"
fileOutput = open("u:\\output\\GDAL-aggregate.json", "w")
fileOutput.write("[")

for path, dir, files in os.walk(inputFolder):
    head, tail = os.path.splitdrive(path)

    head1, tail1 = os.path.split(path)
    head2, tail2 = os.path.splitdrive(path)

    for file in files:
        fileNameNoExt, end = os.path.splitext(file)

        if glob.fnmatch.fnmatch(file, "*slope_contour_properties.dbf"):
            inputFile = "u:" + tail + os.sep + file
            outputCSV = "u:" + tail + os.sep + tail1 + ".csv"
            aggregate = "{\"PARAMETERS\": {\"INPUT\": \"'" + inputFile + "'\",
\"GROUP_BY\": \"'NULL'\", \"AGGREGATES\": \"[{'aggregate':
'count','delimiter': ',','input': '***\"ID***\"','length': 16,'name':
'ID','precision': 0,'type': 4},{'aggregate': 'count','delimiter': ',','input':
'***\"ELEV***\"','length': 18,'name': 'ELEV','precision': 10,'type':
6},{'aggregate': 'sum','delimiter': ',','input': '***\"NPARTS***\"','length':
16,'name': 'NPARTS','precision': 0,'type': 4},{'aggregate': 'sum','delimiter':
',','input': '***\"NPOINTS***\"','length': 16,'name': 'NPOINTS','precision':
0,'type': 6},{'aggregate': 'sum','delimiter': ',','input':
'***\"PERIMETER***\"','length': 18,'name': 'PERIMETER','precision': 10,'type':
```

```
6},{'aggregate': 'sum','delimiter': ',','input': '***\"AREA***\"','length':
18,'name': 'AREA','precision': 10,'type': 6}]\"}, \"OUTPUTS\": {\"OUTPUT\":
\"" + outputCSV + "\"}},"
            fileOutput.write(aggregate + "\n")

fileOutput.write("]\n")

fileOutput.close()
```

This script imports the necessary Python packages, then begins looping through all the relevant files and writing the relevant data to command strings in a script written in .json format (used for batch commands in QGIS). When run in QGIS, this .json script aggregated the data on all the polygons at each contour interval, producing a .csv file for each .dbf file (essentially converting .dbf to .csv).

N.B.: the second last line of the script concludes with a comma that must be removed manually. The "aggregate" line looks especially complicated due to conventions used in Python and Windows; among other things, quotation marks used within the string have to be preceded by a backslash ("\"). Backslashes in the final script also had to be converted to Windows-standard forward slashes ("/") and – to complicate matters even more – the triple-asterix place-holders ("***") had to be converted to triple-backslashes ("\\\") using a standard text editor.

Data summary

Once repaired, relevant data ("properties": number of parts, number of points, area and perimeter of each polygon) for each of the polygons in the contour file could be extracted using the following Python script:

```
import csv
import os
import glob
import string

# change folder address as necessary
inputFolder = "u:\\output-cut"
outputCSV = "u:\\output-cut\\cut-specimens.csv"

temp_content = []

for path, dir, files in os.walk(inputFolder):
    head, tail = os.path.splitdrive(path)

    head1, tail1 = os.path.split(path)
    head2, tail2 = os.path.splitdrive(path)

    with open(outputCSV, "a+", newline='') as fileOutput:
        write_to_file = csv.writer(fileOutput)

        for file in files:
            fileNameNoExt, end = os.path.splitext(file)
```

```
if glob.fnmatch.fnmatch(file, "*.csv"):
    inputCSV = "u:" + tail + os.sep + file

    with open(inputCSV, "r") as fileInput:
        contents = csv.reader(fileInput)
        next(contents, None)
        for c in contents:
            c.append(tail1)
            temp_content.append(c)
            c.append(fileNameNoExt)
            temp_content.append(c)
            write_to_file.writerow(c)
```

This script imports the necessary Python packages, then begins looping through all the relevant files and writing the relevant data to strings in a script written in ".json" format (used for batch commands in QGIS). When run in QGIS, this .json script produced a .csv file which summarised the data aggregated in the previous step.

N.B.: the second last line of the script includes a concluding comma that must be removed manually.

3. E4 configuration for data input (configuration file)

3.1. E4 configuration for data input of technological analyses (configuration file)

```
[E4]
Filename=GST-preliminar.mdb
Sound=Yes
Delaytime=1
Table=GST
BackColor=33023

[Site]
Type=Text
Prompt=Welcome to your database, please enter the Site name:
Length=20
Carry=True

[bag ID]
Type=Text
Prompt=Bag ID :
Length=20

[ARTIFACT_NUMBER]
Type=Text
Prompt=Enter the artifact number :
Length=20

[Layer]
Type=Text
Prompt=Layer:
Length=20
Carry=True

[Locus]
Type=Text
Prompt=Locus:
Length=20

[Square]
Type=Text
Prompt=Square:
Length=20


[RAW_MATERIAL]
Type=Menu
Prompt=ENTER THE ARTIFACT RAW MATERIAL:
Menu=Flint,Quartzite,Quartz,Obsidian,Sandstone,Basalt,Nari,Limestone,Other
Length=20
Carry=True


[type_support]
Type=Menu
Prompt=Select the type of support:
Menu=Pebble,block,boulder
Length=20
Carry=True

[preservation]
Type=Menu
Prompt=preservation:
Menu=complete,broken,small_breakage
Length=20
Carry=True


[Lenght]
Type=Numeric
```

```
Prompt=ENTER THE ARTIFACT Lenght :
Length=10

[Width]
Type=Numeric
Prompt=ENTER THE ARTIFACT Width :
Length=10

[Thickness]
Type=Numeric
Prompt=ENTER THE ARTIFACT Thickness :
Length=10

[WEIGHT]
Type=Numeric
Prompt=ENTER THE ARTIFACT WEIGHT :
Length=10

[Visible-use-wear]
Type=Menu
Prompt=visible use-wear? :
Menu=yes,no
Length=20

[location-use-wear]
Type=Menu
Prompt=Location of use-wear? :
Menu=tip,central,both
Length=20
Condition1=Visible-use-wear yes

[type_use-wear]
Type=Menu
Prompt=type of use-wear :
Menu=pecking,polish,straiations,mix
Length=20
Condition1=Visible-use-wear yes


[Active_areas]
Type=Text
Prompt=Number of active areas :
Length=20
Condition1=Visible-use-wear yes

[Visible-residoues]
Type=Menu
Prompt=visible residues? :
Menu=yes,no
Length=20

[suggest-type]
Type=Menu
Prompt=suggested type of tool :
Menu=Anvil,hummer_stone,Pebble Pestle,Abrader,Hadstone,Mortar,Pestle,Chopper,Undifined,Manuport,Natural,Core
Length=20

[PHOTO_reference]
Type=Text
Prompt=ENTER THE PHOTO ANALYSIS REFERENCE :
Length=20

[OBSERVATIONS]
Type=Text
Prompt=INDICATE ANY OBSERVATIONS :
Length=30
```

3.2. E4 configuration for data input of functional analyses (configuration file)

```
[E4]
Filename=GST-fase2.mdb
Sound=Yes
Delaytime=1
Table=GST
BackColor=33023

[Site]
Type=Text
Prompt=Welcome to your database please enter the Site name:
Length=20
Carry=True

[bag ID]
Type=Text
Prompt=Bag ID :
Length=20

[ARTIFACT_NUMBER]
Type=Text
Prompt=Enter the artifact number :
Length=20

[Layer]
Type=Text
Prompt=Layer:
Length=20
Carry=True

[Locus]
Type=Text
Prompt=Locus:
Length=20

[Squere]
Type=Text
Prompt=Squere:
Length=20


[RAW_MATERIAL]
Type=Menu
Prompt=ENTER THE ARTIFACT RAW MATERIAL :
Menu=Flint,Quartzite,Quartz,Obsidian,Sandstone,Basalt,Nari,Limestone,Other
Length=20
Carry=True

[cortex]
Type=Menu
Prompt=Indicate the level of cortex:
Menu=0%,25%,50%,75%,100%
Length=20
Carry=True


[patina]
Type=Menu
Prompt=Select the degree of patination:
Menu=none,light-patination,heavy-patination
Length=20
Carry=True

[Burned]
Type=Menu
Prompt=Is the artifact burned? :
Menu=No,Yes
Length=20
Carry=True
```

```
[General-photo]
Type=Menu
Prompt=Did you take a general photo :
Menu=No,Yes
Length=20
Carry=True

[Macro-photo]
Type=Menu
Prompt=Did you take a Macro photo? :
Menu=No,Yes
Length=20
Carry=True

[Micro-photo]
Type=Menu
Prompt=Did you take a Micro photo? :
Menu=No,Yes
Length=20
Carry=True

[3D-scnan]
Type=Menu
Prompt=Did you make a 3D-Scan? :
Menu=No,Yes
Length=20
Carry=True

[wear1-marks-type]
Type=Menu
Prompt=Select type of traces in wear1 :
Menu=Polish,Straiation,Polish&Straiation,Impact
Length=20
Carry=True

[wear1-location]
Type=Menu
Prompt=Indicate the location of wear1 :
Menu=A1,A2,A3,A4,A5,A6,A7,A8,A9,B1,B2,B3,B4,B5,B6,B7,B8,B9
Length=20
Carry=True

[wear1-straiation]
Type=Menu
Prompt=Indicate the straiation orientation :
Menu=NA,Parallel,Oblique,Perpendicula
Length=20
Carry=True
Condition1=wear1-marks-type Straiation Polish&Straiation

[wear1-Polish-mesh]
Type=Menu
Prompt=Indicate the Polish-mesh :
Menu=Na,Open,Medium,Compact,Very compact
Length=20
Carry=True
Condition1=wear1-marks-type Polish Polish&Straiation

[wear1-Polish-direction]
Type=Menu
Prompt=Indicate the Polish-direction :
Menu=NA,Parallel,Oblique,Perpendicula
Length=20
Carry=True
Condition1=wear1-marks-type Polish Polish&Straiation

[wear1-Worked-material-hardness]
Type=Menu
Prompt=Indicate the Worked-material-hardness :
Menu=NA,Soft,Semi-hard,Hard
Length=20
```

```
Carry=True

[wear1-Worked-material-type]
Type=Menu
Prompt=Indicate the Worked-material-type :
Menu=NA,Hard animal material,Bone,Antler,Wood,Vegetal,Mineral,Shell,Hide,Dry-hide,Unrecognised
Length=20
Carry=True

[wear2]
Type=Menu
Prompt=have more spot with use-wear? :
Menu=yes,no
Length=20
Carry=True

[wear2-marks-type]
Type=Menu
Prompt=Select type of traces in wear2 :
Menu=Polish,Straiation,Polish&Straiation,Impact
Length=20
Carry=True
Condition1=wear2 yes

[wear2-location]
Type=Menu
Prompt=Indicate the location of wear1 :
Menu=A1,A2,A3,A4,A5,A6,A7,A8,A9,B1,B2,B3,B4,B5,B6,B7,B8,B9
Length=20
Carry=True
Condition1=wear2 yes

[wear2-straiation]
Type=Menu
Prompt=Indicate the straiation orientation :
Menu=NA,Parallel,Oblique,Perpendicula
Length=20
Carry=True
Condition1=wear2-marks-type Straiation Polish&Straiation

[wear2-Polish-mesh]
Type=Menu
Prompt=Indicate the Polish-mesh :
Menu=Na,Open,Medium,Compact,Very compact
Length=20
Carry=True
Condition1=wear2-marks-type Polish Polish&Straiation

[wear2-Polish-direction]
Type=Menu
Prompt=Indicate the Polish-direction :
Menu=NA,Parallel,Oblique,Perpendicula
Length=20
Carry=True
Condition1=wear2-marks-type Polish Polish&Straiation

[wear2-Worked-material-hardness]
Type=Menu
Prompt=Indicate the Worked-material-hardness :
Menu=NA,Soft,Semi-hard,Hard
Length=20
Carry=True
Condition1=wear2 yes

[wear2-Worked-material-type]
Type=Menu
Prompt=Indicate the Worked-material-type :
Menu=NA,Hard animal material,Bone,Antler,Wood,Vegetal,Mineral,Shell,Hide,Dry-hide,Unrecognised
Length=20
Carry=True
Condition1=wear2 yes
```

```
[wear3]
Type=Menu
Prompt=have more spot with use-wear? :
Menu=yes,no
Length=20
Carry=True
Condition1=wear2 yes

[wear3-marks-type]
Type=Menu
Prompt=Select type of traces in wear3 :
Menu=Polish,Straiation,Polish&Straiation,Impact
Length=20
Carry=True
Condition1=wear3 yes

[wear3-location]
Type=Menu
Prompt=Indicate the location of wear1 :
Menu=A1,A2,A3,A4,A5,A6,A7,A8,A9,B1,B2,B3,B4,B5,B6,B7,B8,B9
Length=20
Carry=True
Condition1=wear3 yes

[wear3-straiation]
Type=Menu
Prompt=Indicate the straiation orientation :
Menu=NA,Parallel,Oblique,Perpendicula
Length=20
Carry=True
Condition1=wear3-marks-type Straiation Polish&Straiation

[wear3-Polish-mesh]
Type=Menu
Prompt=Indicate the Polish-mesh :
Menu=Na,Open,Medium,Compact,Very compact
Length=20
Carry=True
Condition1=wear3-marks-type Polish Polish&Straiation

[wear3-Polish-direction]
Type=Menu
Prompt=Indicate the Polish-direction :
Menu=NA,Parallel,Oblique,Perpendicula
Length=20
Carry=True
Condition1=wear3-marks-type Polish Polish&Straiation

[wear3-Worked-material-hardness]
Type=Menu
Prompt=Indicate the Worked-material-hardness :
Menu=NA,Soft,Semi-hard,Hard
Length=20
Carry=True
Condition1=wear3 yes

[wear3-Worked-material-type]
Type=Menu
Prompt=Indicate the Worked-material-type :
Menu=NA,Hard animal material,Bone,Antler,Wood,Vegetal,Mineral,Shell,Hide,Dry-hide,Unrecognised
Length=20
Carry=True
Condition1=wear3 yes

[wear4]
Type=Menu
Prompt=have more spot with use-wear? :
Menu=yes,no
Length=20
Carry=True
Condition1=wear3 yes
```

```
[wear4-marks-type]
Type=Menu
Prompt=Select type of traces in wear4 :
Menu=Polish,Striation,Polish&Straiation,Impact
Length=20
Carry=True
Condition1=wear4 yes

[wear4-location]
Type=Menu
Prompt=Indicate the location of wear1 :
Menu=A1,A2,A3,A4,A5,A6,A7,A8,A9,B1,B2,B3,B4,B5,B6,B7,B8,B9
Length=20
Carry=True
Condition1=wear4 yes

[wear4-straiation]
Type=Menu
Prompt=Indicate the striation orientation :
Menu=NA,Parallel,Oblique,Perpendicula
Length=20
Carry=True
Condition1=wear4-marks-type Straiation Polish&Straiation

[wear4-Polish-mesh]
Type=Menu
Prompt=Indicate the Polish-mesh :
Menu=Na,Open,Medium,Compact,Very compact
Length=20
Carry=True
Condition1=wear4-marks-type Polish Polish&Straiation

[wear4-Polish-direction]
Type=Menu
Prompt=Indicate the Polish-direction :
Menu=NA,Parallel,Oblique,Perpendicula
Length=20
Carry=True
Condition1=wear4-marks-type Polish Polish&Straiation

[wear4-Worked-material-hardness]
Type=Menu
Prompt=Indicate the Worked-material-hardness :
Menu=NA,Soft,Semi-hard,Hard
Length=20
Carry=True
Condition1=wear4 yes

[wear4-Worked-material-type]
Type=Menu
Prompt=Indicate the Worked-material-type :
Menu=NA,Hard animal material,Bone,Antler,Wood,Vegetal,Mineral,Shell,Hide,Dry-hide,Unrecognised
Length=20
Carry=True
Condition1=wear4 yes

[Tool Micro-wear preservation]
Type=Menu
Prompt=Indicate the  preservation state 0-All surface is demage 3-surface very well preserved :
Menu=1,2,3
Length=20
Carry=True

[Tool Movement]
Type=Menu
Prompt=Indicate the  type of movement :
Menu=NA,Passive tool,Cutting,scraping,piercing,grinding,crushing,polishing,knaping,breaking
Length=20
Carry=True

[Visible-residoues]
Type=Menu
```

```
Prompt=visible residues? :
Menu=yes,no
Length=20

[suggest-type]
Type=Menu
Prompt=suggested type of tool :
Menu=Anvil,hammerstone,Pebble Pestle,Abrader,Hadstone,Mortar,Pestle,Chopper,Undifined,Manuport,Natural,Core
Length=20

[OBSERVATIONS]
Type=Text
Prompt=INDICATE ANY OBSERVATIONS :
Length=30
```

3.3. E4 configuration for data input of experimental samples / polish characterization (configuration file)

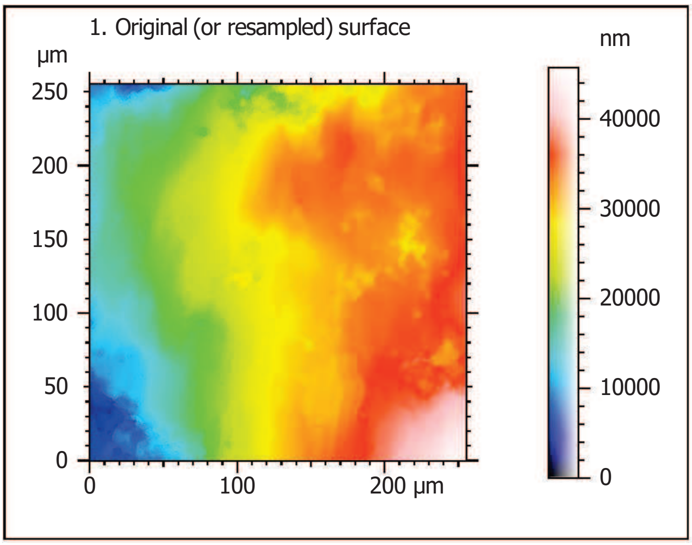
```
[E4]
Filename=exp-materials.mdb
Sound=Yes
Delaytime=1
Table=exp
BackColor=33023

[SAMPLE_ID]
Type=Text
Prompt=Welcome to your database, sample ID:
Length=20
Carry=True

[RAW_MATERIAL]
Type=Menu
Prompt=ENTER THE ARTIFACT RAW MATERIAL :
Menu=Flint,Quartzite,Quartz,Obsidian,Sandstone,Basalt,Nari,Limestone,Other
Length=20
Carry=True

[TYPE_EXPERIMENT]
Type=Menu
Prompt=Select the type of experiment
Menu=Mechanical,Manual
Length=20
Carry=True

[TYPE_MOVEMENT]
Type=Menu
Prompt=Select the type of MOVEMENT
Menu=Impact,linear,circular
Length=20
Carry=True

[WEIGHT_APLIED]
Type=Numeric
Prompt=ENTER THE WEIGHT APLIED (kG) :
Length=10

[NUMBER OF MOVEMENTS]
Type=Numeric
Prompt=ENTER THE NUMBER OF MOVEMENTS :
Length=10

[POLISH]
Type=Menu
Prompt=There is polish?:
Menu=Yes,No
Length=20
Carry=True

[DISTRIBUTION]
Type=Menu
```

```
Prompt=DISTRIBUTION (on the surface) :
Menu=sparse,covering,concentrated
Length=20
Condition1=POLISH yes

[MESH]
Type=Menu
Prompt=DENSITY (MESH) :
Menu=separated,closed,connected
Length=20
Condition1=POLISH yes

[MICROTOPOGRAPHIC_CONTEXT]
Type=Menu
Prompt=MICROTOPOGRAPHIC CONTEXT:
Menu=only on high,penetrating on low,high and low
Length=20
Condition1=POLISH yes

[MORPHOLOGY_IN_CROSS_SECTION]
Type=Menu
Prompt=MORPHOLOGY IN CROSS SECTION :
Menu=domed,sinous,flat
Length=20
Condition1=POLISH yes

[TEXTURE]
Type=Menu
Prompt=TEXTURE :
Menu=rough,fluid,smooth
Length=20
Condition1=POLISH yes

[CONTOURS]
Type=Menu
Prompt=CONTOURS :
Menu=sharp,diffuse
Length=20
Condition1=POLISH yes

[OPACITY]
Type=Menu
Prompt=OPACITY :
Menu=translucent,opaque,trans/opaque
Length=20
Condition1=POLISH yes

[BRIGHTNESS]
Type=Menu
Prompt=BRIGHTNESS :
Menu=high,medium,low
Length=20
Condition1=POLISH yes

[SPECIAL_FEATURES]
Type=Menu
Prompt=SPECIAL FEATURES :
Menu=none,abraded area,pits,striations,abrasive track
Length=20
Condition1=POLISH yes

[STRIATIONS]
Type=Text
Prompt=DESCRIBE THE STRIATIONS:
Length=30

[OBSERVATIONS]
Type=Text
Prompt=INDICATE ANY OBSERVATIONS :
Length=30
```

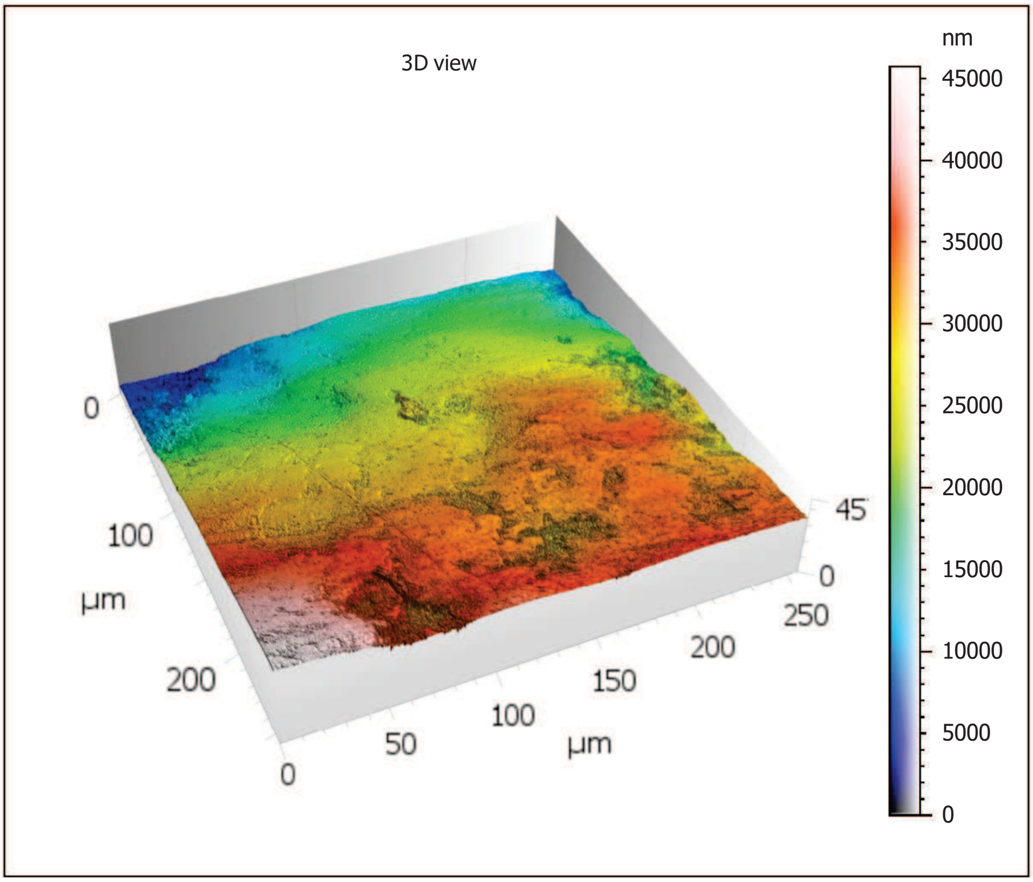
4. Confocal output

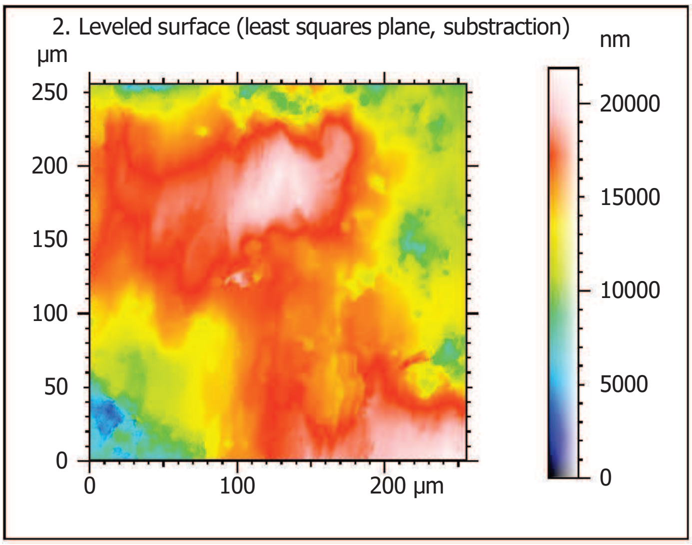
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

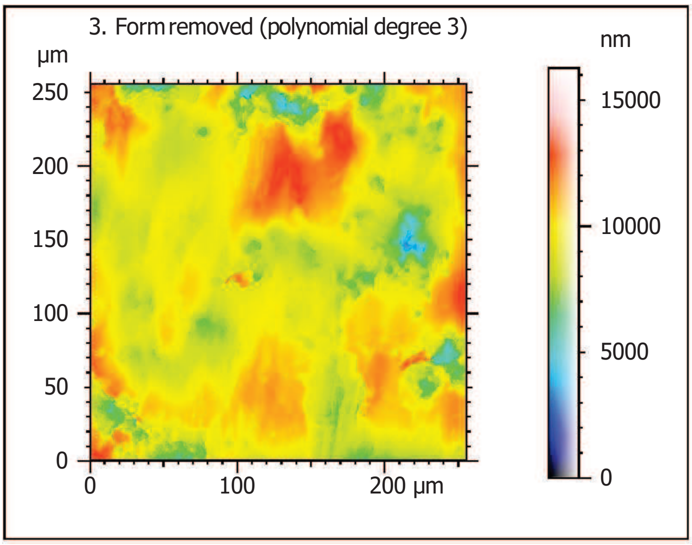
Processing

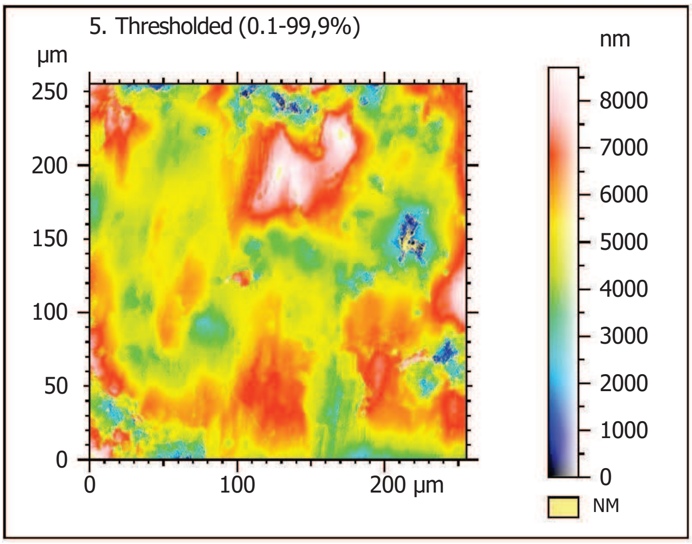


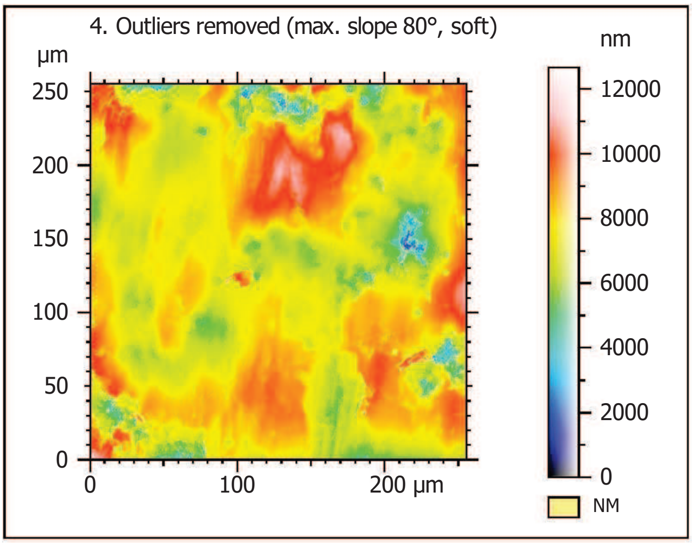
Identity card			
Name:	NRQ_5100_LSM_50x_075_surface1_Topo		
Created on:	5/5/2020 2:16:35 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	45708	nm	
Size:	65531	digits	
Spacing:	0.6975	nm	
NM-points ratio:	0.000 % (0 Pts)		

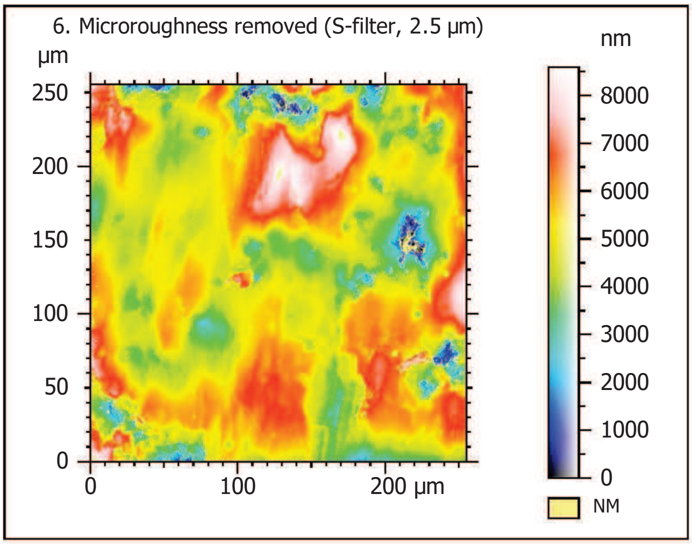



2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
20000
15000
10000
5000
0

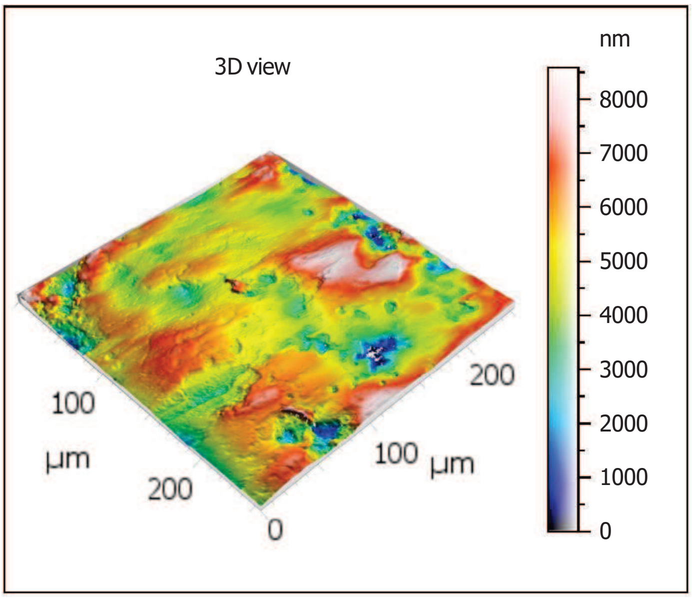

3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0

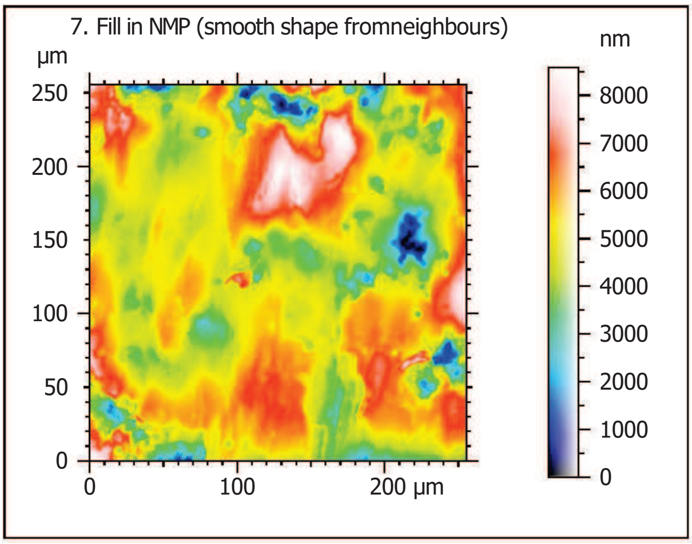

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
8000
7000
6000
5000
4000
3000
2000
1000
0
NM

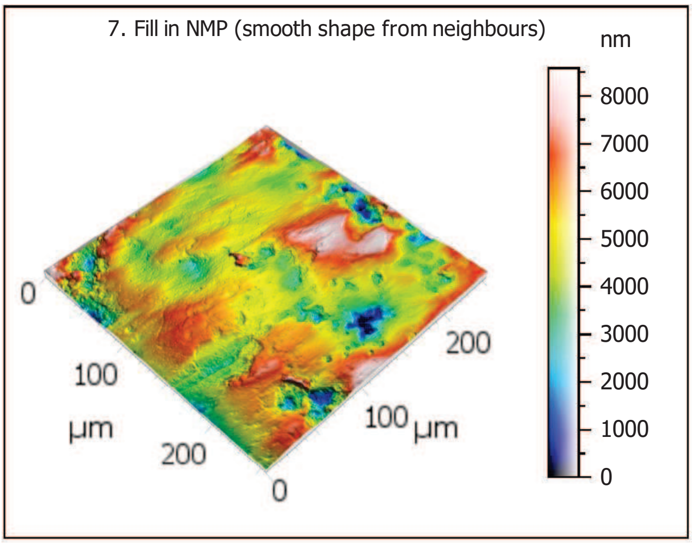

4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
12000
10000
8000
6000
4000
2000
0
NM



Identity card			
Name:	NRQ_5100_LSM_50x_...filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R...75_surface1_Topo.sur		
Created on:	5/5/2020 2:16:35 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	0.000	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	-255.5	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	8580	nm	
Min:	-5060	nm	
Max:	3521	nm	
Size:	123014	digits	
Spacing:	0.06975	nm	
NM-points ratio:	4.803 % (432235 Pts)		





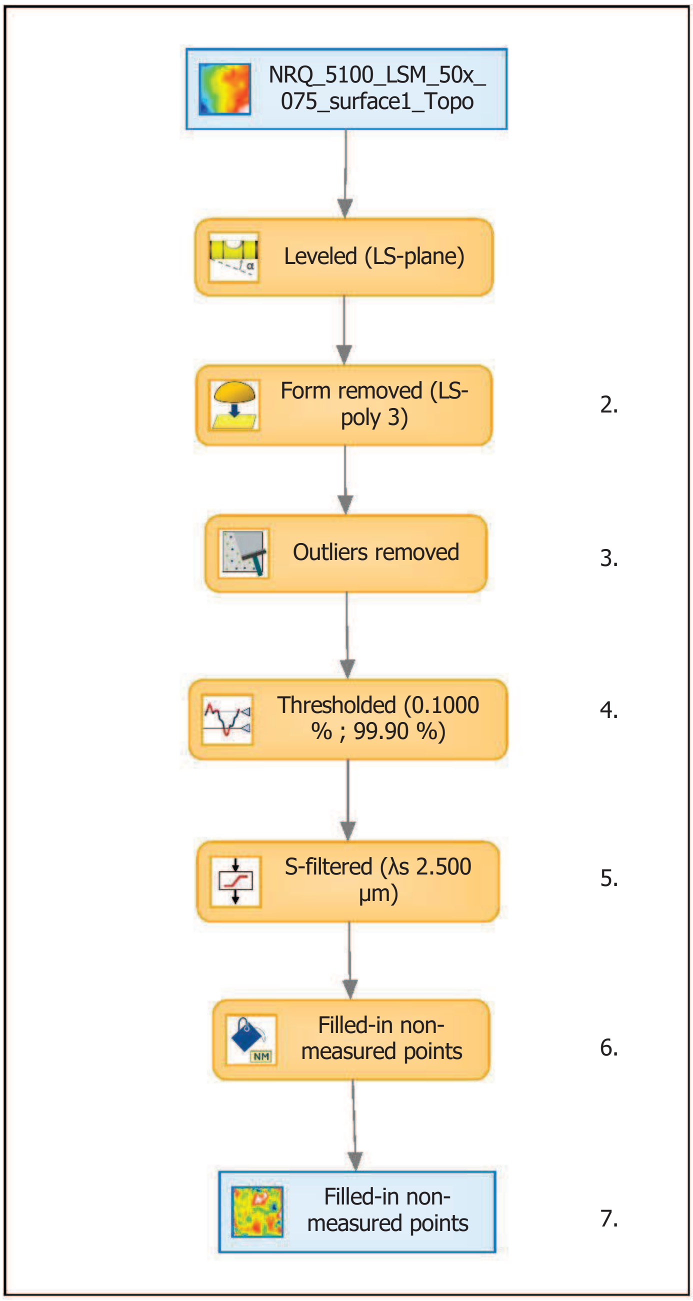


Identity card			
Name:	NRQ_5100_LSM_50x_0...in non-measured points		
Created on:	5/5/2020 2:16:35 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	8580	nm	
Size:	123014	digits	
Spacing:	0.06975	nm	
NM-points ratio:	0.000 % (0 Pts)		

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface			
F: [Workflow] Form removed (LS-poly 3)			
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)			
Height parameters			
Sq	1273	nm	
Ssk	-0.2246		
Sku	3.879		
Sp	3513	nm	
Sv	5067	nm	
Sz	8580	nm	
Sa	972.7	nm	
Functional parameters			
Smr	2.807	%	
Smc	1594	nm	
Sxp	2708	nm	
Spatial parameters			
Sal	23.82	µm	
Str	0.8951		
Std	85.00	°	
Hybrid parameters			
Sdq	0.3091		
Sdr	3.874	%	
Functional parameters (Volume)			
Vm	0.06604	µm³/µm²	
Vv	1.660	µm³/µm²	
Vmp	0.06604	µm³/µm²	
Vmc	1.035	µm³/µm²	
Vvc	1.496	µm³/µm²	
Vvv	0.1639	µm³/µm²	



Analyses:

ISO 25178 8.

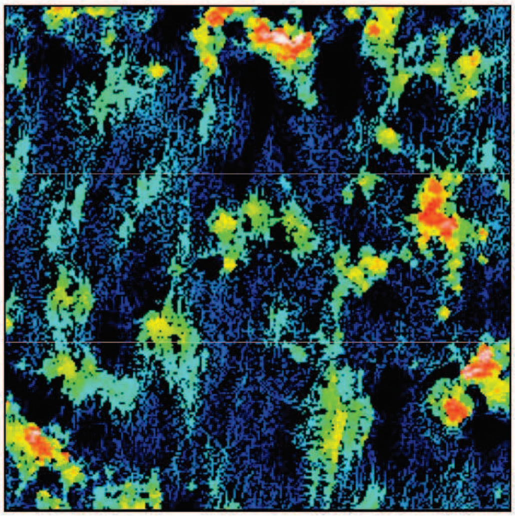
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

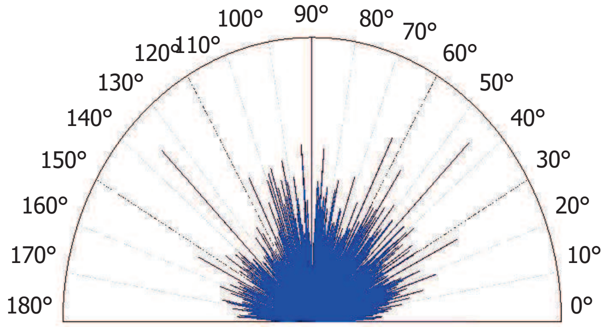
9. Furrow analysis on surface #7



All furrows are shown.

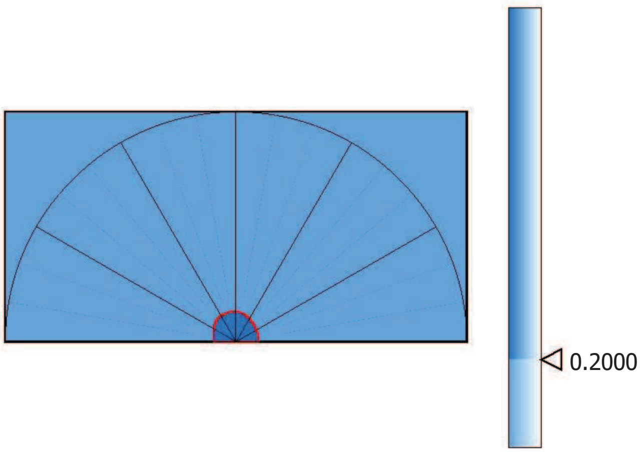
Parameters	Value	Unit
Maximum depth of furrows	5250	nm
Mean depth of furrows	1329	nm
Mean density of furrows	3714	cm/cm2

10. Texture direction on surface #7



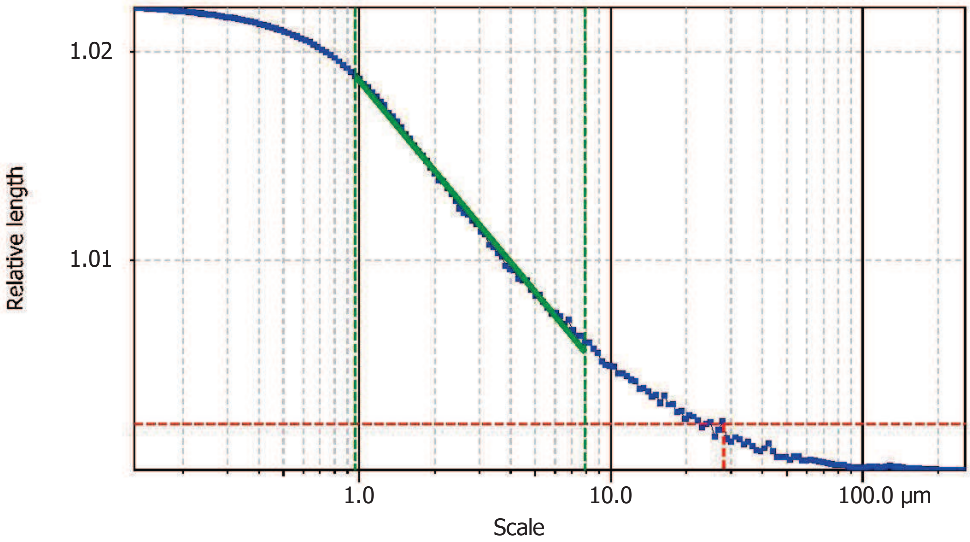
Parameters	Value	Unit
First direction	90.01	°
Second direction	44.98	°
Third direction	135.0	°

11. Texture isotropy on surface #7



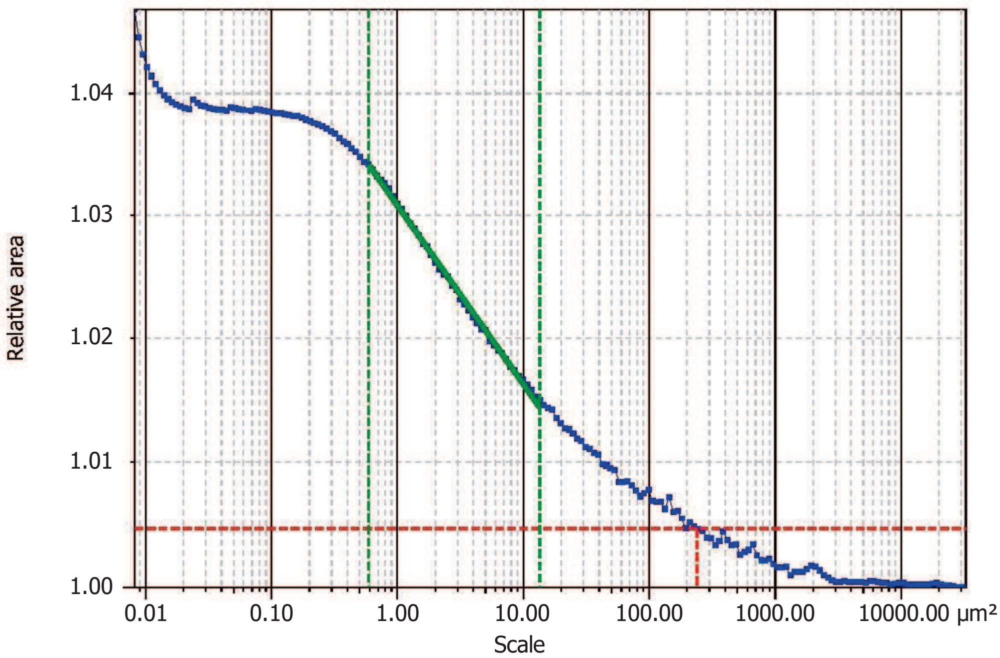
Parameters	Value	Unit
Isotropy	73.13	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.002074		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01702		*Length-scale anisotropy (1.8 µm, 5°)*

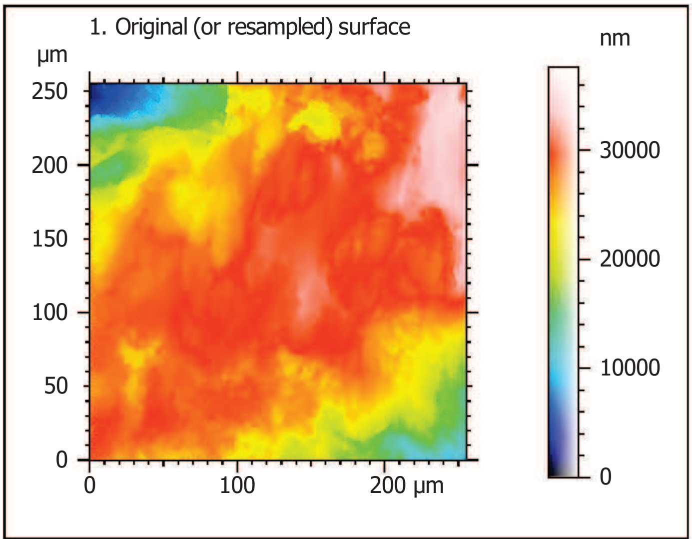


Information	
Method	Area-scale (four corners)

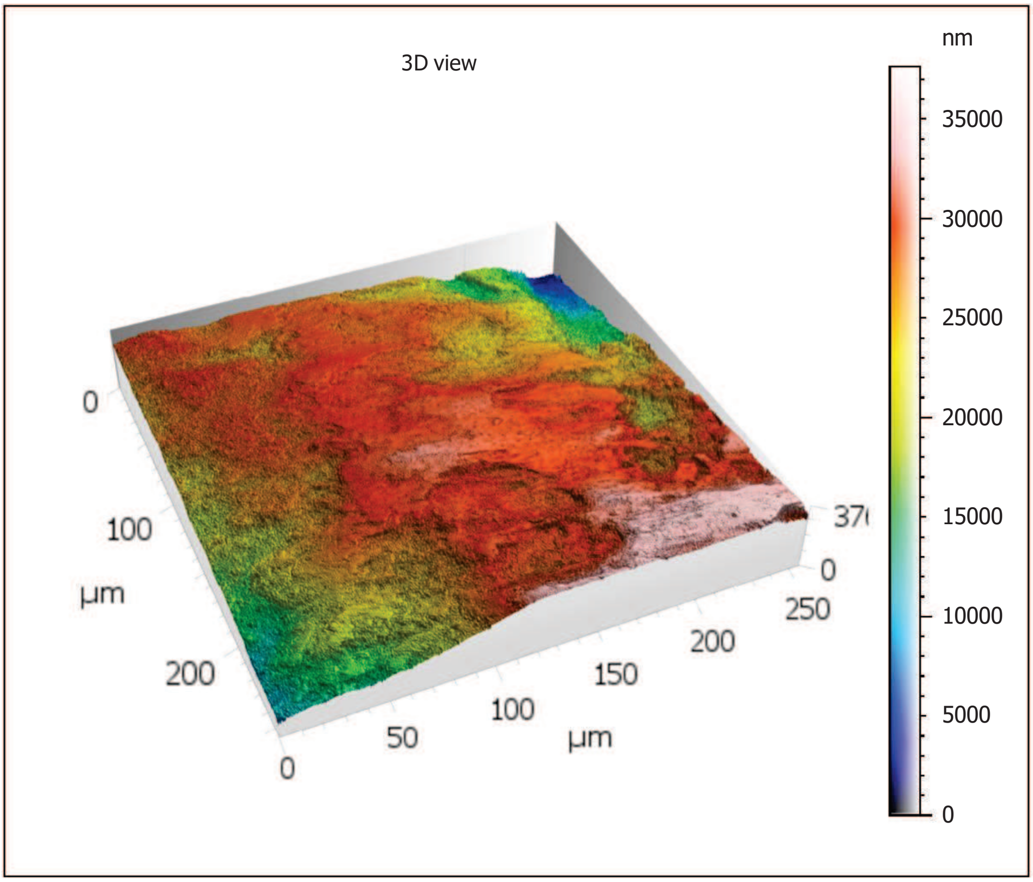
Parameters	Value	Unit	Comment
Asfc	6.155		*Fractal complexity*
Smfc	1.997	µm²	*Scale of max complexity*
HAsfc9	0.6296		*Heterogeneity of Asfc (3x3)*
HAsfc81	1.381		*Heterogeneity of Asfc (9x9)*

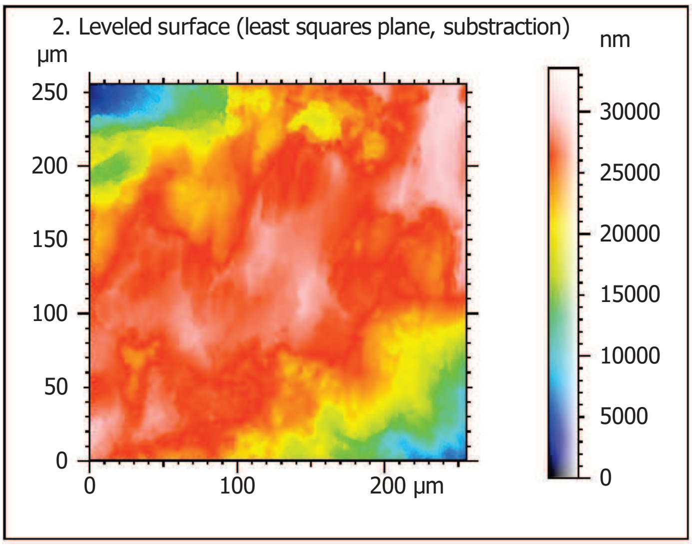
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

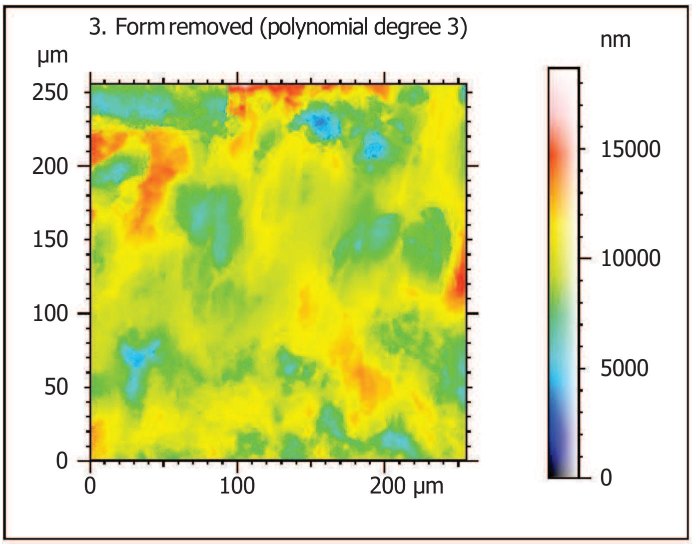
Processing

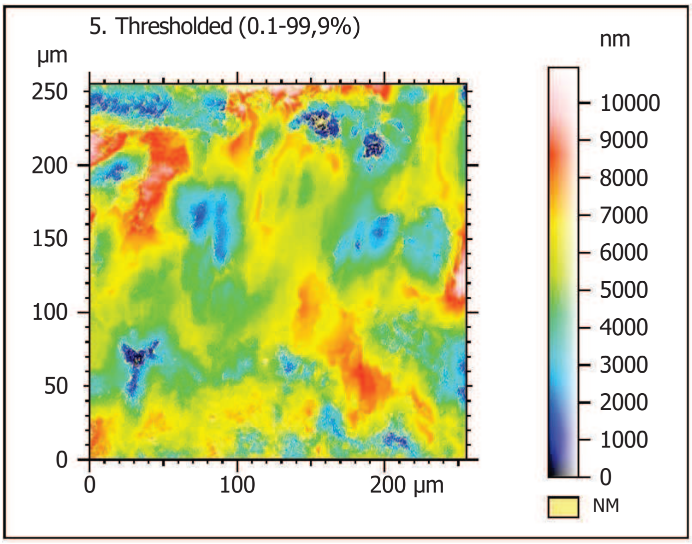


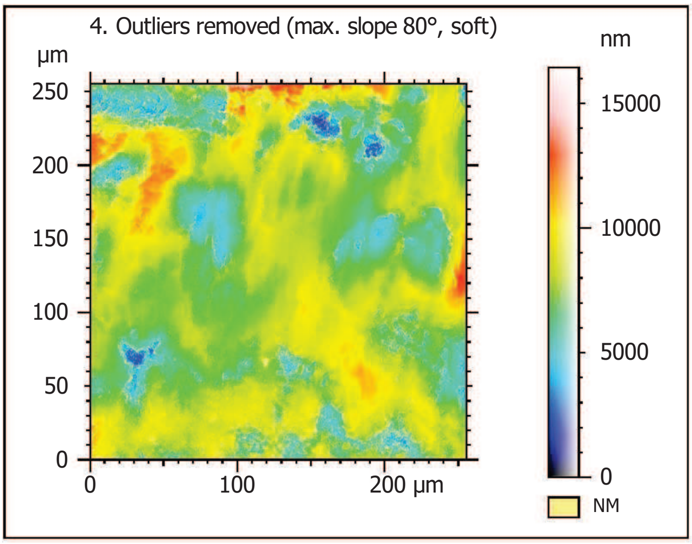
Identity card		
Name:	NRQ_5100_LSM_50x_075_surface2_Topo	
Created on:	5/5/2020 2:31:39 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	37632	nm
Size:	65532	digits
Spacing:	0.5743	nm
NM-points ratio:	0.000 % (0 Pts)	



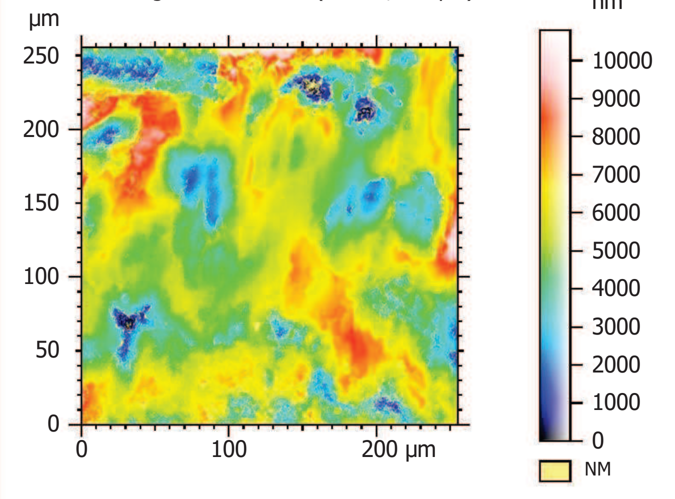

2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
30000
25000
20000
15000
10000
5000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0

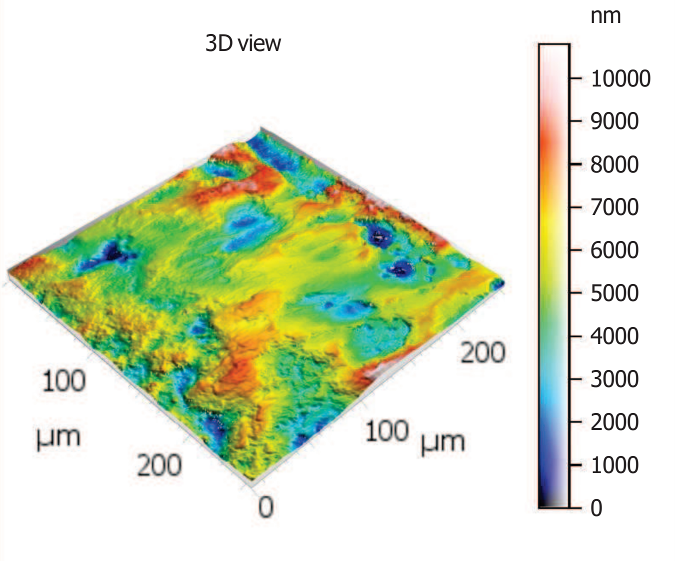

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0
NM

6. Microroughness removed (S-filter, 2.5 µm)

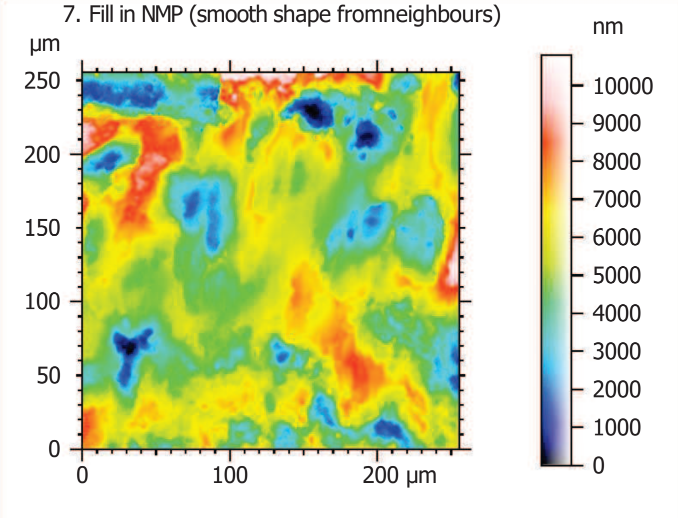


3D view

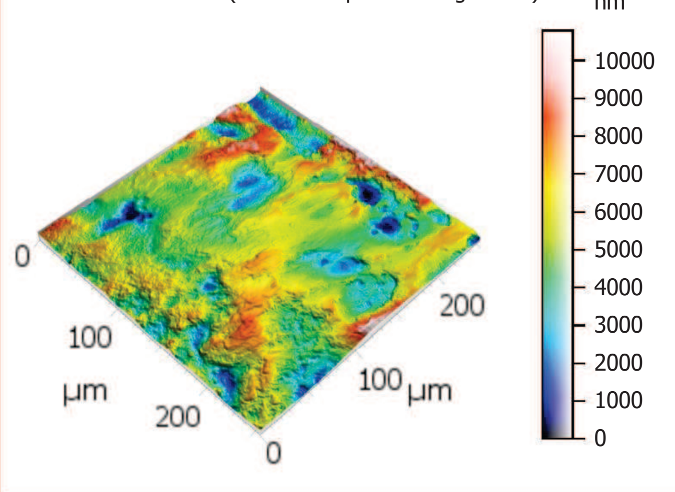


Identity card		
Name:	NRQ_5100_LSM_50x_...filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R...75_surface2_Topo.sur	
Created on:	5/5/2020 2:31:39 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	10790	nm
Min:	-5233	nm
Max:	5557	nm
Size:	187888	digits
Spacing:	0.05743	nm
NM-points ratio:	12.00 % (1079692 Pts)	

7. Fill in NMP (smooth shape fromneighbours)



7. Fill in NMP (smooth shape from neighbours)

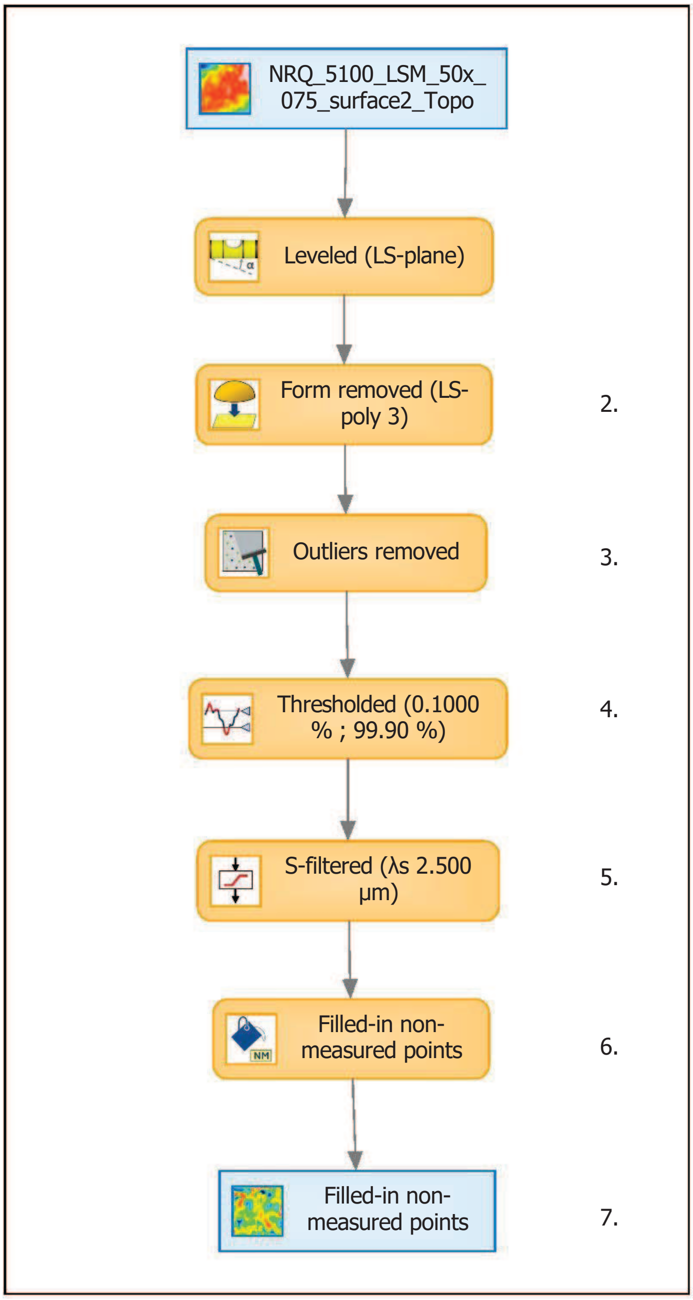


Identity card		
Name:	NRQ_5100_LSM_50x_0...in non-measured points	
Created on:	5/5/2020 2:31:39 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	10790	nm
Size:	187888	digits
Spacing:	0.05743	nm
NM-points ratio:	0.000 % (0 Pts)	

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1627	nm
Ssk	-0.04036	
Sku	3.269	
Sp	5541	nm
Sv	5249	nm
Sz	10790	nm
Sa	1279	nm
Functional parameters		
Smr	0.5356	%
Smc	1929	nm
Sxp	3361	nm
Spatial parameters		
Sal	18.38	µm
Str	0.6101	
Std	81.51	°
Hybrid parameters		
Sdq	0.4143	
Sdr	6.709	%
Functional parameters (Volume)		
Vm	0.09104	µm³/µm²
Vv	2.021	µm³/µm²
Vmp	0.09104	µm³/µm²
Vmc	1.421	µm³/µm²
Vvc	1.821	µm³/µm²
Vvv	0.1994	µm³/µm²



Analyses:

ISO 25178 8.

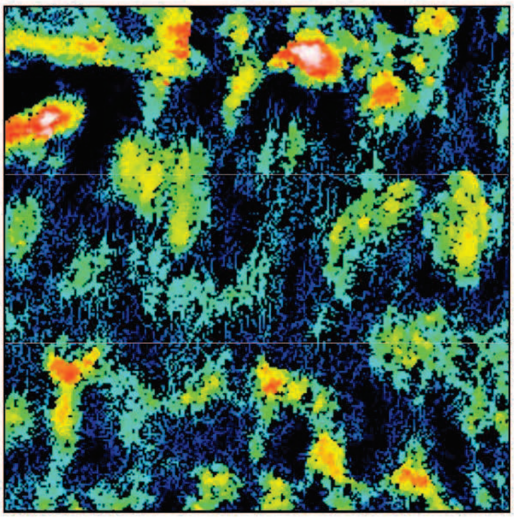
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

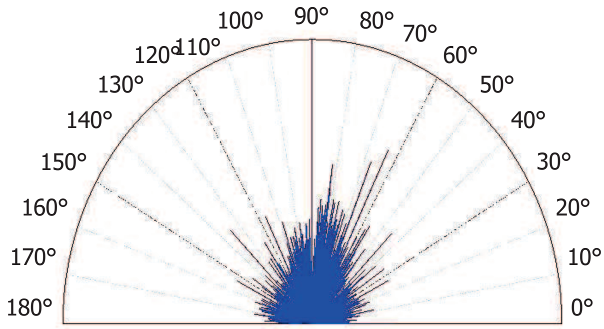
9. Furrow analysis on surface #7



All furrows are shown.

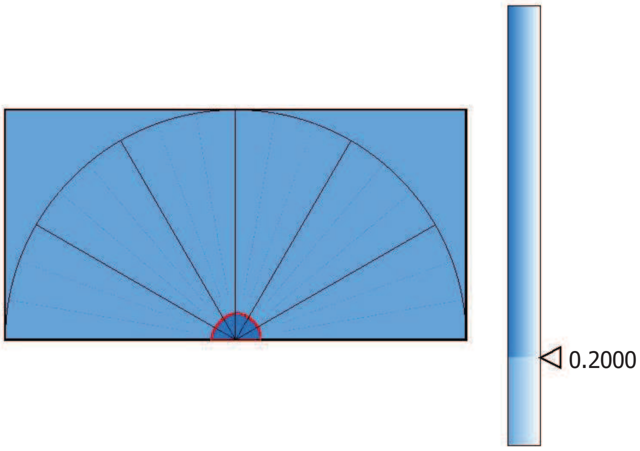
Parameters	Value	Unit
Maximum depth of furrows	6949	nm
Mean depth of furrows	2059	nm
Mean density of furrows	3757	cm/cm2

10. Texture direction on surface #7



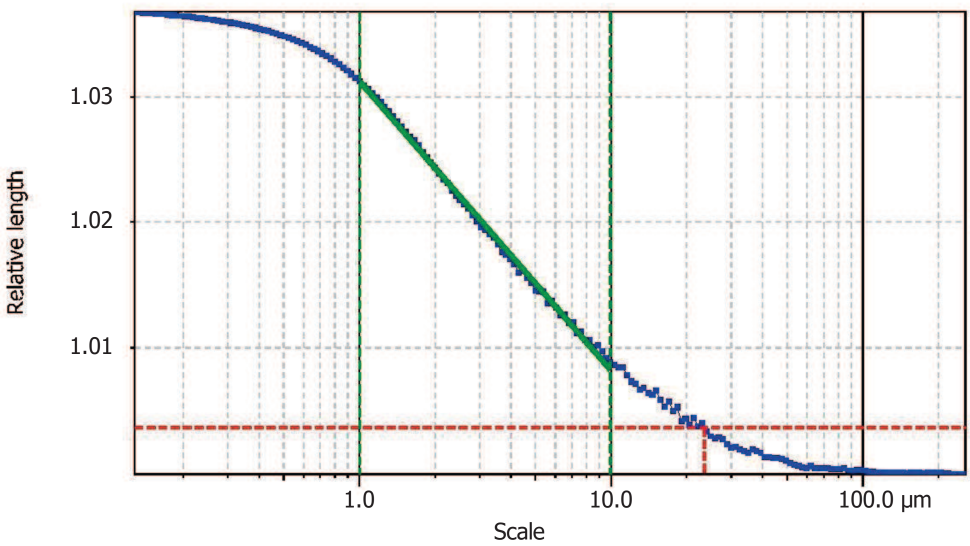
Parameters	Value	Unit
First direction	90.00	°
Second direction	63.52	°
Third direction	81.72	°

11. Texture isotropy on surface #7



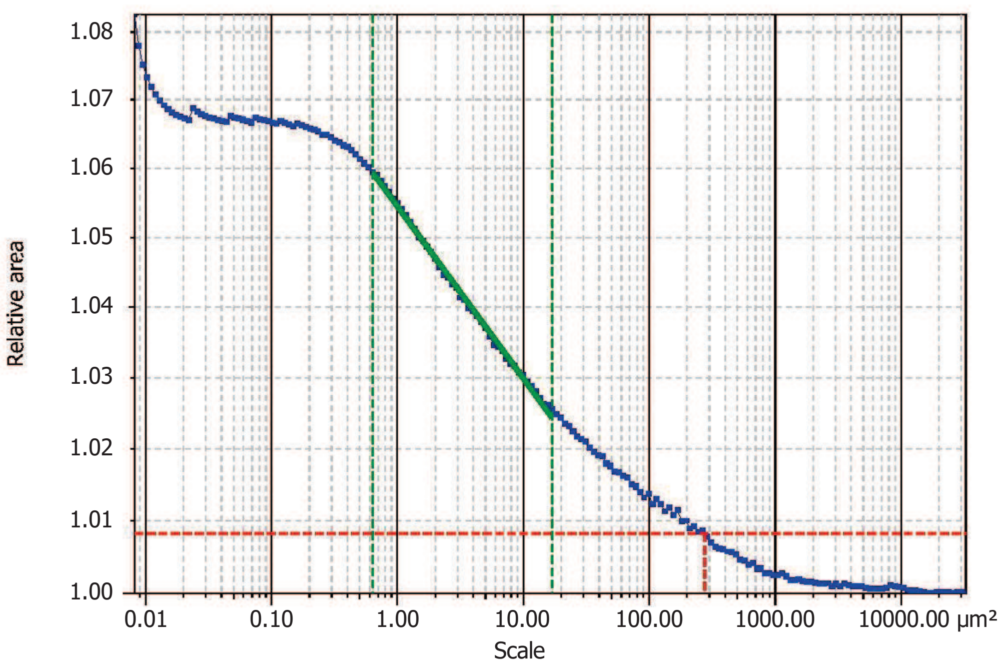
Parameters	Value	Unit
Isotropy	88.83	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.00143		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01718		*Length-scale anisotropy (1.8 µm, 5°)*

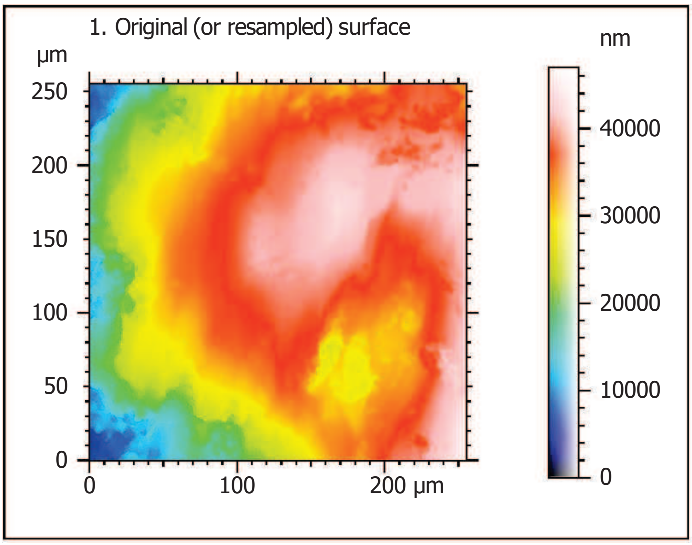


Information	
Method	Area-scale (four corners)

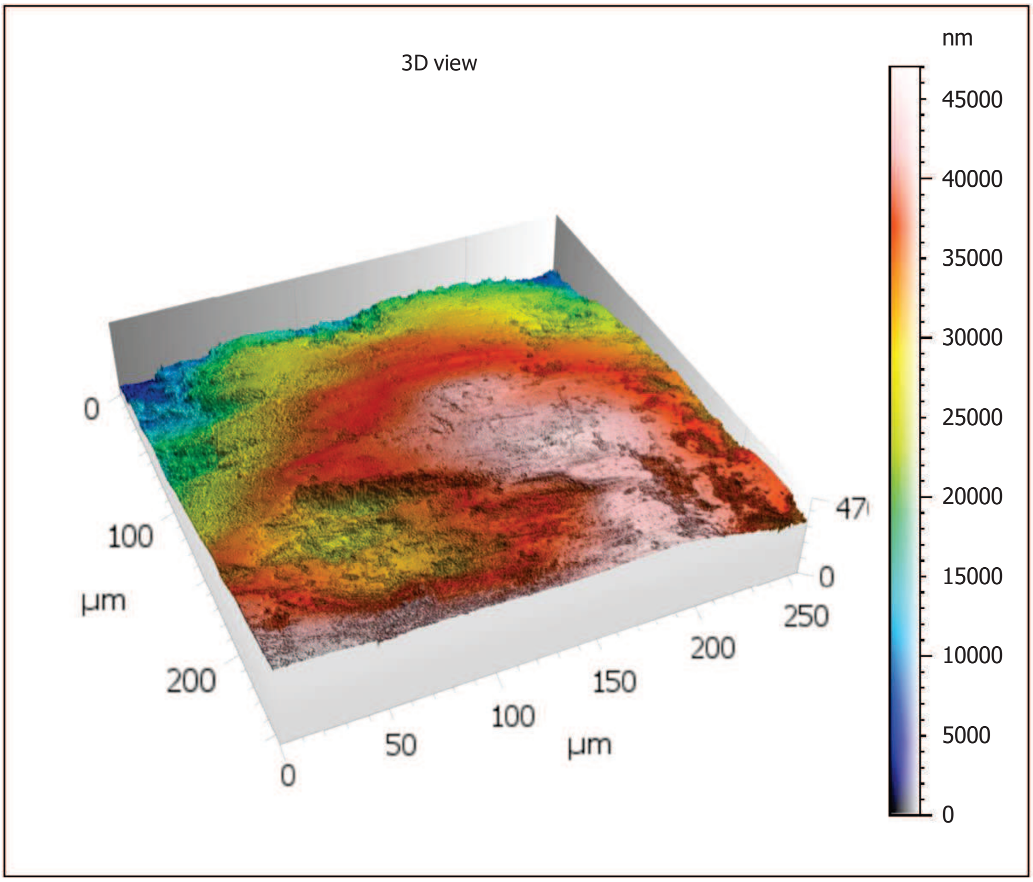
Parameters	Value	Unit	Comment
Asfc	10.23		*Fractal complexity*
Smfc	2.156	µm²	*Scale of max complexity*
HAsfc9	0.6152		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.9553		*Heterogeneity of Asfc (9x9)*

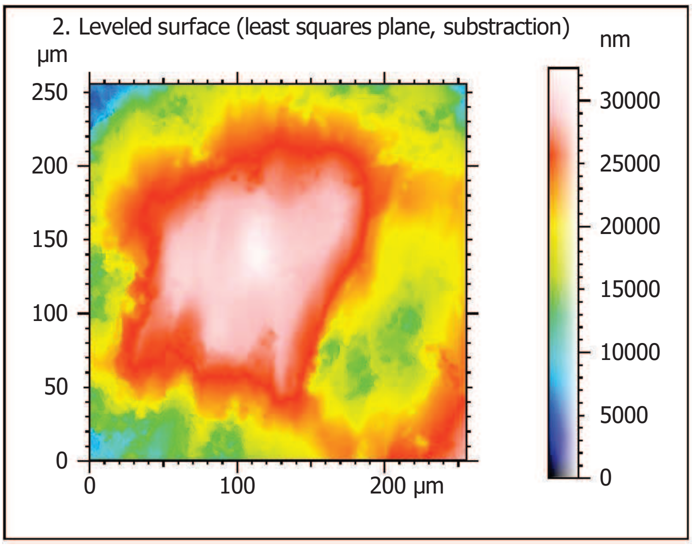
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

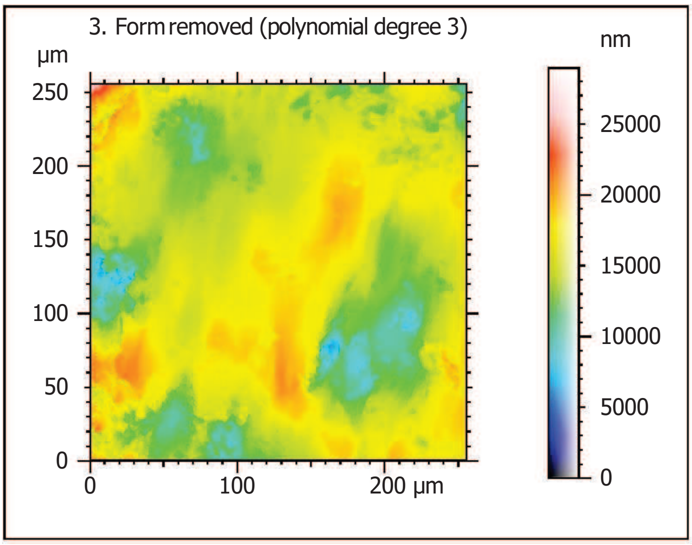
Processing

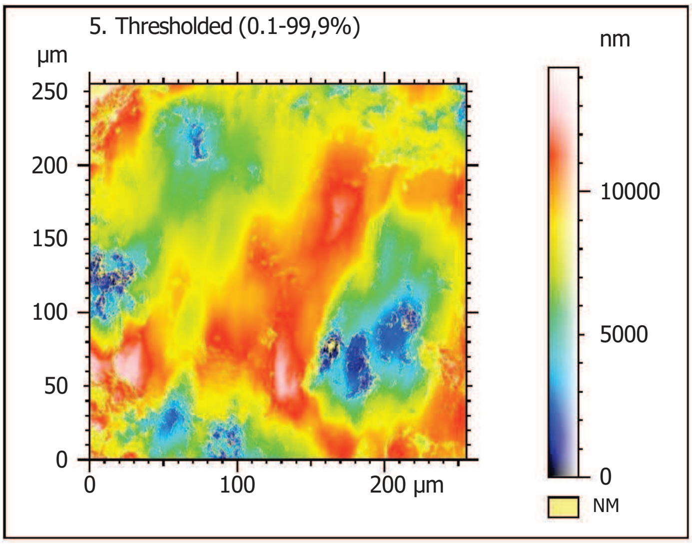


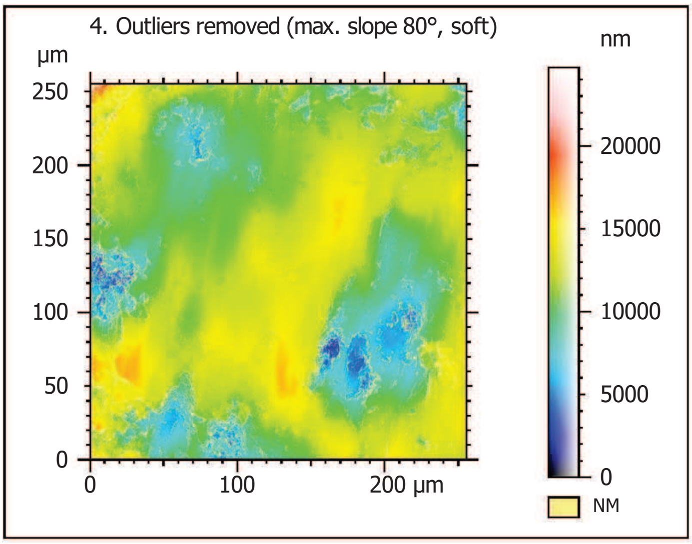
Identity card			
Name:	NRQ_5100_LSM_50x_075_surface3_Topo		
Created on:	5/5/2020 2:48:22 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	47023	nm	
Size:	65532	digits	
Spacing:	0.7176	nm	
NM-points ratio:	0.000 % (0 Pts)		

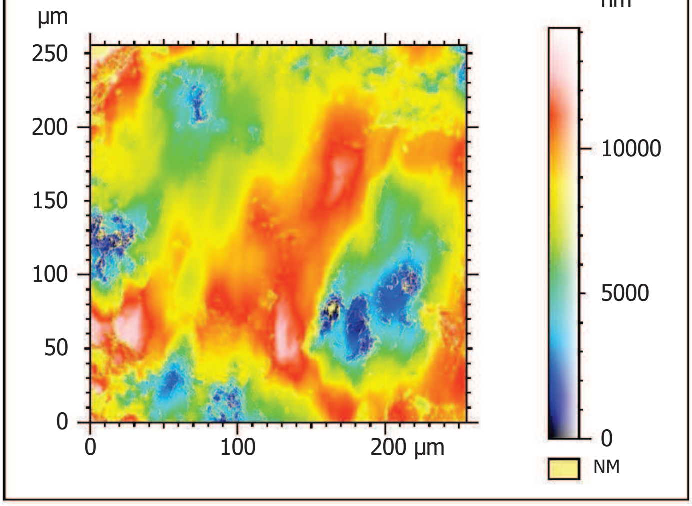



2. Leveled surface (least squares plane, substraction)
µm
nm
250
200
150
100
50
0
0
100
200 µm
30000
25000
20000
15000
10000
5000
0


3. Form removed (polynomial degree 3)
µm
nm
250
200
150
100
50
0
0
100
200 µm
25000
20000
15000
10000
5000
0

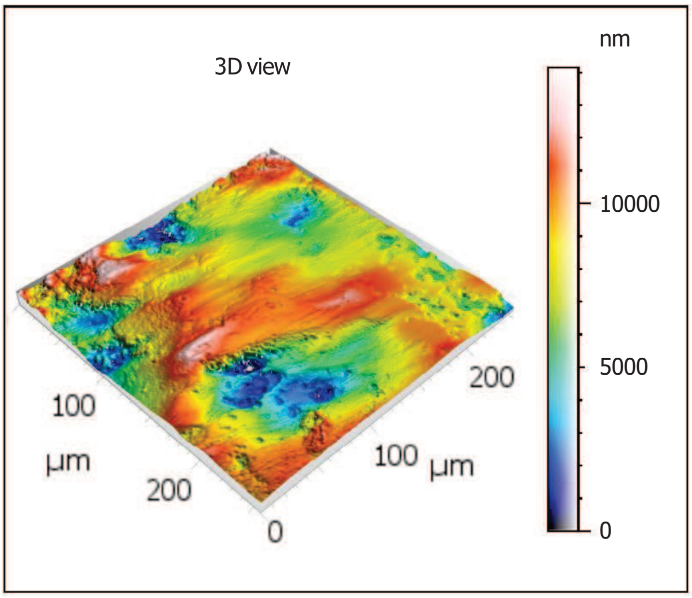

5. Thresholded (0.1-99,9%)
µm
nm
250
200
150
100
50
0
0
100
200 µm
10000
5000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
nm
250
200
150
100
50
0
0
100
200 µm
20000
15000
10000
5000
0
NM

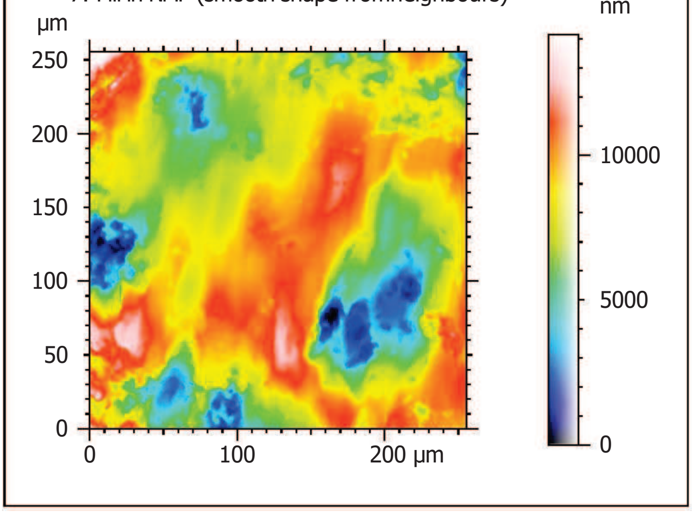


6. Microroughness removed (S-filter, 2.5 µm)

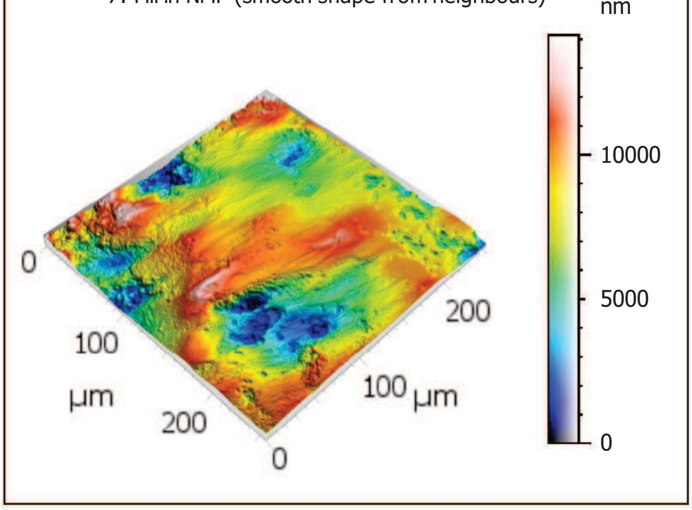
Identity card		
Name:	NRQ_5100_LSM_50x_...filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R...75_surface3_Topo.sur	
Created on:	5/5/2020 2:48:22 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	14142	nm
Min:	-7834	nm
Max:	6308	nm
Size:	197084	digits
Spacing:	0.07176	nm
NM-points ratio:	11.21 % (1008810 Pts)	



3D view

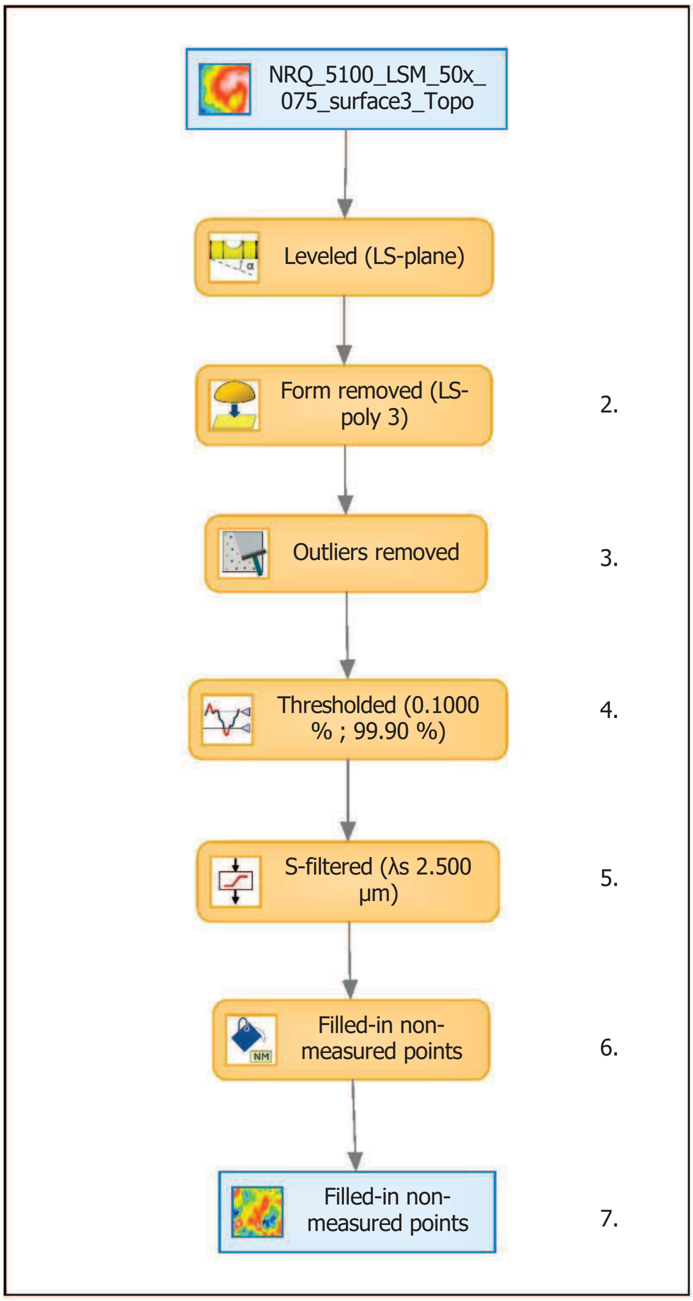


7. Fill in NMP (smooth shape fromneighbours)



7. Fill in NMP (smooth shape from neighbours)

Identity card			
Name:	NRQ_5100_LSM_50x_0...in non-measured points		
Created on:	5/5/2020 2:48:22 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	14142	nm	
Size:	197084	digits	
Spacing:	0.07176	nm	
NM-points ratio:	0.000 % (0 Pts)		



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface			
F: [Workflow] Form removed (LS-poly 3)			
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)			
Height parameters			
Sq	2478	nm	
Ssk	-0.5696		
Sku	2.943		
Sp	6292	nm	
Sv	7849	nm	
Sz	14142	nm	
Sa	1988	nm	
Functional parameters			
Smr	0.2278	%	
Smc	2848	nm	
Sxp	5909	nm	
Spatial parameters			
Sal	31.83	µm	
Str	*****		
Std	81.25	°	
Hybrid parameters			
Sdq	0.4193		
Sdr	6.773	%	
Functional parameters (Volume)			
Vm	0.07341	µm³/µm²	
Vv	2.922	µm³/µm²	
Vmp	0.07341	µm³/µm²	
Vmc	2.327	µm³/µm²	
Vvc	2.565	µm³/µm²	
Vvv	0.3564	µm³/µm²	

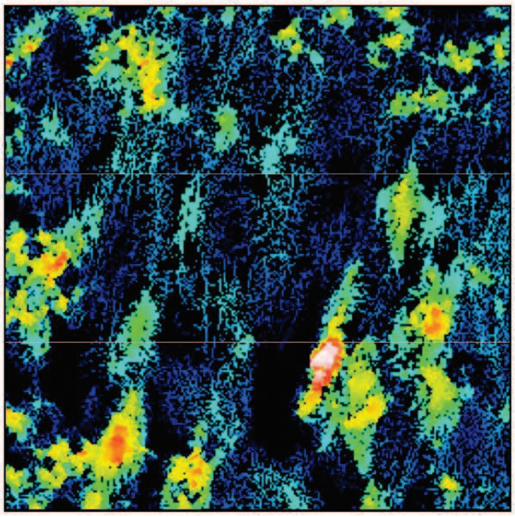
Analyses:

ISO 25178	8.
Furrow	9.
Texture direction	10.
Texture isotropy	11.
SSFA	12.

Warnings

Str: The autocorrelation lobe touches the edges. Try to level the...

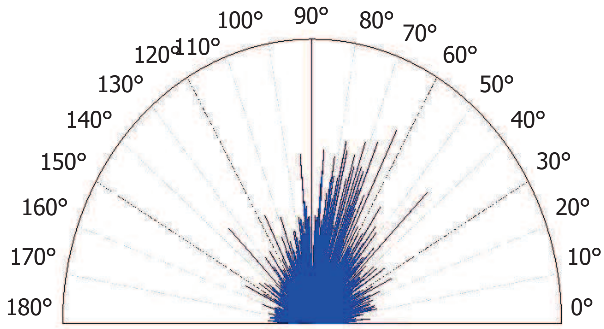
9. Furrow analysis on surface #7



All furrows are shown.

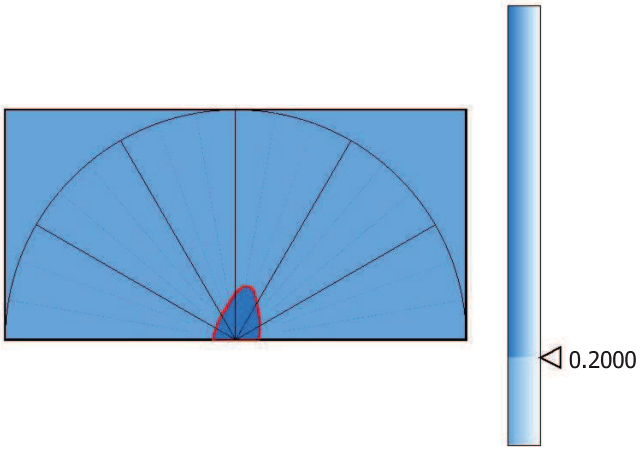
Parameters	Value	Unit
Maximum depth of furrows	7362	nm
Mean depth of furrows	1891	nm
Mean density of furrows	3605	cm/cm2

10. Texture direction on surface #7



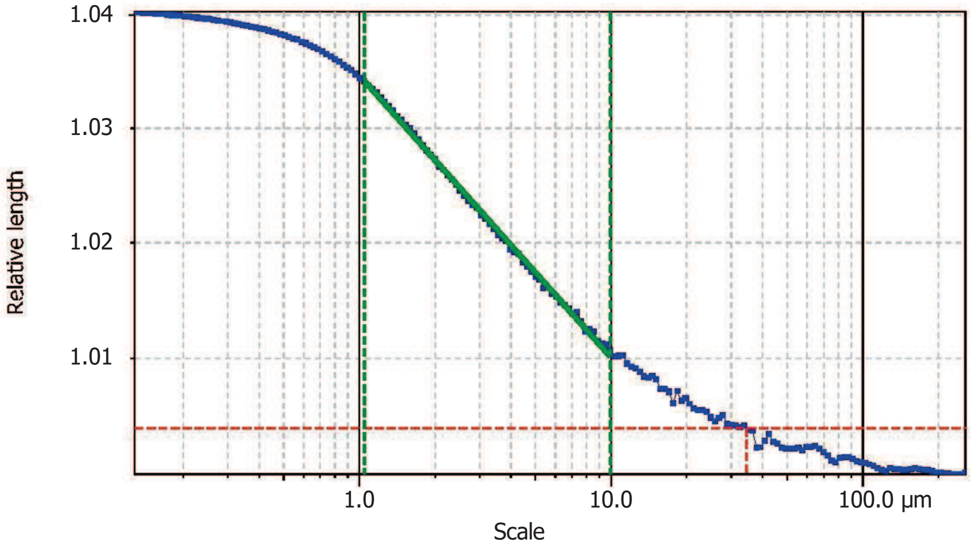
Parameters	Value	Unit
First direction	90.01	°
Second direction	63.53	°
Third direction	71.48	°

11. Texture isotropy on surface #7



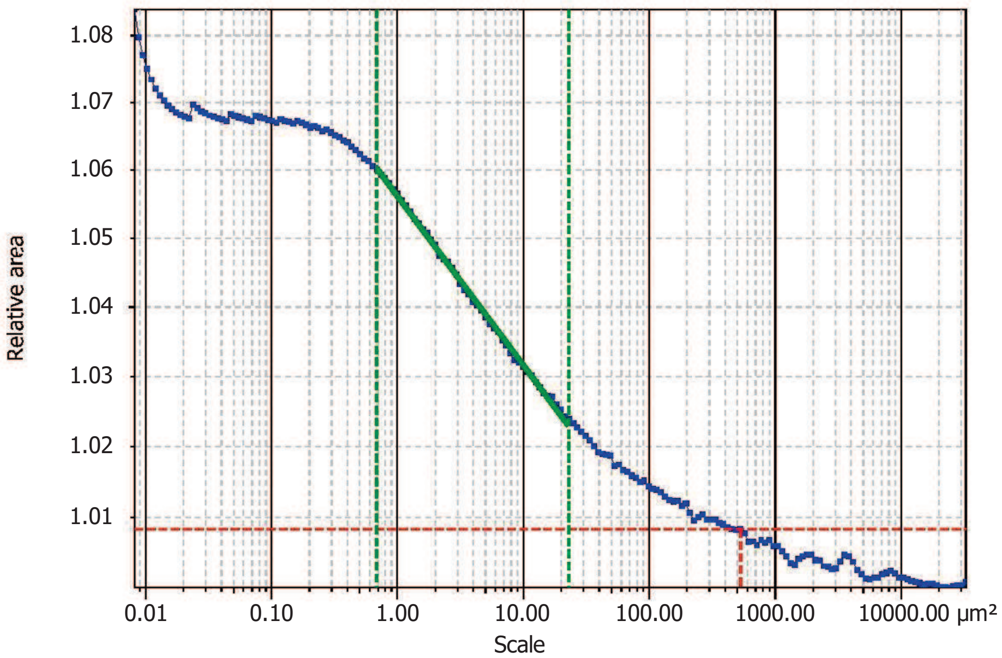
Parameters	Value	Unit
Isotropy	41.24	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.003763		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01742		*Length-scale anisotropy (1.8 µm, 5°)*

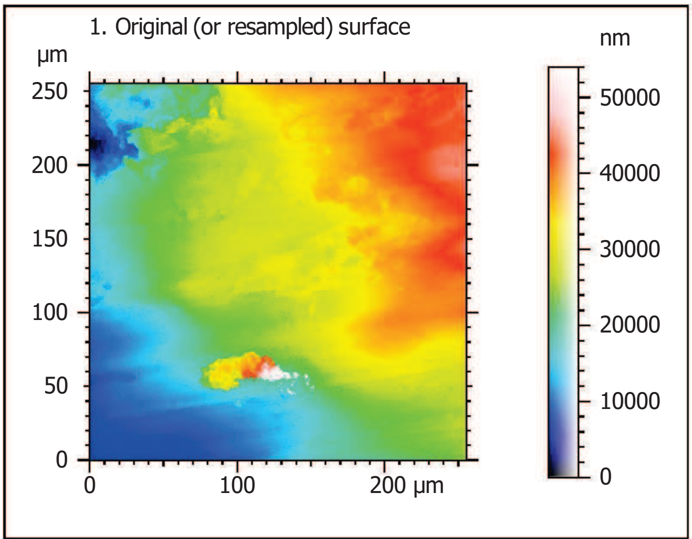


Information	
Method	Area-scale (four corners)

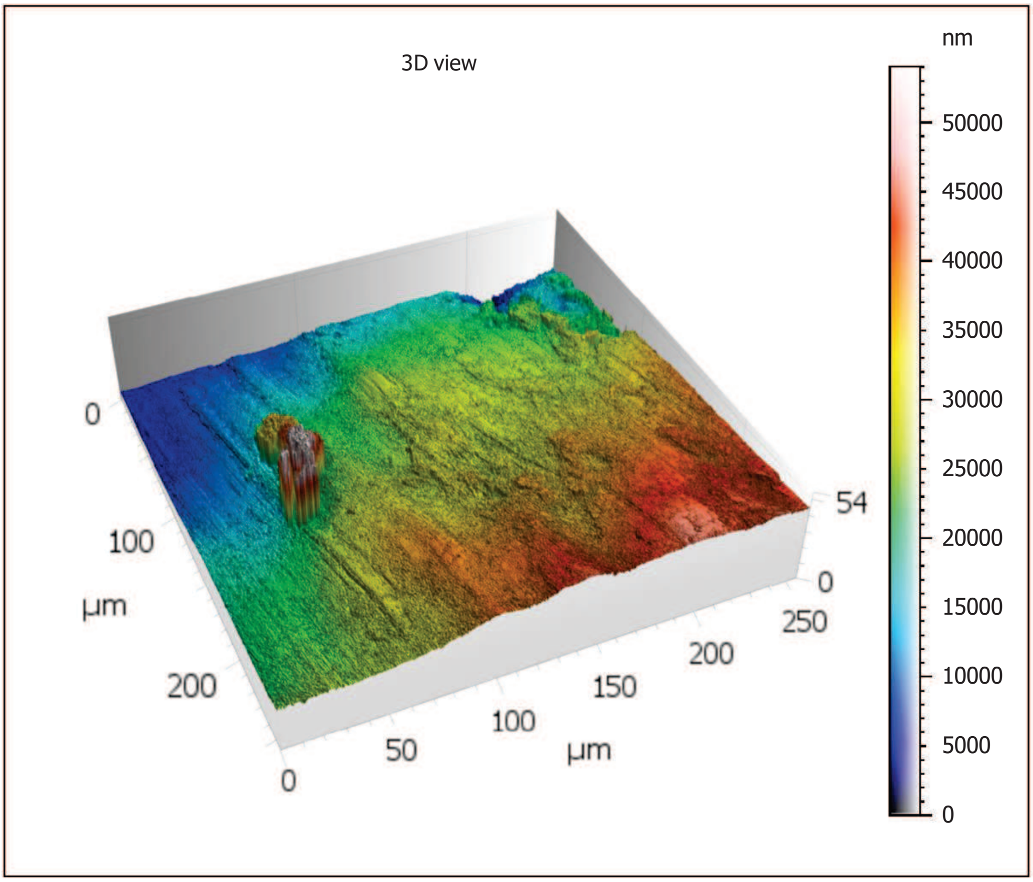
Parameters	Value	Unit	Comment
Asfc	10.19		*Fractal complexity*
Smfc	2.711	µm²	*Scale of max complexity*
HAsfc9	0.5068		*Heterogeneity of Asfc (3x3)*
HAsfc81	1.536		*Heterogeneity of Asfc (9x9)*

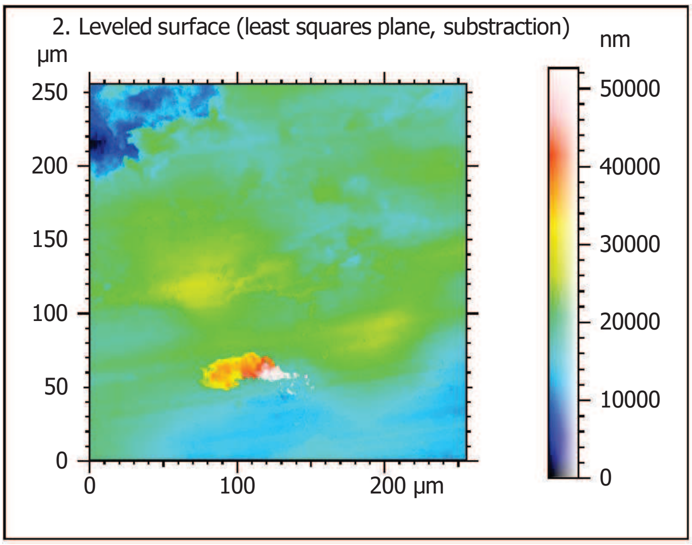
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

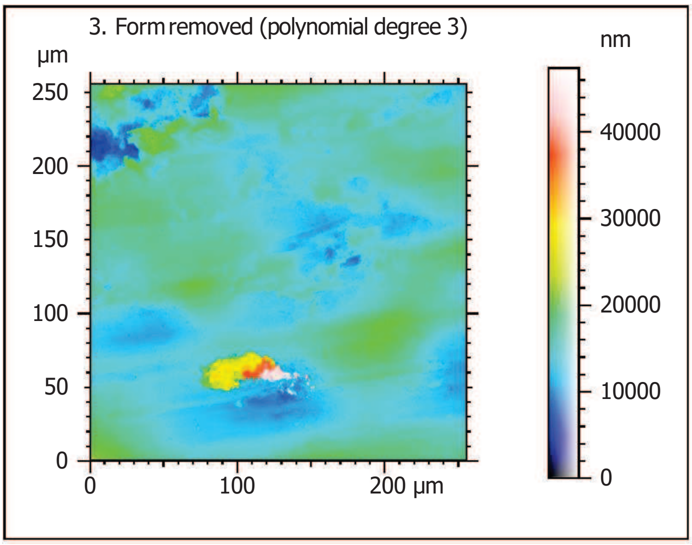
Processing

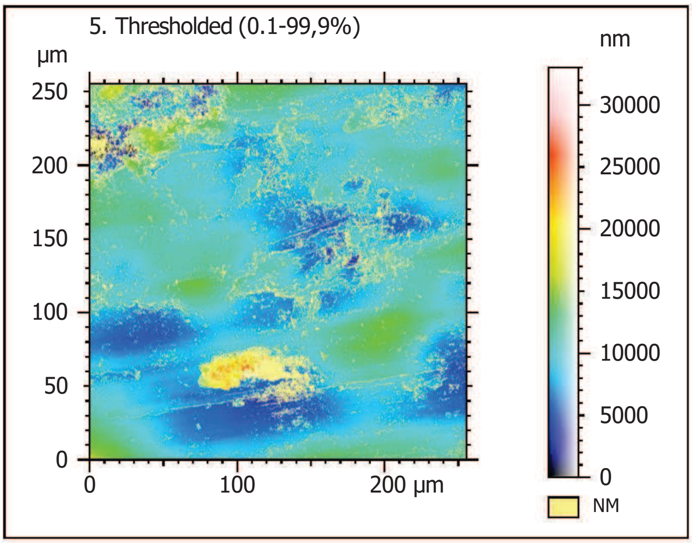


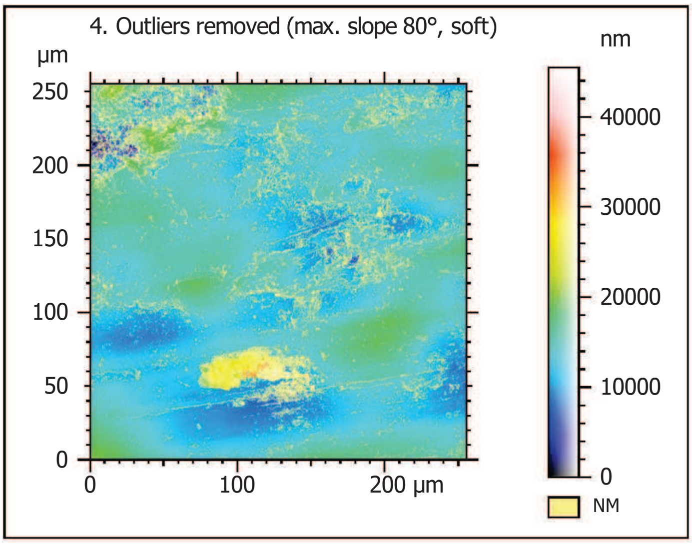
Identity card			
Name:	NRQ_8646_LSM_50x_075_surface1_Topo		
Created on:	5/5/2020 10:56:09 AM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	54018	nm	
Size:	65532	digits	
Spacing:	0.8243	nm	
NM-points ratio:	0.000 % (0 Pts)		

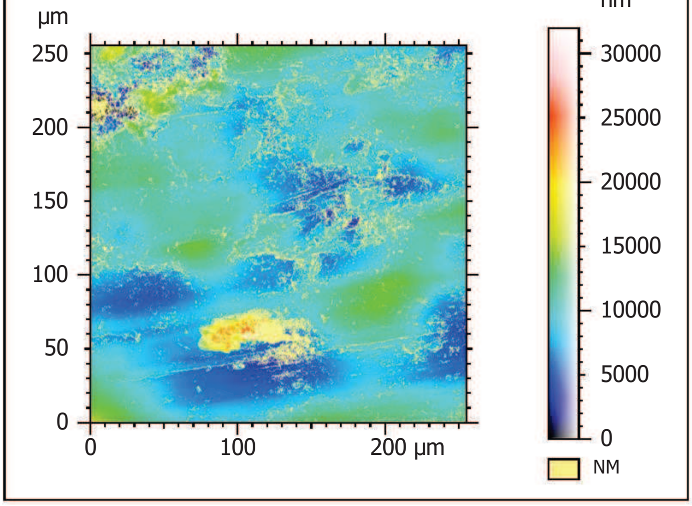



2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
50000
40000
30000
20000
10000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
40000
30000
20000
10000
0

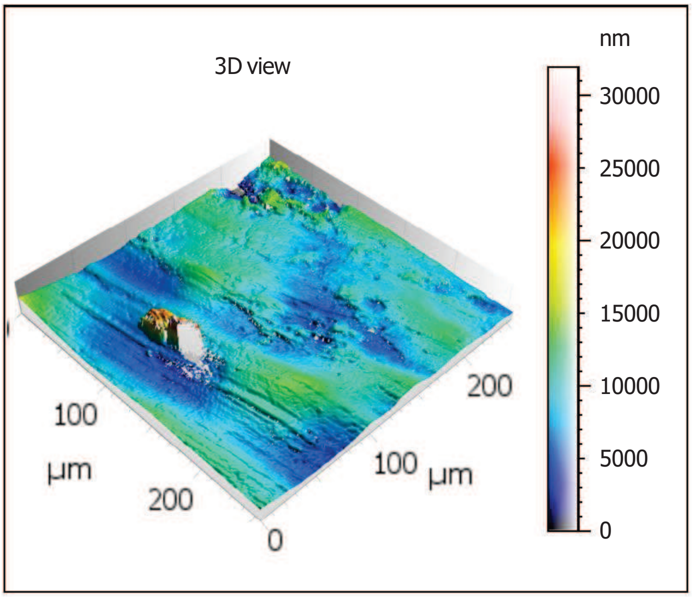

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
30000
25000
20000
15000
10000
5000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
40000
30000
20000
10000
0
NM

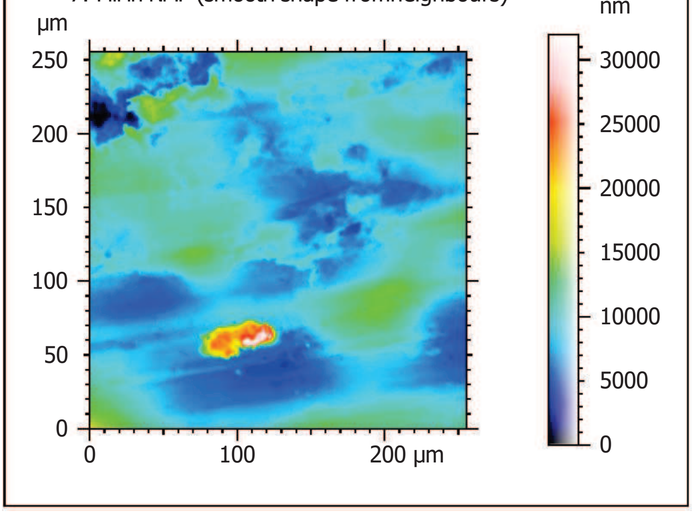


6. Microroughness removed (S-filter, 2.5 µm)

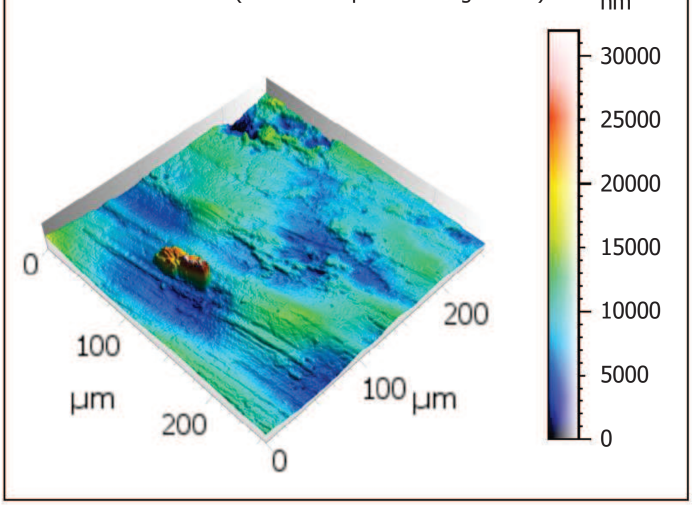
Identity card		
Name:	NRQ_8646_LSM_50x_...filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R...75_surface1_Topo.sur	
Created on:	5/5/2020 10:56:09 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	31950	nm
Min:	-9007	nm
Max:	22943	nm
Size:	387604	digits
Spacing:	0.08243	nm
NM-points ratio:	20.21 % (1819205 Pts)	



3D view

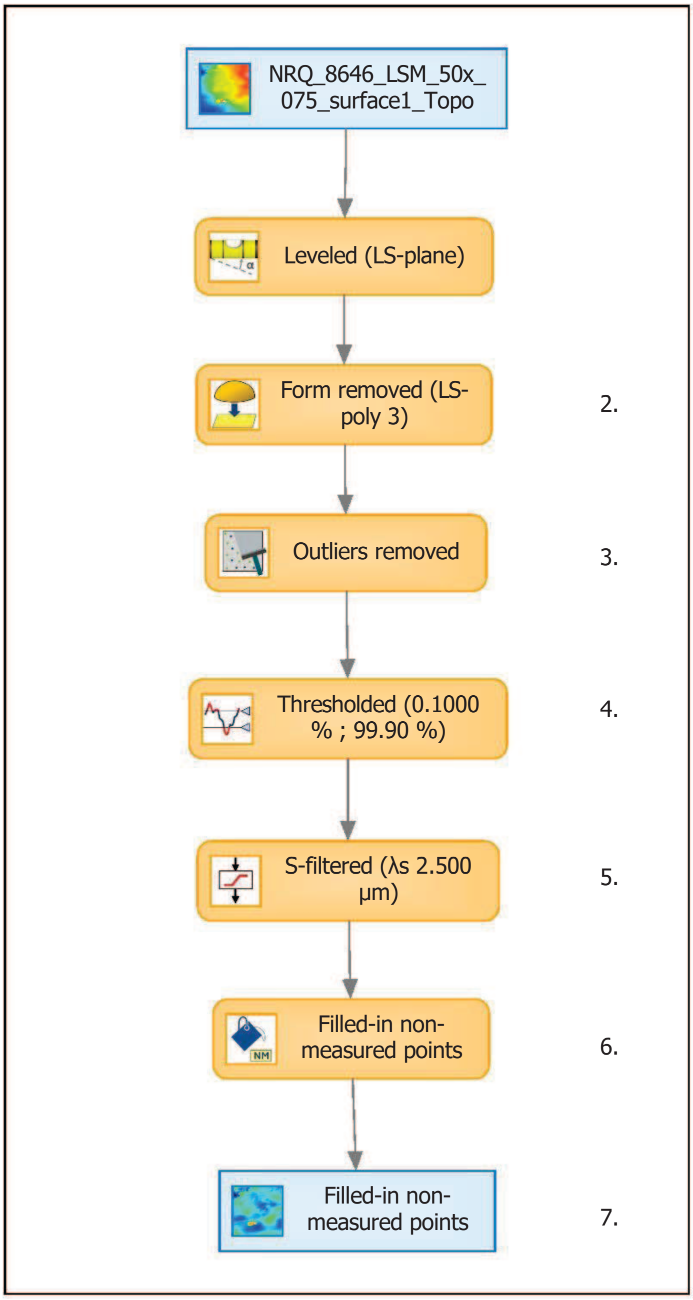


7. Fill in NMP (smooth shape fromneighbours)



7. Fill in NMP (smooth shape from neighbours)

Identity card		
Name:	NRQ_8646_LSM_50x_0...in non-measured points	
Created on:	5/5/2020 10:56:09 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	31950	nm
Size:	387604	digits
Spacing:	0.08243	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

Analyses:

ISO 25178 8.

Furrow 9.

Texture direction 10.

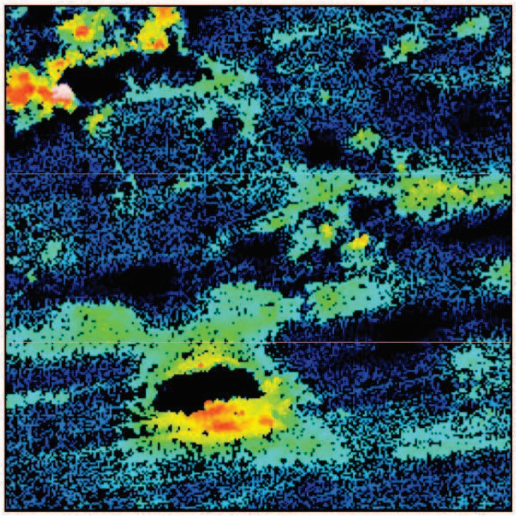
Texture isotropy 11.

SSFA 12.

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	2613	nm
Ssk	1.719	
Sku	13.59	
Sp	22981	nm
Sv	8969	nm
Sz	31950	nm
Sa	1854	nm
Functional parameters		
Smr	0.0271	%
Smc	2633	nm
Sxp	4088	nm
Spatial parameters		
Sal	16.77	µm
Str	0.4581	
Std	8.497	°
Hybrid parameters		
Sdq	0.7278	
Sdr	12.29	%
Functional parameters (Volume)		
Vm	0.2113	µm³/µm²
Vv	2.844	µm³/µm²
Vmp	0.2113	µm³/µm²
Vmc	2.003	µm³/µm²
Vvc	2.600	µm³/µm²
Vvv	0.2438	µm³/µm²

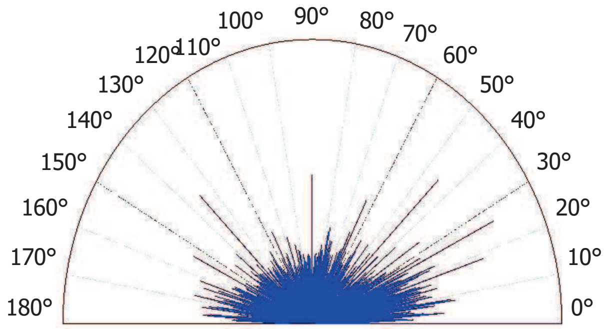
9. Furrow analysis on surface #7



All furrows are shown.

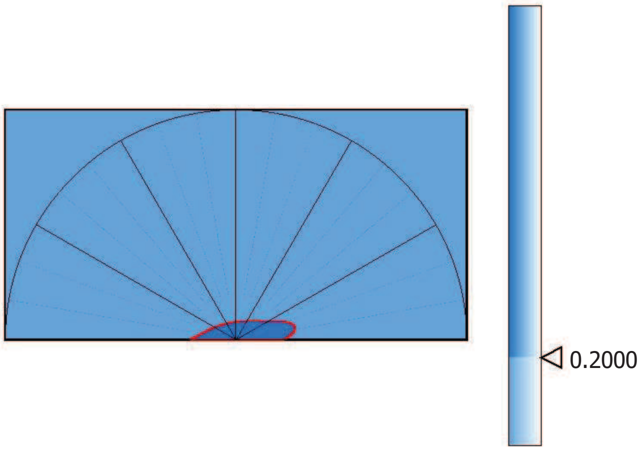
Parameters	Value	Unit
Maximum depth of furrows	9746	nm
Mean depth of furrows	2382	nm
Mean density of furrows	4364	cm/cm2

10. Texture direction on surface #7



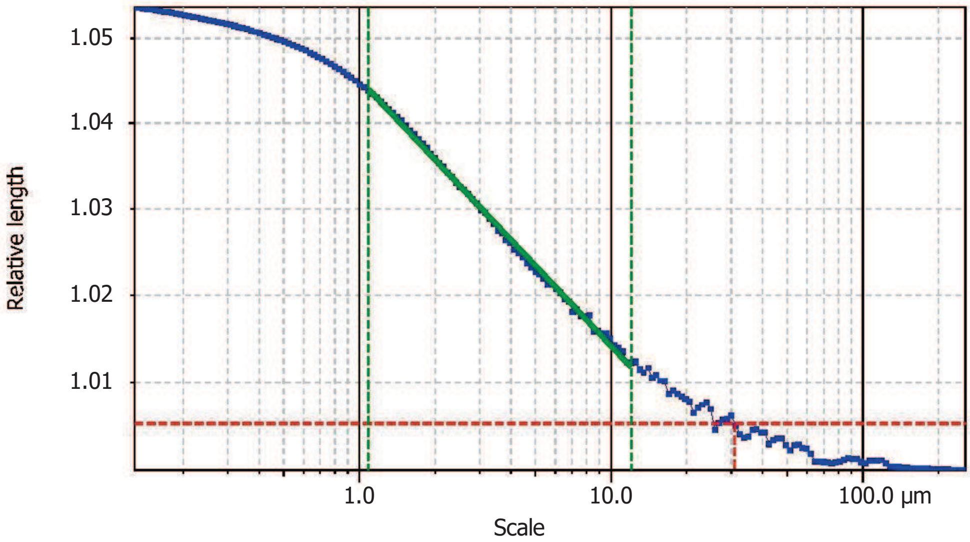
Parameters	Value	Unit
First direction	0.01634	°
Second direction	26.46	°
Third direction	18.52	°

11. Texture isotropy on surface #7



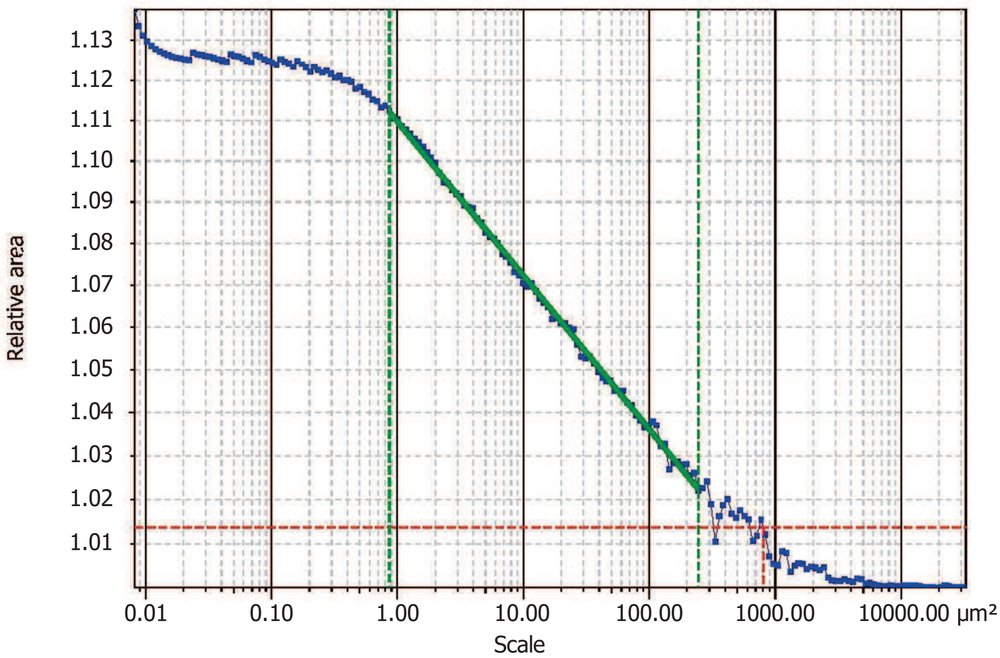
Parameters	Value	Unit
Isotropy	29.72	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.003529		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01893		*Length-scale anisotropy (1.8 µm, 5°)*

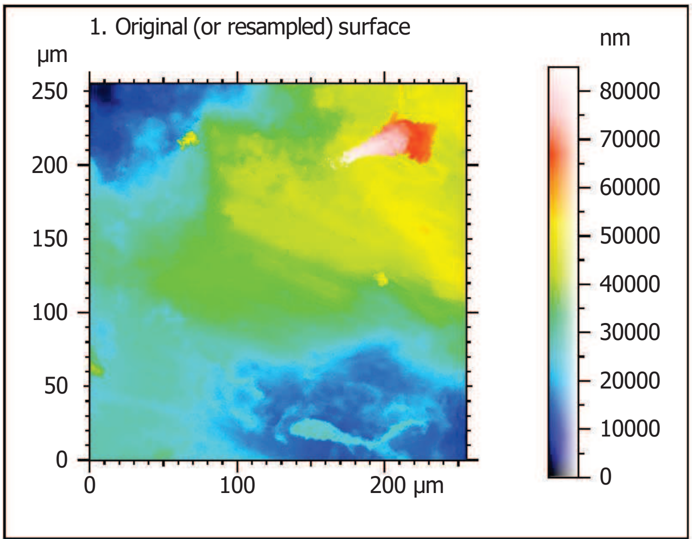


Information	
Method	Area-scale (four corners)

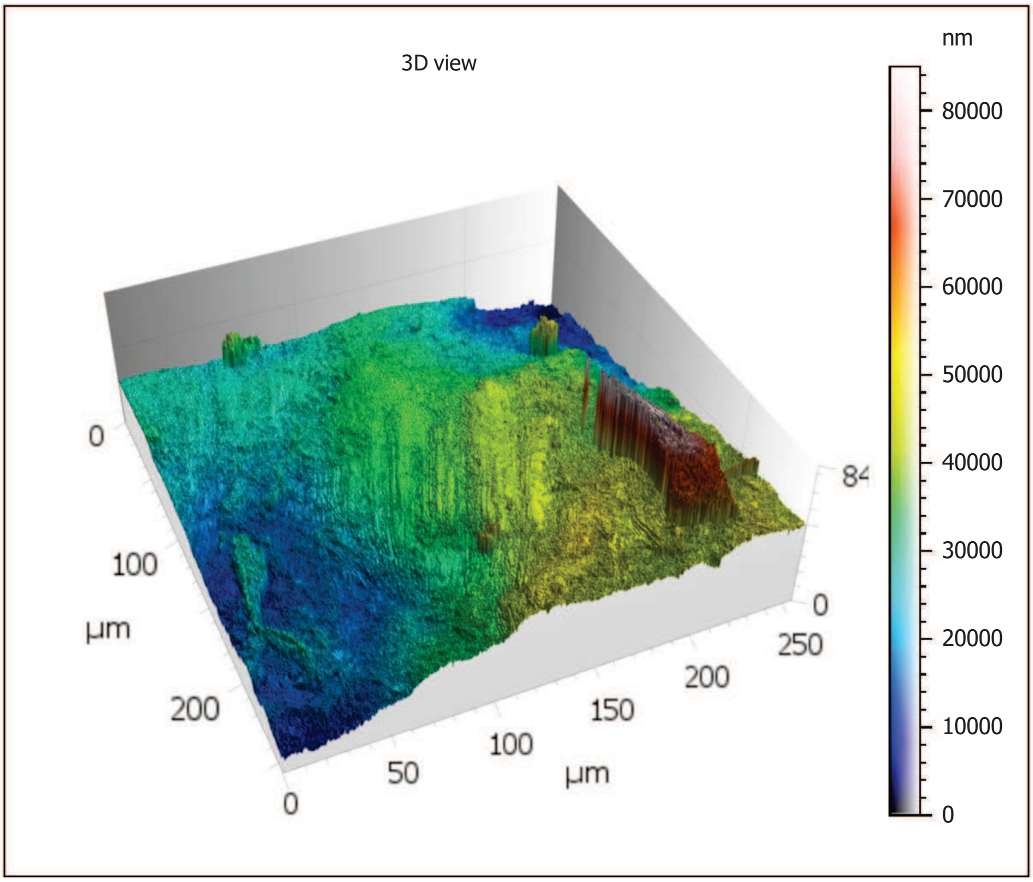
Parameters	Value	Unit	Comment
Asfc	14.90		*Fractal complexity*
Smfc	3.410	µm²	*Scale of max complexity*
HAsfc9	1.200		*Heterogeneity of Asfc (3x3)*
HAsfc81	2.546		*Heterogeneity of Asfc (9x9)*

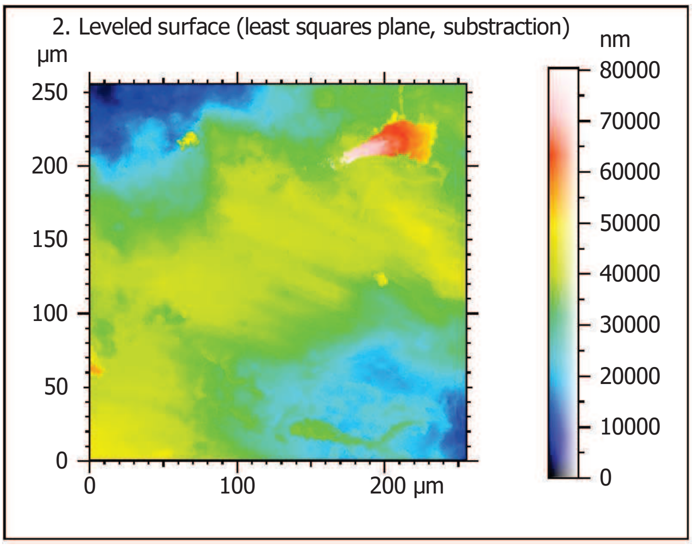
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

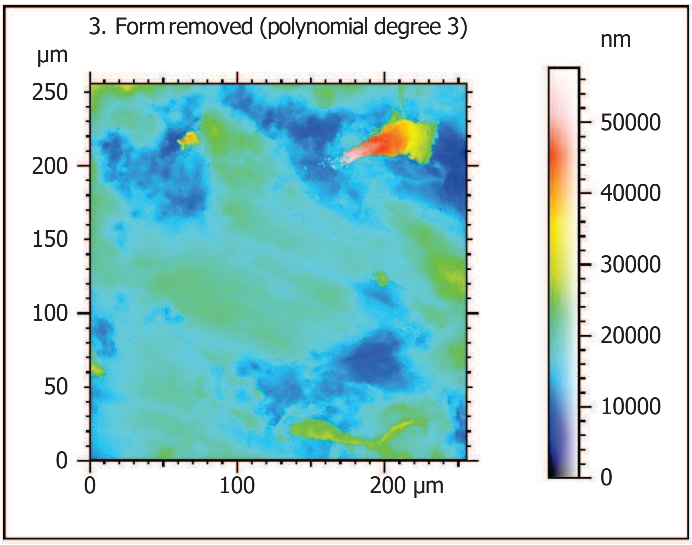
Processing

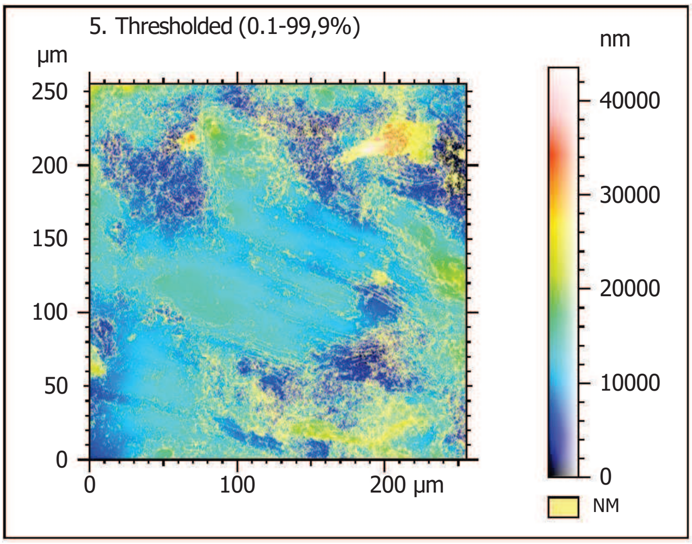


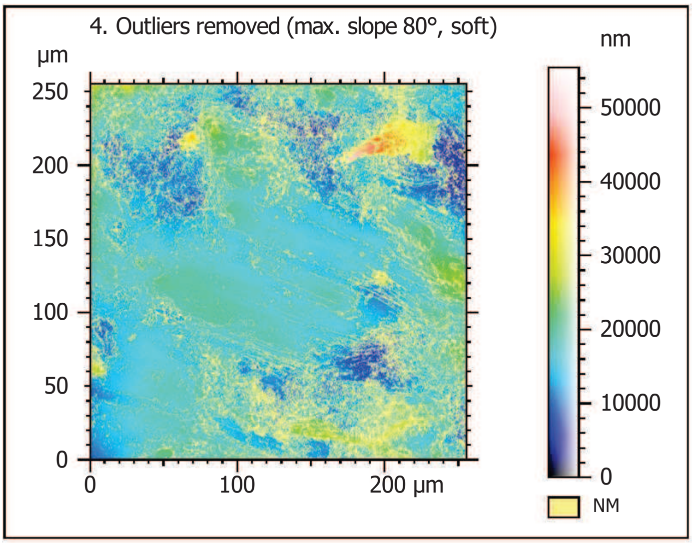
Identity card			
Name:	NRQ_8646_LSM_50x_075_surface2_Topo		
Created on:	5/5/2020 11:24:37 AM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	84987	nm	
Size:	65532	digits	
Spacing:	1.297	nm	
NM-points ratio:	0.000 % (0 Pts)		



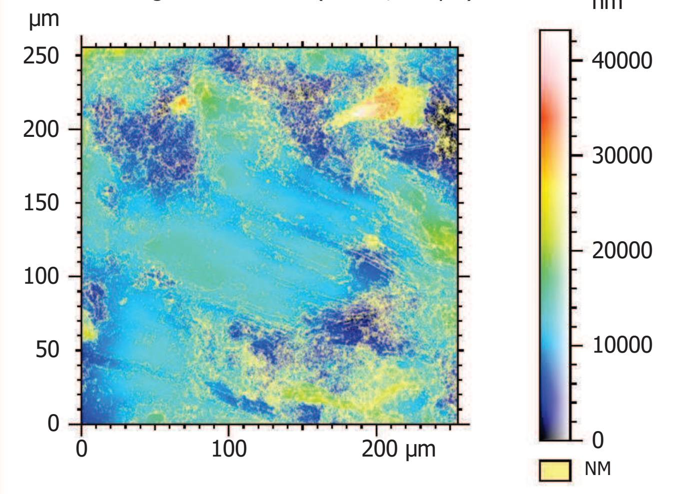

2. Leveled surface (least squares plane, substraction)
µm
nm
250
200
150
100
50
0
0
100
200 µm
80000
70000
60000
50000
40000
30000
20000
10000
0

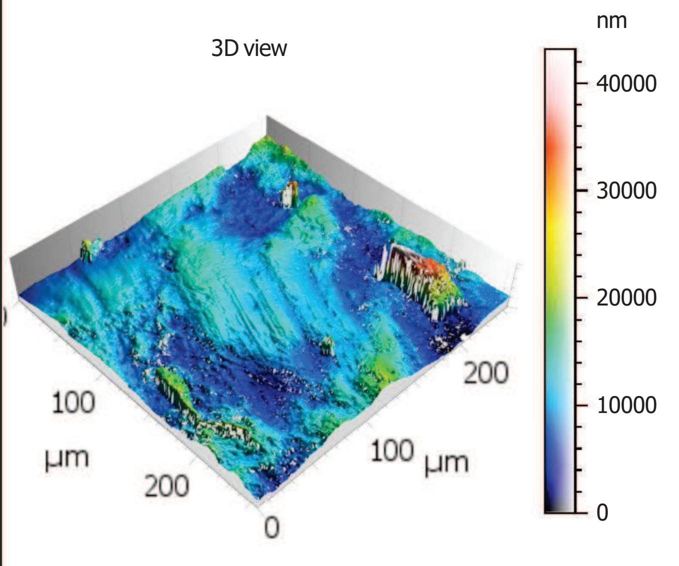

3. Form removed (polynomial degree 3)
µm
nm
250
200
150
100
50
0
0
100
200 µm
50000
40000
30000
20000
10000
0


5. Thresholded (0.1-99,9%)
µm
nm
250
200
150
100
50
0
0
100
200 µm
40000
30000
20000
10000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
nm
250
200
150
100
50
0
0
100
200 µm
50000
40000
30000
20000
10000
0
NM

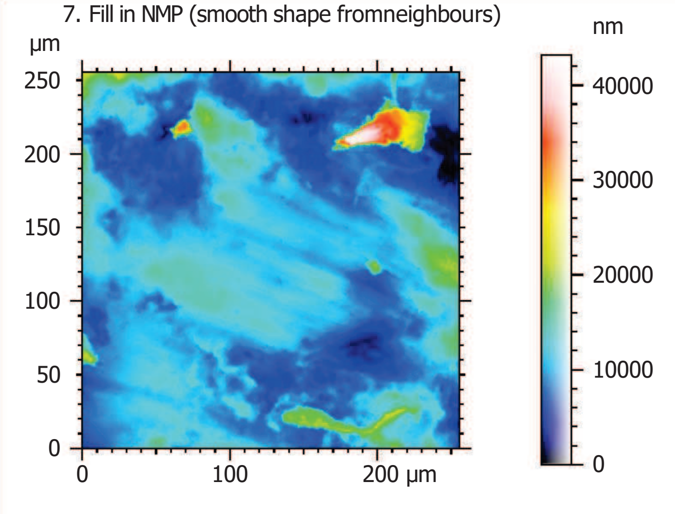
6. Microroughness removed (S-filter, 2.5 µm)



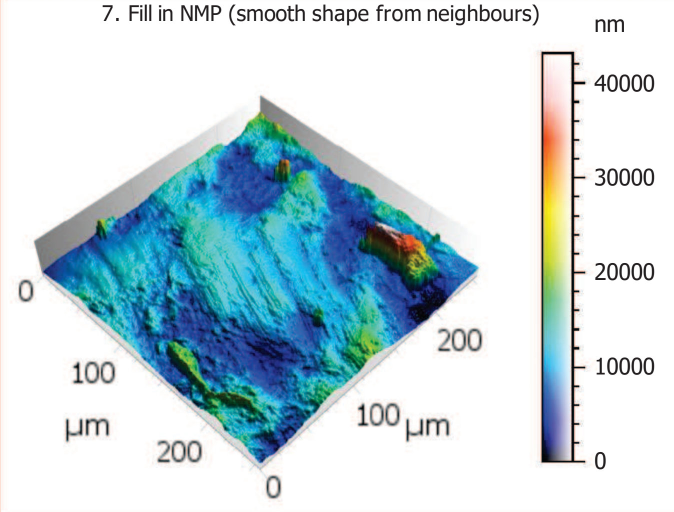


Identity card			
Name:	NRQ_8646_LSM_50x_...filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R...75_surface2_Topo.sur		
Created on:	5/5/2020 11:24:37 AM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	0.000	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	-255.5	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	43159	nm	
Min:	-10391	nm	
Max:	32768	nm	
Size:	332795	digits	
Spacing:	0.1297	nm	
NM-points ratio:	36.69 % (3301751 Pts)		

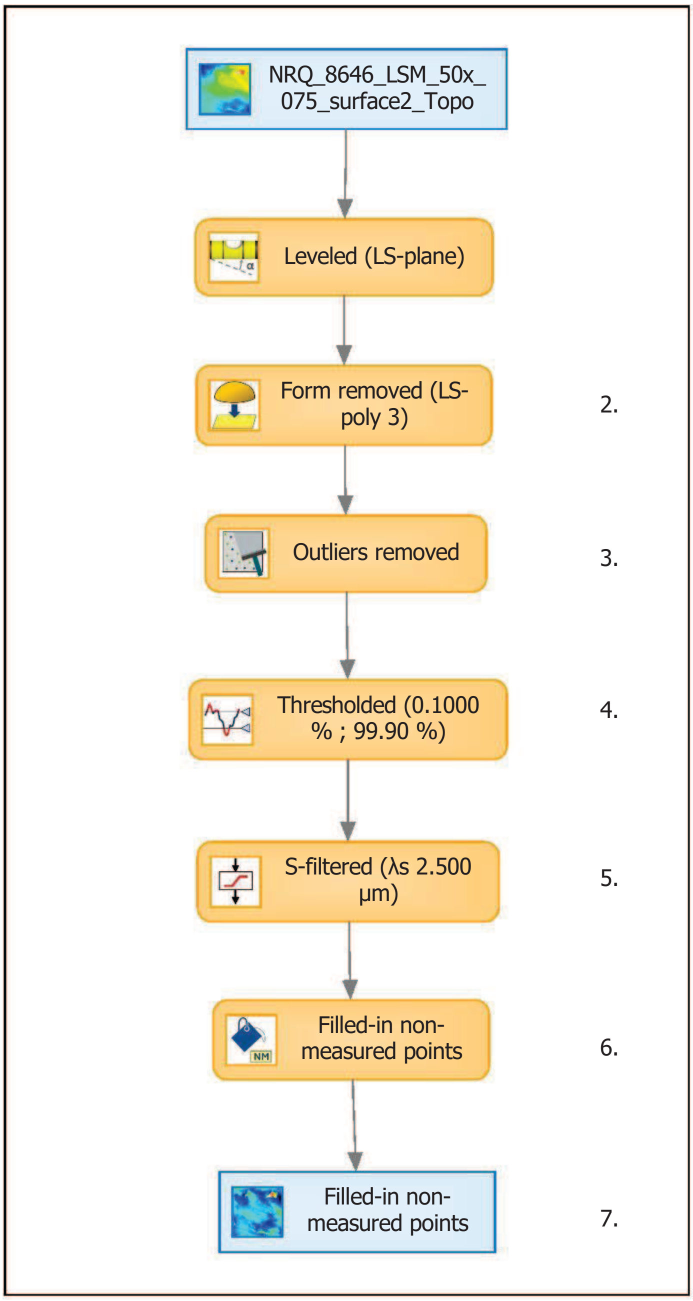
7. Fill in NMP (smooth shape fromneighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card		
Name:	NRQ_8646_LSM_50x_0...in non-measured points	
Created on:	5/5/2020 11:24:37 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	43159	nm
Size:	332795	digits
Spacing:	0.1297	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	4199	nm
Ssk	2.220	
Sku	15.31	
Sp	32724	nm
Sv	10436	nm
Sz	43159	nm
Sa	2801	nm
Functional parameters		
Smr	0.03899	%
Smc	3562	nm
Sxp	6720	nm
Spatial parameters		
Sal	16.89	µm
Str	0.6078	
Std	176.5	°
Hybrid parameters		
Sdq	1.258	
Sdr	26.72	%
Functional parameters (Volume)		
Vm	0.4514	µm³/µm²
Vv	4.013	µm³/µm²
Vmp	0.4514	µm³/µm²
Vmc	3.006	µm³/µm²
Vvc	3.656	µm³/µm²
Vvv	0.3573	µm³/µm²

Analyses:

ISO 25178 8.

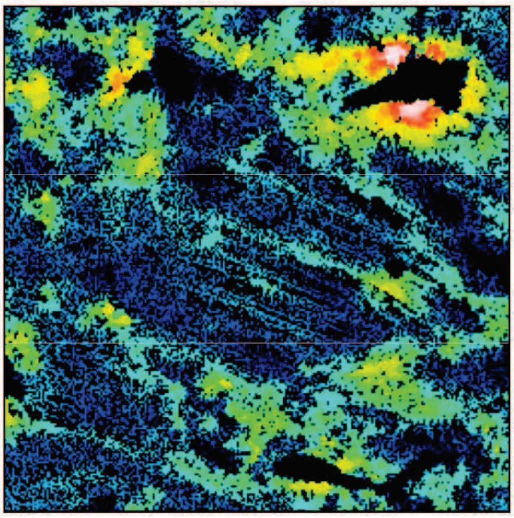
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

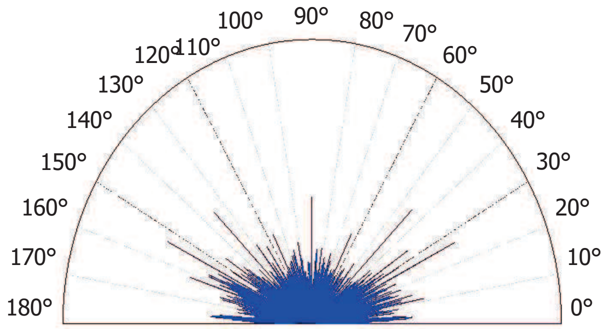
9. Furrow analysis on surface #7



All furrows are shown.

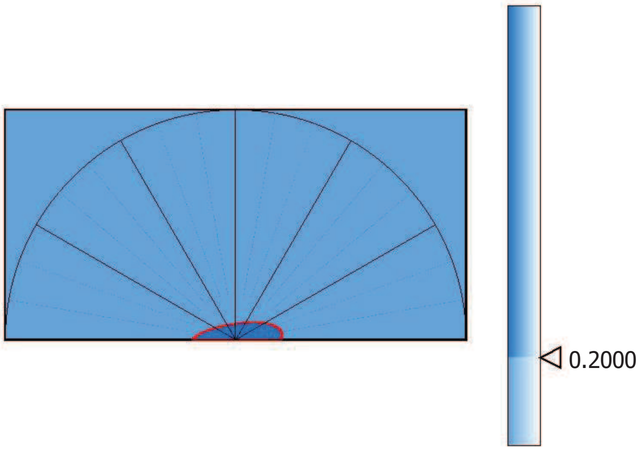
Parameters	Value	Unit	
Maximum depth of furrows	14689	nm	
Mean depth of furrows	4048	nm	
Mean density of furrows	4082	cm/cm2	

10. Texture direction on surface #7



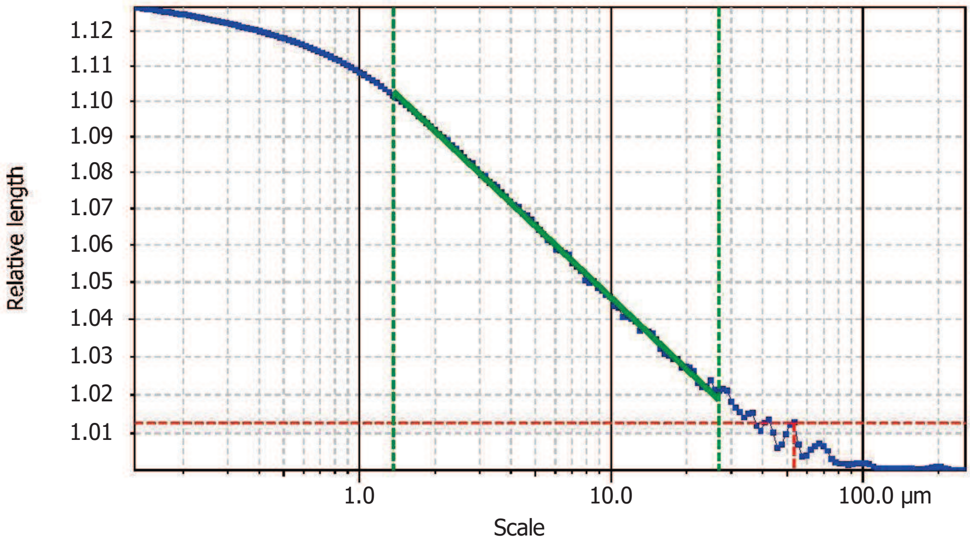
Parameters	Value	Unit	
First direction	0.001966	°	
Second direction	153.5	°	
Third direction	26.52	°	

11. Texture isotropy on surface #7



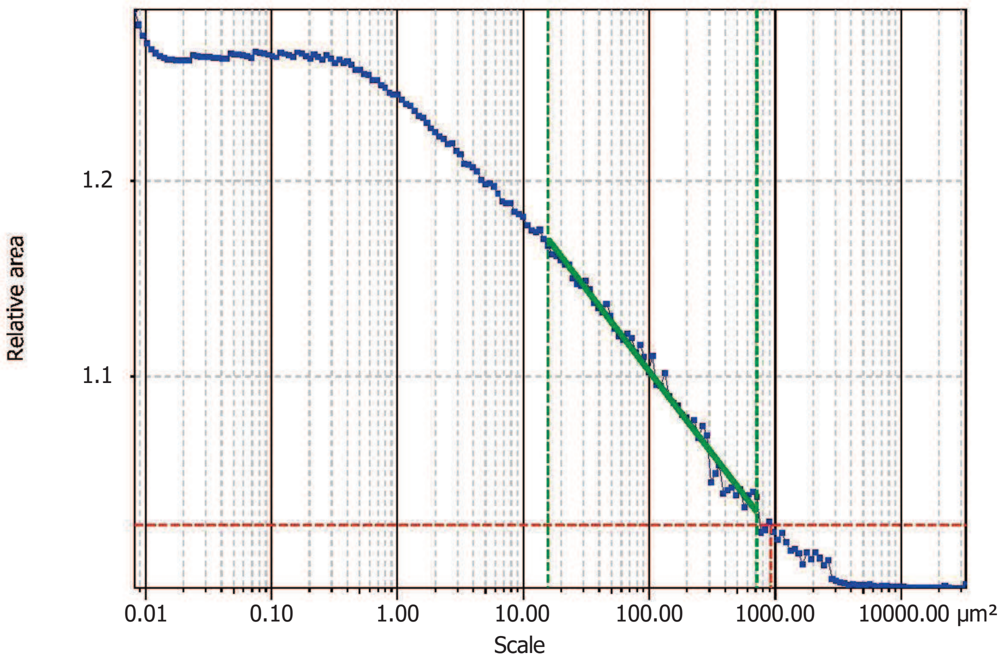
Parameters	Value	Unit	
Isotropy	34.51	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001704		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01844		*Length-scale anisotropy (1.8 µm, 5°)*



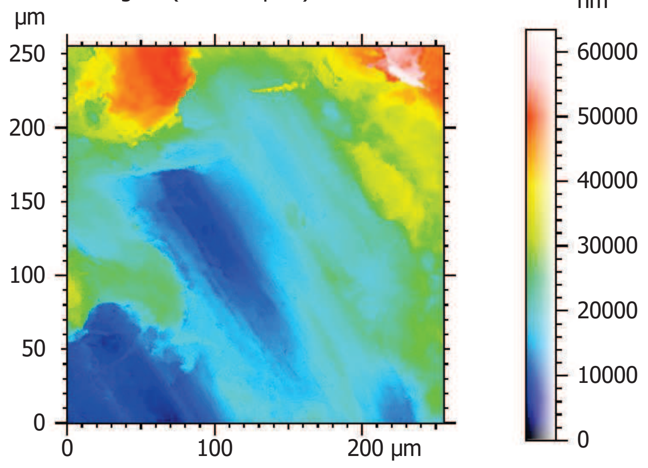
Information	
Method	Area-scale (four corners)

Parameters	Value	Unit	Comment
Asfc	31.77		*Fractal complexity*
Smfc	181.0	µm²	*Scale of max complexity*
HAsfc9	1.520		*Heterogeneity of Asfc (3x3)*
HAsfc81	2.165		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

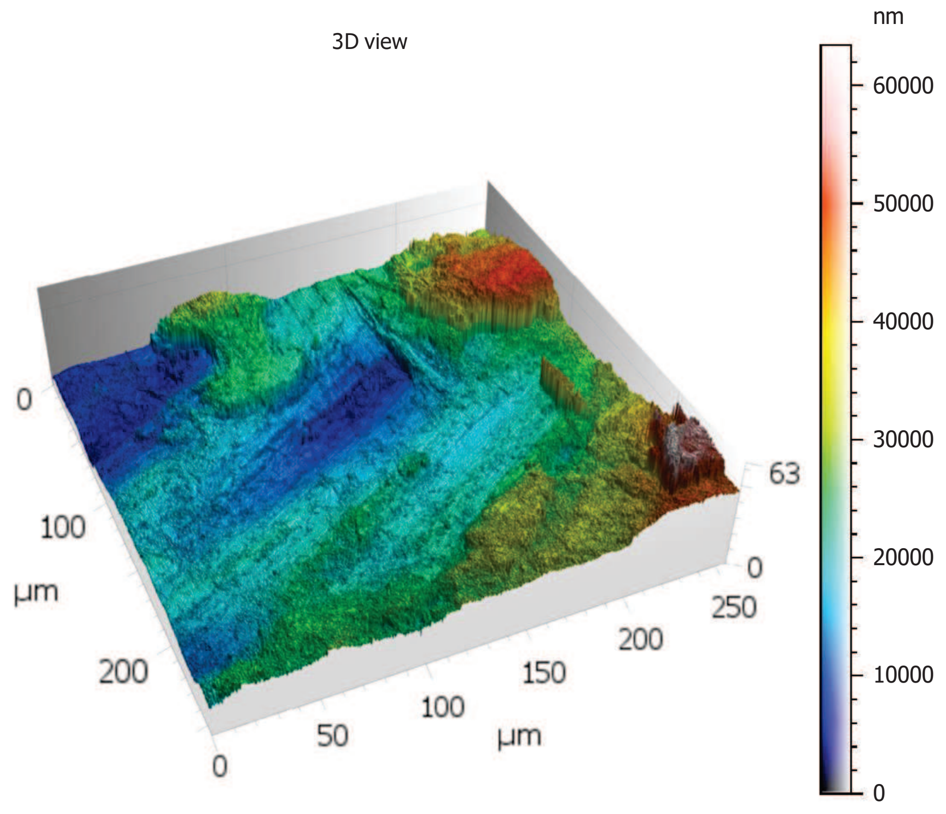
Processing

1. Original (or resampled) surface

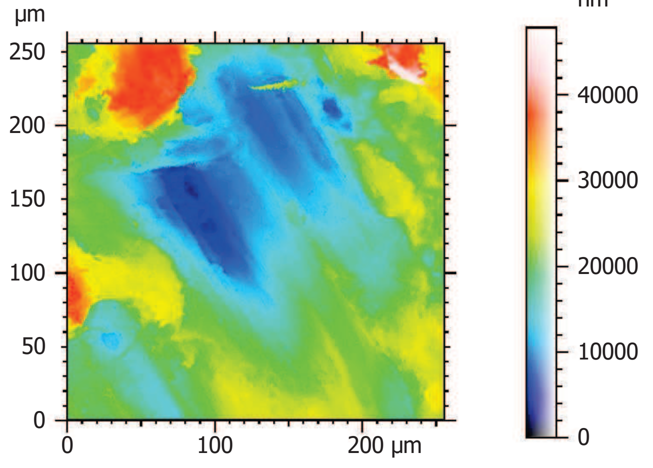


Identity card			
Name:	NRQ_8646_LSM_50x_075_surface3_Topo		
Created on:	5/5/2020 11:48:29 AM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	63402	nm	
Size:	65532	digits	
Spacing:	0.9675	nm	
NM-points ratio:	0.000 % (0 Pts)		

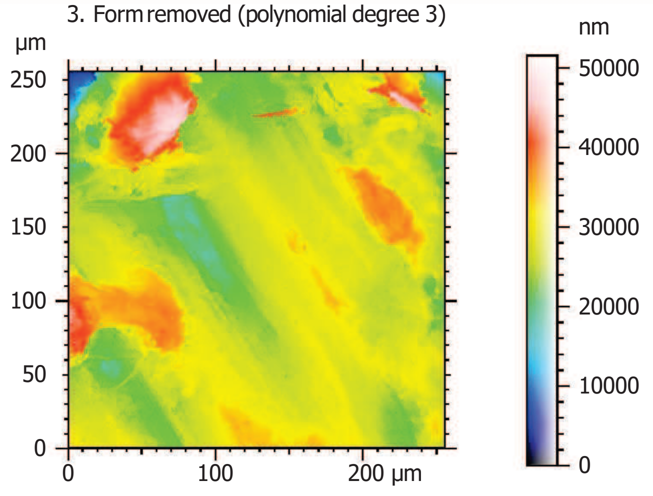
3D view



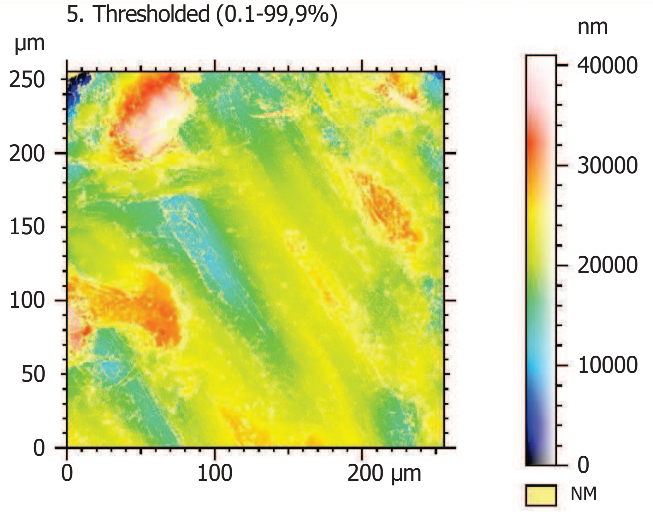
2. Leveled surface (least squares plane, substraction)



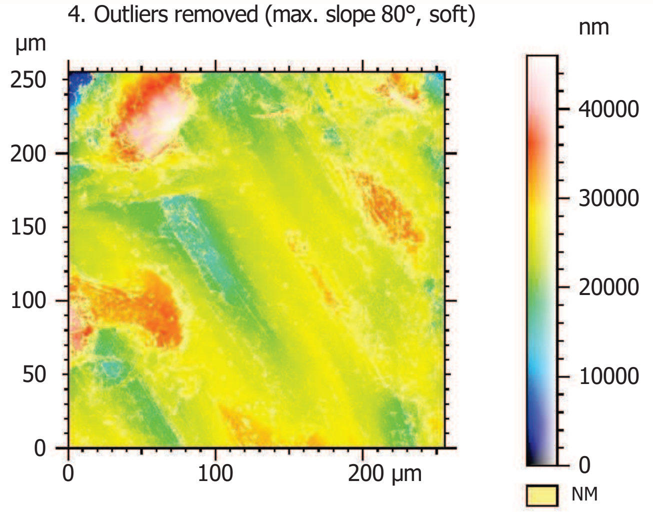
3. Form removed (polynomial degree 3)

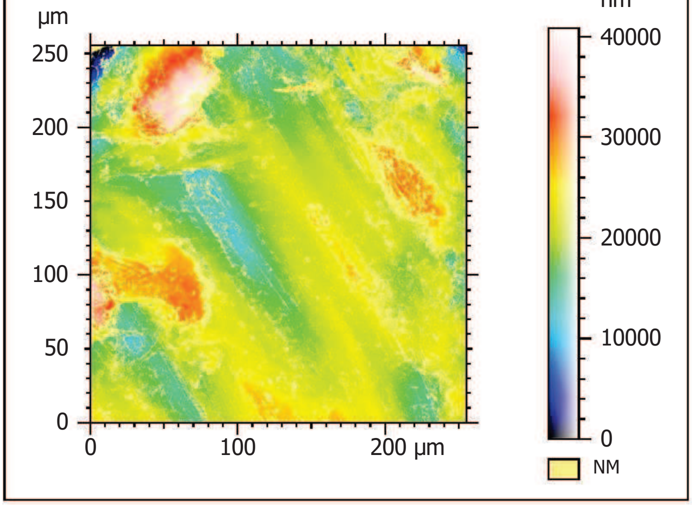


5. Thresholded (0.1-99,9%)



4. Outliers removed (max. slope 80°, soft)

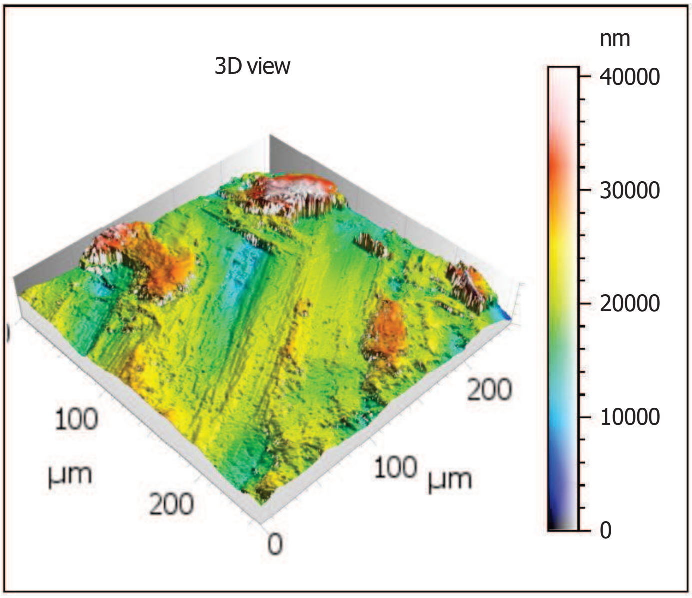




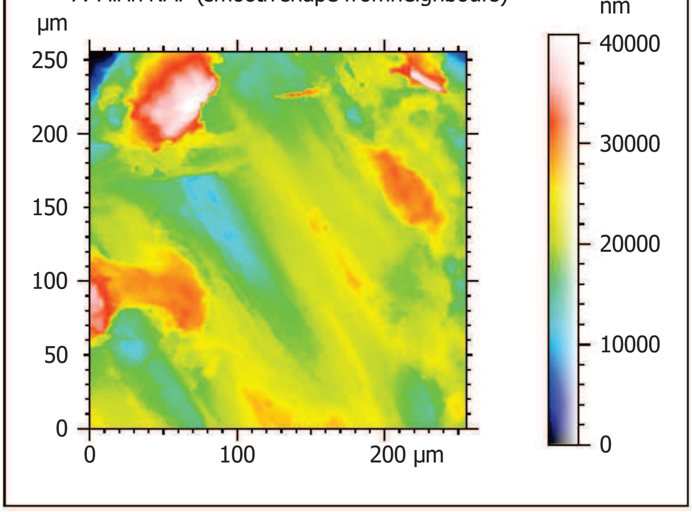
6. Microroughness removed (S-filter, 2.5 µm)

Identity card

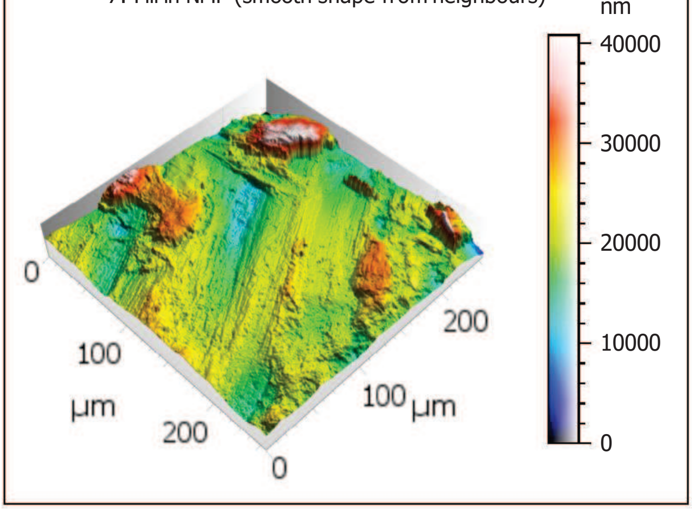
Name:	NRQ_8646_LSM_50x_...filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R...75_surface3_Topo.sur		
Created on:	5/5/2020 11:48:29 AM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	0.000	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	-255.5	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	40826	nm	
Min:	-20911	nm	
Max:	19915	nm	
Size:	421974	digits	
Spacing:	0.09675	nm	
NM-points ratio:	31.61 % (2845182 Pts)		



3D view

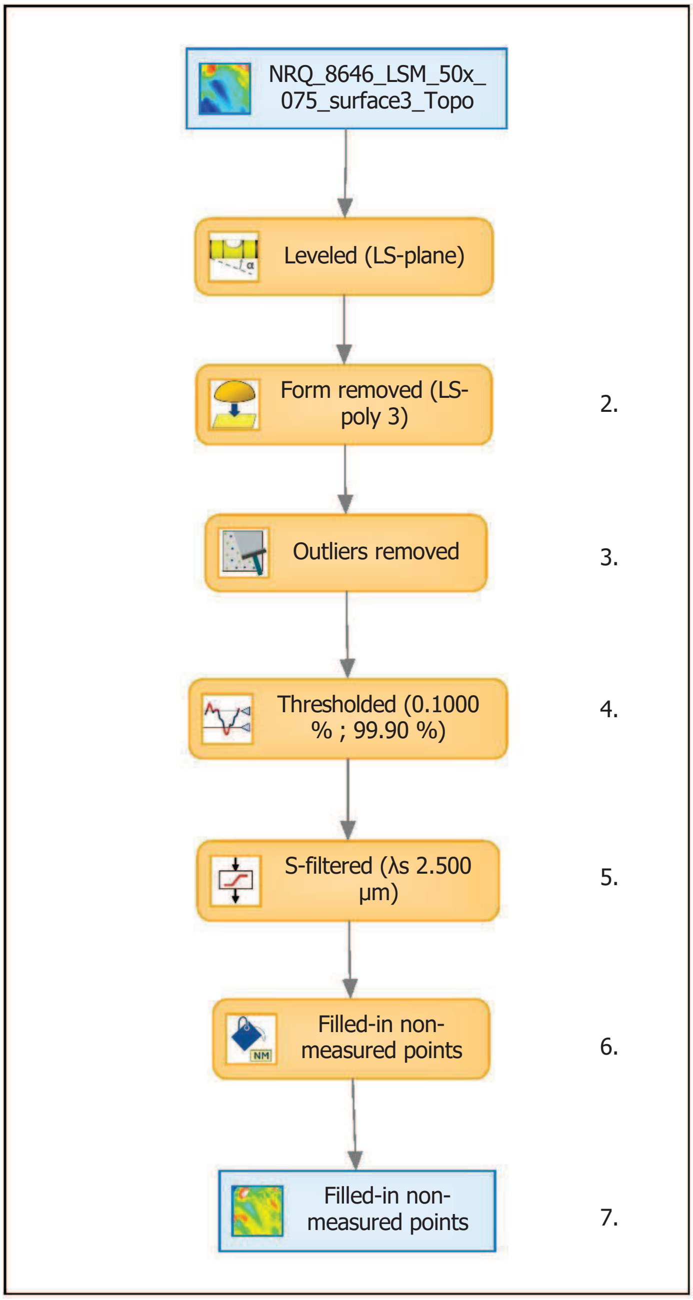


7. Fill in NMP (smooth shape fromneighbours)



7. Fill in NMP (smooth shape from neighbours)

Identity card		
Name:	NRQ_8646_LSM_50x_0...in non-measured points	
Created on:	5/5/2020 11:48:29 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	40826	nm
Size:	421974	digits
Spacing:	0.09675	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	4916	nm
Ssk	0.7836	
Sku	5.624	
Sp	19828	nm
Sv	20998	nm
Sz	40826	nm
Sa	3458	nm
Functional parameters		
Smr	0.1974	%
Smc	6385	nm
Sxp	7781	nm
Spatial parameters		
Sal	25.59	µm
Str	0.8155	
Std	121.5	°
Hybrid parameters		
Sdq	1.061	
Sdr	25.19	%
Functional parameters (Volume)		
Vm	0.4149	µm³/µm²
Vv	6.800	µm³/µm²
Vmp	0.4149	µm³/µm²
Vmc	3.548	µm³/µm²
Vvc	6.311	µm³/µm²
Vvv	0.4896	µm³/µm²

Analyses:

ISO 25178 8.

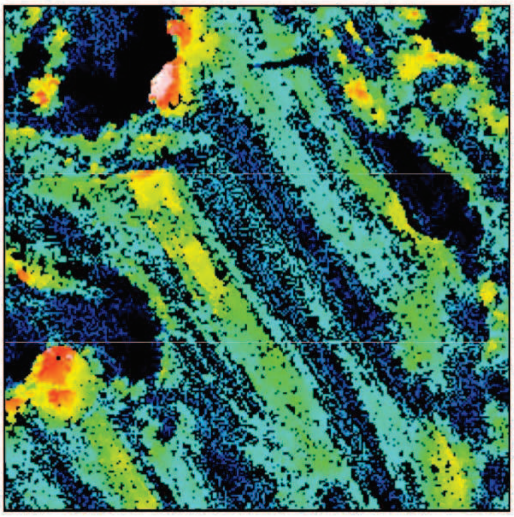
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

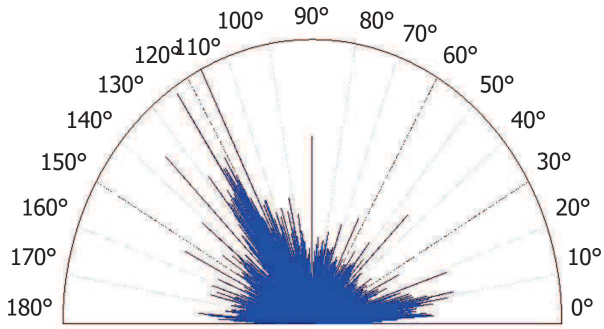
9. Furrow analysis on surface #7



All furrows are shown.

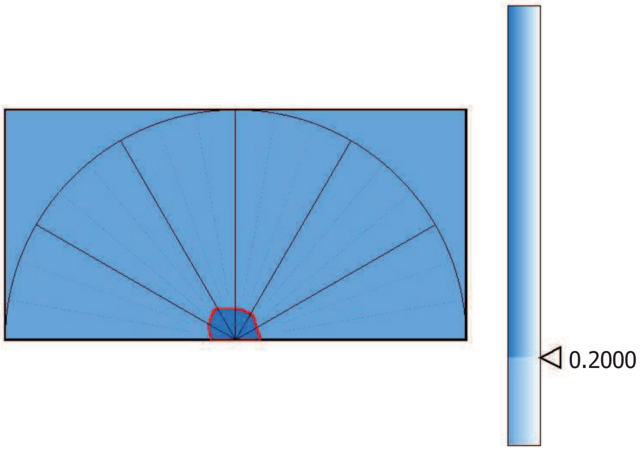
Parameters	Value	Unit
Maximum depth of furrows	15605	nm
Mean depth of furrows	4817	nm
Mean density of furrows	4047	cm/cm2

10. Texture direction on surface #7



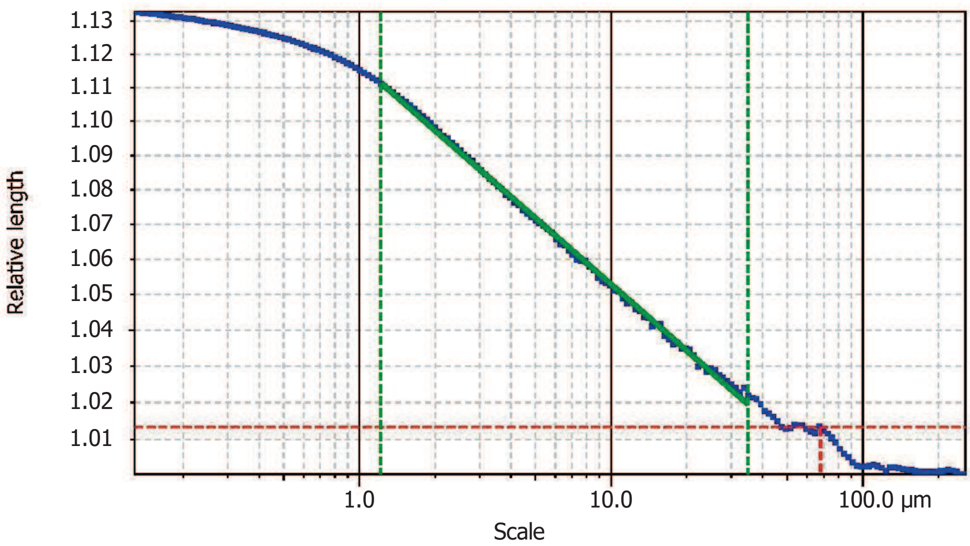
Parameters	Value	Unit
First direction	116.5	°
Second direction	123.7	°
Third direction	180.0	°

11. Texture isotropy on surface #7



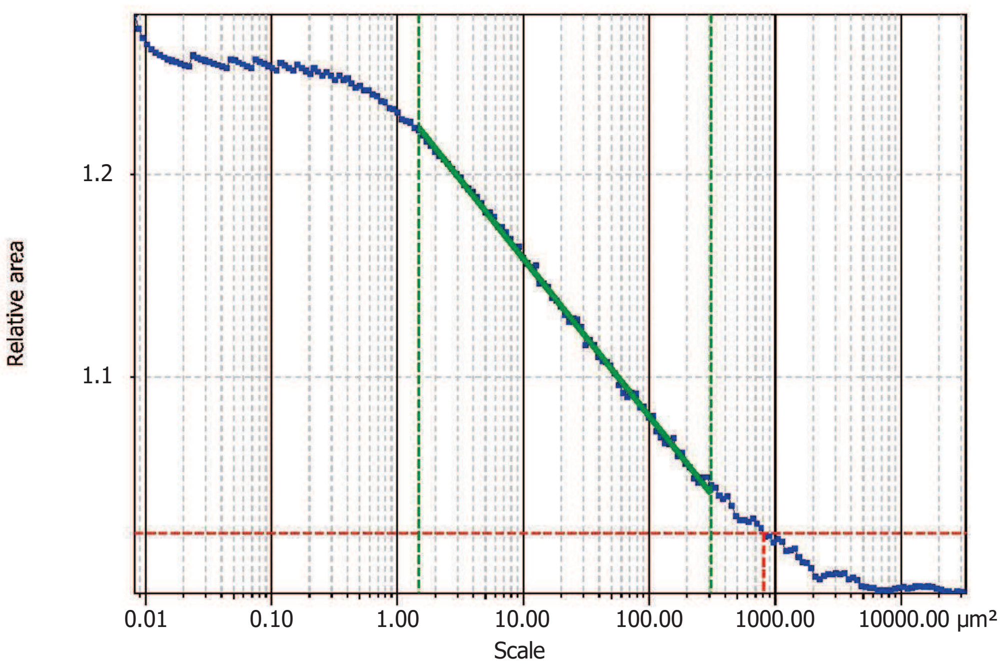
Parameters	Value	Unit
Isotropy	64.20	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0003969		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.0177		*Length-scale anisotropy (1.8 µm, 5°)*

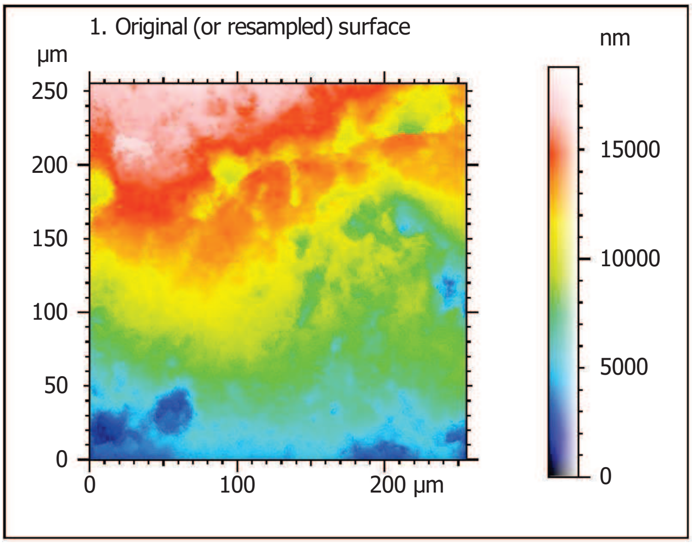


Information	
Method	Area-scale (four corners)

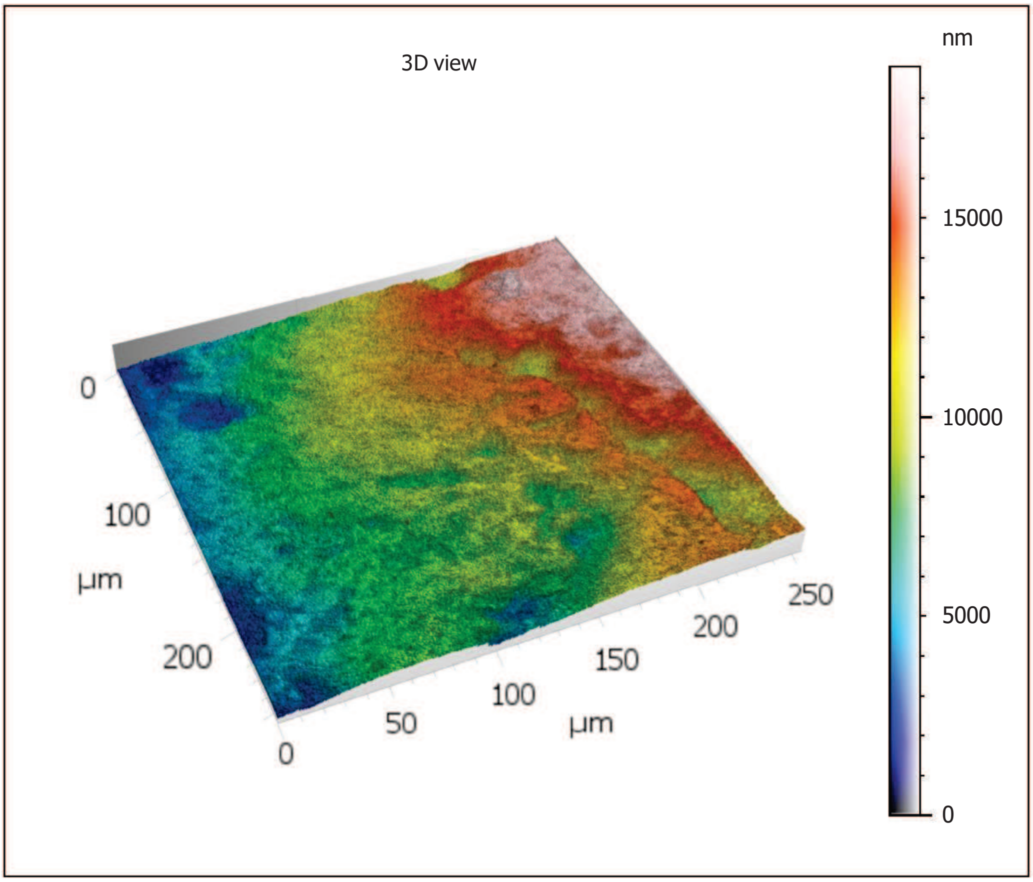
Parameters	Value	Unit	Comment
Asfc	29.43		*Fractal complexity*
Smfc	21.33	µm²	*Scale of max complexity*
HAsfc9	0.8048		*Heterogeneity of Asfc (3x3)*
HAsfc81	1.233		*Heterogeneity of Asfc (9x9)*

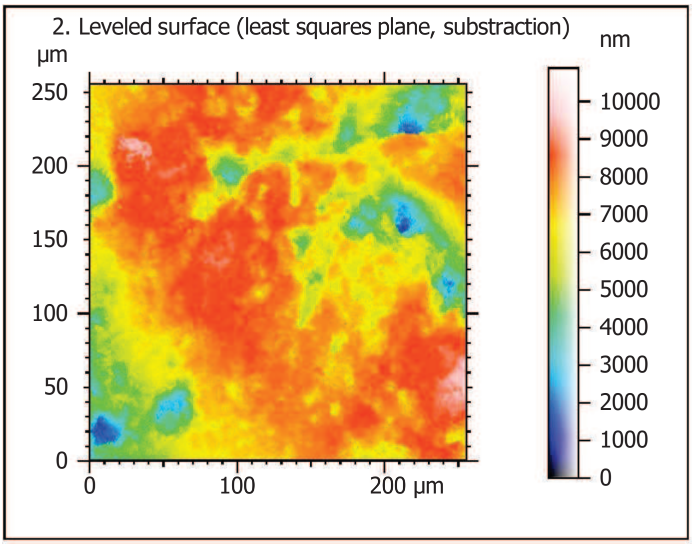
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

Processing

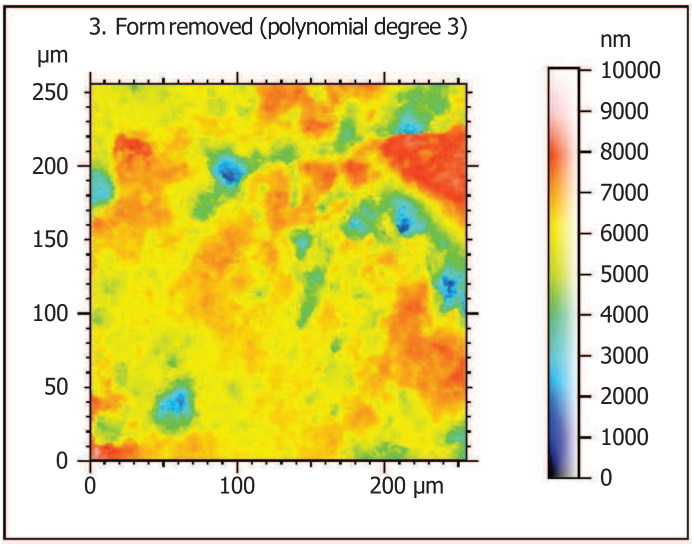


Identity card			
Name:	NRQ_8718_LSM_50x_075_surface1_Topo		
Created on:	5/5/2020 12:05:25 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	18795	nm	
Size:	65532	digits	
Spacing:	0.2868	nm	
NM-points ratio:	0.000 % (0 Pts)		

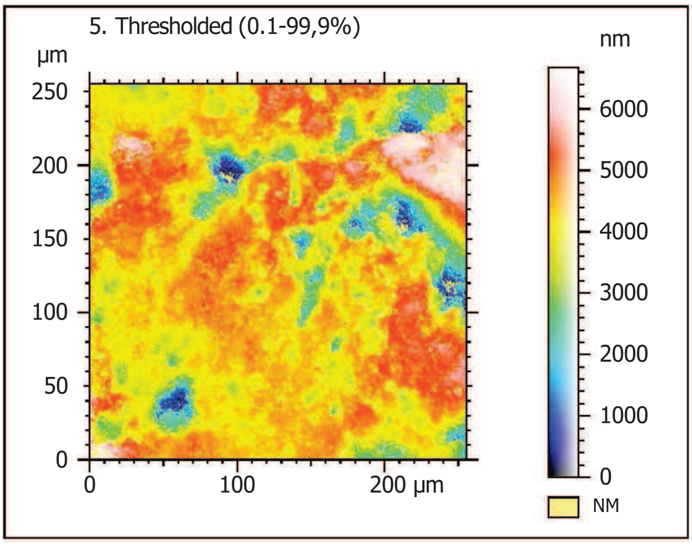




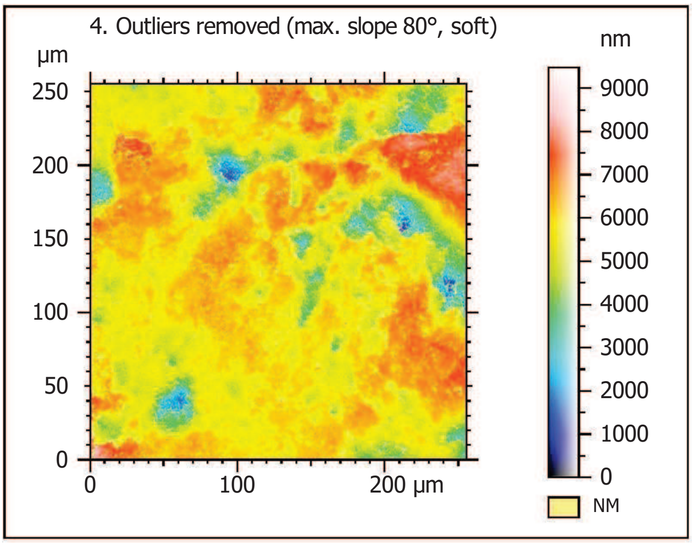
2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0



3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0

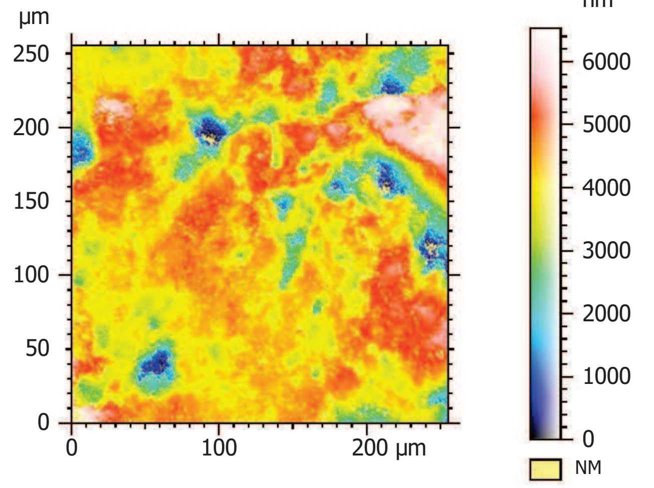


5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
6000
5000
4000
3000
2000
1000
0
NM



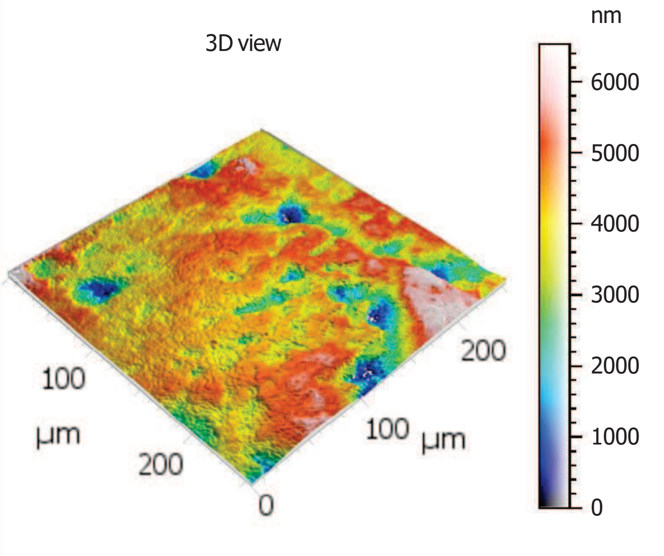
4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
NM

6. Microroughness removed (S-filter, 2.5 µm)

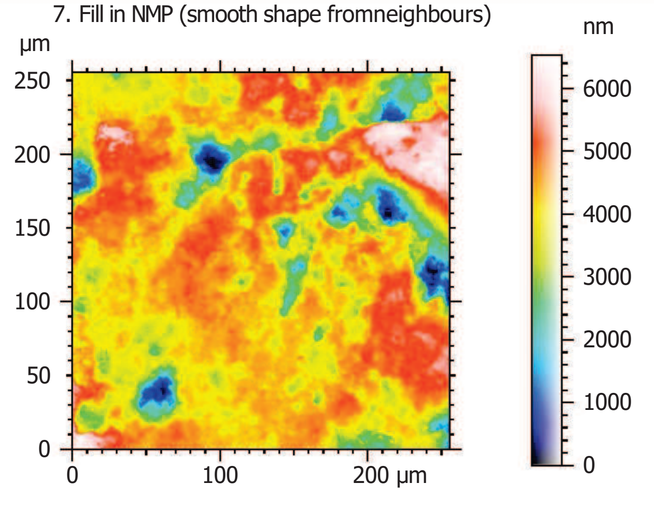


Identity card			
Name:	NRQ_8718_LSM_50x_...filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R...75_surface1_Topo.sur		
Created on:	5/5/2020 12:05:25 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	0.000	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	-255.5	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	6527	nm	
Min:	-4058	nm	
Max:	2469	nm	
Size:	227583	digits	
Spacing:	0.02868	nm	
NM-points ratio:	16.54 % (1488526 Pts)		

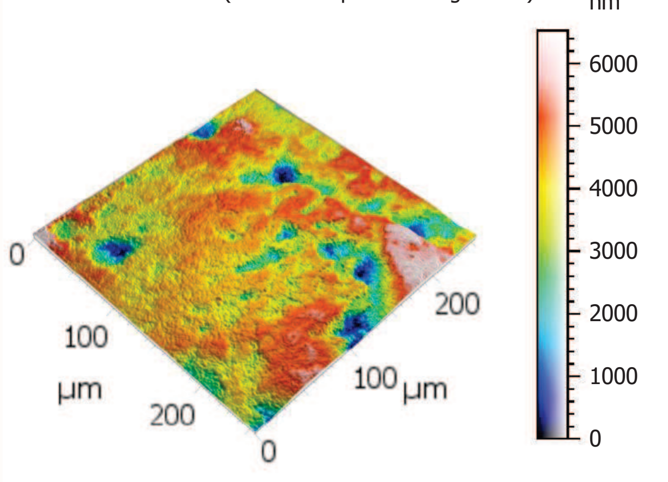
3D view



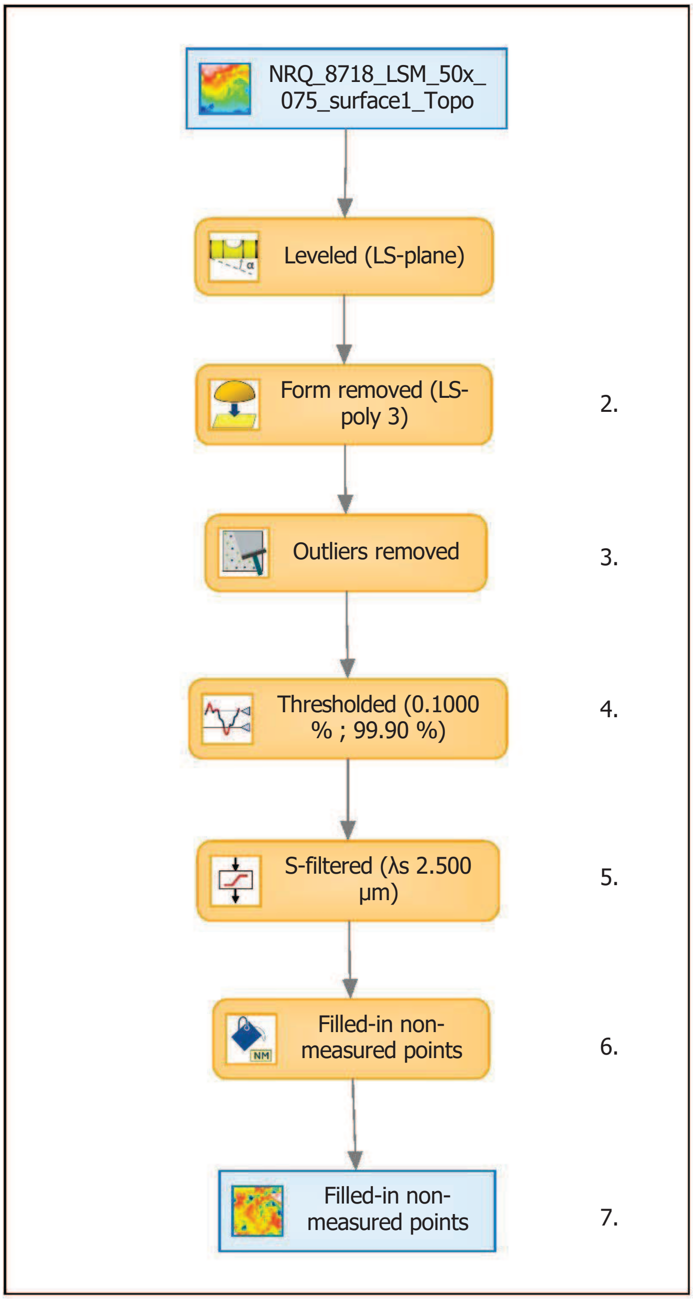
7. Fill in NMP (smooth shape fromneighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card			
Name:	NRQ_8718_LSM_50x_0...in non-measured points		
Created on:	5/5/2020 12:05:25 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	6527	nm	
Size:	227583	digits	
Spacing:	0.02868	nm	
NM-points ratio:	0.000 % (0 Pts)		



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	962.0	nm
Ssk	-1.016	
Sku	5.117	
Sp	2465	nm
Sv	4062	nm
Sz	6527	nm
Sa	685.8	nm
Functional parameters		
Smr	3.853	%
Smc	987.9	nm
Sxp	2715	nm
Spatial parameters		
Sal	19.34	µm
Str	0.8446	
Std	98.24	°
Hybrid parameters		
Sdq	0.2865	
Sdr	3.636	%
Functional parameters (Volume)		
Vm	0.04556	µm³/µm²
Vv	1.033	µm³/µm²
Vmp	0.04556	µm³/µm²
Vmc	0.6627	µm³/µm²
Vvc	0.8430	µm³/µm²
Vvv	0.1904	µm³/µm²

Analyses:

ISO 25178 8.

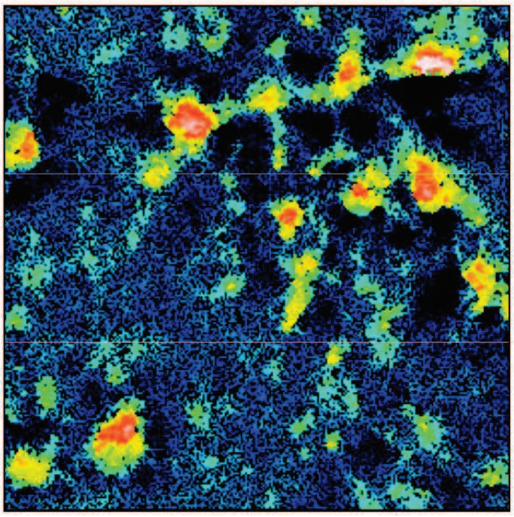
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

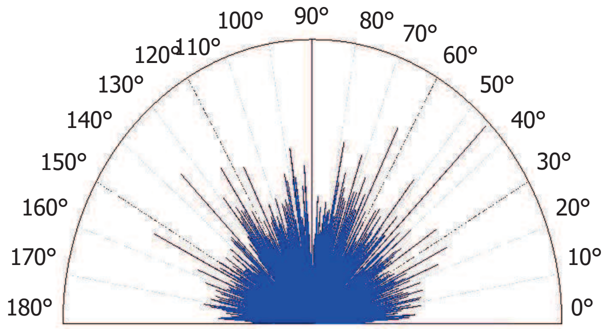
9. Furrow analysis on surface #7



All furrows are shown.

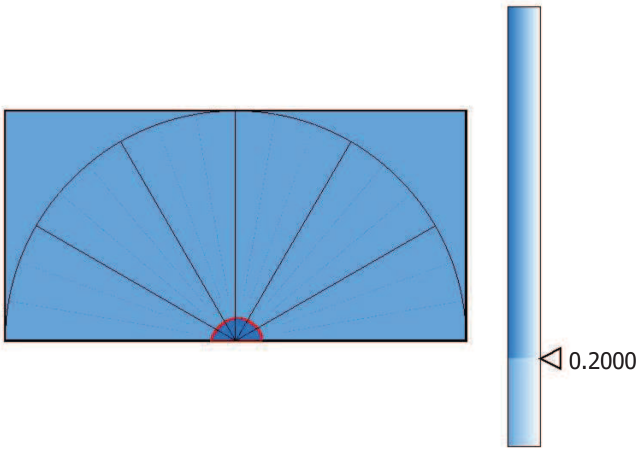
Parameters	Value	Unit
Maximum depth of furrows	4465	nm
Mean depth of furrows	954.8	nm
Mean density of furrows	4856	cm/cm2

10. Texture direction on surface #7



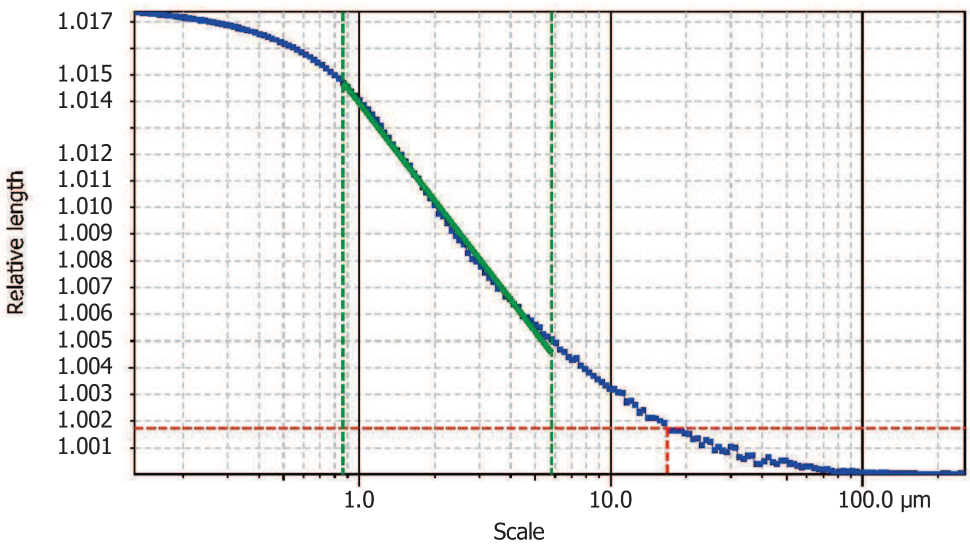
Parameters	Value	Unit
First direction	89.99	°
Second direction	44.99	°
Third direction	180.0	°

11. Texture isotropy on surface #7



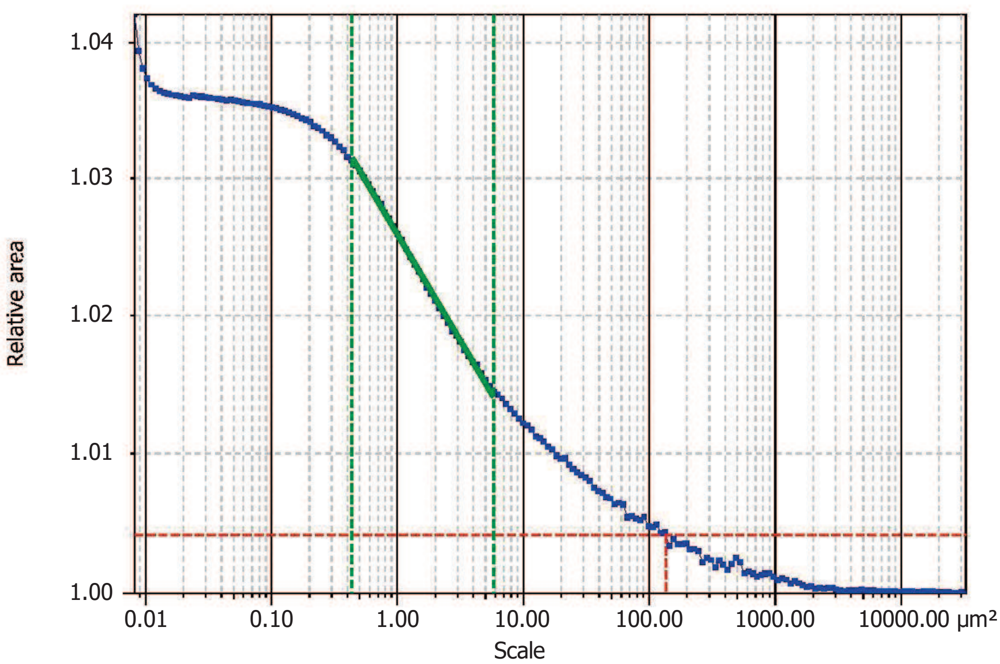
Parameters	Value	Unit
Isotropy	83.09	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.002016		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01823		*Length-scale anisotropy (1.8 µm, 5°)*

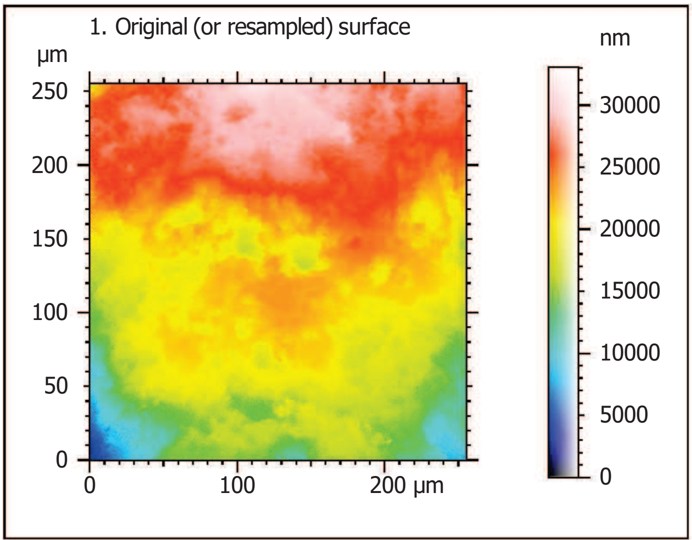


Information	
Method	Area-scale (four corners)

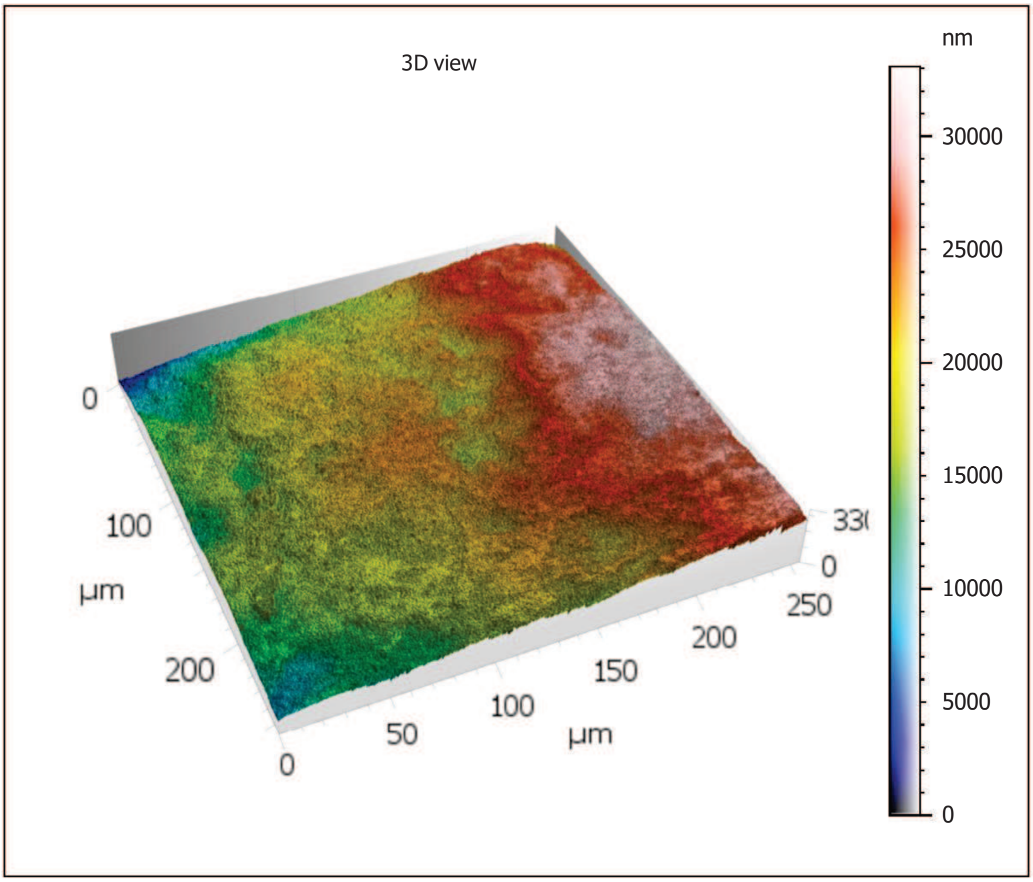
Parameters	Value	Unit	Comment
Asfc	6.569		*Fractal complexity*
Smfc	1.363	µm²	*Scale of max complexity*
HAsfc9	0.2750		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.4034		*Heterogeneity of Asfc (9x9)*

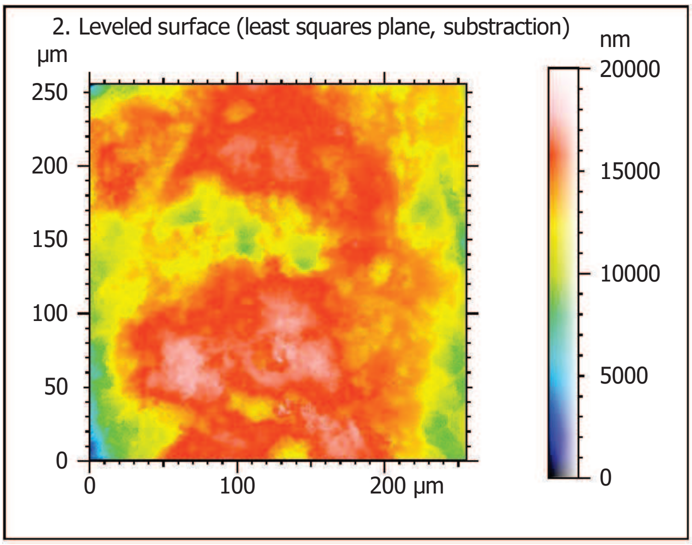
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

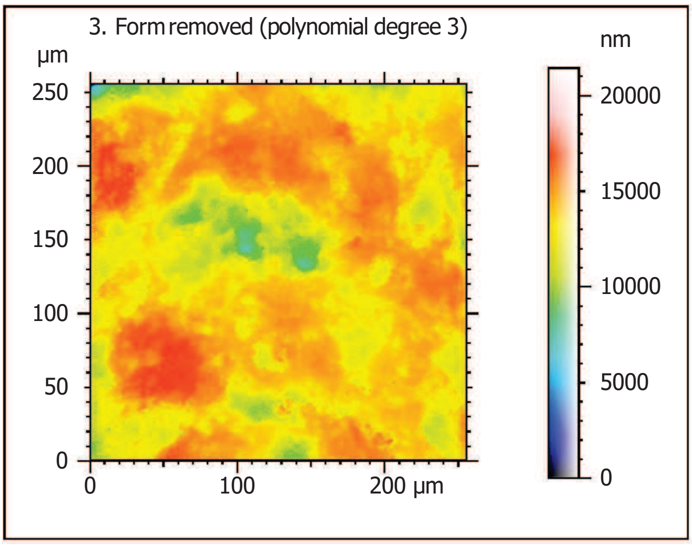
Processing

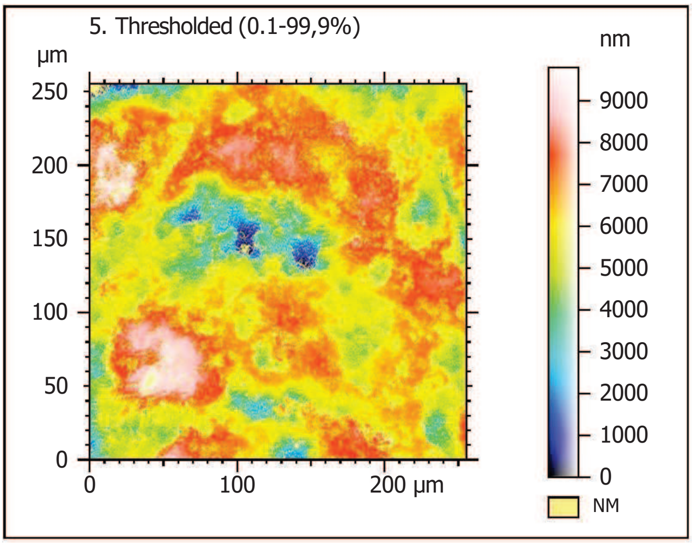


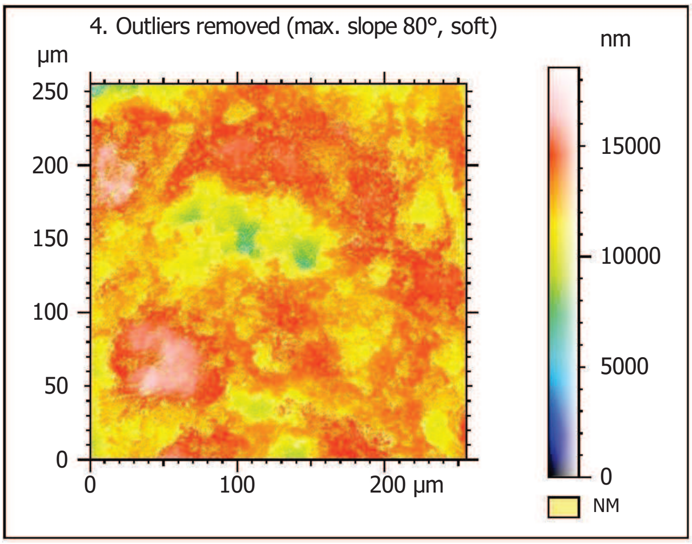
Identity card			
Name:	NRQ_8718_LSM_50x_075_surface2_Topo		
Created on:	5/5/2020 12:23:10 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	33072	nm	
Size:	65532	digits	
Spacing:	0.5047	nm	
NM-points ratio:	0.000 % (0 Pts)		



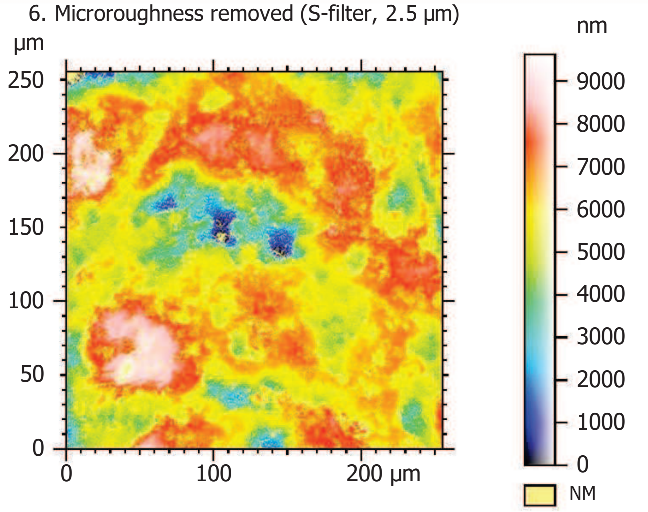

2. Leveled surface (least squares plane, substraction)
µm
nm
250
200
150
100
50
0
0
100
200 µm
20000
15000
10000
5000
0


3. Form removed (polynomial degree 3)
µm
nm
250
200
150
100
50
0
0
100
200 µm
20000
15000
10000
5000
0


5. Thresholded (0.1-99,9%)
µm
nm
250
200
150
100
50
0
0
100
200 µm
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
NM

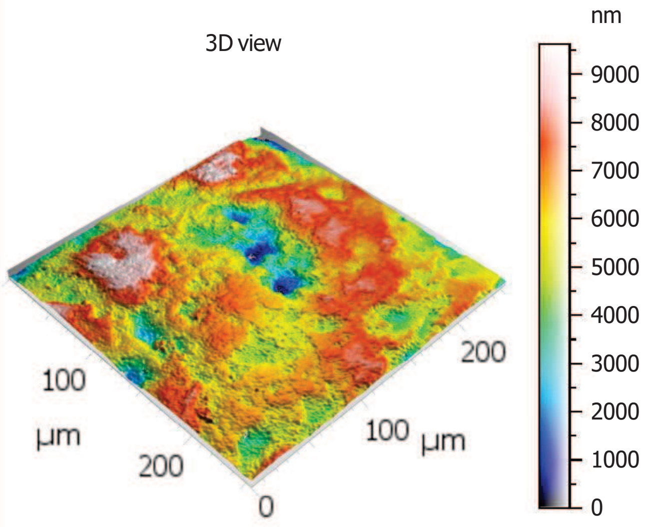

4. Outliers removed (max. slope 80°, soft)
µm
nm
250
200
150
100
50
0
0
100
200 µm
15000
10000
5000
0
NM

6. Microroughness removed (S-filter, 2.5 µm)

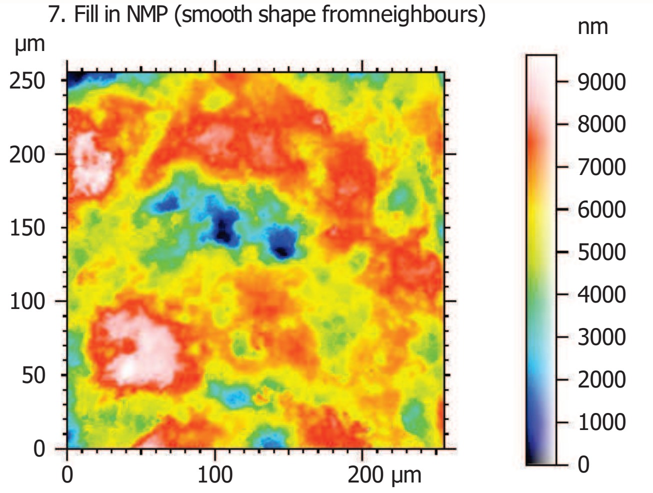


Identity card			
Name:	NRQ_8718_LSM_50x_...filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R...75_surface2_Topo.sur		
Created on:	5/5/2020 12:23:10 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	0.000	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	-255.5	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	9620	nm	
Min:	-5931	nm	
Max:	3689	nm	
Size:	190612	digits	
Spacing:	0.05047	nm	
NM-points ratio:	23.39 % (2104704 Pts)		

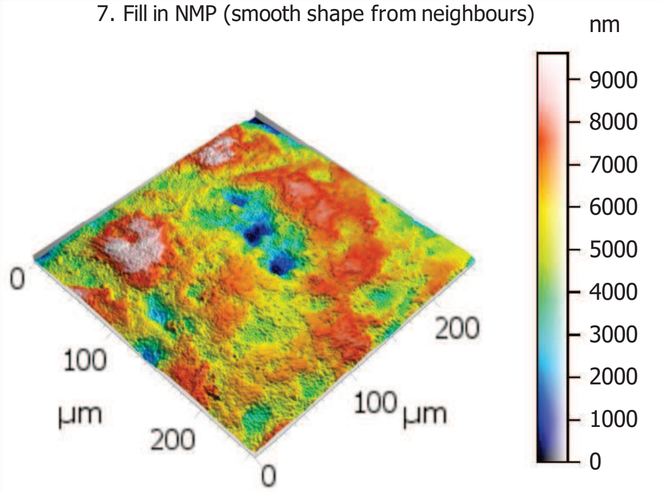
3D view



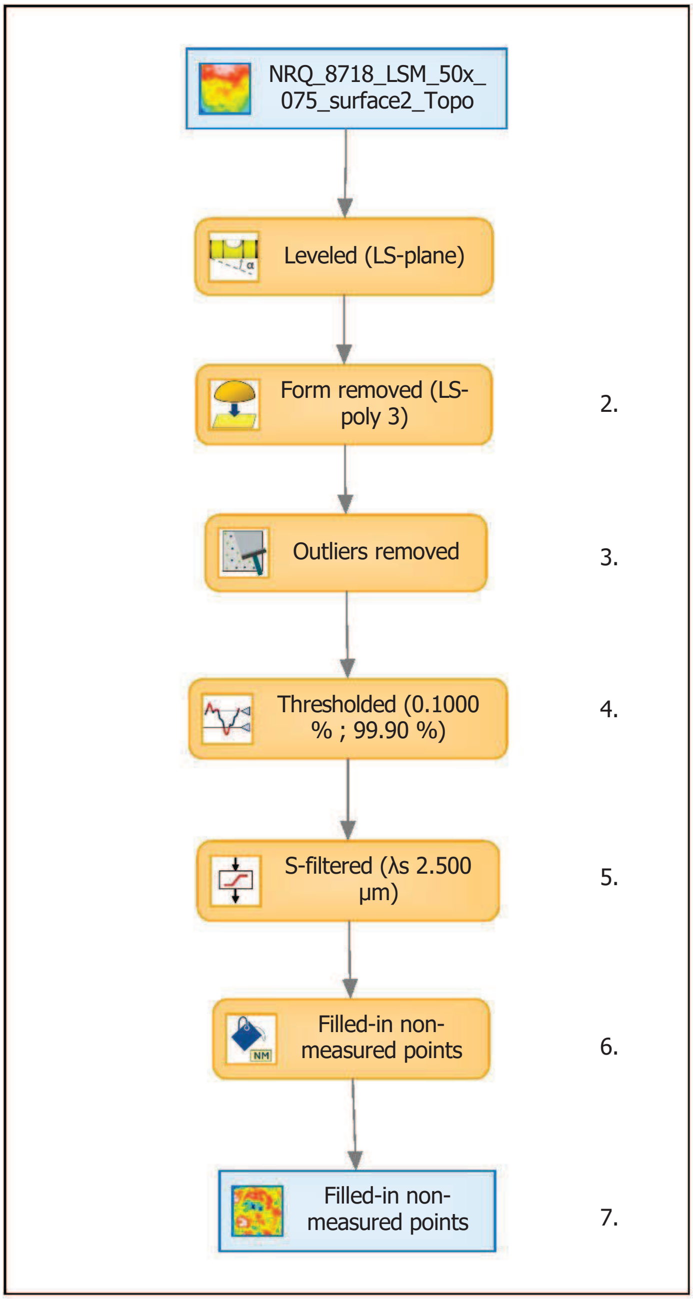
7. Fill in NMP (smooth shape fromneighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card			
Name:	NRQ_8718_LSM_50x_0...in non-measured points		
Created on:	5/5/2020 12:23:10 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	9620	nm	
Size:	190612	digits	
Spacing:	0.05047	nm	
NM-points ratio:	0.000 % (0 Pts)		



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface			
F: [Workflow] Form removed (LS-poly 3)			
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)			
Height parameters			
Sq	1475	nm	
Ssk	-0.6796		
Sku	4.004		
Sp	3681	nm	
Sv	5938	nm	
Sz	9620	nm	
Sa	1130	nm	
Functional parameters			
Smr	2.419	%	
Smc	1697	nm	
Sxp	3640	nm	
Spatial parameters			
Sal	26.00	µm	
Str	0.6043		
Std	3.509	°	
Hybrid parameters			
Sdq	0.3653		
Sdr	5.870	%	
Functional parameters (Volume)			
Vm	0.05915	µm³/µm²	
Vv	1.756	µm³/µm²	
Vmp	0.05915	µm³/µm²	
Vmc	1.225	µm³/µm²	
Vvc	1.525	µm³/µm²	
Vvv	0.2310	µm³/µm²	

Analyses:

ISO 25178 8.

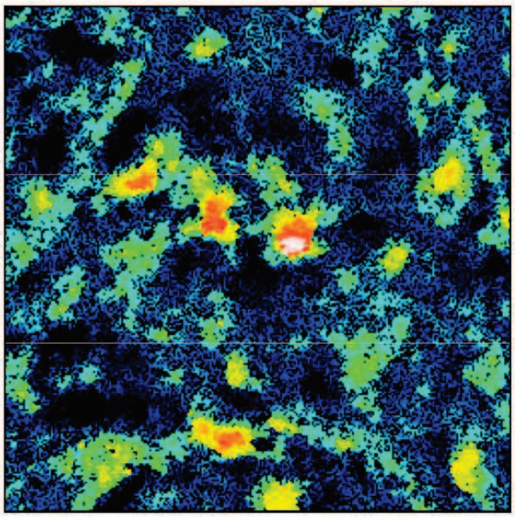
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

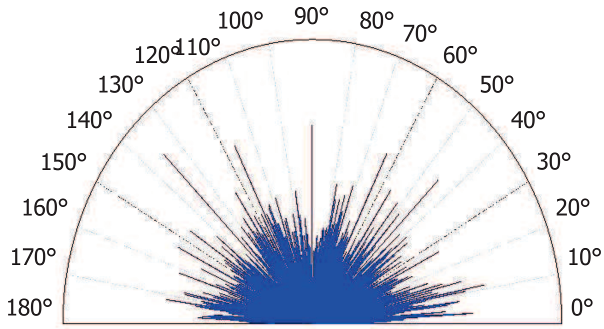
9. Furrow analysis on surface #7



All furrows are shown.

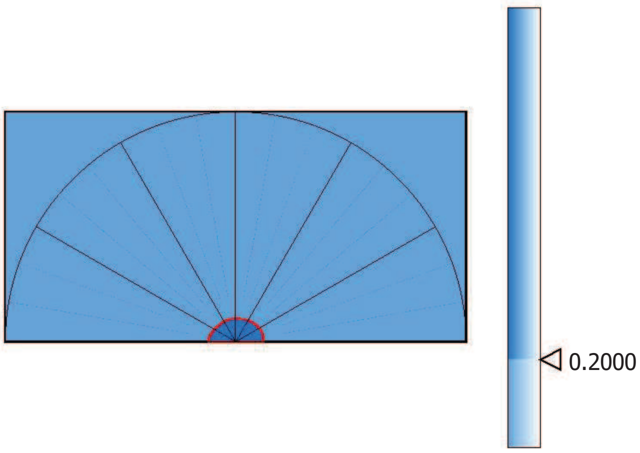
Parameters	Value	Unit	
Maximum depth of furrows	5645	nm	
Mean depth of furrows	1224	nm	
Mean density of furrows	4842	cm/cm2	

10. Texture direction on surface #7



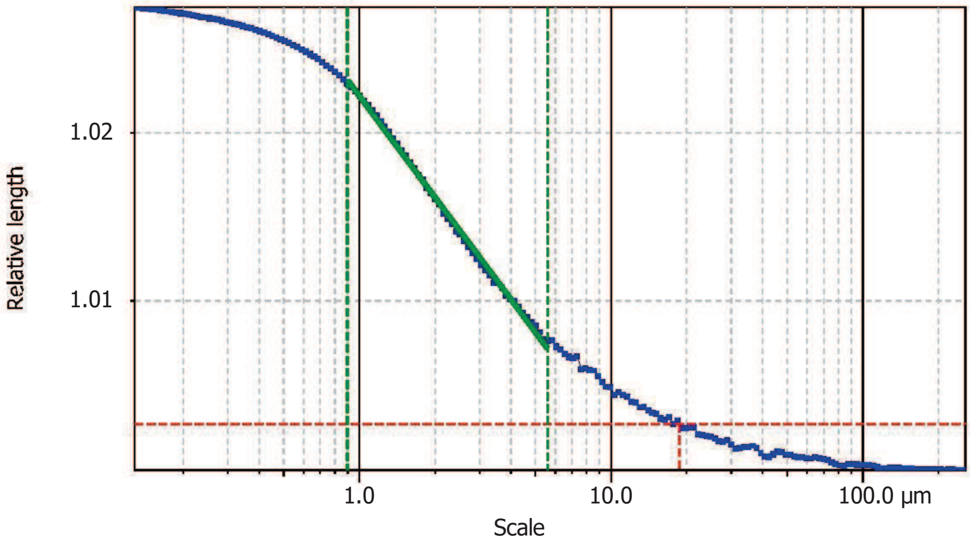
Parameters	Value	Unit	
First direction	180.0	°	
Second direction	135.0	°	
Third direction	45.00	°	

11. Texture isotropy on surface #7



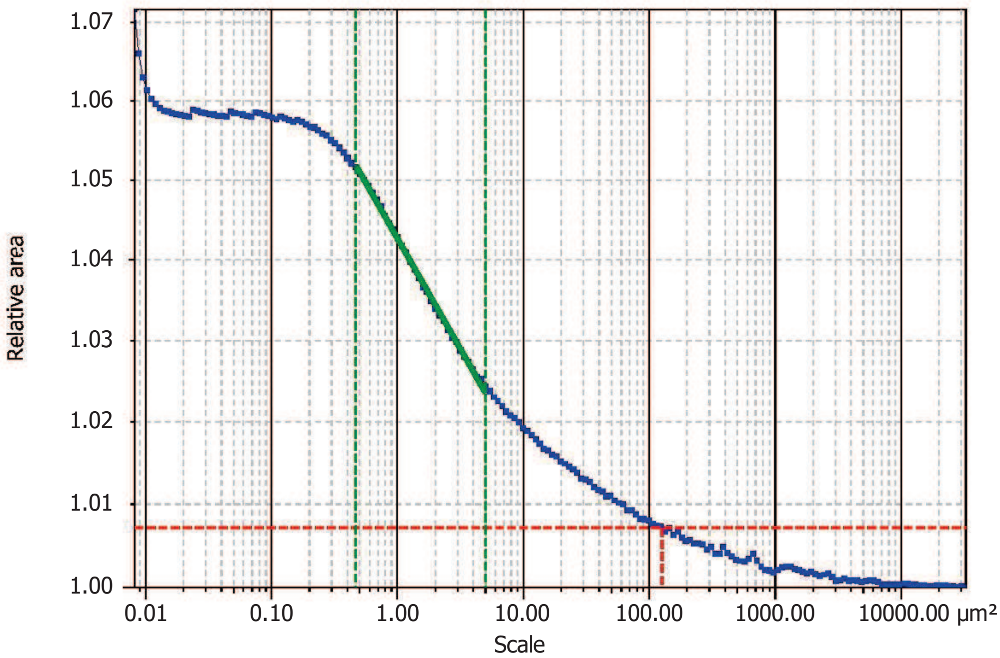
Parameters	Value	Unit	
Isotropy	83.46	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0005011		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01792		*Length-scale anisotropy (1.8 µm, 5°)*

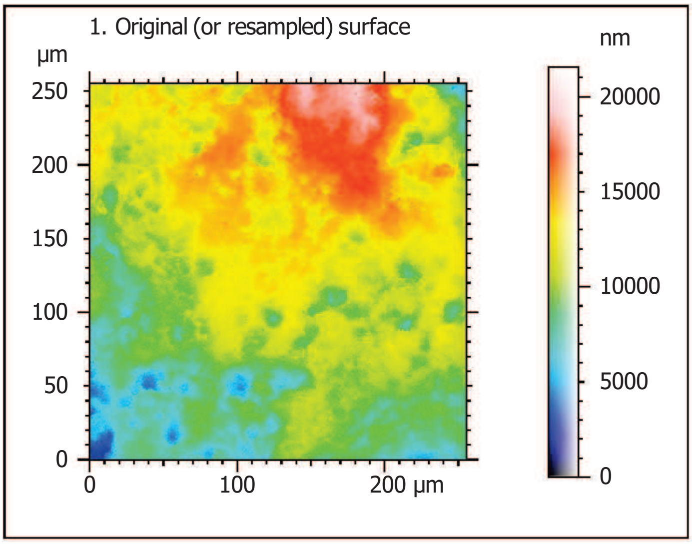


Information	
Method	Area-scale (four corners)

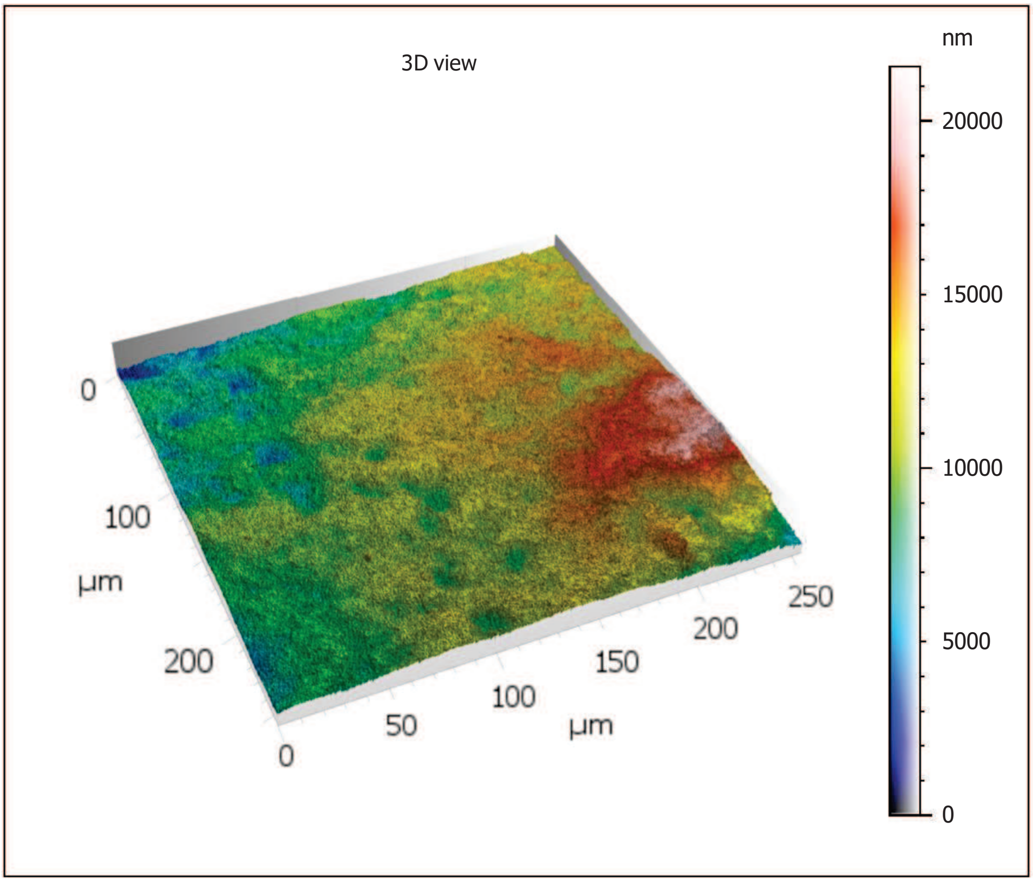
Parameters	Value	Unit	Comment
Asfc	11.48		*Fractal complexity*
Smfc	1.363	µm²	*Scale of max complexity*
HAsfc9	0.1205		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2785		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

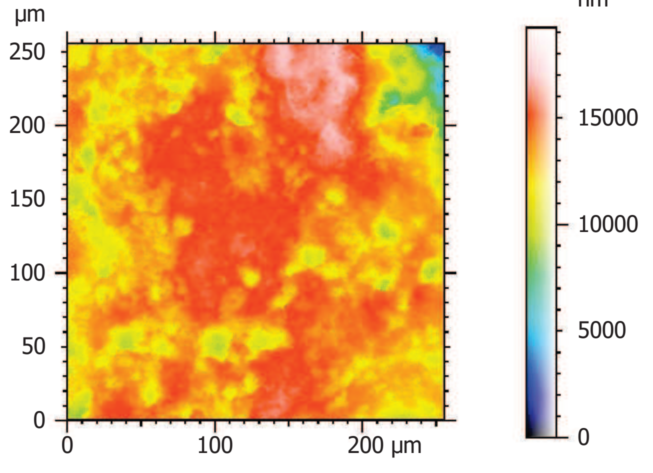
Processing



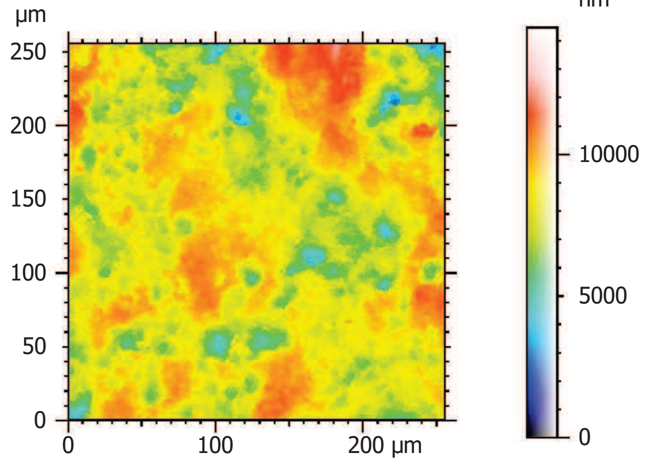
Identity card		
Name:	NRQ_8718_LSM_50x_075_surface3_Topo	
Created on:	5/5/2020 12:36:27 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	21562	nm
Size:	65532	digits
Spacing:	0.3290	nm
NM-points ratio:	0.000 % (0 Pts)	



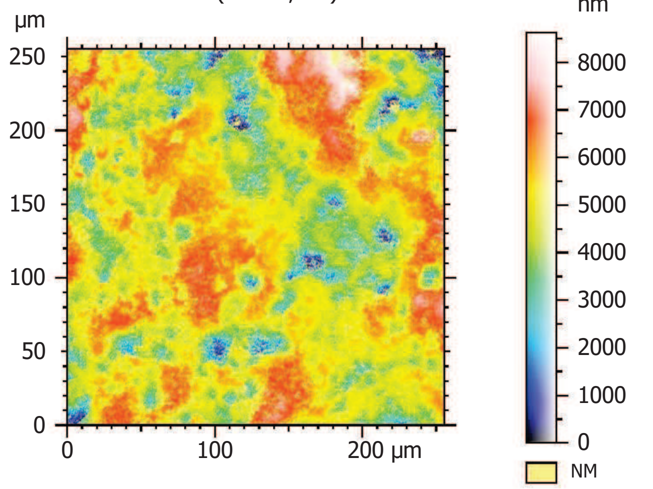
2. Leveled surface (least squares plane, substraction)



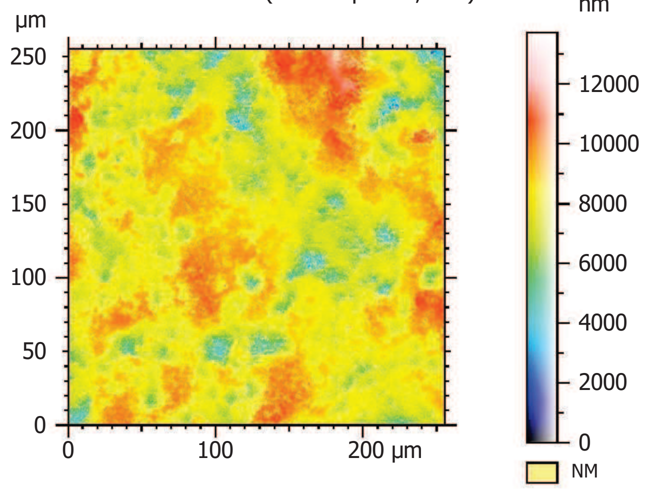
3. Form removed (polynomial degree 3)



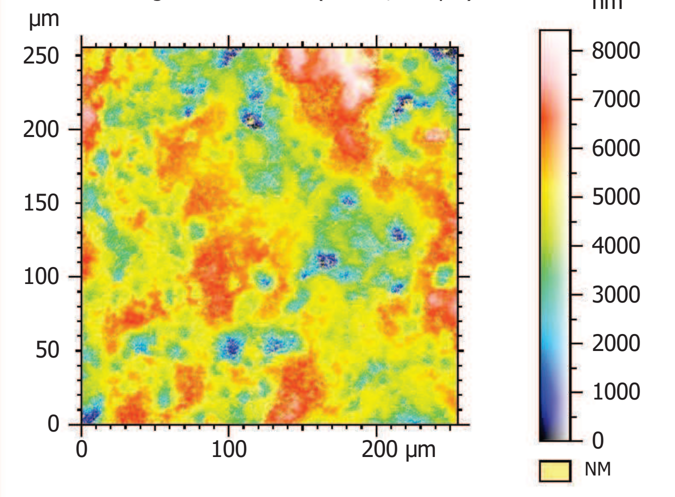
5. Thresholded (0.1-99,9%)



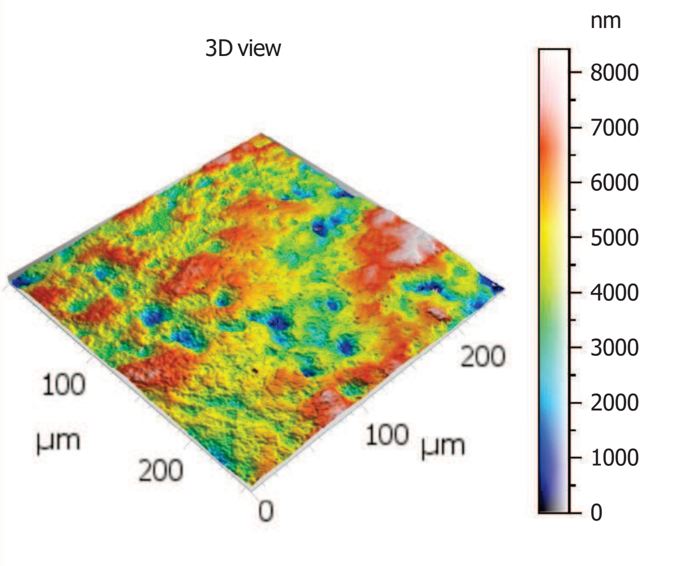
4. Outliers removed (max. slope 80°, soft)



6. Microroughness removed (S-filter, 2.5 µm)

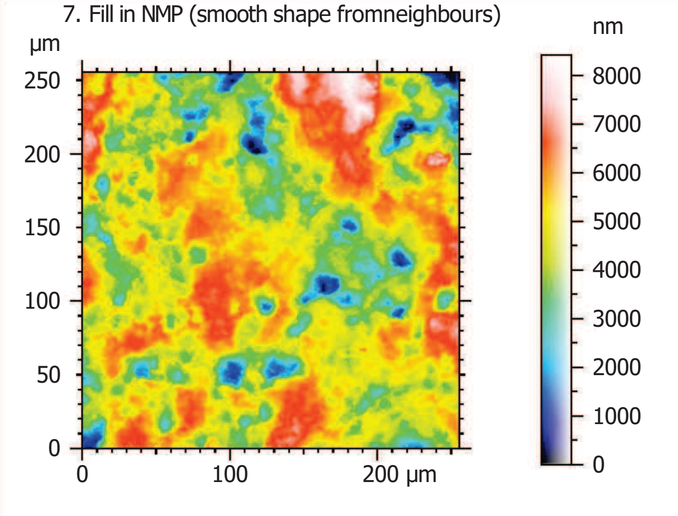


3D view

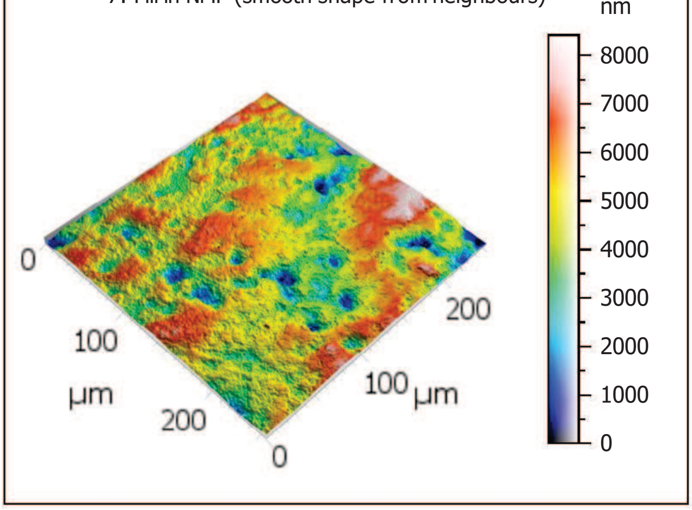


Identity card			
Name:	NRQ_8718_LSM_50x_...filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R...75_surface3_Topo.sur		
Created on:	5/5/2020 12:36:27 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	0.000	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	-255.5	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	8417	nm	
Min:	-4733	nm	
Max:	3684	nm	
Size:	255812	digits	
Spacing:	0.0329	nm	
NM-points ratio:	27.75 % (2497725 Pts)		

7. Fill in NMP (smooth shape fromneighbours)



7. Fill in NMP (smooth shape from neighbours)

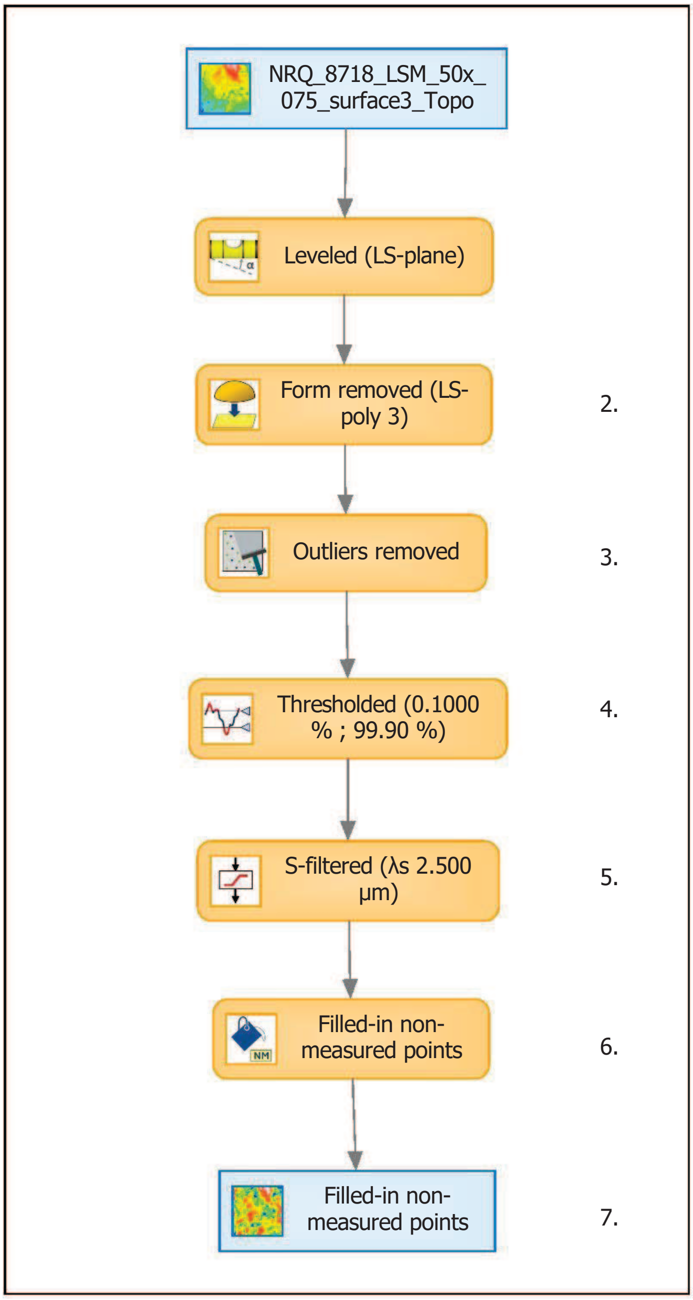


Identity card		
Name:	NRQ_8718_LSM_50x_0...in non-measured points	
Created on:	5/5/2020 12:36:27 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	8417	nm
Size:	255812	digits
Spacing:	0.0329	nm
NM-points ratio:	0.000 % (0 Pts)	

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1303	nm
Ssk	-0.3974	
Sku	3.440	
Sp	3674	nm
Sv	4743	nm
Sz	8417	nm
Sa	1019	nm
Functional parameters		
Smr	1.321	%
Smc	1574	nm
Sxp	2996	nm
Spatial parameters		
Sal	21.27	µm
Str	0.6849	
Std	31.99	°
Hybrid parameters		
Sdq	0.3975	
Sdr	6.839	%
Functional parameters (Volume)		
Vm	0.05412	µm³/µm²
Vv	1.628	µm³/µm²
Vmp	0.05412	µm³/µm²
Vmc	1.137	µm³/µm²
Vvc	1.451	µm³/µm²
Vvv	0.1767	µm³/µm²



Analyses:

ISO 25178 8.

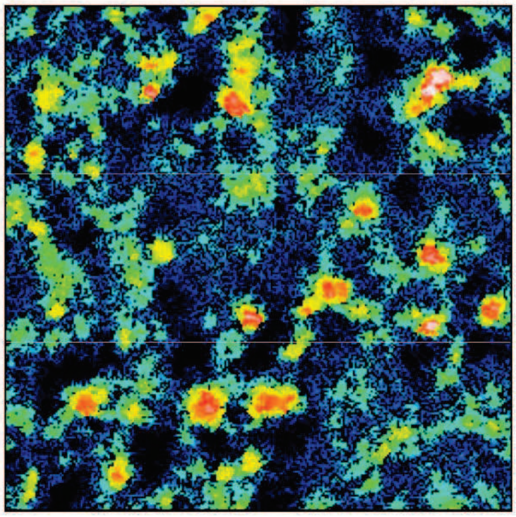
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

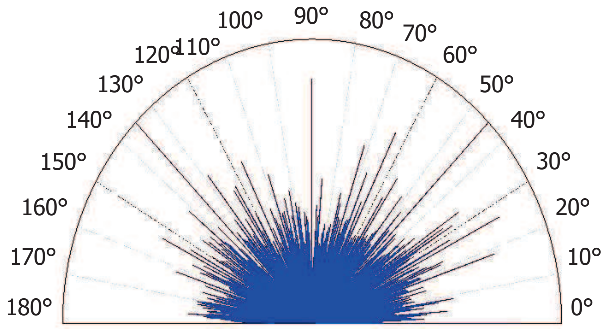
9. Furrow analysis on surface #7



All furrows are shown.

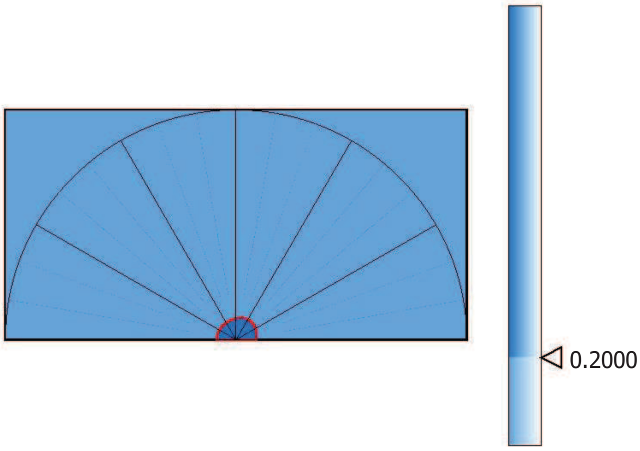
Parameters	Value	Unit
Maximum depth of furrows	5727	nm
Mean depth of furrows	1348	nm
Mean density of furrows	4768	cm/cm2

10. Texture direction on surface #7



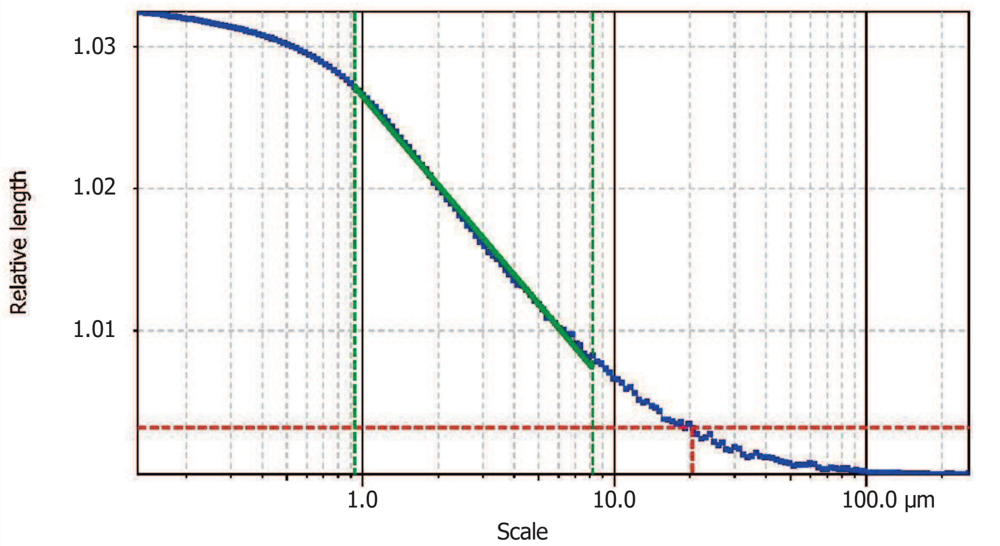
Parameters	Value	Unit
First direction	135.0	°
Second direction	45.00	°
Third direction	90.00	°

11. Texture isotropy on surface #7



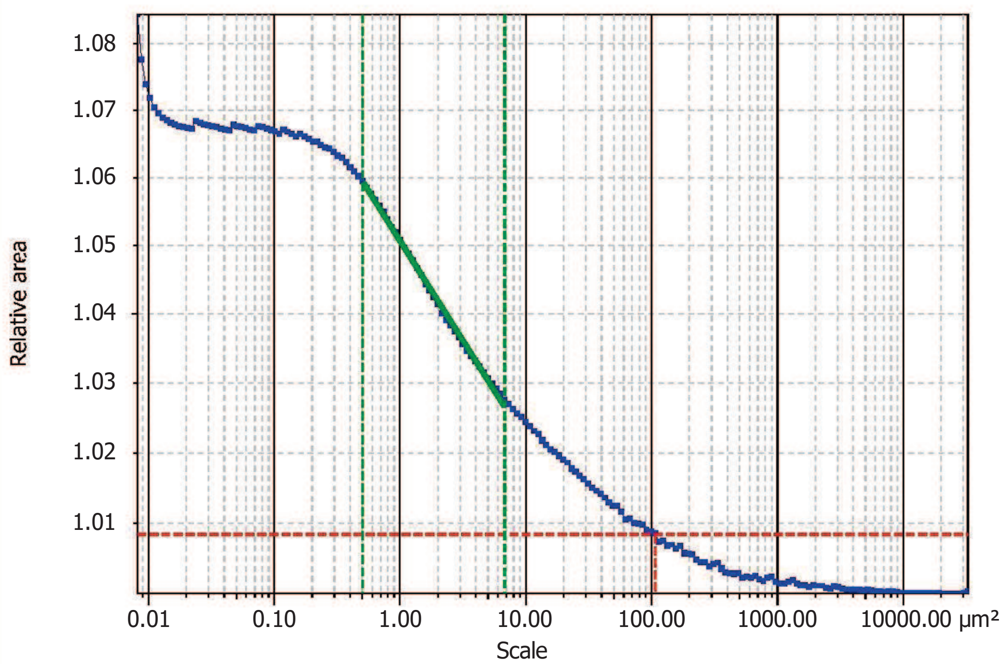
Parameters	Value	Unit
Isotropy	83.04	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001066		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01777		*Length-scale anisotropy (1.8 µm, 5°)*

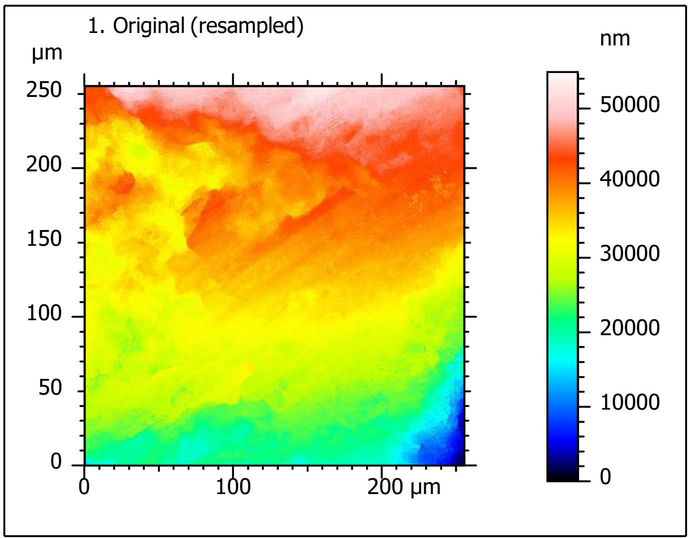


Information	
Method	Area-scale (four corners)

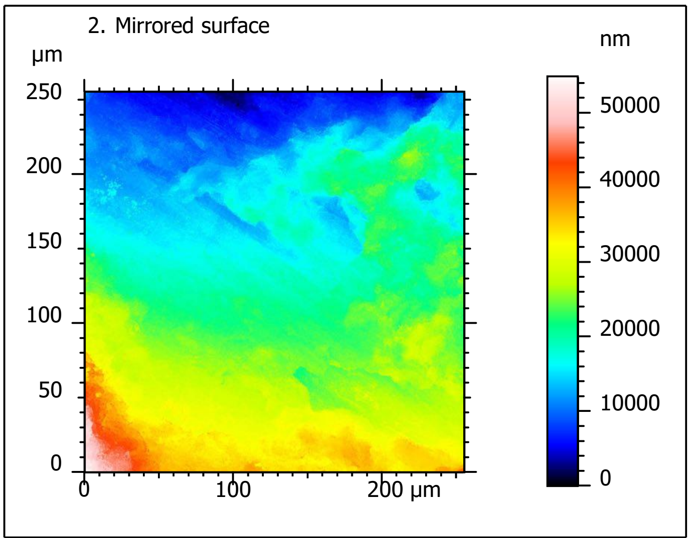
Parameters	Value	Unit	Comment
Asfc	12.11		*Fractal complexity*
Smfc	1.363	µm²	*Scale of max complexity*
HAsfc9	0.1493		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2825		*Heterogeneity of Asfc (9x9)*

Template - Mirroring surfaces (impressions)
Template to mirror the surfaces in x and z that have been acquired with the LSM 800 based on moulds instead of the original artefact surface.

Mirroring



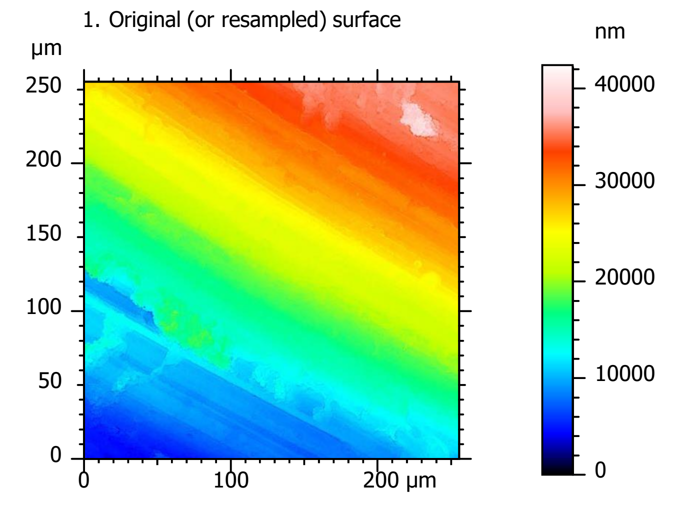
Identity card		
Name:	lime3-3_lsm_50x-0.75_...0914_surf1_Topo-mold	
Created on:	3/10/2020 4:25:37 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	54908	nm
Size:	65532	digits
Spacing:	0.8379	nm
NM-points ratio:	0.000 % (0 Pts)	



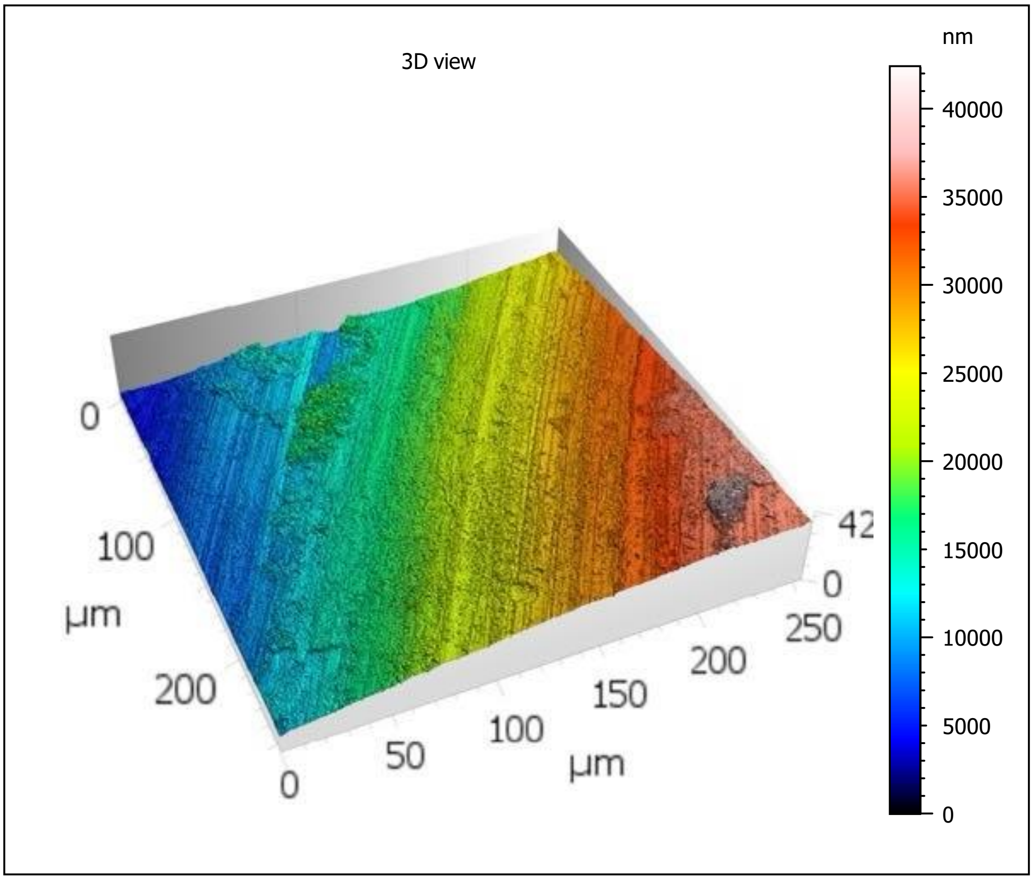
Identity card		
Name:	lime3-3_lsm_50x-0.75_... > Mirrored (in X and Z)	
Created on:	3/10/2020 4:25:37 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	54908	nm
Size:	65532	digits
Spacing:	0.8379	nm
NM-points ratio:	0.000 % (0 Pts)	

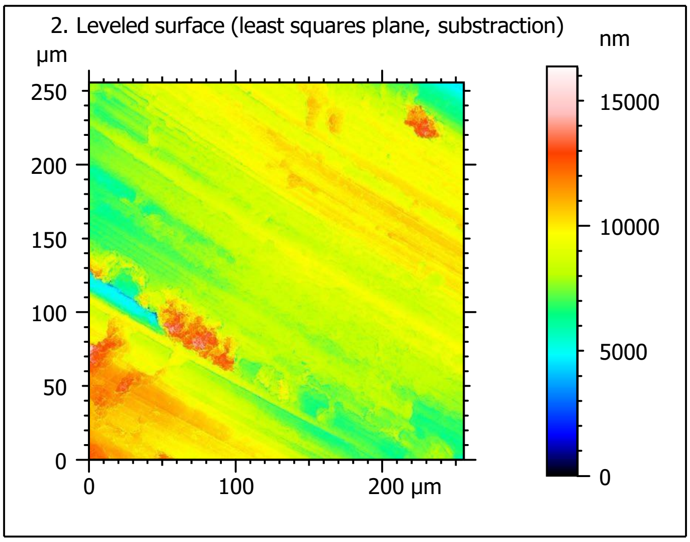
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

Processing

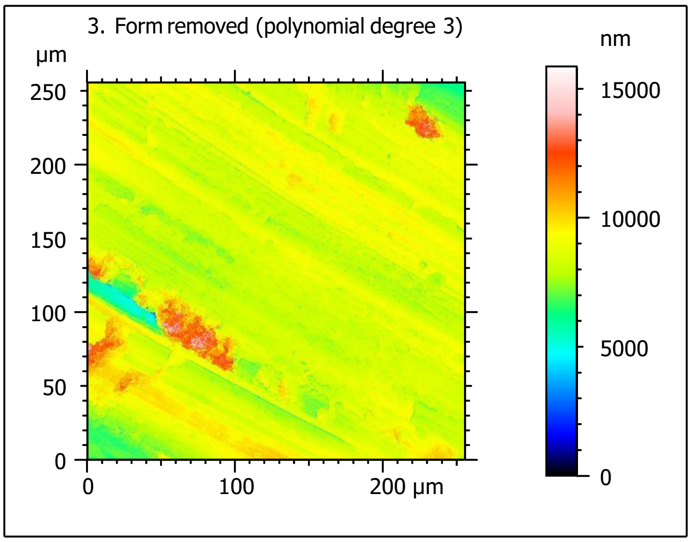


Identity card			
Name:	Lime2-5_LSM_50x075_suf1_Topo		
Created on:	6/24/2020 12:03:05 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	42418	nm	
Size:	65532	digits	
Spacing:	0.6473	nm	
NM-points ratio:	0.000 % (0 Pts)		

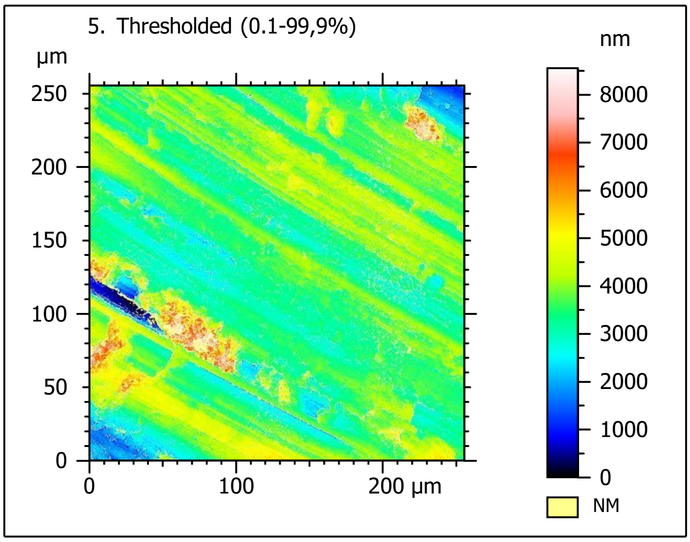




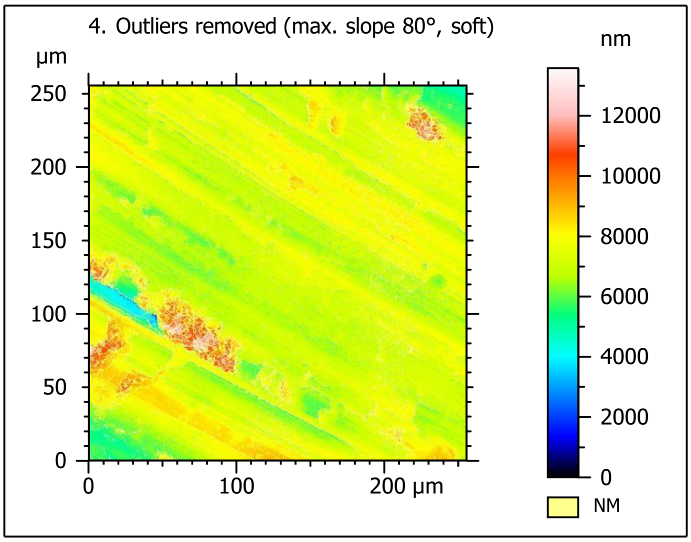
2. Leveled surface (least squares plane, substraction)
µm
nm
250
200
150
100
50
0
0
100
200 µm
15000
10000
5000
0



3. Form removed (polynomial degree 3)
µm
nm
250
200
150
100
50
0
0
100
200 µm
15000
10000
5000
0

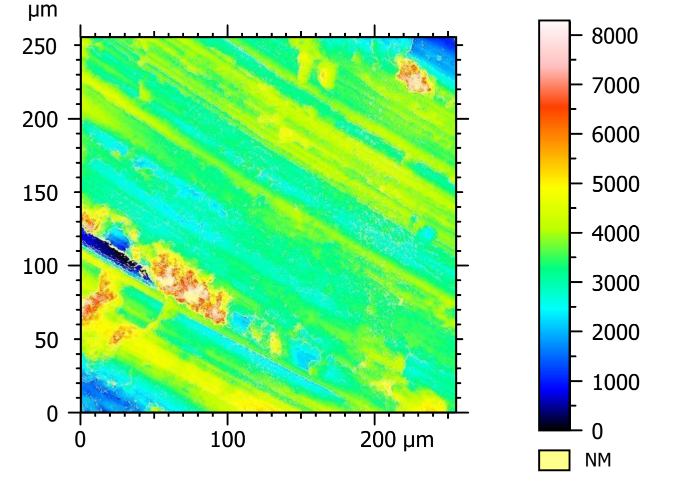


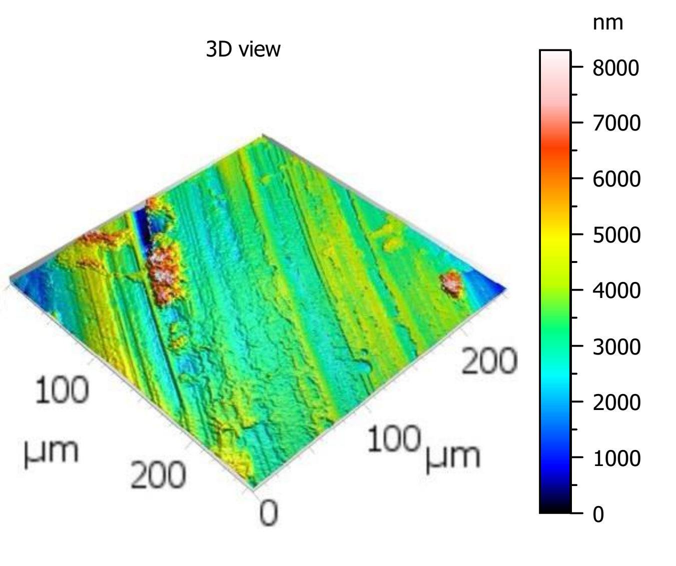
5. Thresholded (0.1-99,9%)
µm
nm
250
200
150
100
50
0
0
100
200 µm
8000
7000
6000
5000
4000
3000
2000
1000
0
NM



4. Outliers removed (max. slope 80°, soft)
µm
nm
250
200
150
100
50
0
0
100
200 µm
12000
10000
8000
6000
4000
2000
0
NM

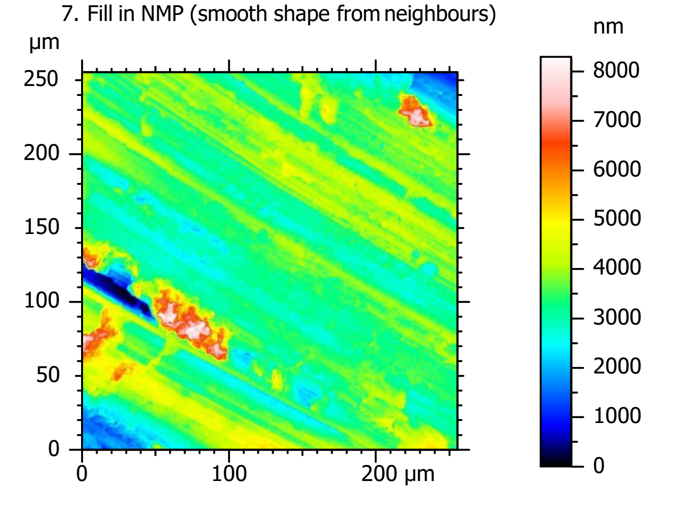
6. Microroughness removed (S-filter, 2.5 µm)



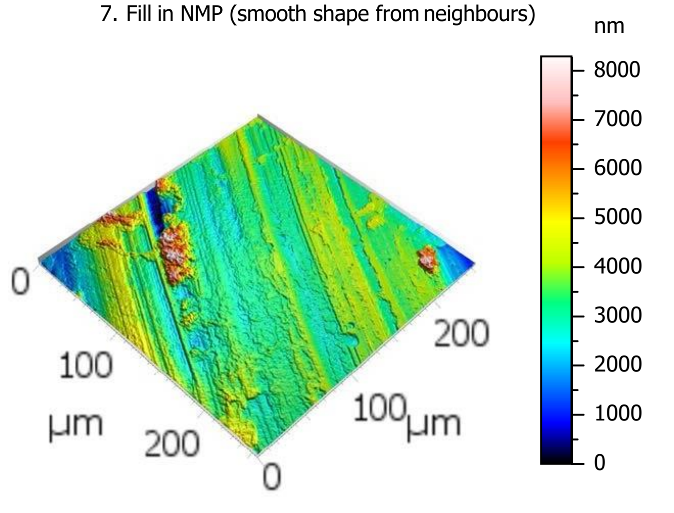


Identity card			
Name:	Lime2-5_LSM_50x075…filtered (λs 2.500 µm)		
File path:	C:\Us…\Lime2-5_LSM_50x075_suf1_Topo.sur		
Created on:	6/24/2020 12:03:05 PM		
Studiable type:	Surface		
Axis:	X		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	0.000	µm	
Axis:	Y		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	-255.5	µm	
Axis:	Z		
Layer type:	Topography		
Length:	8296	nm	
Min:	-3481	nm	
Max:	4814	nm	
Size:	128164	digits	
Spacing:	0.06473	nm	
NM-points ratio:	8.211 % (738953 Pts)		

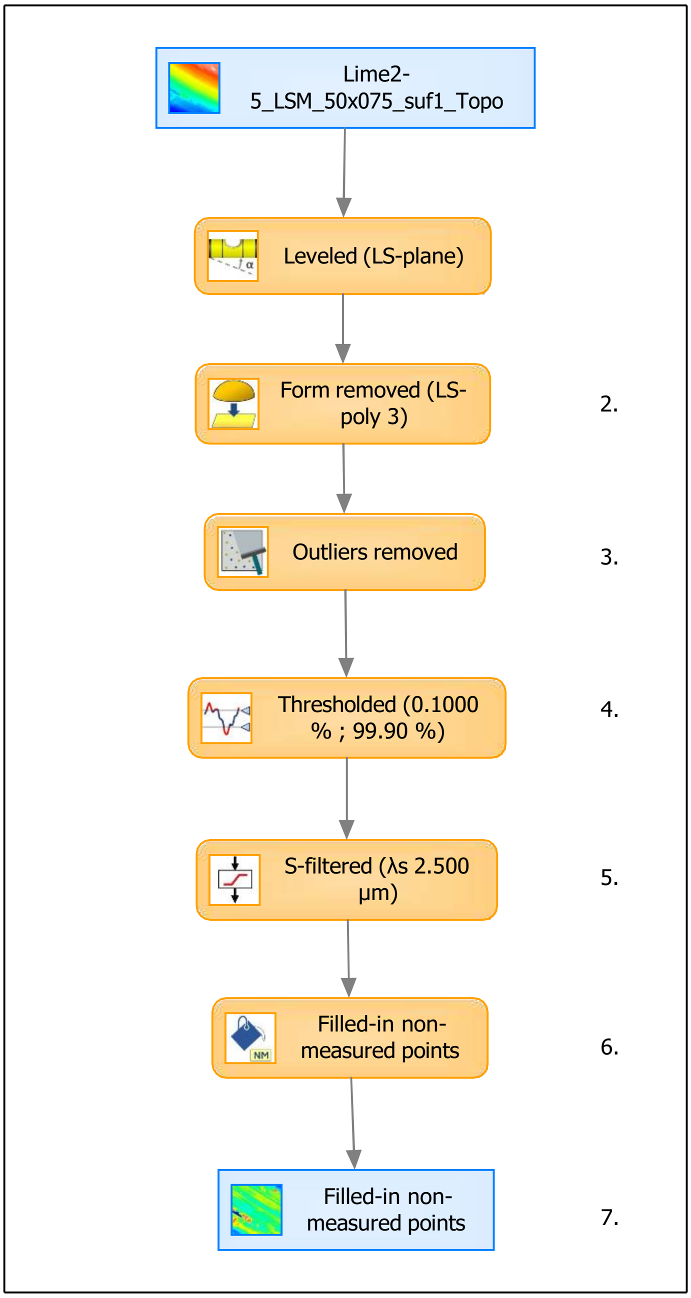
7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card			
Name:	Lime2-5_LSM_50x075_s…in non-measured points		
Created on:	6/24/2020 12:03:05 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	8296	nm	
Size:	128164	digits	
Spacing:	0.06473	nm	
NM-points ratio:	0.000 % (0 Pts)		



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface			
F: [Workflow] Form removed (LS-poly 3)			
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)			
Height parameters			
Sq	836.4	nm	
Ssk	0.9972		
Sku	8.633		
Sp	4803	nm	
Sv	3493	nm	
Sz	8296	nm	
Sa	572.2	nm	
Functional parameters			
Smr	0.4643	%	
Smc	774.9	nm	
Sxp	1535	nm	
Spatial parameters			
Sal	13.53	µm	
Str	0.3709		
Std	149.2	°	
Hybrid parameters			
Sdq	0.3283		
Sdr	4.361	%	
Functional parameters (Volume)			
Vm	0.08656	µm³/µm²	
Vv	0.8614	µm³/µm²	
Vmp	0.08656	µm³/µm²	
Vmc	0.5283	µm³/µm²	
Vvc	0.7691	µm³/µm²	
Vvv	0.09233	µm³/µm²	

Analyses:

ISO 25178 8.

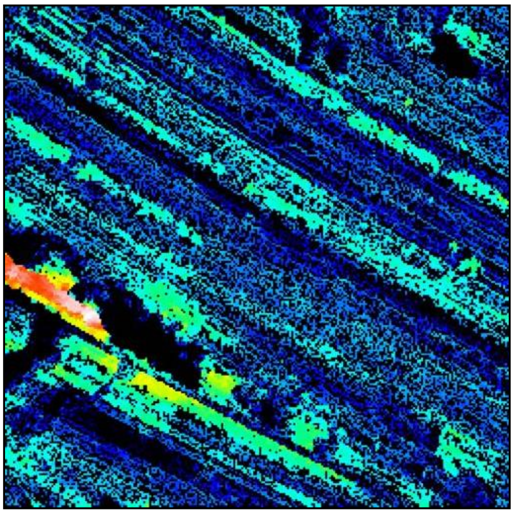
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

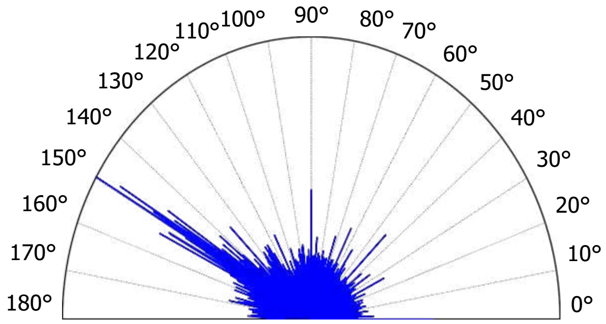
9. Furrow analysis on surface #7



All furrows are shown.

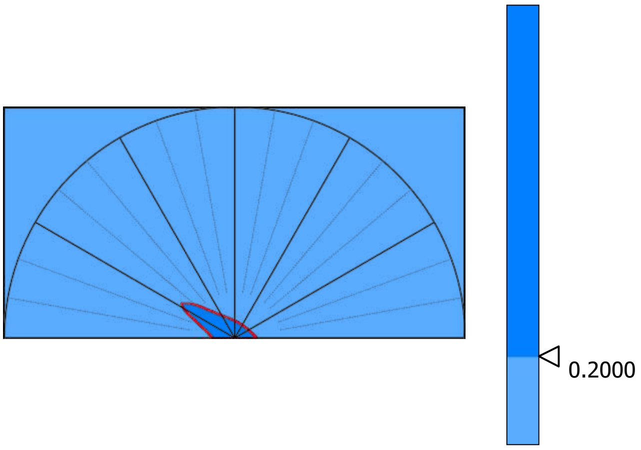
Parameters	Value	Unit
Maximum depth of furrows	4563	nm
Mean depth of furrows	961.9	nm
Mean density of furrows	4523	cm/cm2

10. Texture direction on surface #7



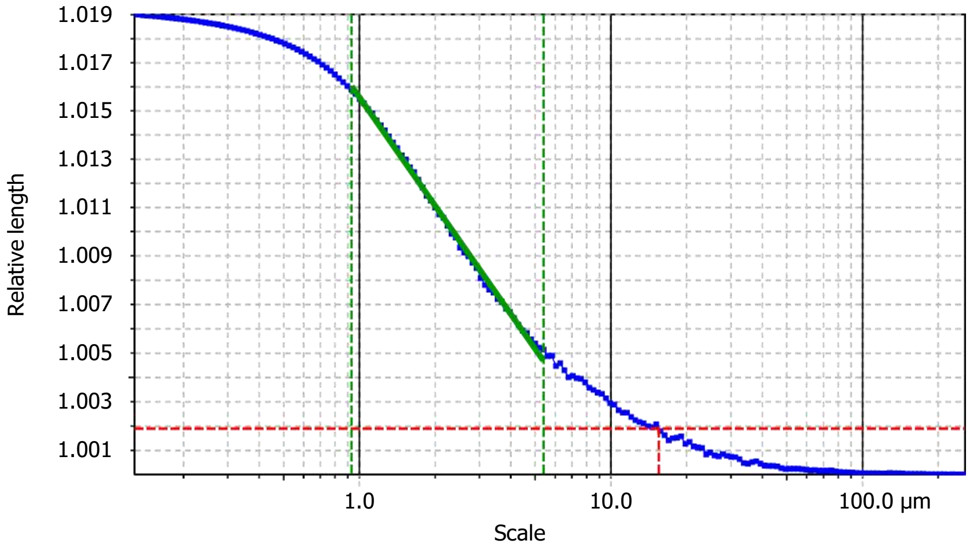
Parameters	Value	Unit
First direction	149.7	°
Second direction	180.0	°
Third direction	141.3	°

11. Texture isotropy on surface #7



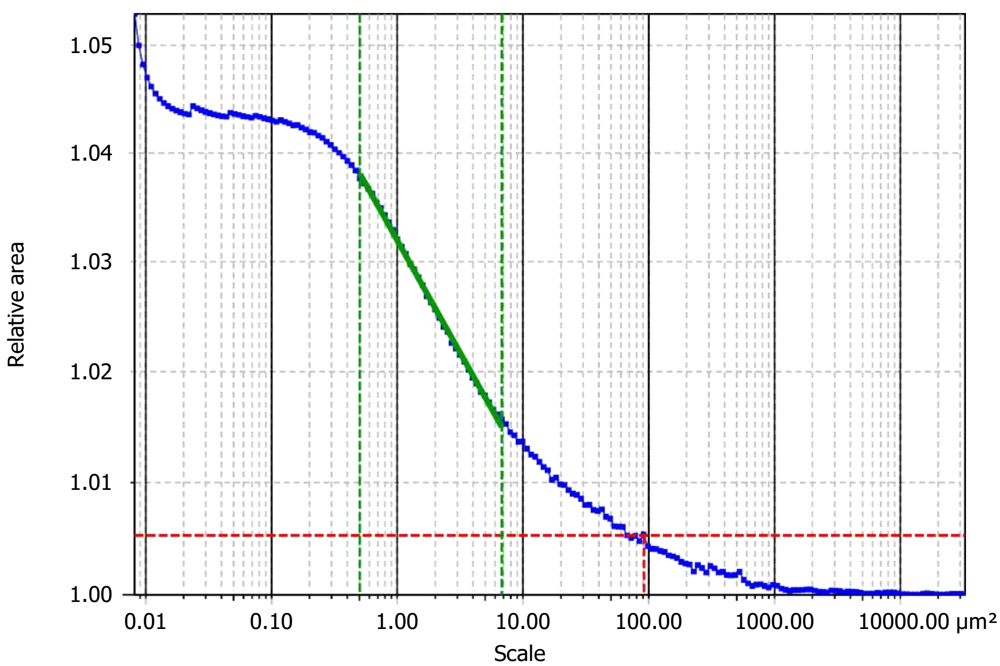
Parameters	Value	Unit
Isotropy	23.50	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.003813		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01868		*Length-scale anisotropy (1.8 µm, 5°)*

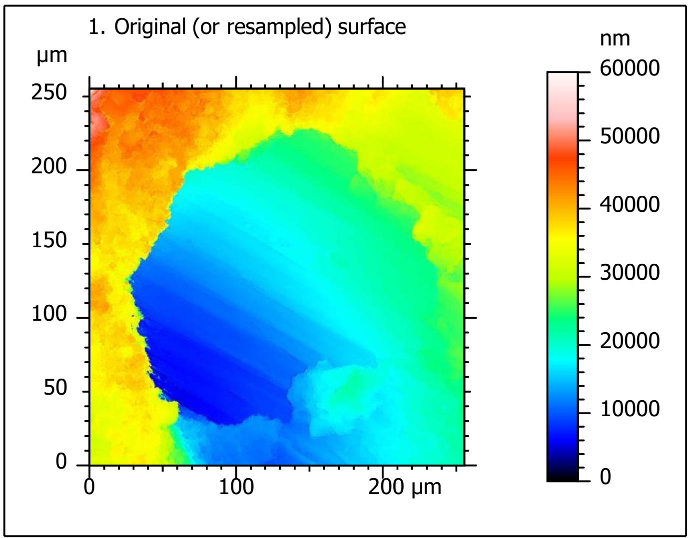


Information	
Method	Area-scale (four corners)

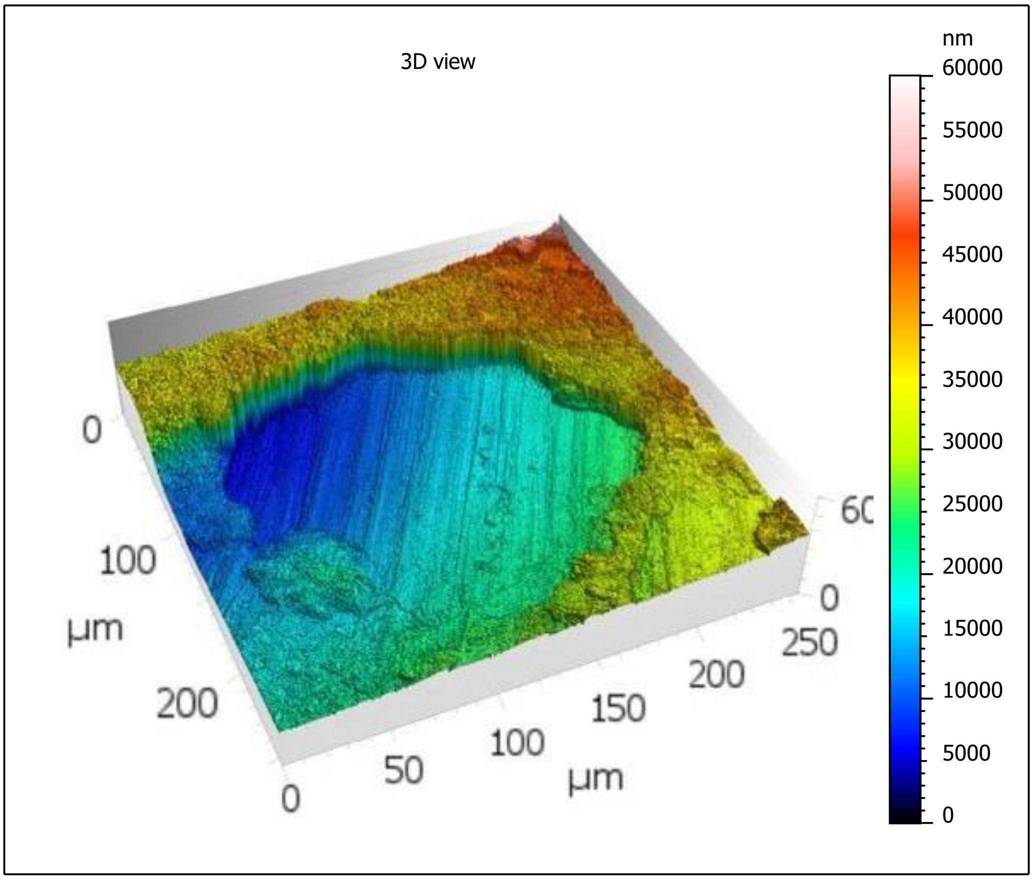
Parameters	Value	Unit	Comment
Asfc	8.658		*Fractal complexity*
Smfc	1.714	µm²	*Scale of max complexity*
HAsfc9	0.4485		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.6589		*Heterogeneity of Asfc (9x9)*

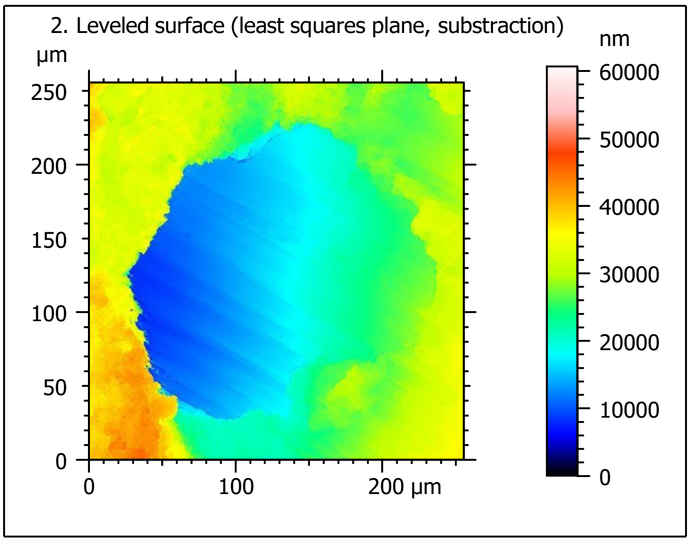
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

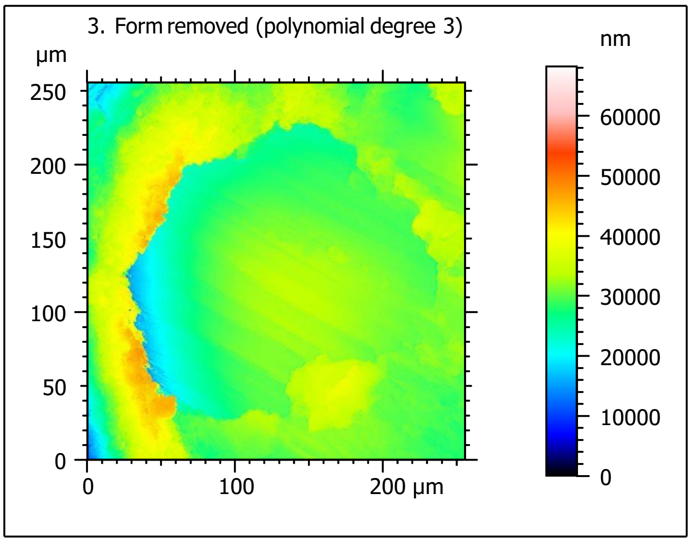
Processing

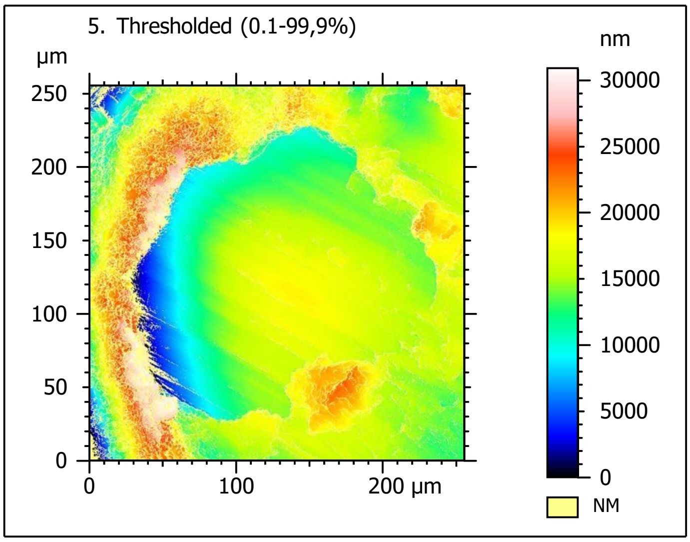


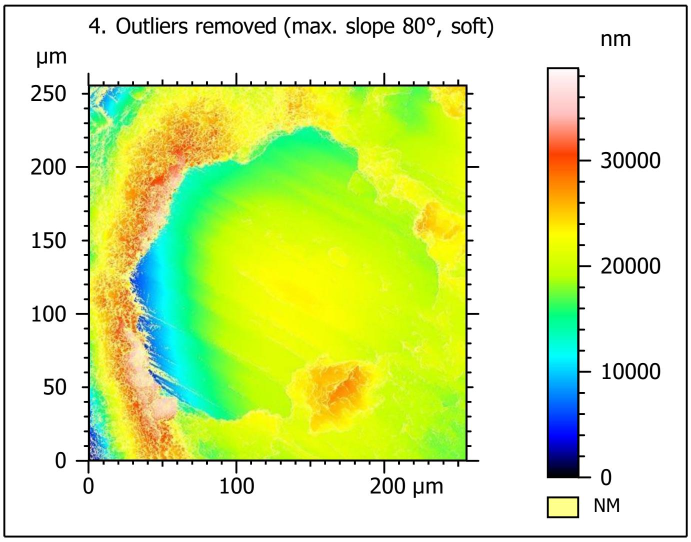
Identity card		
Name:	Lime2-5_LSM_50x075_suf2_Topo	
Created on:	6/24/2020 12:21:59 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	60038	nm
Size:	65532	digits
Spacing:	0.9162	nm
NM-points ratio:	0.000 % (0 Pts)	

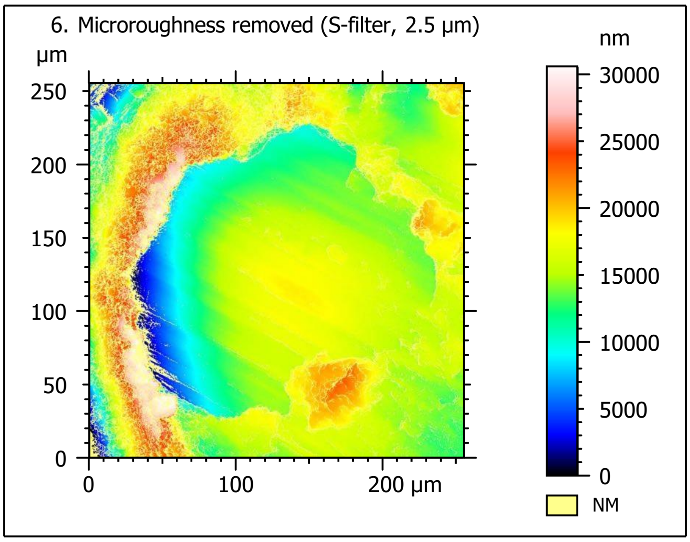



2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
60000
50000
40000
30000
20000
10000
0

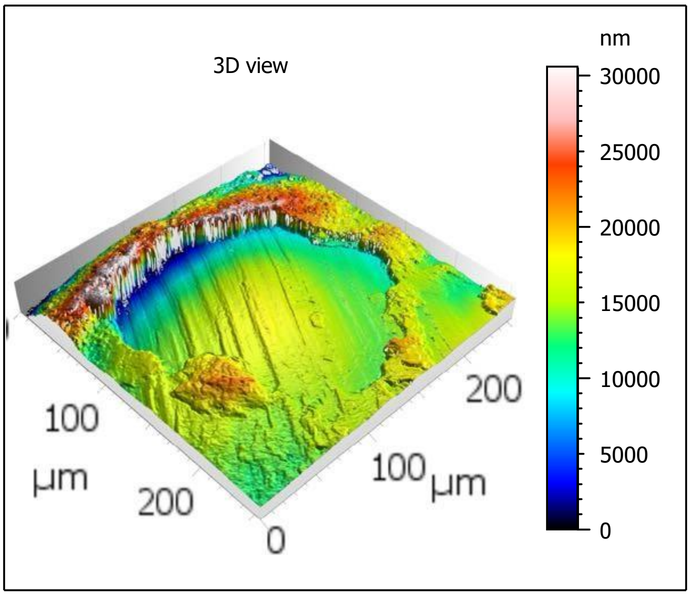

3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
60000
50000
40000
30000
20000
10000
0

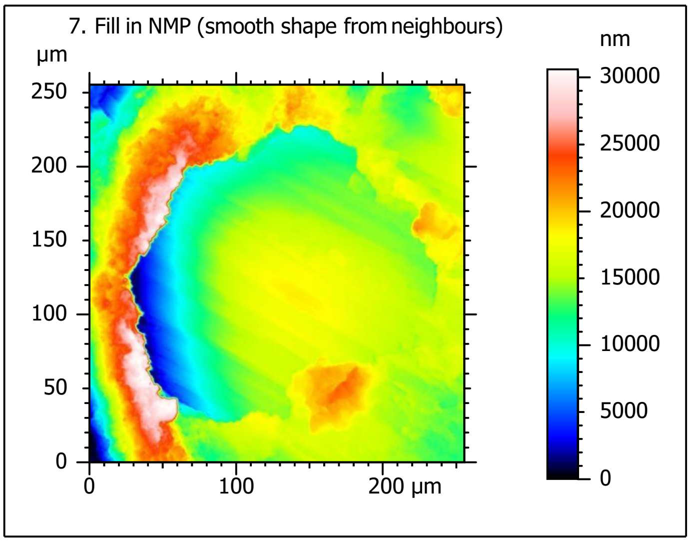

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
30000
25000
20000
15000
10000
5000
0
NM

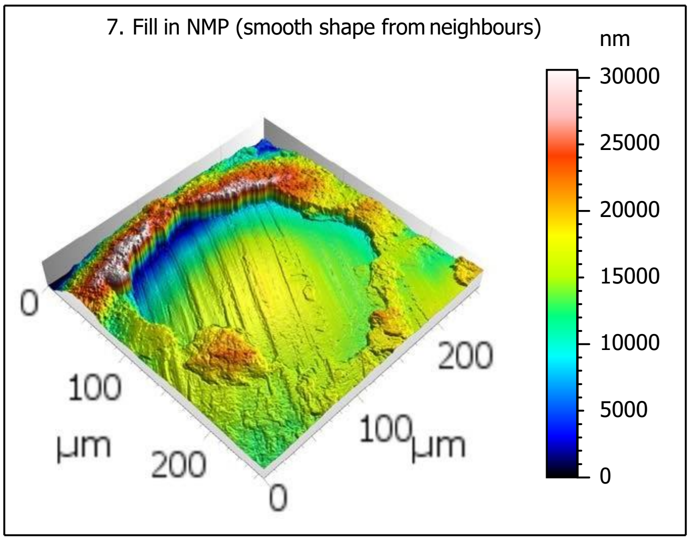

4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
30000
20000
10000
0
NM



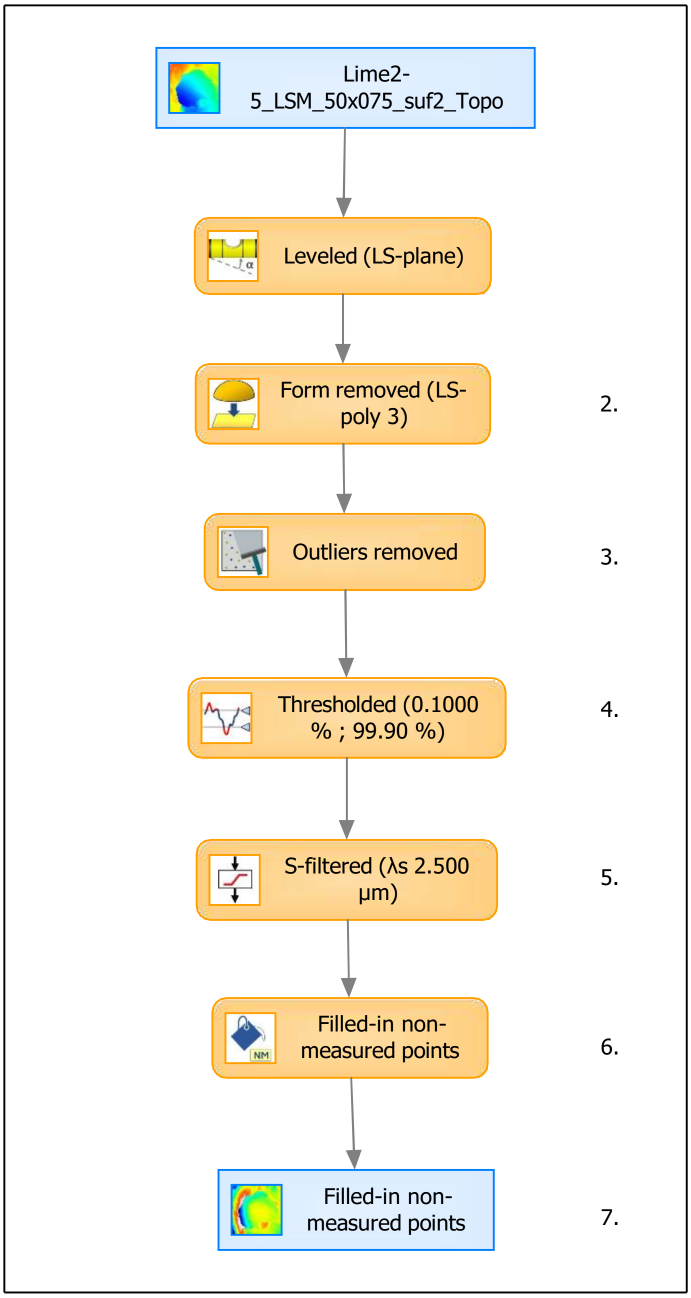
Identity card		
Name:	Lime2-5_LSM_50x075…filtered (λs 2.500 µm)	
File path:	C:\Us…\Lime2-5_LSM_50x075_suf2_Topo.sur	
Created on:	6/24/2020 12:21:59 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	Z	
Layer type:	Topography	
Length:	30595	nm
Min:	-15554	nm
Max:	15041	nm
Size:	333950	digits
Spacing:	0.09162	nm
NM-points ratio:	15.81 % (1422908 Pts)	







Identity card		
Name:	Lime2-5_LSM_50x075_s…in non-measured points	
Created on:	6/24/2020 12:21:59 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	30595	nm
Size:	333950	digits
Spacing:	0.09162	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses:

ISO 25178 8.

Furrow 9.

Texture direction 10.

Texture isotropy 11.

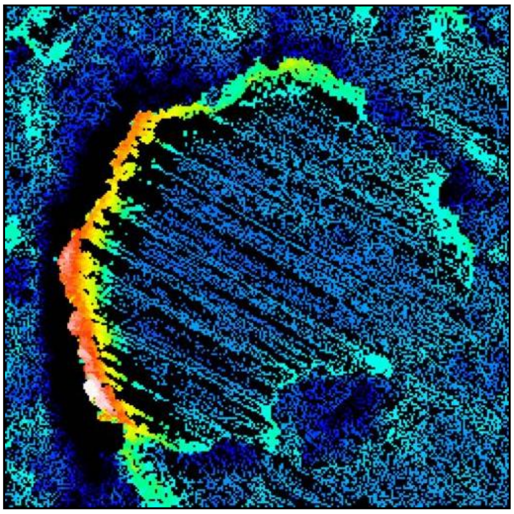
SSFA 12.

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	4619	nm
Ssk	0.1072	
Sku	4.477	
Sp	15016	nm
Sv	15579	nm
Sz	30595	nm
Sa	3244	nm
Functional parameters		
Smr	0.4972	%
Smc	5691	nm
Sxp	10610	nm
Spatial parameters		
Sal	18.88	µm
Str	0.4160	
Std	65.00	°
Hybrid parameters		
Sdq	1.153	
Sdr	20.02	%
Functional parameters (Volume)		
Vm	0.3378	µm³/µm²
Vv	6.029	µm³/µm²
Vmp	0.3378	µm³/µm²
Vmc	3.111	µm³/µm²
Vvc	5.335	µm³/µm²
Vvv	0.6940	µm³/µm²

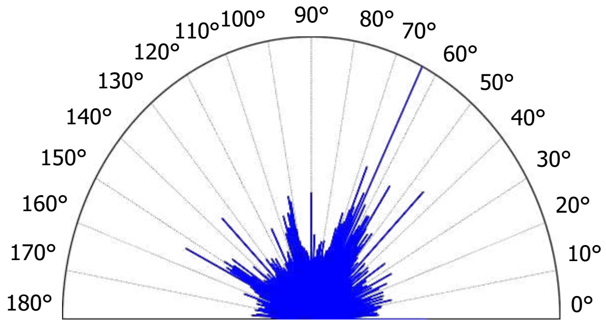
9. Furrow analysis on surface #7



All furrows are shown.

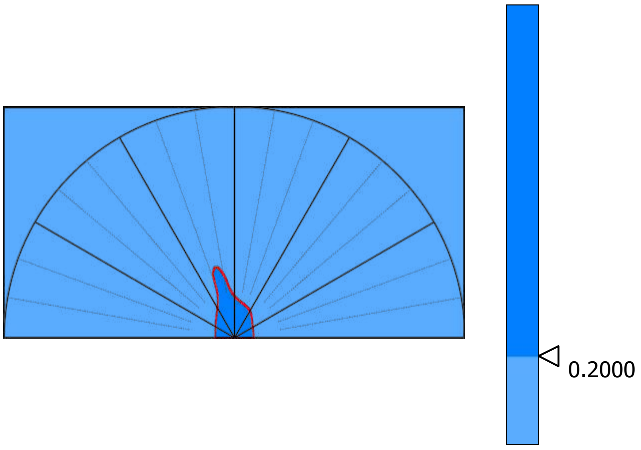
Parameters	Value	Unit
Maximum depth of furrows	20628	nm
Mean depth of furrows	4630	nm
Mean density of furrows	3830	cm/cm2

10. Texture direction on surface #7



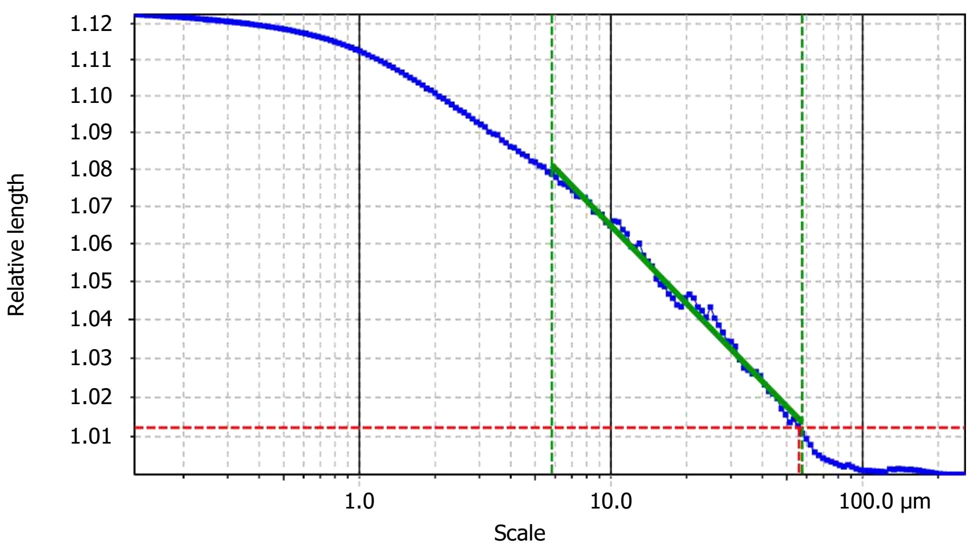
Parameters	Value	Unit
First direction	63.57	°
Second direction	45.04	°
Third direction	56.22	°

11. Texture isotropy on surface #7



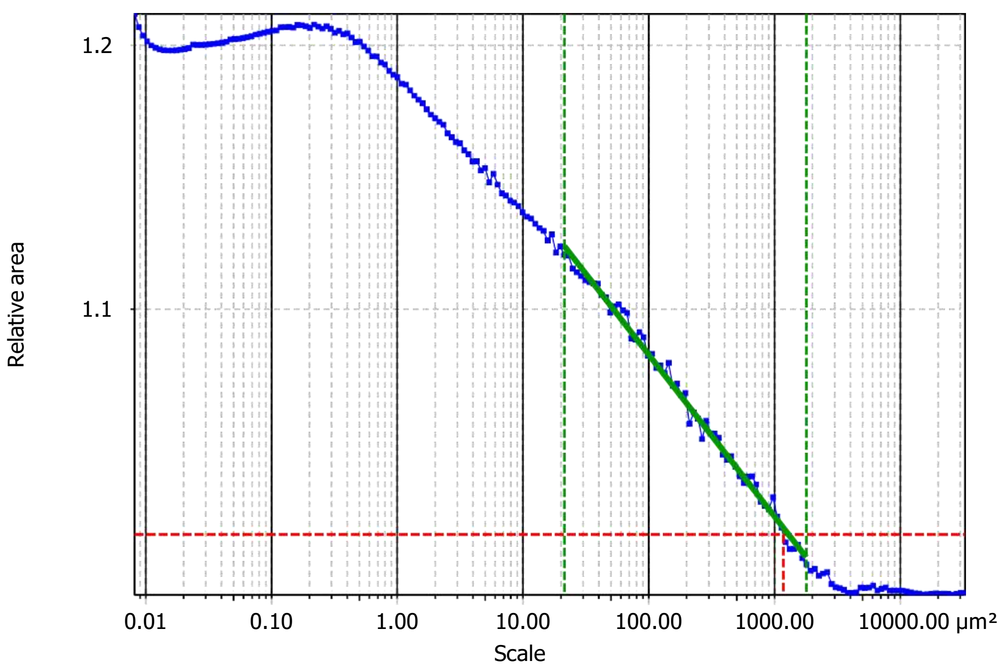
Parameters	Value	Unit
Isotropy	26.24	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.002517		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01677		*Length-scale anisotropy (1.8 µm, 5°)*

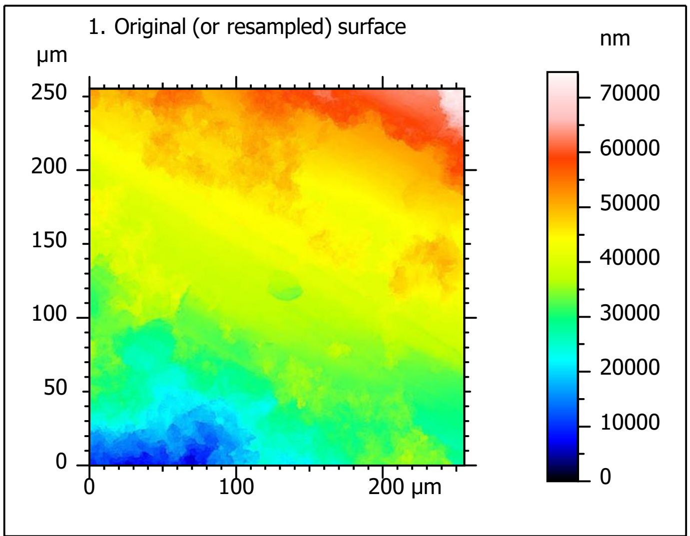


Information	
Method	Area-scale (four corners)

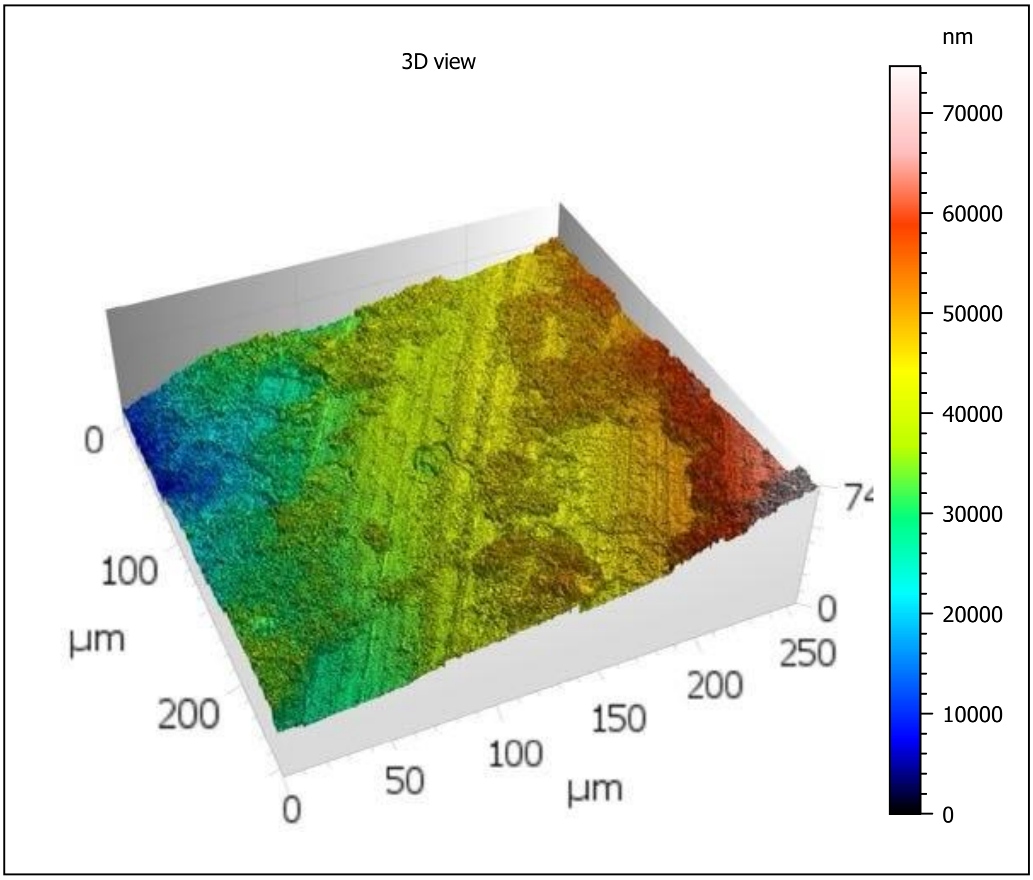
Parameters	Value	Unit	Comment
Asfc	23.18		*Fractal complexity*
Smfc	181.0	µm²	*Scale of max complexity*
HAsfc9	2.496		*Heterogeneity of Asfc (3x3)*
HAsfc81	3.446		*Heterogeneity of Asfc (9x9)*

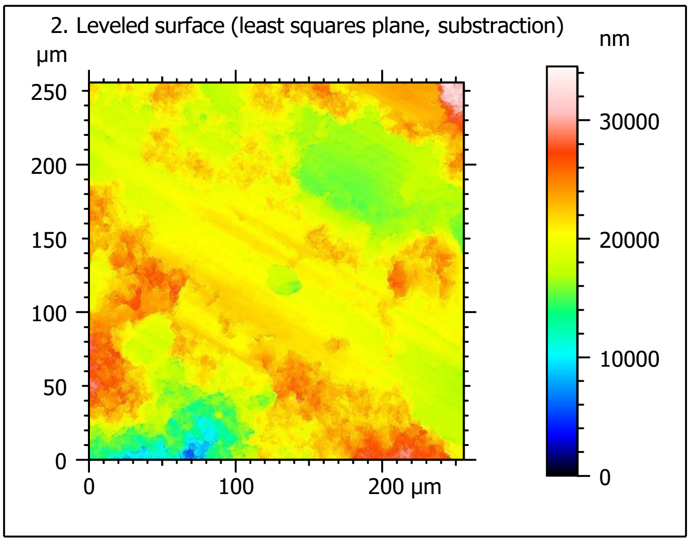
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

Processing

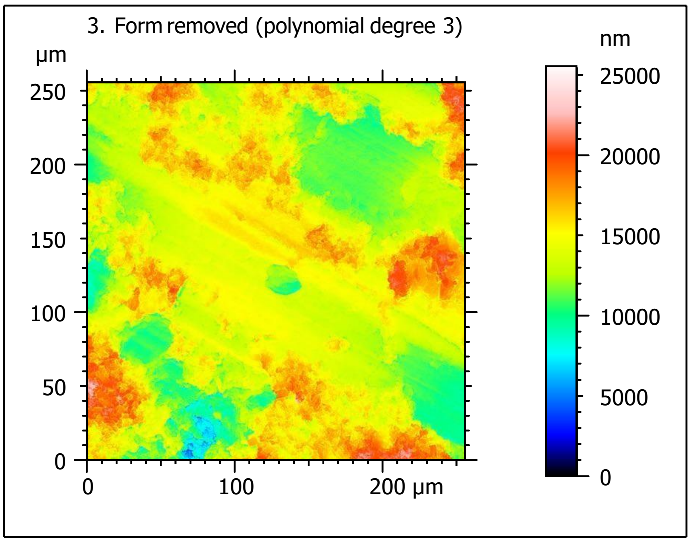


Identity card			
Name:	Lime2-5_LSM_50x075_suf3_Topo		
Created on:	6/24/2020 1:26:11 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	74667	nm	
Size:	65532	digits	
Spacing:	1.139	nm	
NM-points ratio:	0.000 % (0 Pts)		

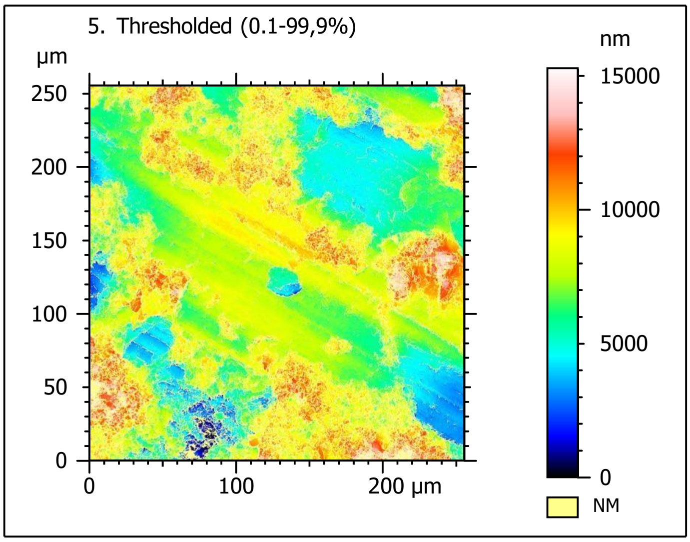




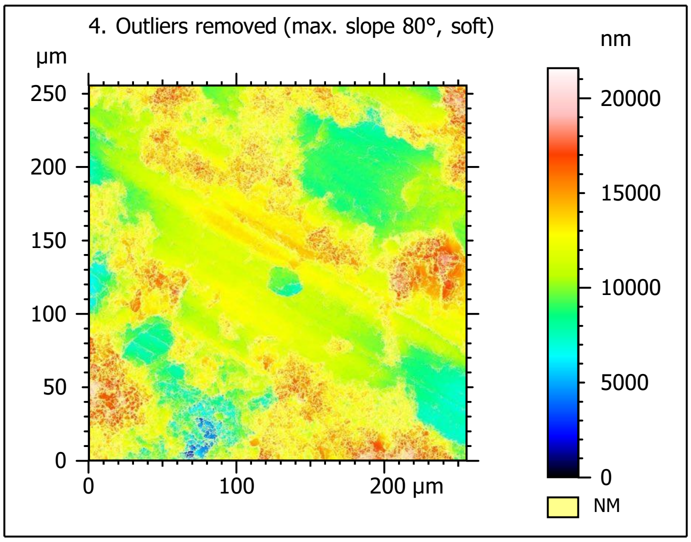
2. Leveled surface (least squares plane, substraction)



3. Form removed (polynomial degree 3)

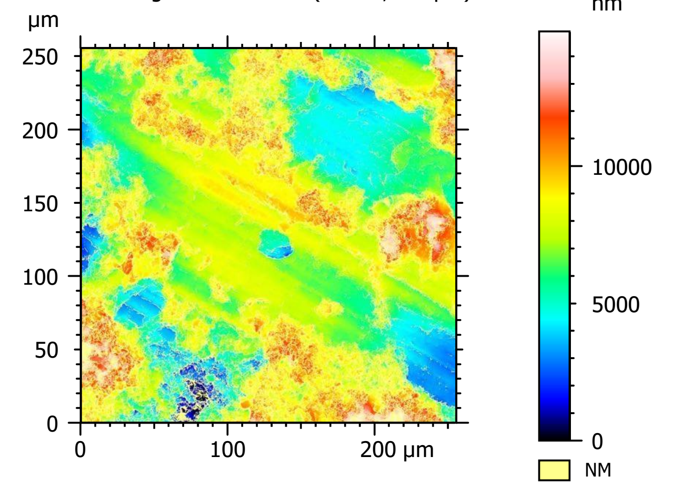


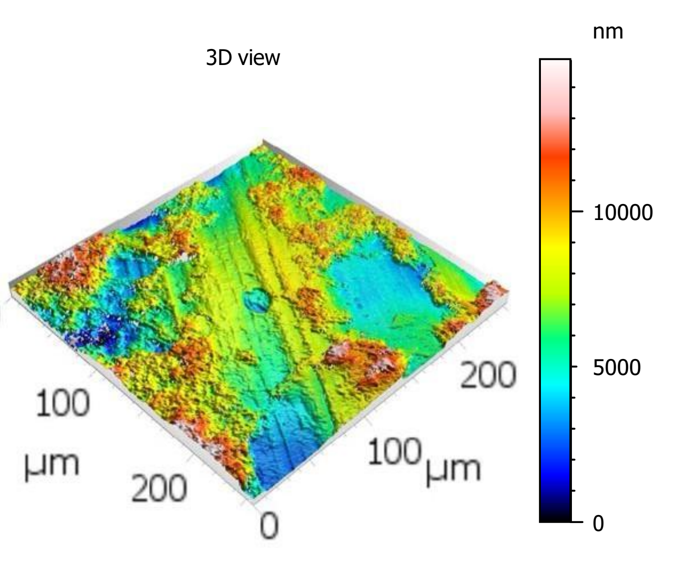
5. Thresholded (0.1-99,9%)



4. Outliers removed (max. slope 80°, soft)

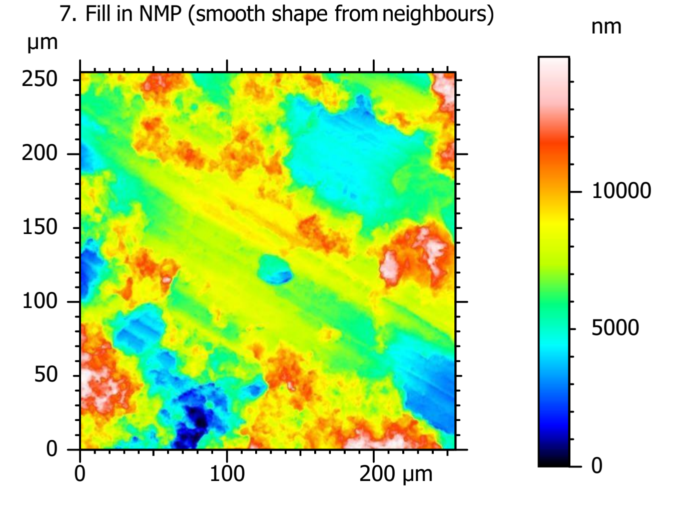
6. Microroughness removed (S-filter, 2.5 µm)



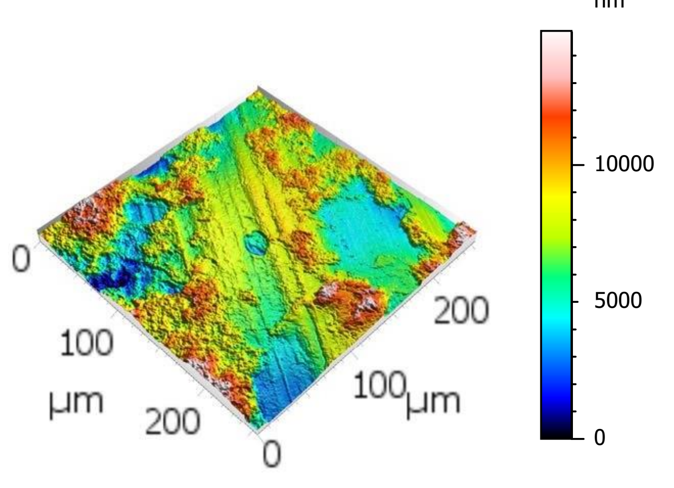


Identity card		
Name:	Lime2-5_LSM_50x075…filtered (λs 2.500 µm)	
File path:	C:\Us…\Lime2-5_LSM_50x075_suf3_Topo.sur	
Created on:	6/24/2020 1:26:11 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	Z	
Layer type:	Topography	
Length:	14905	nm
Min:	-7399	nm
Max:	7506	nm
Size:	130813	digits
Spacing:	0.1139	nm
NM-points ratio:	26.92 % (2422931 Pts)	

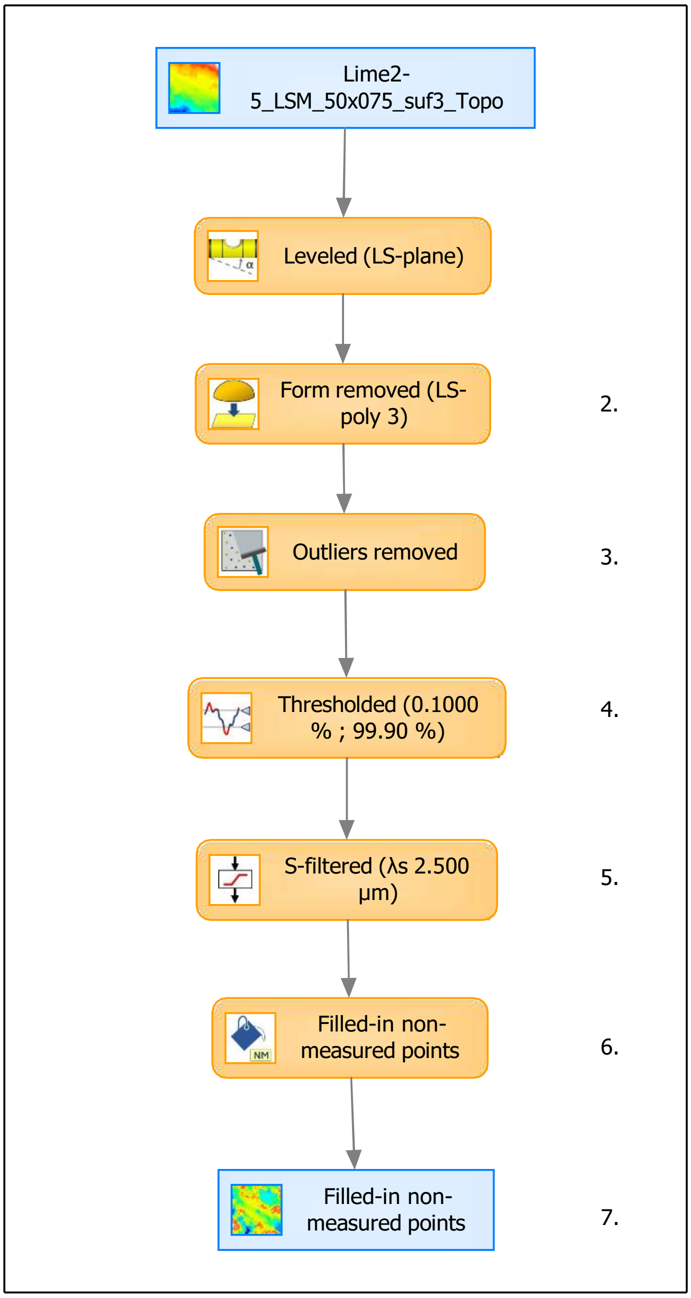
7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card		
Name:	Lime2-5_LSM_50x075_s...in non-measured points	
Created on:	6/24/2020 1:26:11 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	14905	nm
Size:	130813	digits
Spacing:	0.1139	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	2321	nm
Ssk	0.1415	
Sku	3.107	
Sp	7456	nm
Sv	7449	nm
Sz	14905	nm
Sa	1819	nm
Functional parameters		
Smr	0.4479	%
Smc	2944	nm
Sxp	4295	nm
Spatial parameters		
Sal	20.12	µm
Str	0.5918	
Std	150.0	°
Hybrid parameters		
Sdq	0.6885	
Sdr	16.47	%
Functional parameters (Volume)		
Vm	0.1331	µm³/µm²
Vv	3.078	µm³/µm²
Vmp	0.1331	µm³/µm²
Vmc	2.097	µm³/µm²
Vvc	2.824	µm³/µm²
Vvv	0.2534	µm³/µm²

Analyses:

ISO 25178 8.

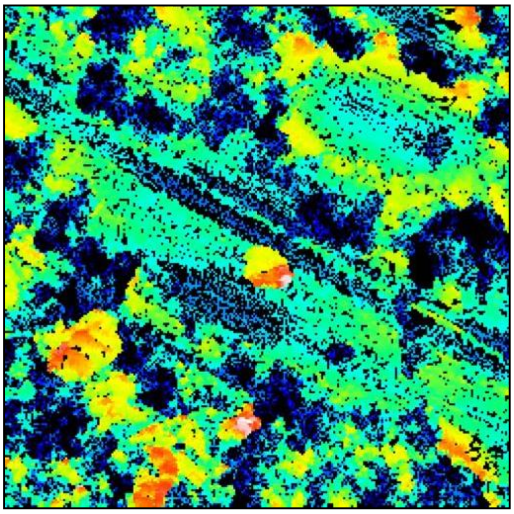
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

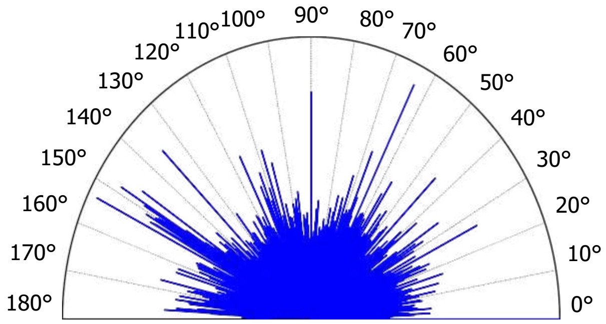
9. Furrow analysis on surface #7



All furrows are shown.

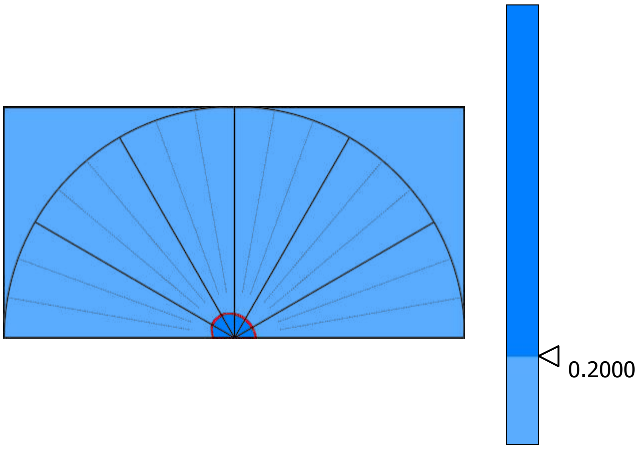
Parameters	Value	Unit
Maximum depth of furrows	7652	nm
Mean depth of furrows	2490	nm
Mean density of furrows	4509	cm/cm2

10. Texture direction on surface #7



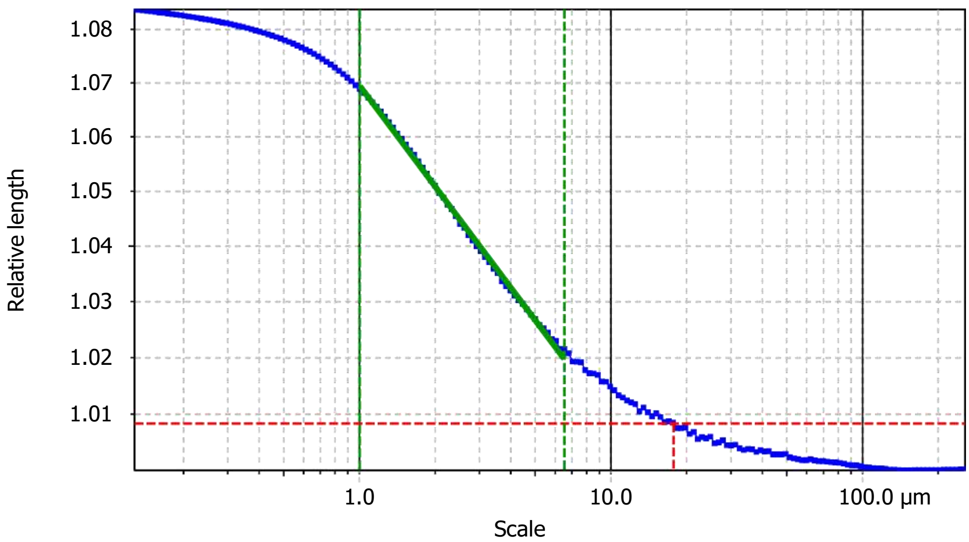
Parameters	Value	Unit
First direction	0.002662	°
Second direction	153.5	°
Third direction	63.51	°

11. Texture isotropy on surface #7



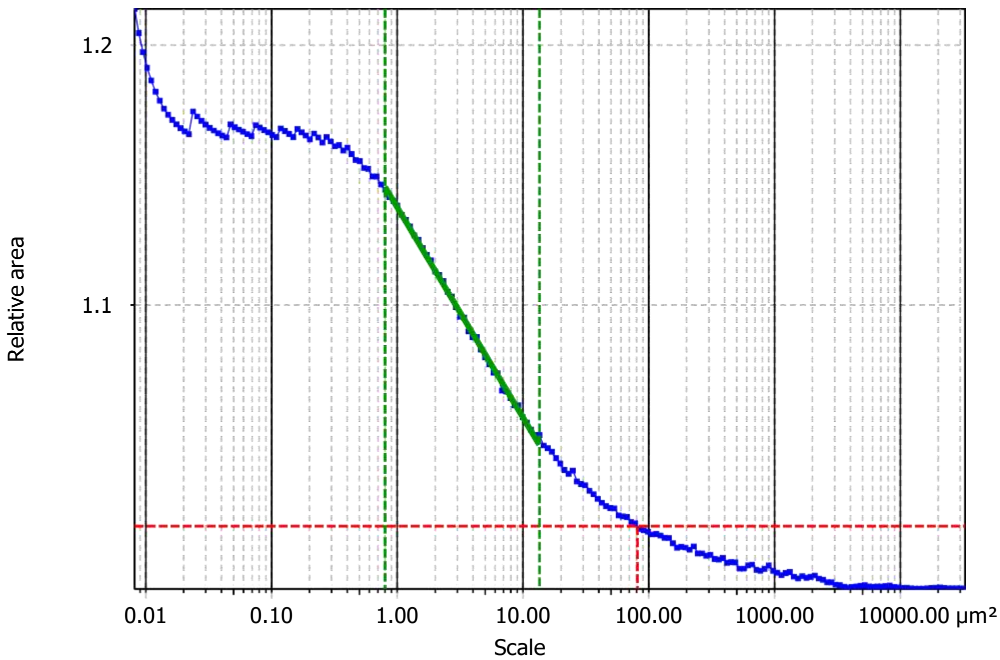
Parameters	Value	Unit
Isotropy	77.82	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0006392		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01749		*Length-scale anisotropy (1.8 µm, 5°)*

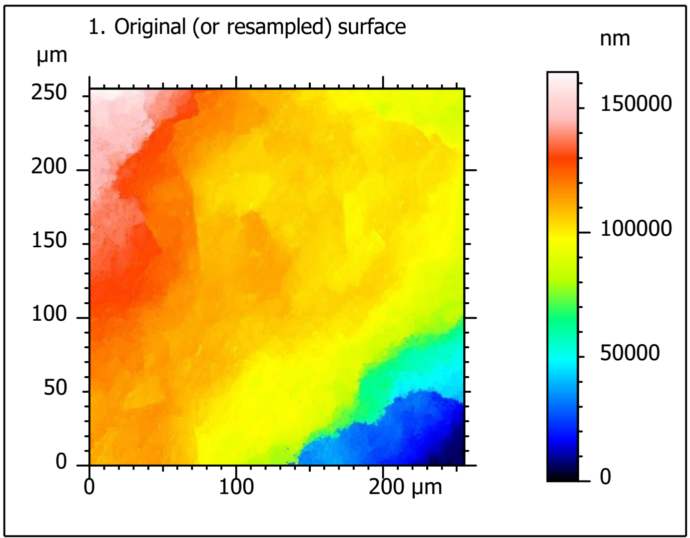


Information	
Method	Area-scale (four corners)

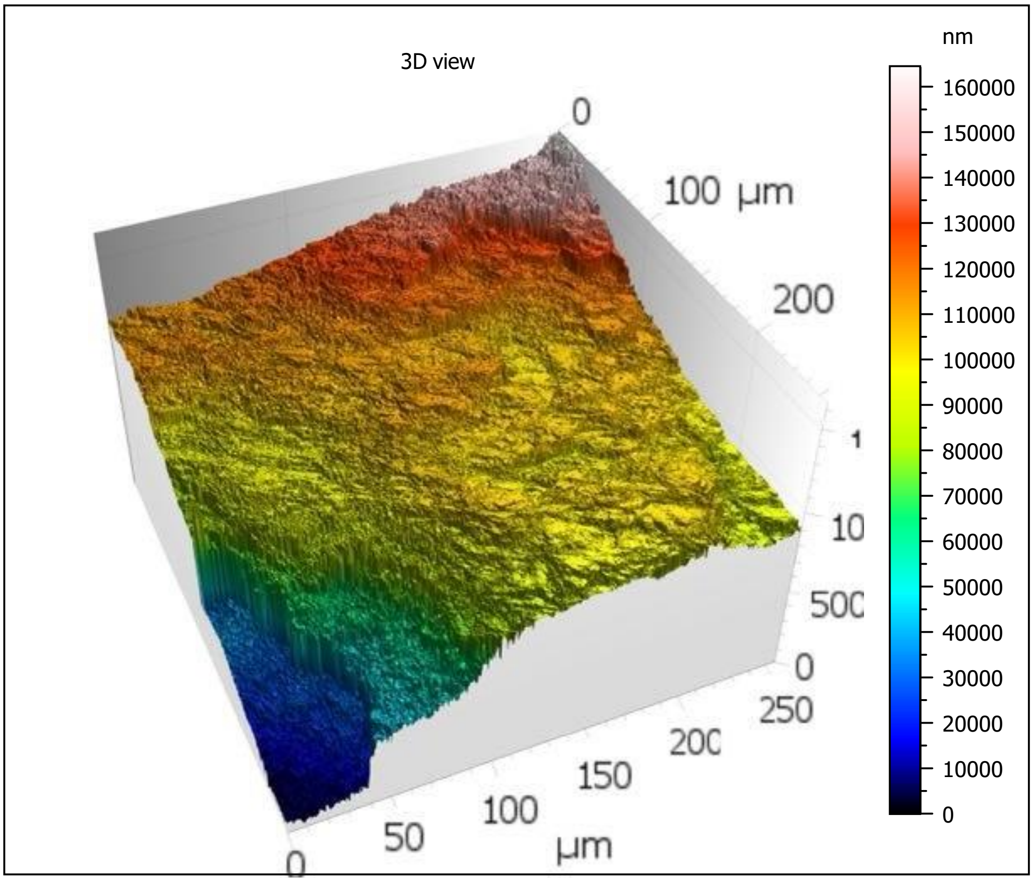
Parameters	Value	Unit	Comment
Asfc	30.55		*Fractal complexity*
Smfc	2.711	µm²	*Scale of max complexity*
HAsfc9	0.3876		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.4811		*Heterogeneity of Asfc (9x9)*

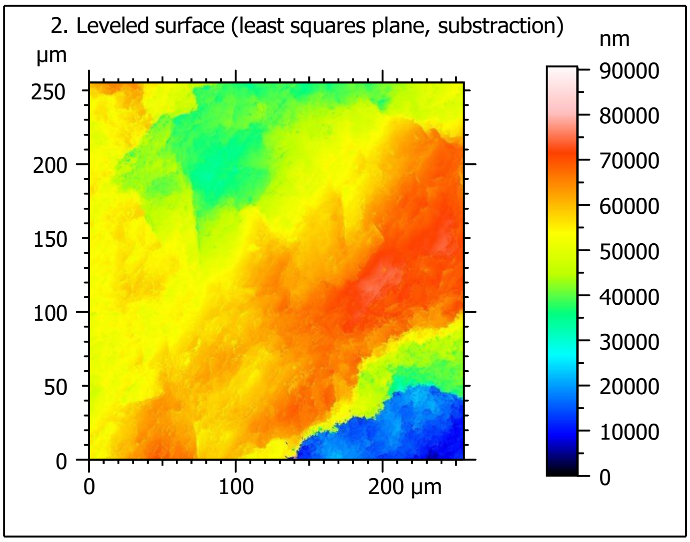
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

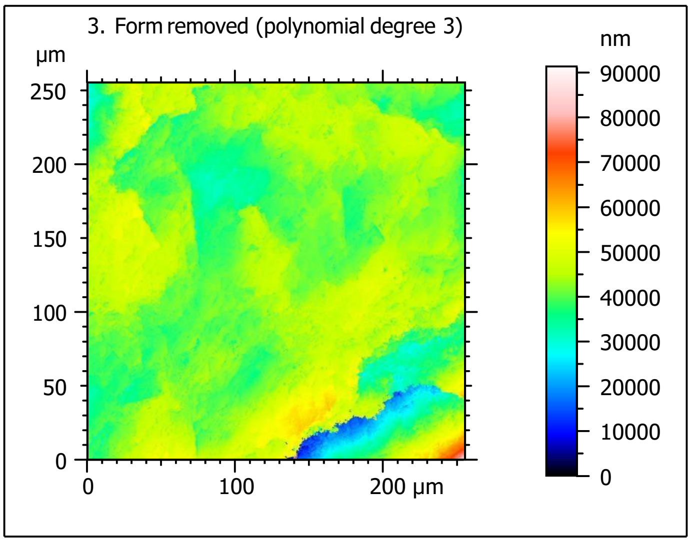
Processing

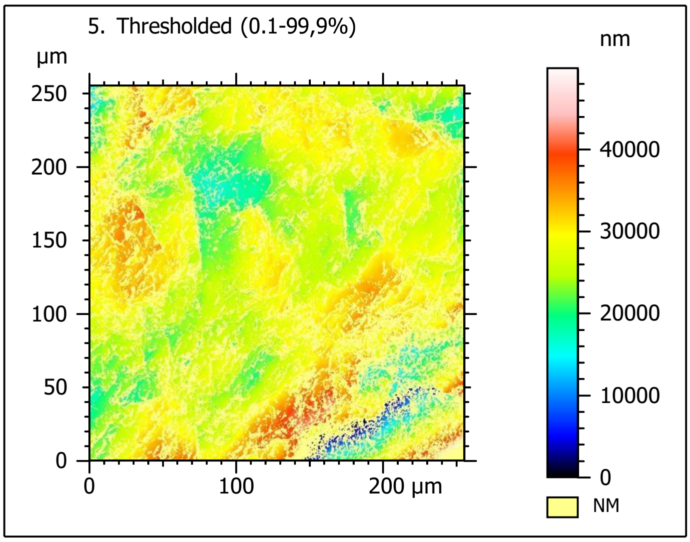


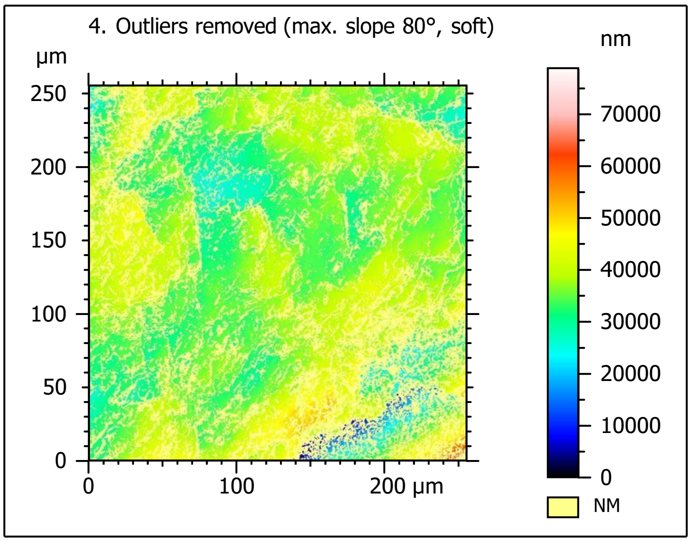
Identity card		
Name:	lime3-3_lsm_50x-0.75_20200914_surf2_Topo	
Created on:	9/14/2020 12:02:32 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	164543	nm
Size:	65532	digits
Spacing:	2.511	nm
NM-points ratio:	0.000 % (0 Pts)	

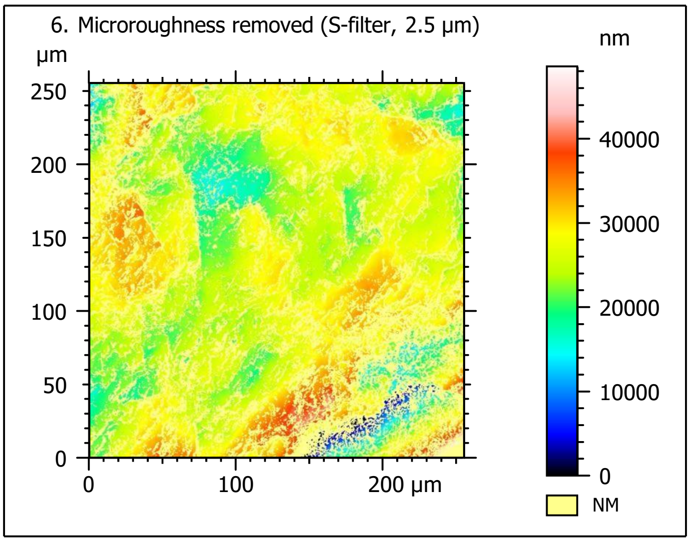



2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
90000
80000
70000
60000
50000
40000
30000
20000
10000
0

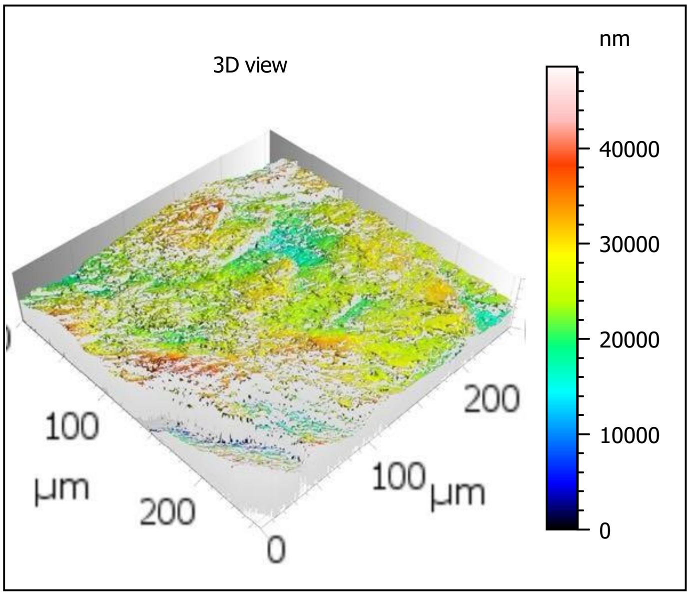

3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
90000
80000
70000
60000
50000
40000
30000
20000
10000
0


5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
40000
30000
20000
10000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
70000
60000
50000
40000
30000
20000
10000
0
NM

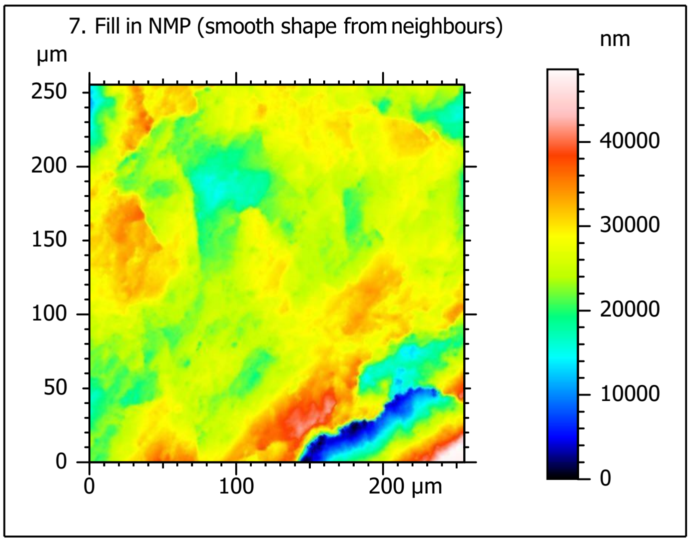


6. Microroughness removed (S-filter, 2.5 µm)

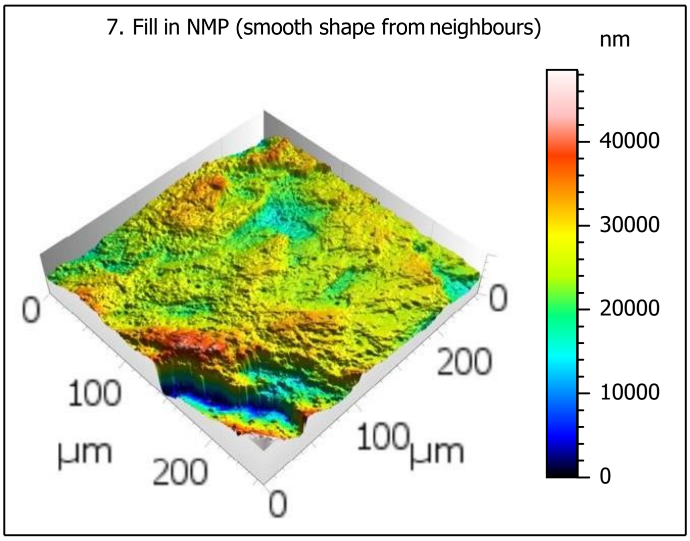


3D view

Identity card		
Name:	lime3-3_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…0914_surf2_Topo.sur	
Created on:	9/14/2020 12:02:32 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	48584	nm
Min:	-25327	nm
Max:	23257	nm
Size:	193492	digits
Spacing:	0.2511	nm
NM-points ratio:	37.35 % (391652 Pts)	

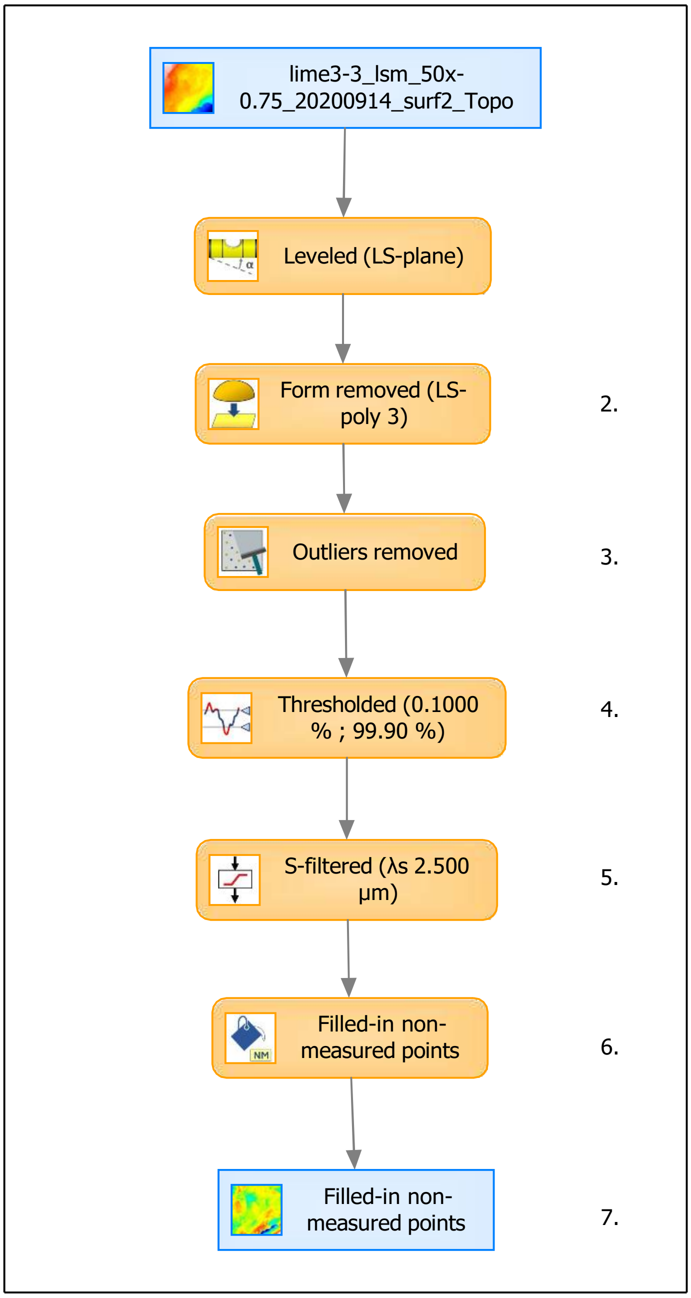


7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)

Identity card		
Name:	lime3-3_lsm_50x-0.75_...in non-measured points	
Created on:	9/14/2020 12:02:32 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	48584	nm
Size:	193492	digits
Spacing:	0.2511	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	5348	nm
Ssk	-0.4908	
Sku	5.974	
Sp	22999	nm
Sv	25584	nm
Sz	48584	nm
Sa	3887	nm
Functional parameters		
Smr	0.1802	%
Smc	5799	nm
Sxp	11654	nm
Spatial parameters		
Sal	18.68	µm
Str	0.4682	
Std	50.99	°
Hybrid parameters		
Sdq	1.126	
Sdr	31.23	%
Functional parameters (Volume)		
Vm	0.3133	µm³/µm²
Vv	6.113	µm³/µm²
Vmp	0.3133	µm³/µm²
Vmc	3.932	µm³/µm²
Vvc	5.330	µm³/µm²
Vvv	0.7826	µm³/µm²

Analyses:

ISO 25178 8.

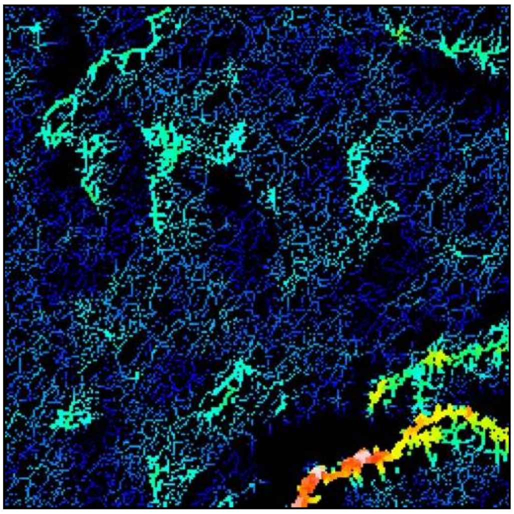
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

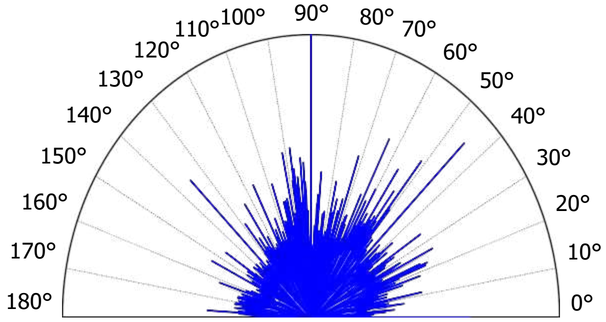
9. Furrow analysis on surface #7



All furrows are shown.

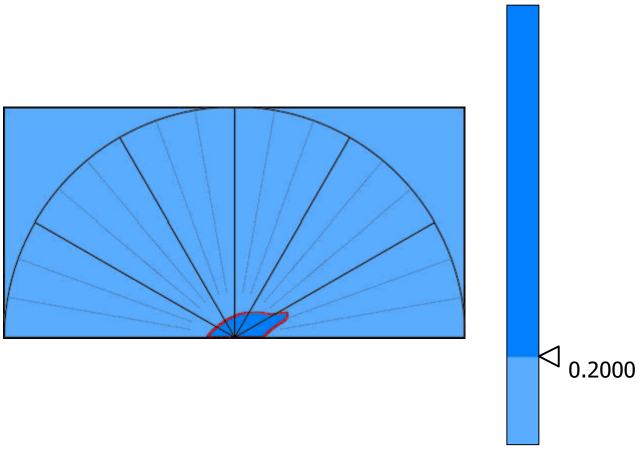
Parameters	Value	Unit	
Maximum depth of furrows	25685	nm	
Mean depth of furrows	5112	nm	
Mean density of furrows	2286	cm/cm2	

10. Texture direction on surface #7



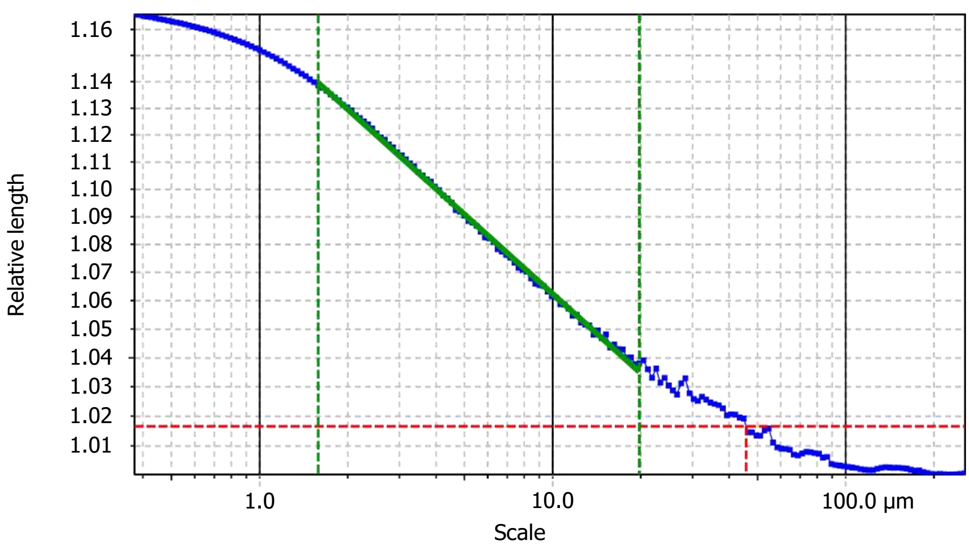
Parameters	Value	Unit	
First direction	90.00	°	
Second direction	45.01	°	
Third direction	51.19	°	

11. Texture isotropy on surface #7



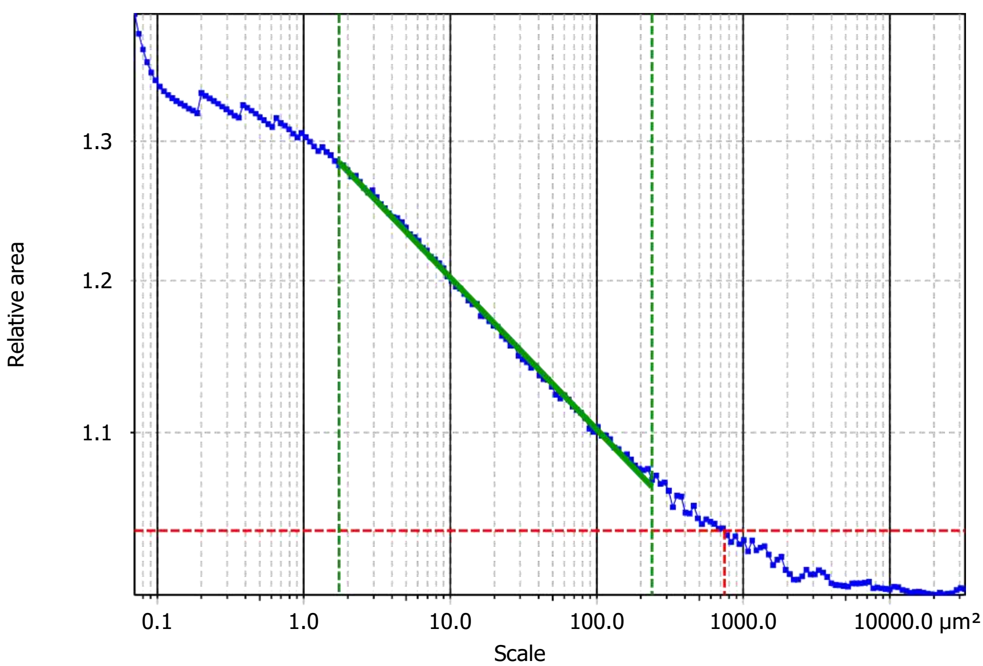
Parameters	Value	Unit	
Isotropy	33.07	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0004932		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01769		*Length-scale anisotropy (1.8 µm, 5°)*

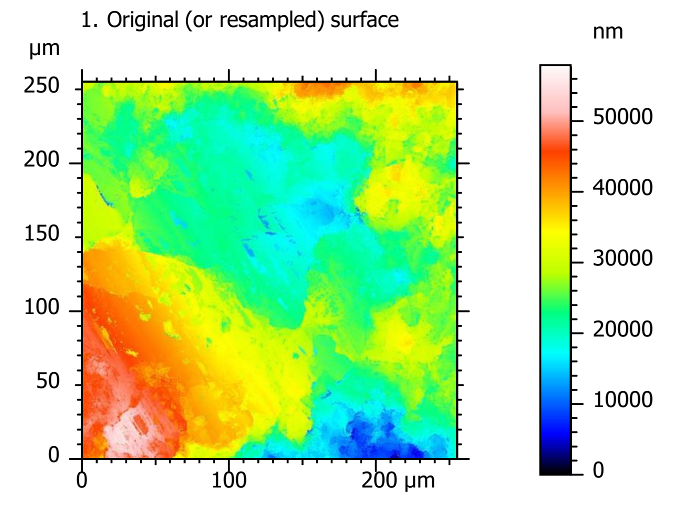


Information	
Method	Area-scale (four corners)

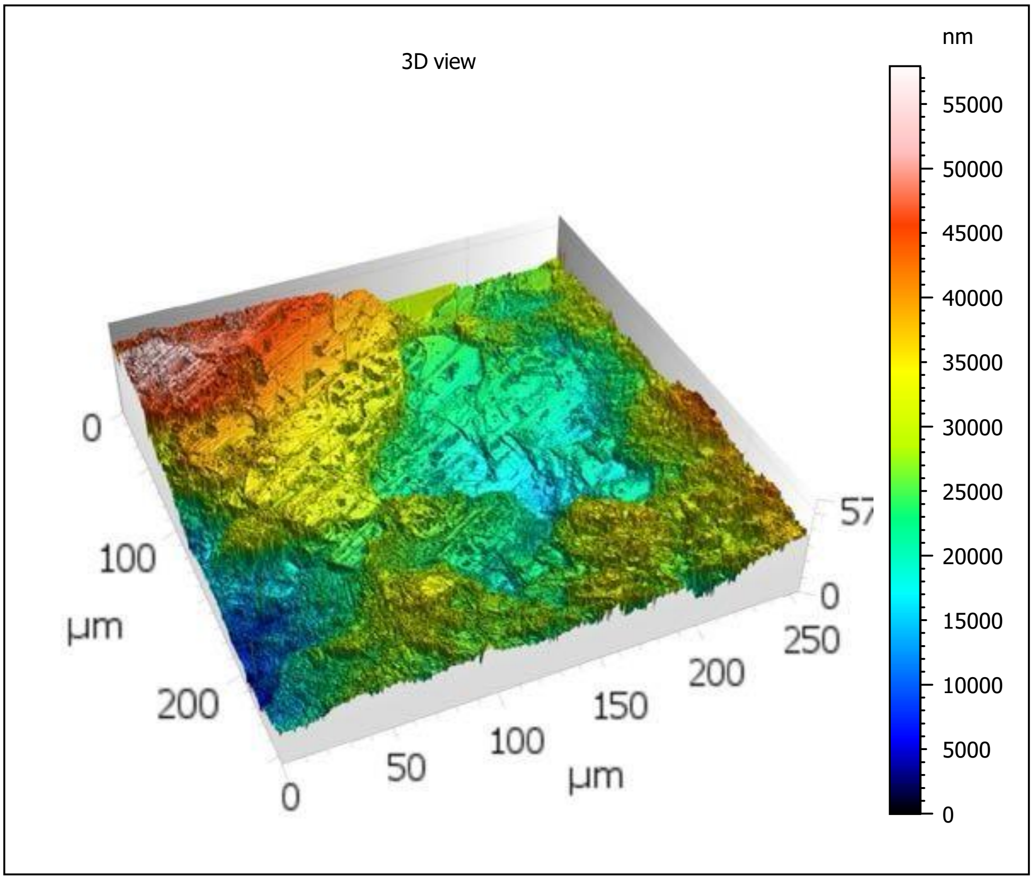
Parameters	Value	Unit	Comment
Asfc	37.79		*Fractal complexity*
Smfc	11.67	µm²	*Scale of max complexity*
HAsfc9	0.5444		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.7012		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

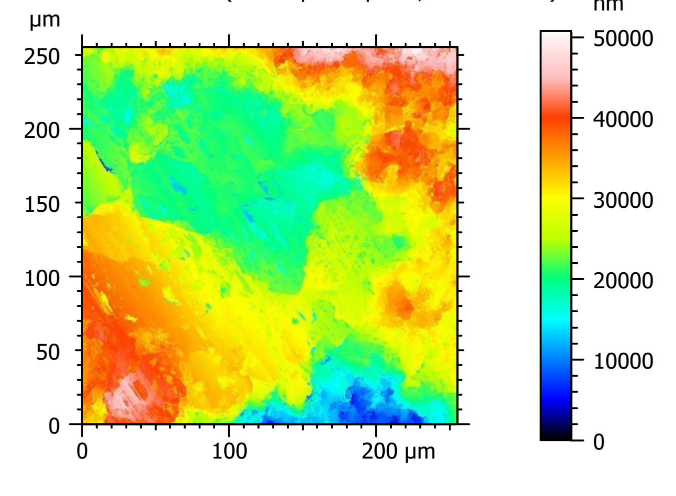
Processing



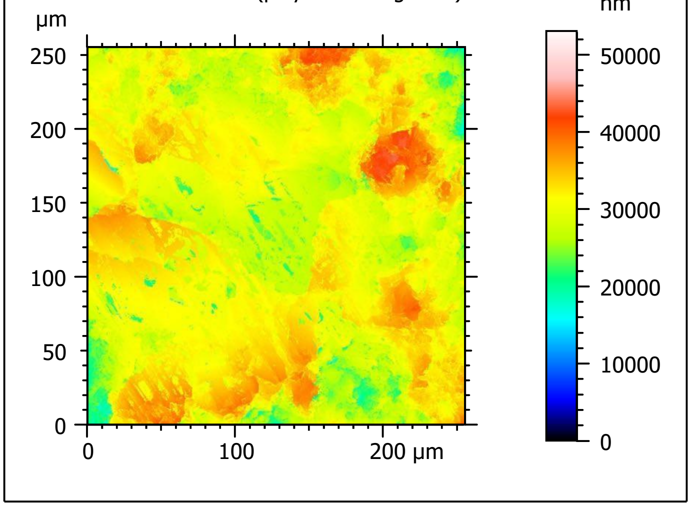
Identity card		
Name:	lime3-3_lsm_50x-0.75_20200914_surf3_Topo	
Created on:	9/14/2020 1:58:59 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	57928	nm
Size:	65532	digits
Spacing:	0.8840	nm
NM-points ratio:	0.000 % (0 Pts)	



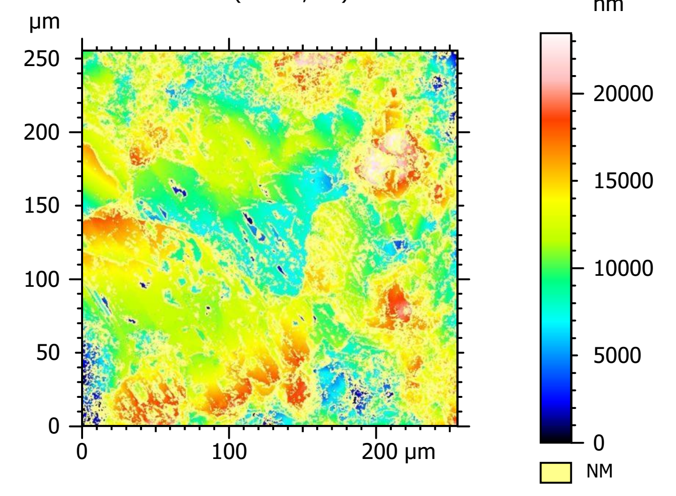
2. Leveled surface (least squares plane, substraction)



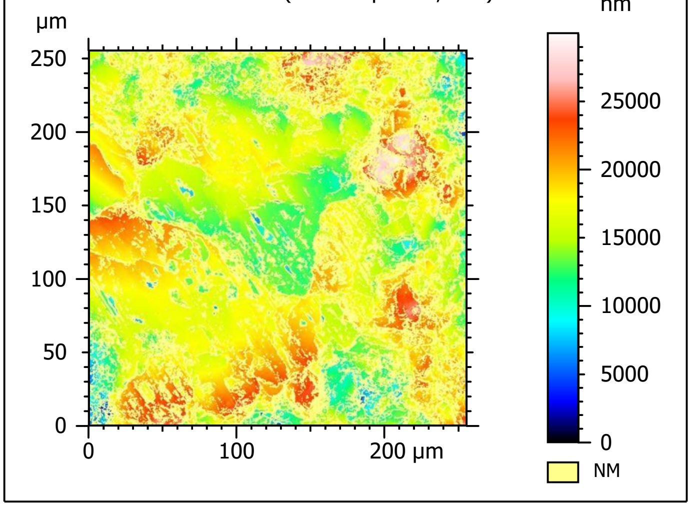
3. Form removed (polynomial degree 3)

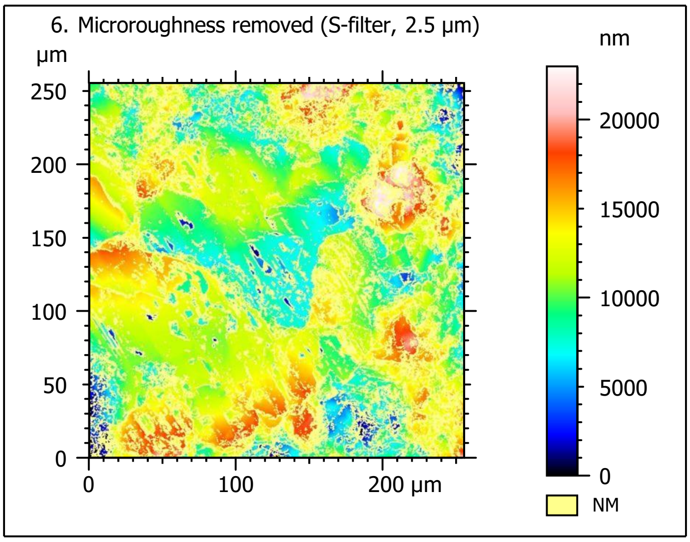


5. Thresholded (0.1-99,9%)

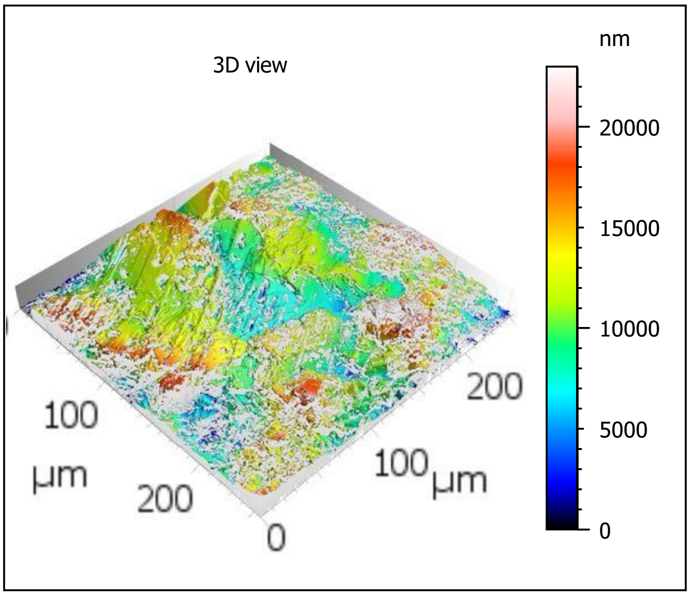


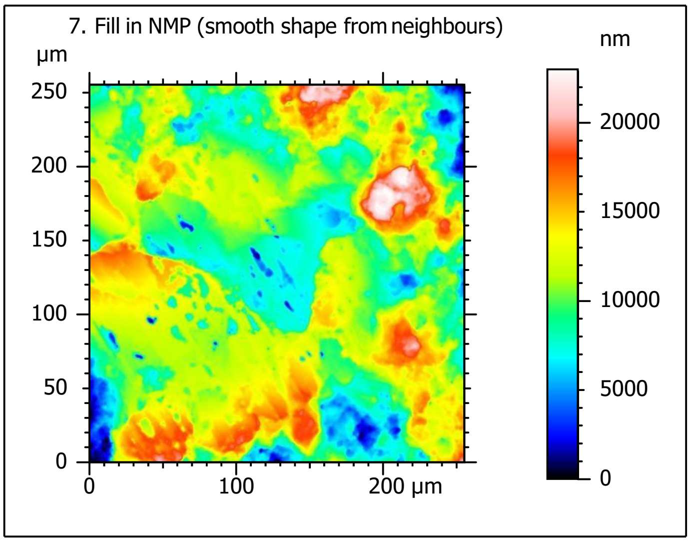
4. Outliers removed (max. slope 80°, soft)

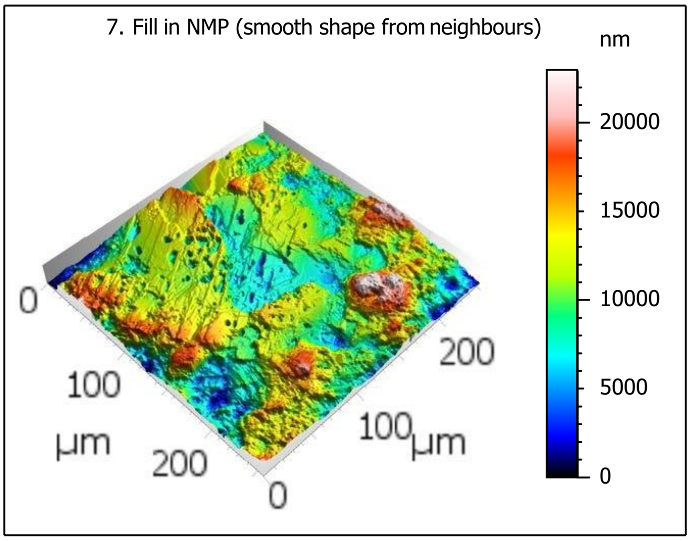




Identity card			
Name:	lime3-3_lsm_50x-0.75…filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R…0914_surf3_Topo.sur		
Created on:	9/14/2020 1:58:59 PM		
Studiable type:	Surface		
Axis:	X		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Offset:	0.000	µm	
Axis:	Y		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Offset:	-255.3	µm	
Axis:	Z		
Layer type:	Topography		
Length:	22990	nm	
Min:	-10827	nm	
Max:	12162	nm	
Size:	260079	digits	
Spacing:	0.0884	nm	
NM-points ratio:	40.00 % (419391 Pts)		





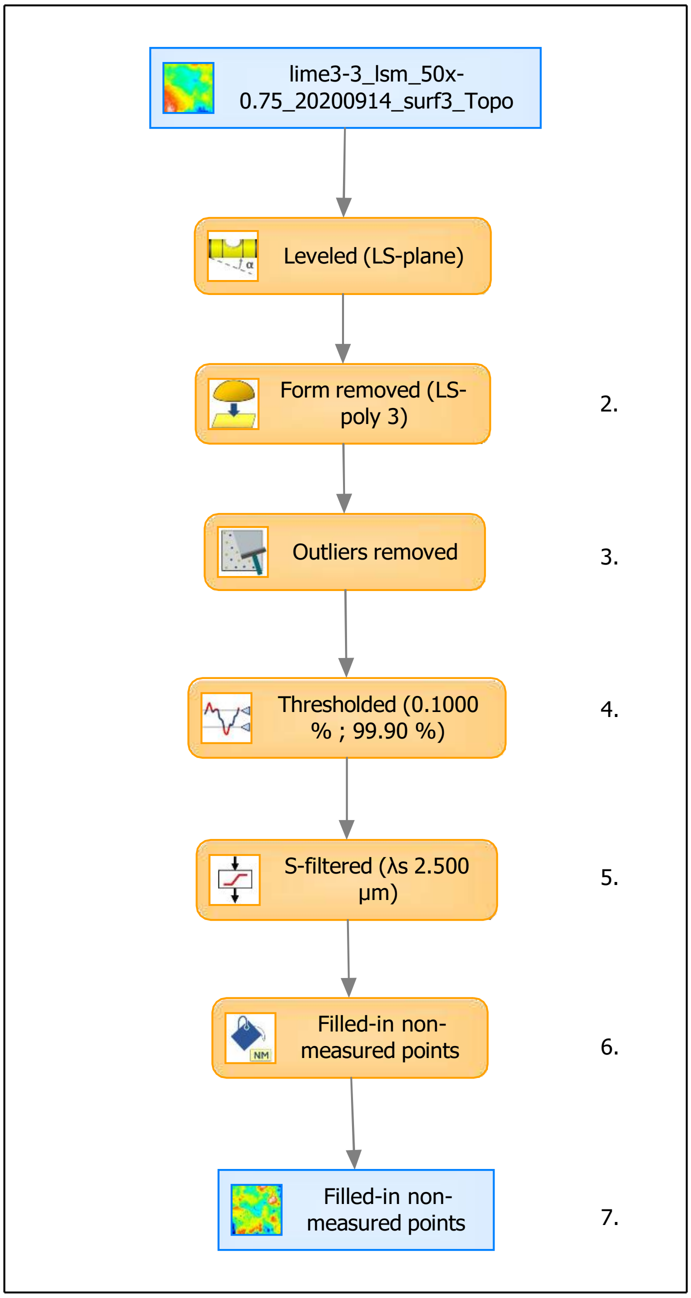


Identity card		
Name:	lime3-3_lsm_50x-0.75_...in non-measured points	
Created on:	9/14/2020 1:58:59 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	22990	nm
Size:	260079	digits
Spacing:	0.0884	nm
NM-points ratio:	0.000 % (0 Pts)	

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	3491	nm
Ssk	0.2010	
Sku	3.457	
Sp	11877	nm
Sv	11113	nm
Sz	22990	nm
Sa	2699	nm
Functional parameters		
Smr	0.3539	%
Smc	4436	nm
Sxp	6740	nm
Spatial parameters		
Sal	22.92	µm
Str	0.8031	
Std	123.5	°
Hybrid parameters		
Sdq	0.8966	
Sdr	24.60	%
Functional parameters (Volume)		
Vm	0.2114	µm³/µm²
Vv	4.648	µm³/µm²
Vmp	0.2114	µm³/µm²
Vmc	3.146	µm³/µm²
Vvc	4.303	µm³/µm²
Vvv	0.3444	µm³/µm²



Analyses:

ISO 25178 8.

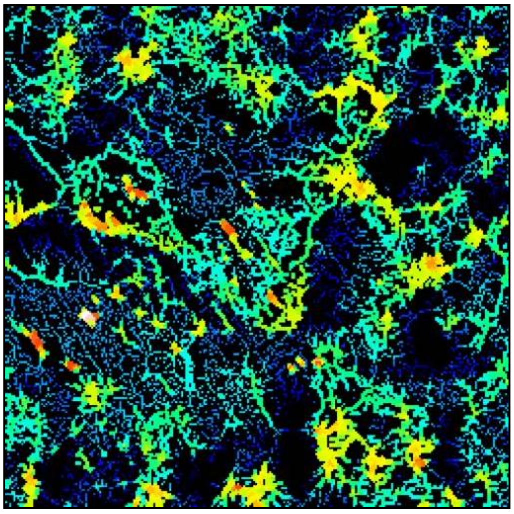
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

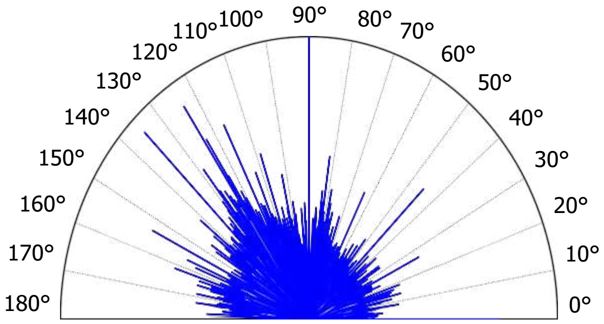
9. Furrow analysis on surface #7



All furrows are shown.

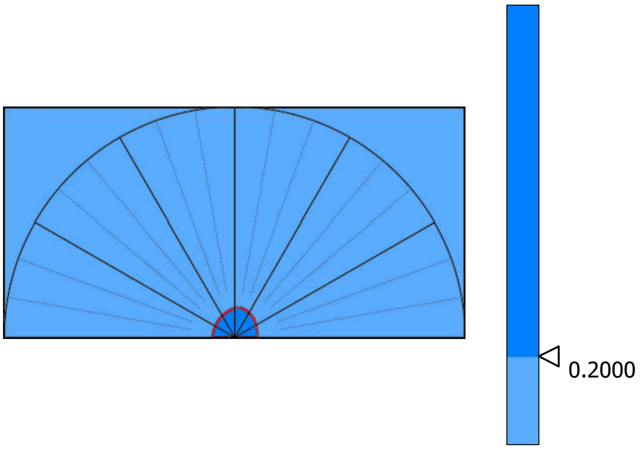
Parameters	Value	Unit	
Maximum depth of furrows	13880	nm	
Mean depth of furrows	3932	nm	
Mean density of furrows	2201	cm/cm2	

10. Texture direction on surface #7



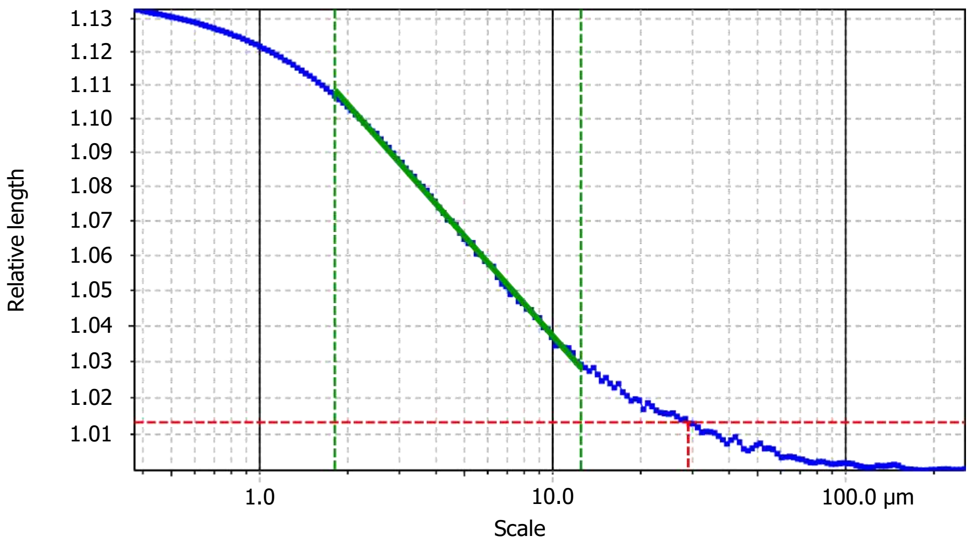
Parameters	Value	Unit	
First direction	90.01	°	
Second direction	135.0	°	
Third direction	123.7	°	

11. Texture isotropy on surface #7



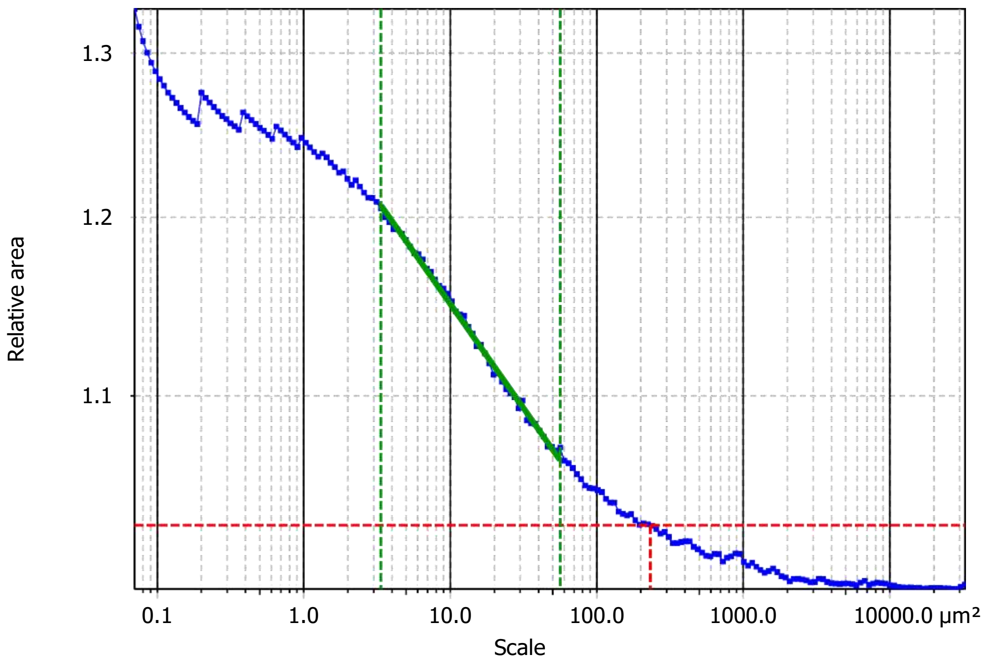
Parameters	Value	Unit	
Isotropy	73.83	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001218		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.0172		*Length-scale anisotropy (1.8 µm, 5°)*

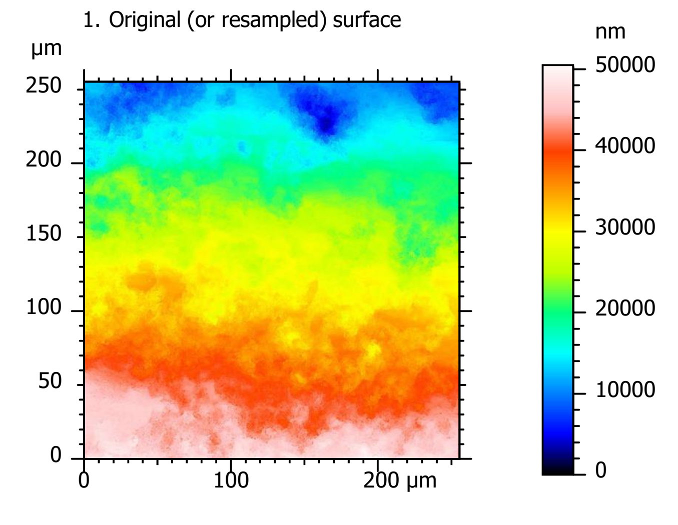


Information	
Method	Area-scale (four corners)

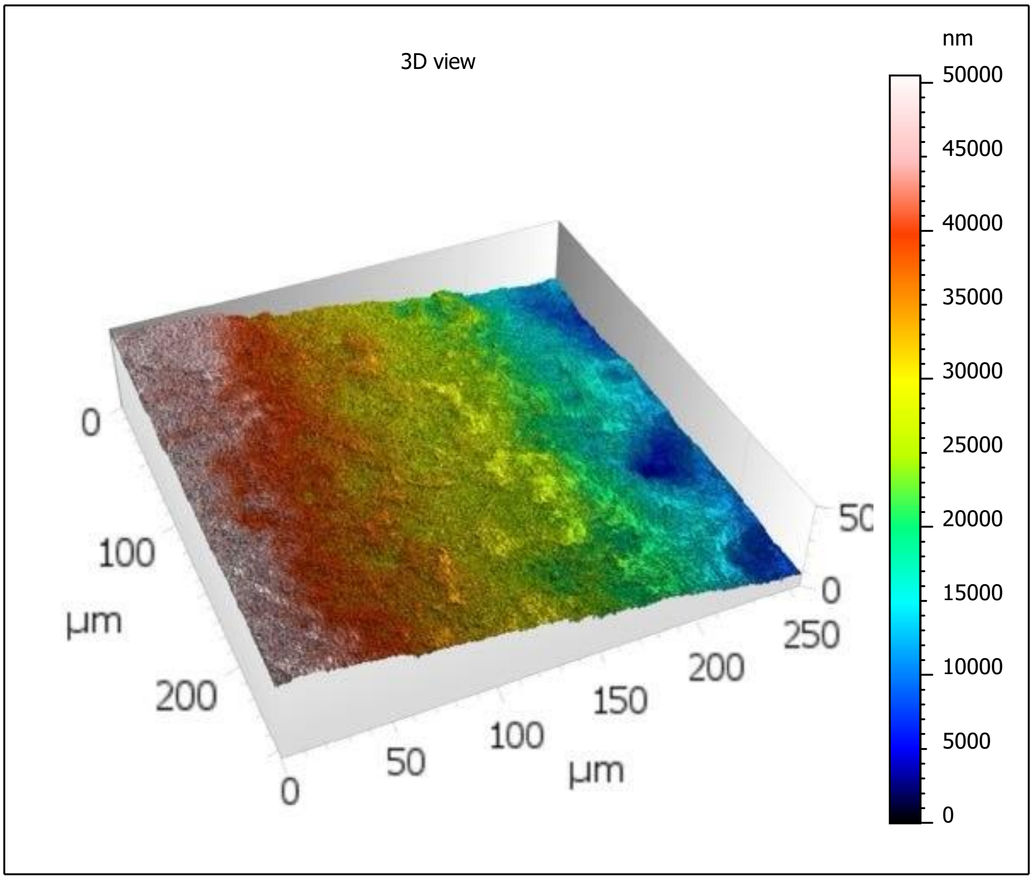
Parameters	Value	Unit	Comment
Asfc	44.11		*Fractal complexity*
Smfc	15.17	µm²	*Scale of max complexity*
HAsfc9	0.2543		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.4870		*Heterogeneity of Asfc (9x9)*

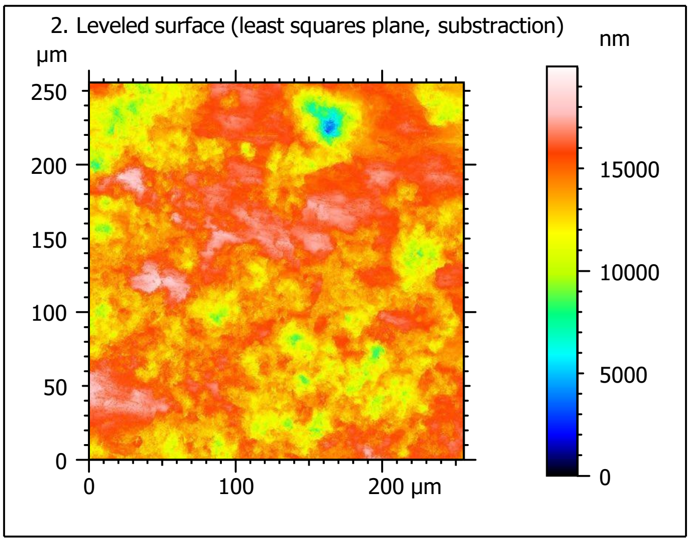
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

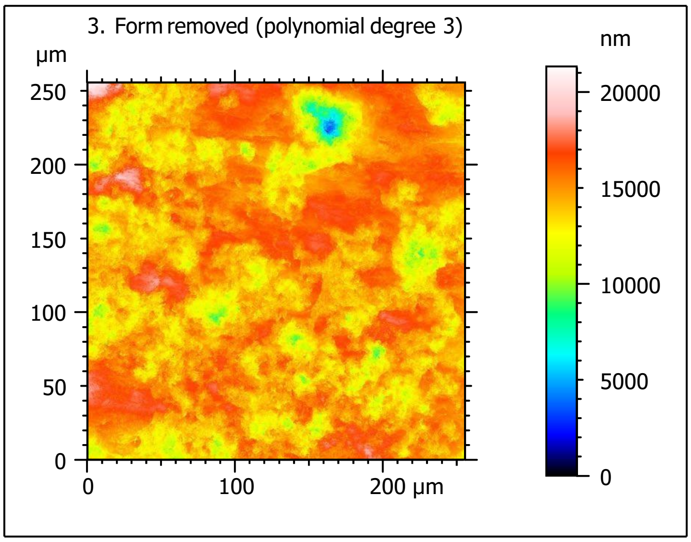
Processing

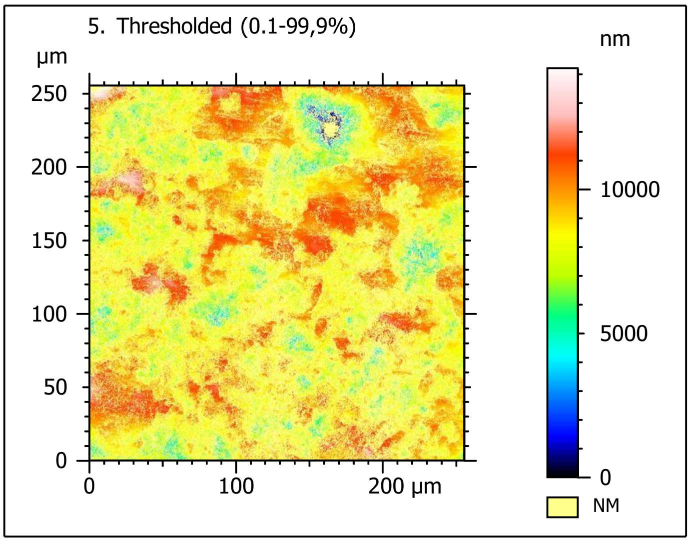


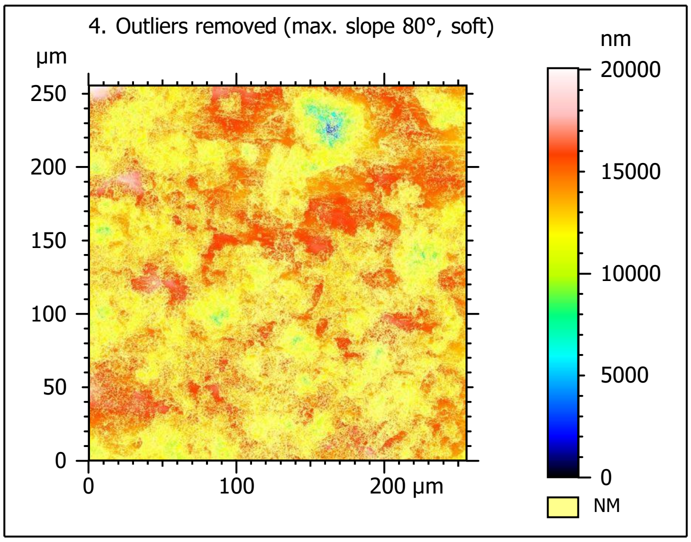
Identity card		
Name:	Lime3-8_LSM_50x075_surface1_Topo	
Created on:	3/10/2020 11:06:51 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	50494	nm
Size:	65532	digits
Spacing:	0.7705	nm
NM-points ratio:	0.000 % (0 Pts)	

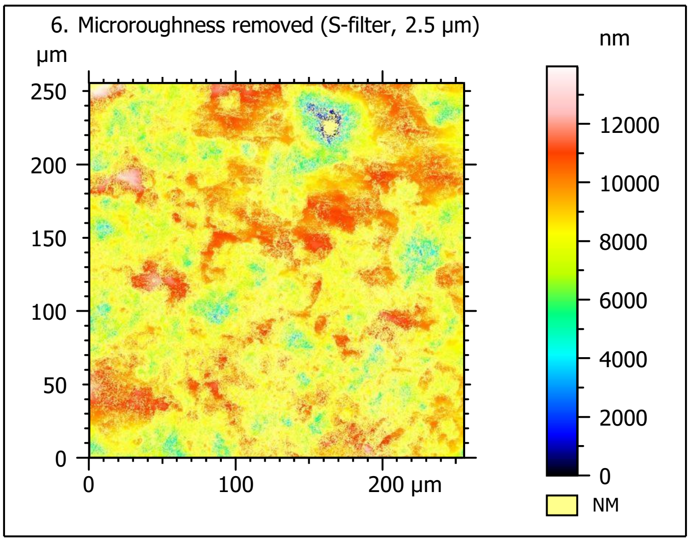


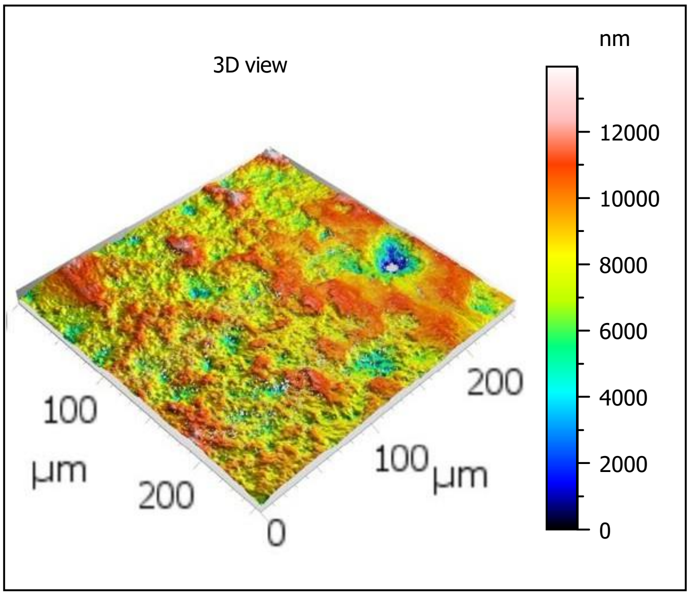

2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
20000
15000
10000
5000
0

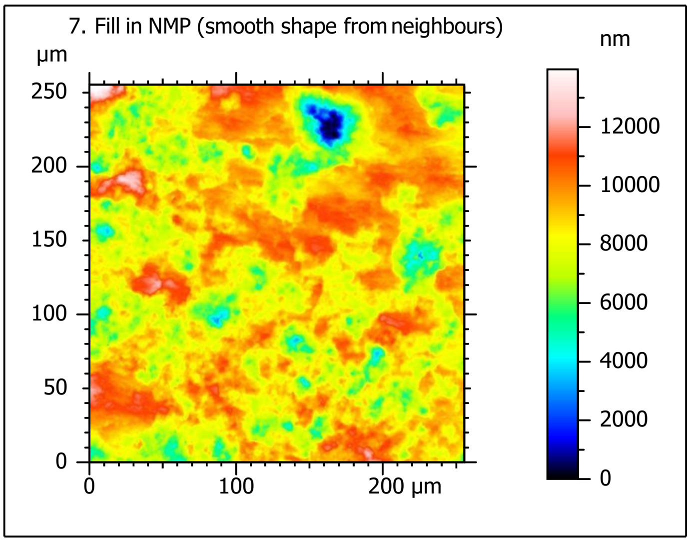

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
5000
0
NM

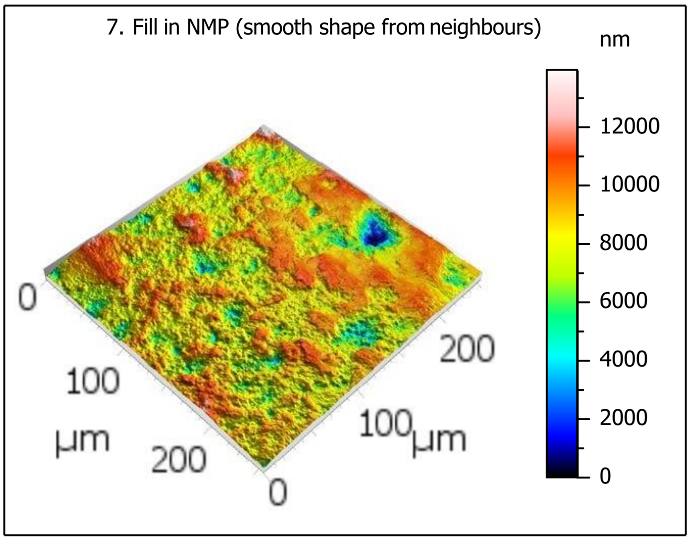

4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
20000
15000
10000
5000
0
NM



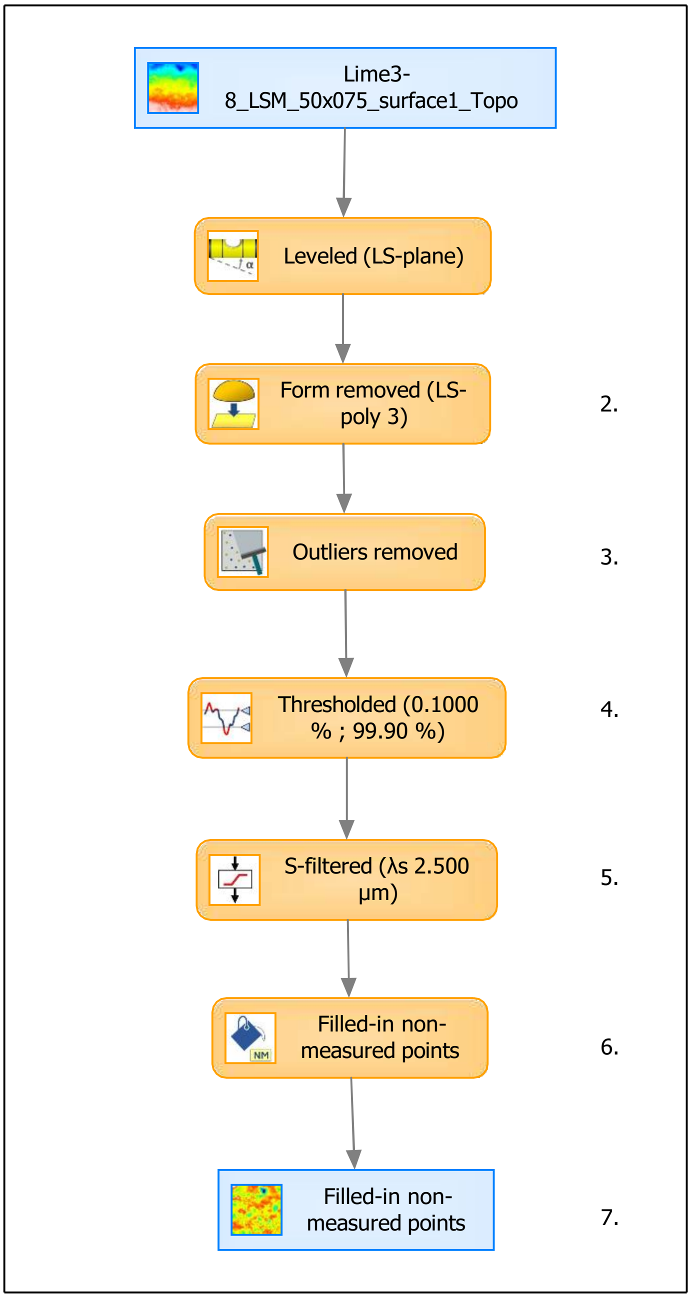


Identity card		
Name:	Lime3-8_LSM_50x075…filtered (λs 2.500 µm)	
File path:	C…\Lime3-8_LSM_50x075_surface1_Topo.sur	
Created on:	3/10/2020 11:06:51 AM	
Studiable type:	Surface	
Axis:	X	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	Z	
Layer type:	Topography	
Length:	13966	nm
Min:	-8327	nm
Max:	5639	nm
Size:	181249	digits
Spacing:	0.07705	nm
NM-points ratio:	46.50 % (4185322 Pts)	





Identity card		
Name:	Lime3-8_LSM_50x075_s...in non-measured points	
Created on:	3/10/2020 11:06:51 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	13966	nm
Size:	181249	digits
Spacing:	0.07705	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1537	nm
Ssk	-0.7253	
Sku	5.221	
Sp	5531	nm
Sv	8435	nm
Sz	13966	nm
Sa	1181	nm
Functional parameters		
Smr	0.1428	%
Smc	1803	nm
Sxp	3320	nm
Spatial parameters		
Sal	17.57	µm
Str	0.7492	
Std	170.0	°
Hybrid parameters		
Sdq	0.5168	
Sdr	11.20	%
Functional parameters (Volume)		
Vm	0.05835	µm³/µm²
Vv	1.861	µm³/µm²
Vmp	0.05835	µm³/µm²
Vmc	1.309	µm³/µm²
Vvc	1.650	µm³/µm²
Vvv	0.2113	µm³/µm²

Analyses:

ISO 25178 8.

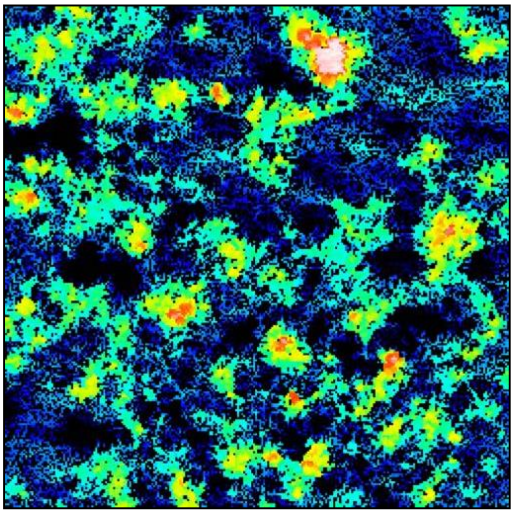
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

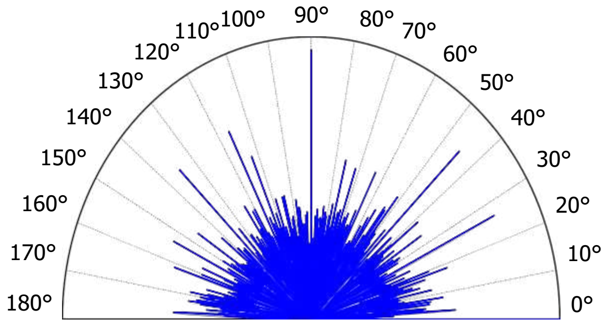
9. Furrow analysis on surface #7



All furrows are shown.

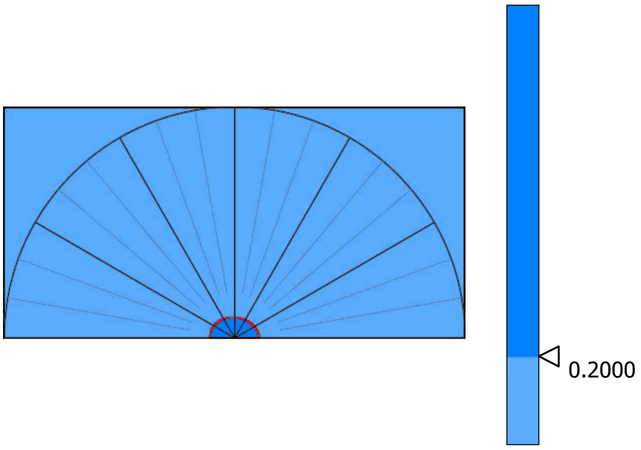
Parameters	Value	Unit
Maximum depth of furrows	7610	nm
Mean depth of furrows	1958	nm
Mean density of furrows	4196	cm/cm2

10. Texture direction on surface #7



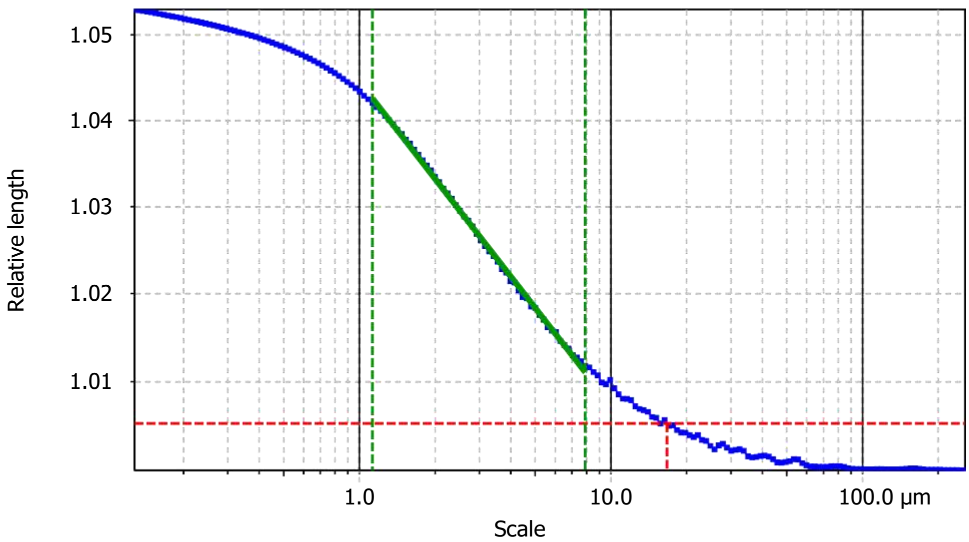
Parameters	Value	Unit
First direction	0.02007	°
Second direction	90.01	°
Third direction	45.01	°

11. Texture isotropy on surface #7



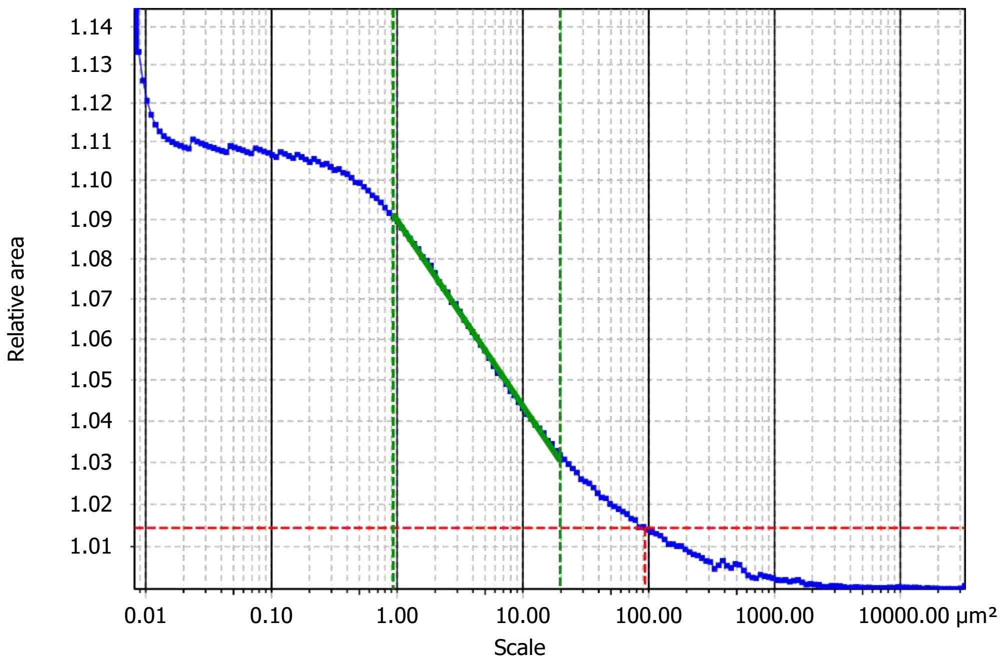
Parameters	Value	Unit
Isotropy	81.21	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0009702		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01796		*Length-scale anisotropy (1.8 µm, 5°)*

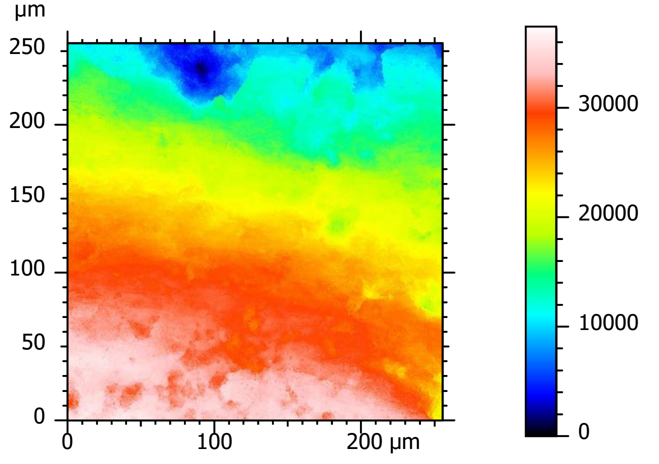


Information	
Method	Area-scale (four corners)

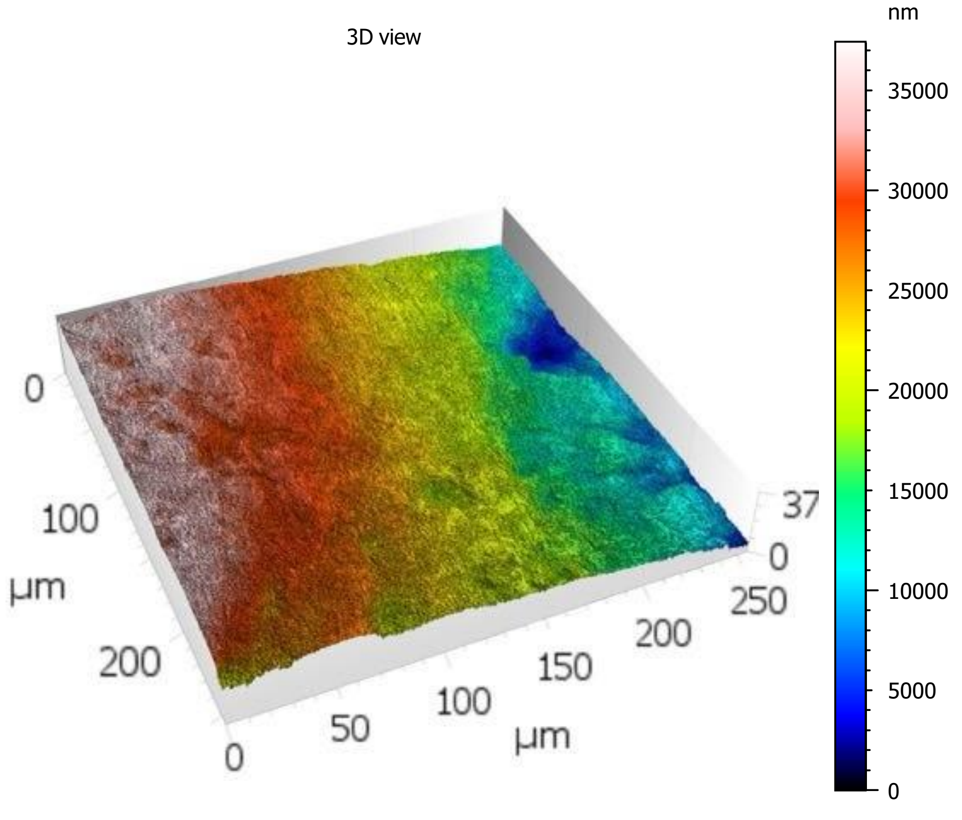
Parameters	Value	Unit	Comment
Asfc	18.78		*Fractal complexity*
Smfc	3.972	µm²	*Scale of max complexity*
HAsfc9	0.1898		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2692		*Heterogeneity of Asfc (9x9)*

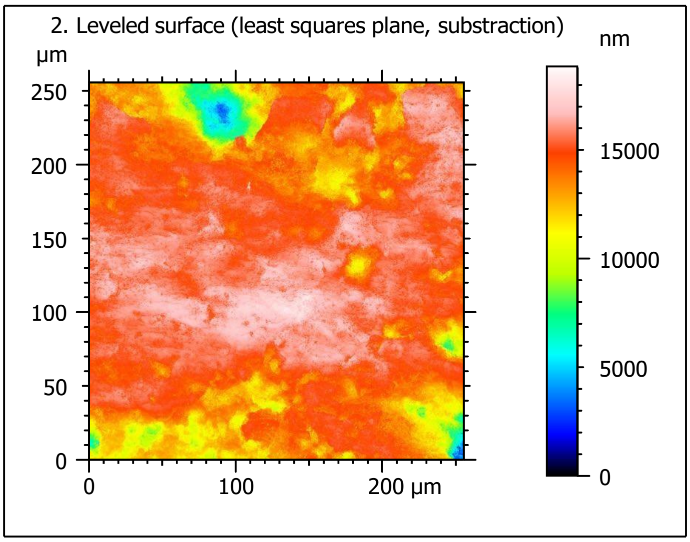
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

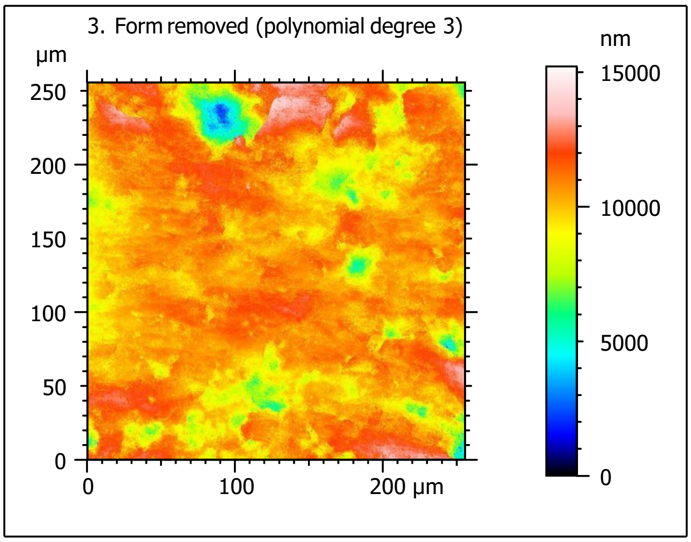
Processing

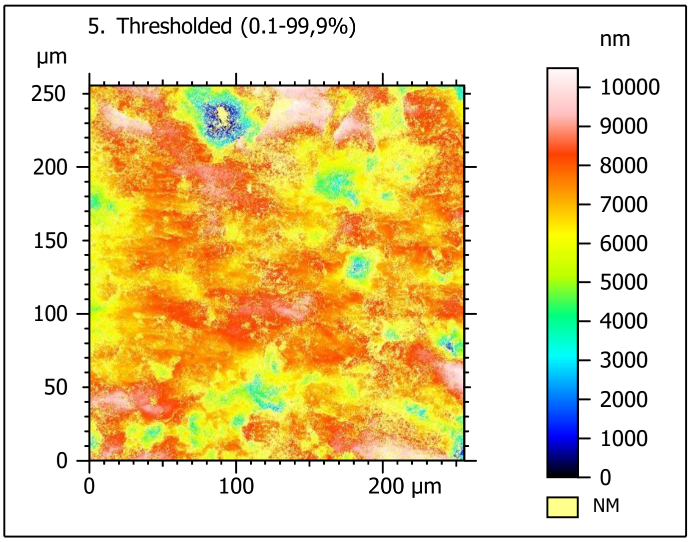


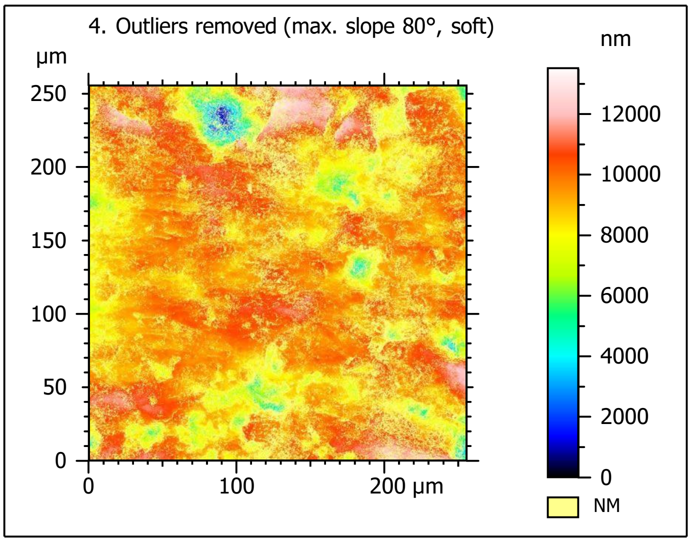
Identity card		
Name:	Lime3-8_LSM_50x075_surface2_Topo	
Created on:	3/10/2020 11:55:44 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	37431	nm
Size:	65532	digits
Spacing:	0.5712	nm
NM-points ratio:	0.000 % (0 Pts)	



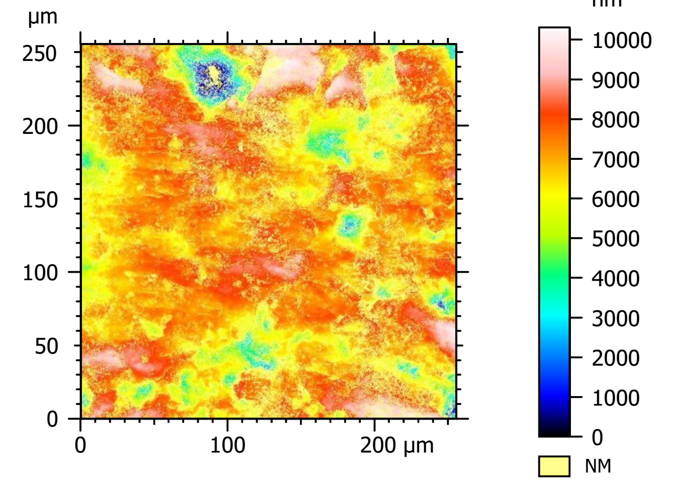

2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0

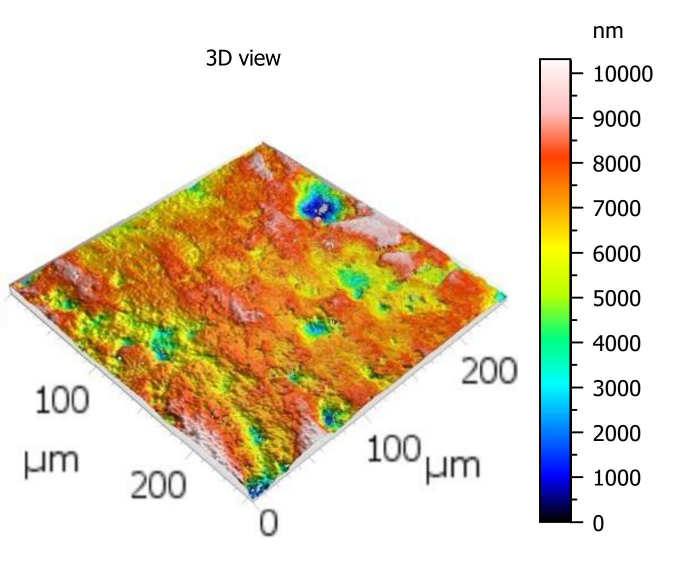

3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0


5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
12000
10000
8000
6000
4000
2000
0
NM

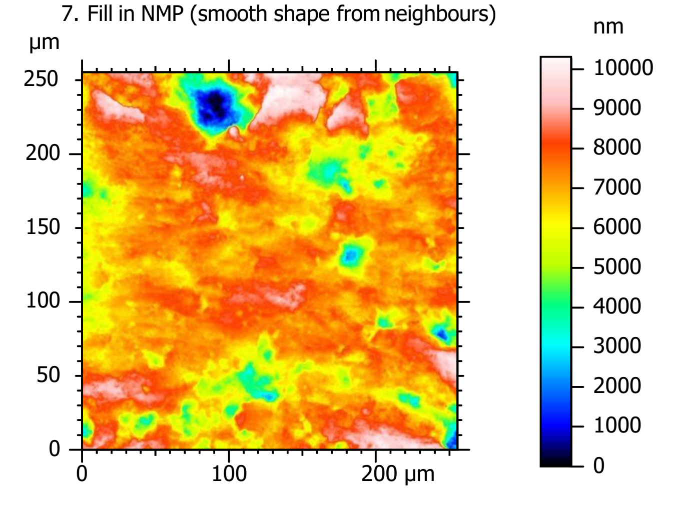
6. Microroughness removed (S-filter, 2.5 µm)



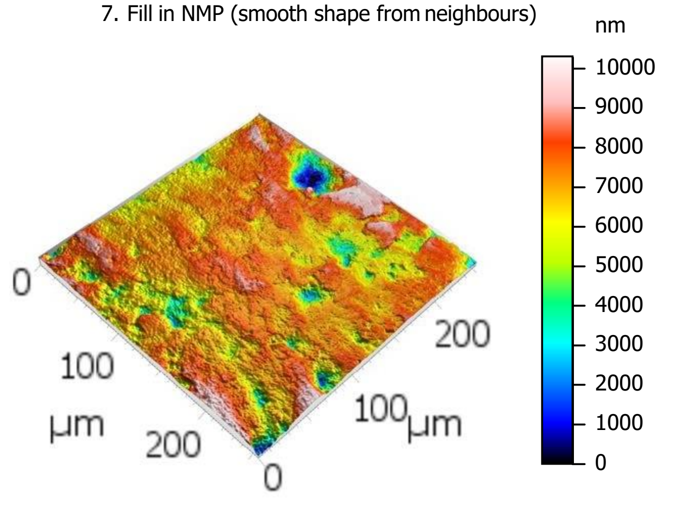


Identity card		
Name:	Lime3-8_LSM_50x075…filtered (λs 2.500 µm)	
File path:	C…\Lime3-8_LSM_50x075_surface2_Topo.sur	
Created on:	3/10/2020 11:55:44 AM	
Studiable type:	Surface	
Axis:	X	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	Z	
Layer type:	Topography	
Length:	10309	nm
Min:	-6913	nm
Max:	3396	nm
Size:	180484	digits
Spacing:	0.05712	nm
NM-points ratio:	26.45 % (2380438 Pts)	

7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)

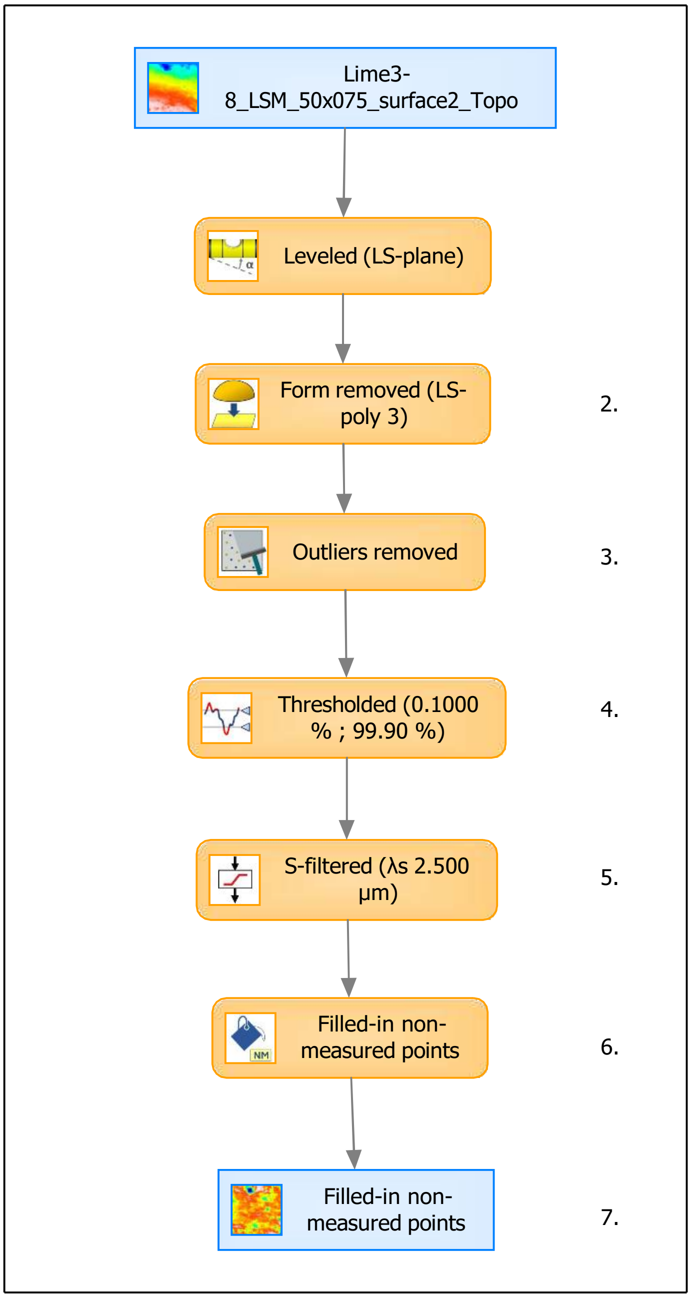


Identity card		
Name:	Lime3-8_LSM_50x075_s...in non-measured points	
Created on:	3/10/2020 11:55:44 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	10309	nm
Size:	180484	digits
Spacing:	0.05712	nm
NM-points ratio:	0.000 % (0 Pts)	

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1303	nm
Ssk	-1.296	
Sku	6.843	
Sp	3353	nm
Sv	6956	nm
Sz	10309	nm
Sa	922.5	nm
Functional parameters		
Smr	2.173	%
Smc	1335	nm
Sxp	3426	nm
Spatial parameters		
Sal	19.64	µm
Str	0.7244	
Std	177.0	°
Hybrid parameters		
Sdq	0.4076	
Sdr	6.659	%
Functional parameters (Volume)		
Vm	0.05897	µm³/µm²
Vv	1.394	µm³/µm²
Vmp	0.05897	µm³/µm²
Vmc	0.9398	µm³/µm²
Vvc	1.157	µm³/µm²
Vvv	0.2371	µm³/µm²



Analyses:

ISO 25178 8.

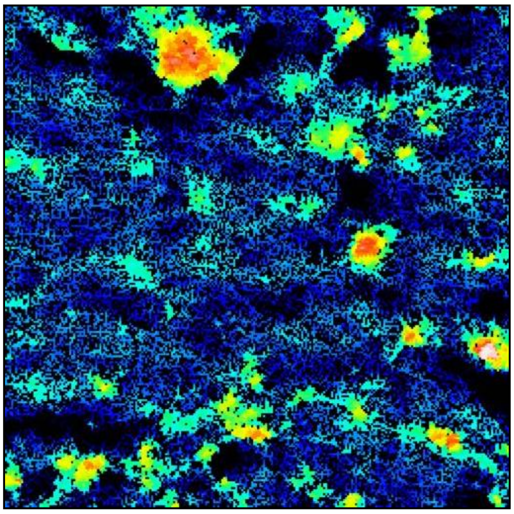
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

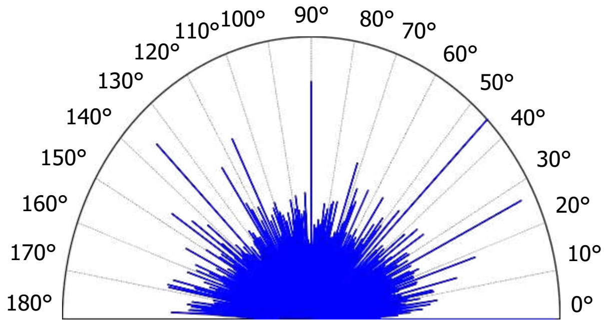
9. Furrow analysis on surface #7



All furrows are shown.

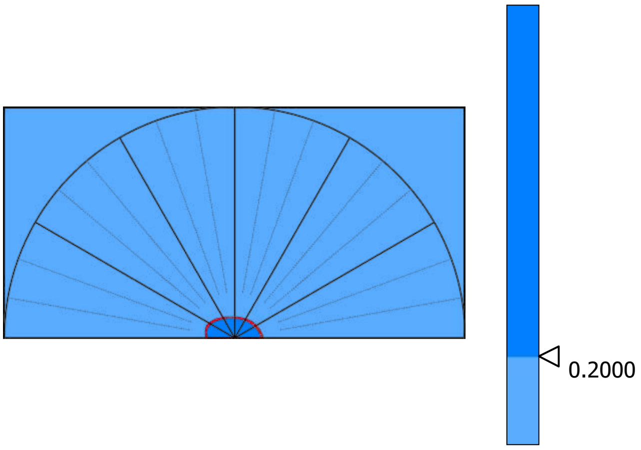
Parameters	Value	Unit
Maximum depth of furrows	6927	nm
Mean depth of furrows	1404	nm
Mean density of furrows	4508	cm/cm2

10. Texture direction on surface #7



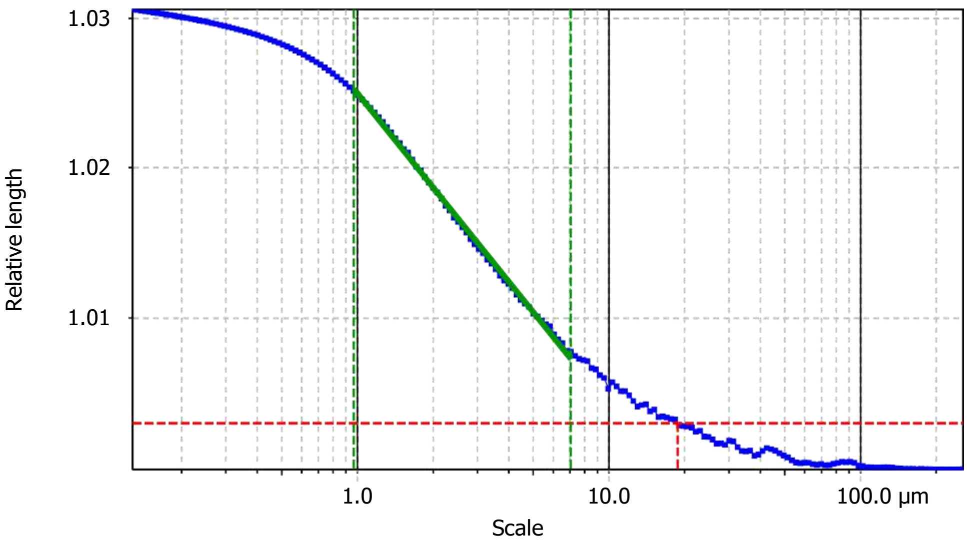
Parameters	Value	Unit
First direction	45.01	°
Second direction	180.0	°
Third direction	26.49	°

11. Texture isotropy on surface #7



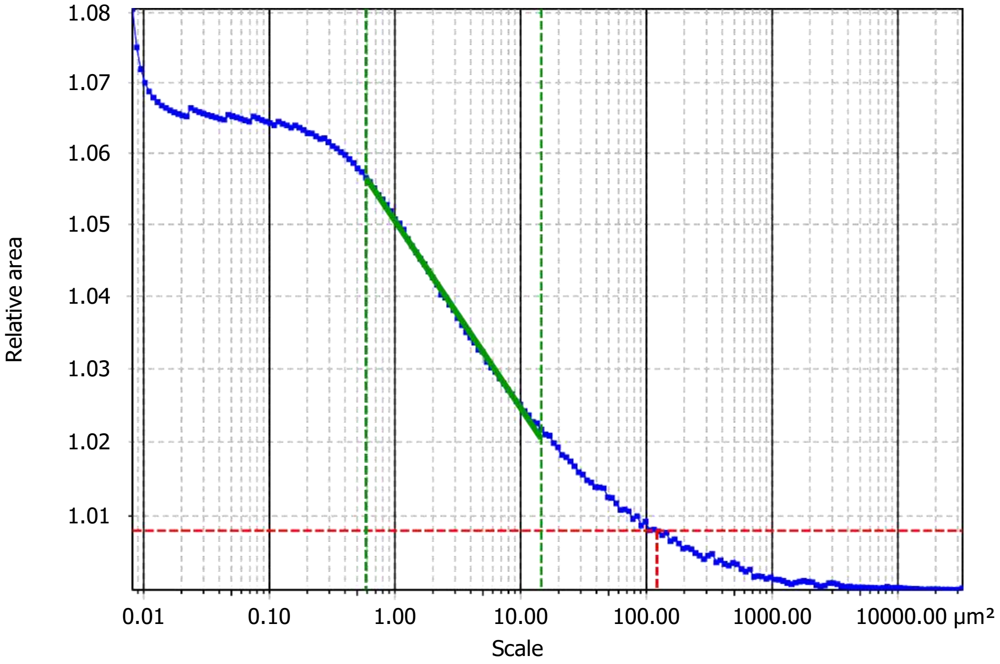
Parameters	Value	Unit
Isotropy	68.14	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001608		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01797		*Length-scale anisotropy (1.8 µm, 5°)*

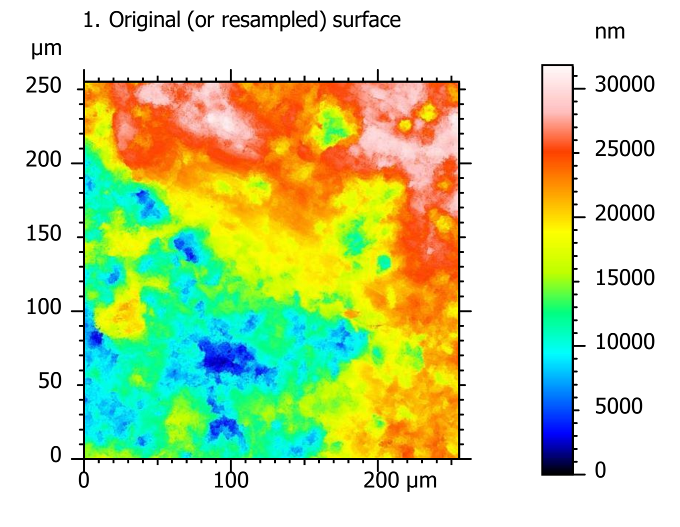


Information	
Method	Area-scale (four corners)

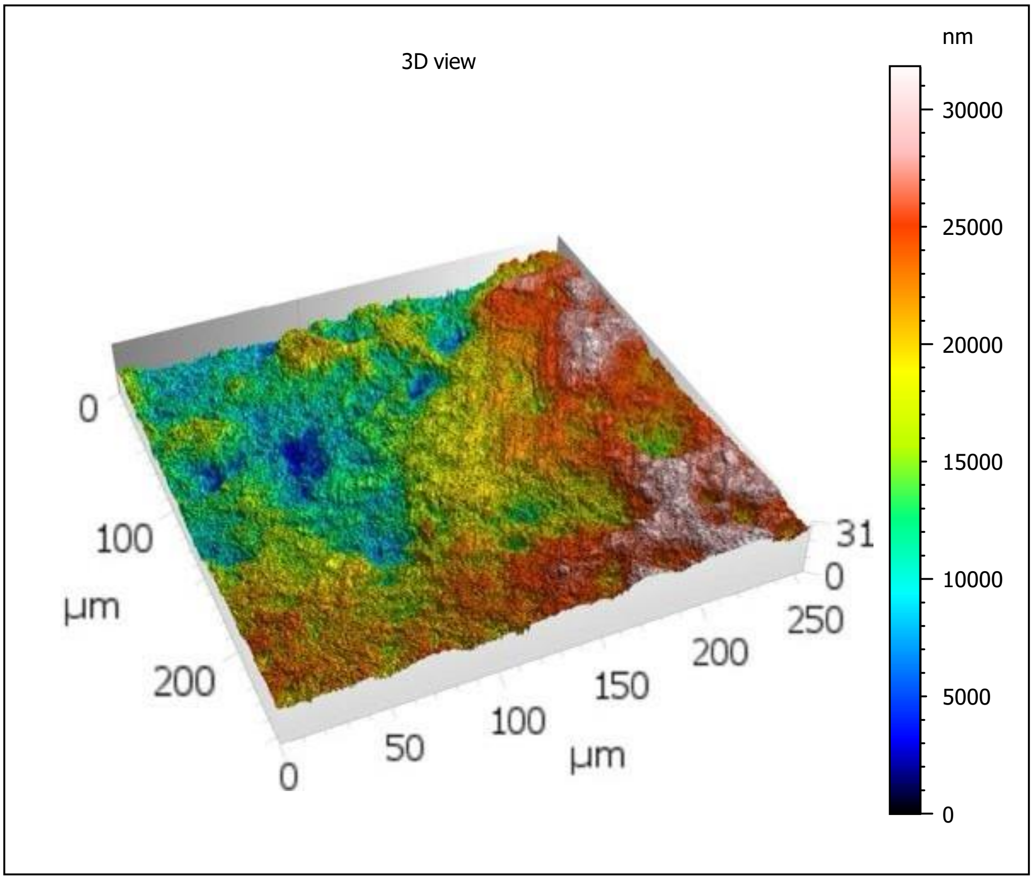
Parameters	Value	Unit	Comment
Asfc	10.81		*Fractal complexity*
Smfc	1.997	µm²	*Scale of max complexity*
HAsfc9	0.1977		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.3580		*Heterogeneity of Asfc (9x9)*

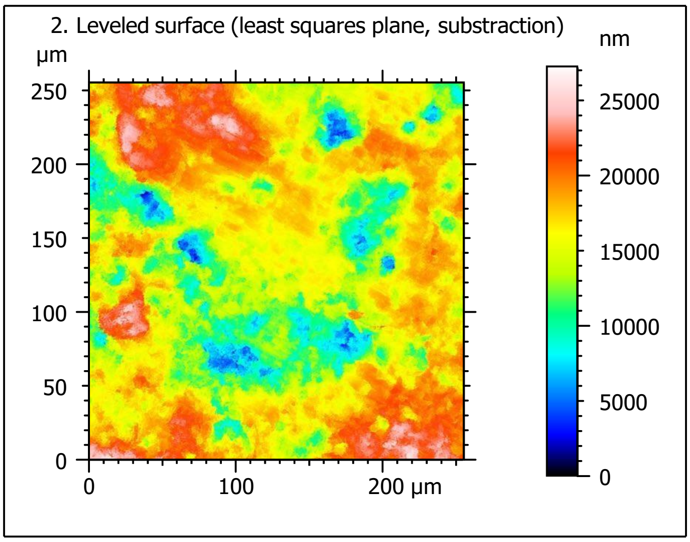
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

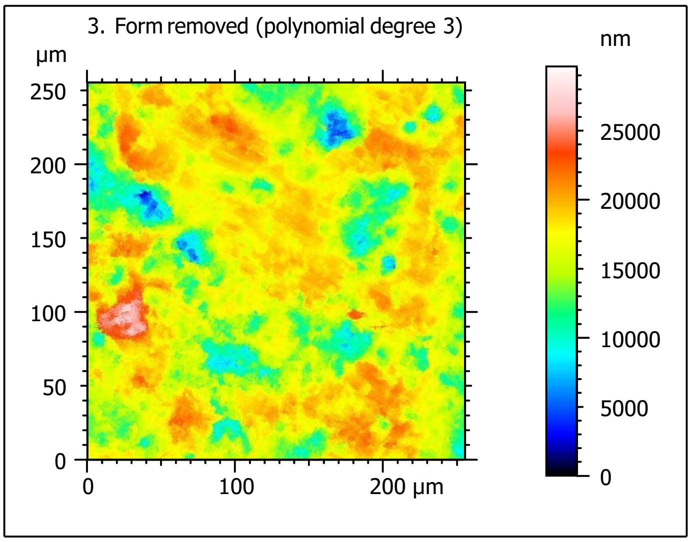
Processing

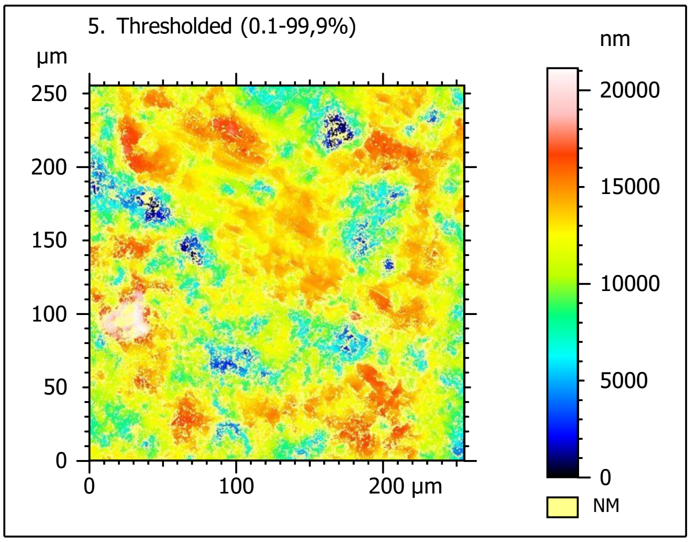


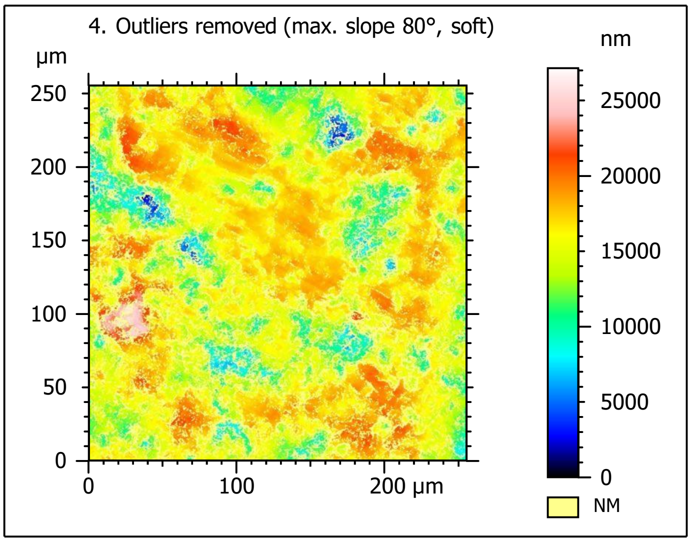
Identity card		
Name:	Lime3-8_LSM_50x075_surface3_Topo	
Created on:	9/14/2020 10:17:46 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	31841	nm
Size:	65532	digits
Spacing:	0.4859	nm
NM-points ratio:	0.000 % (0 Pts)	

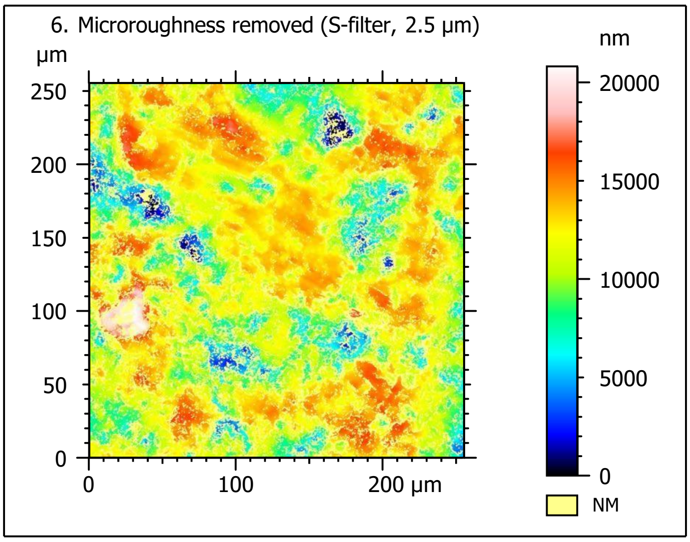



2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
25000
20000
15000
10000
5000
0

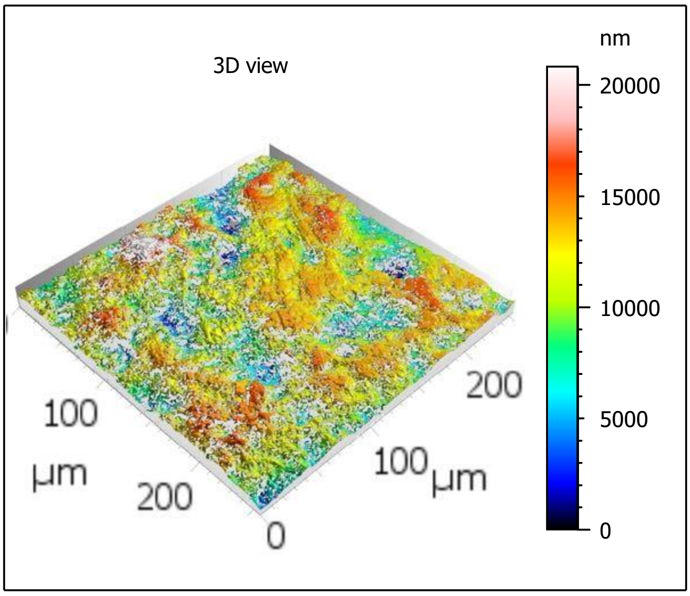

3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
25000
20000
15000
10000
5000
0


5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
20000
15000
10000
5000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
25000
20000
15000
10000
5000
0
NM



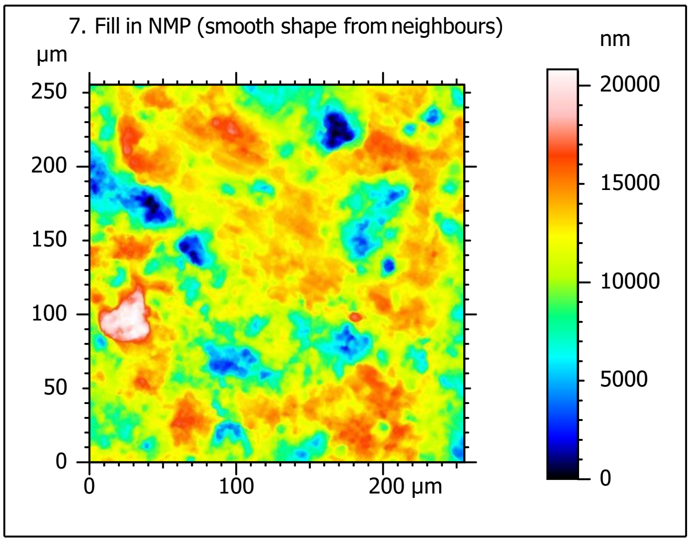
6. Microroughness removed (S-filter, 2.5 µm)



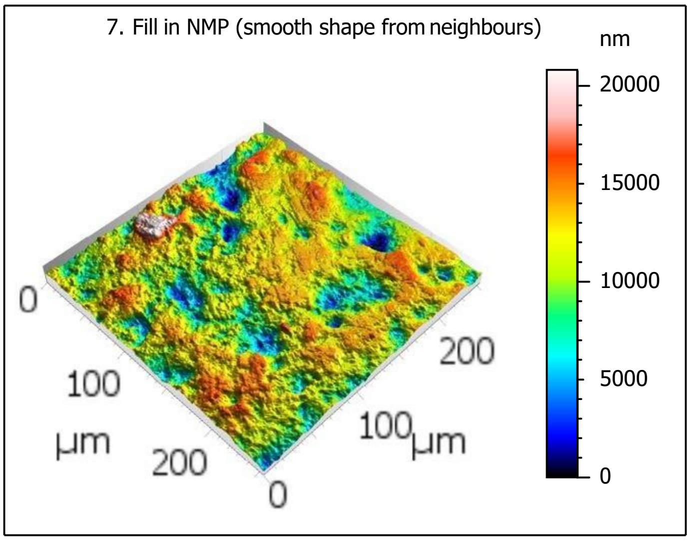
3D view

Identity card	

Name:	Lime3-8_LSM_50x075…filtered (λs 2.500 µm)	
File path:	C…\Lime3-8_LSM_50x075_surface3_Topo.sur	
Created on:	9/14/2020 10:17:46 AM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	20820	nm
Min:	-11030	nm
Max:	9790	nm
Size:	428496	digits
Spacing:	0.04859	nm
NM-points ratio:	28.71 % (301089 Pts)	

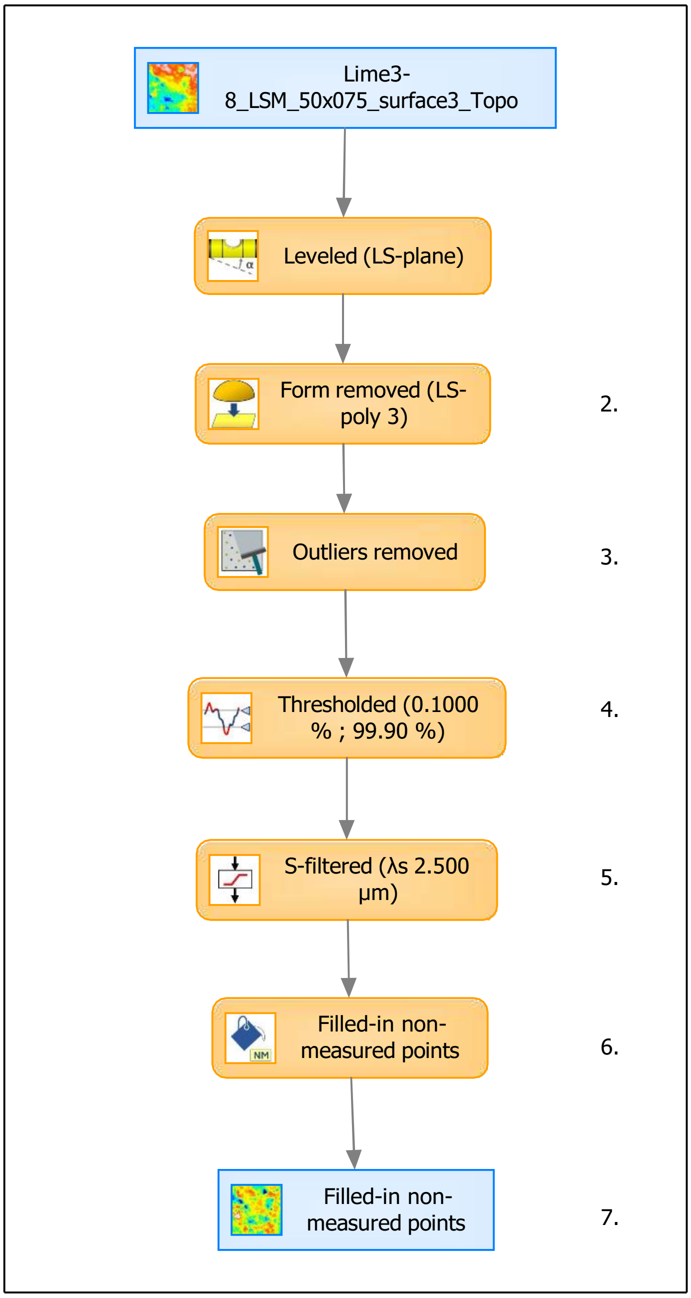


7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)

Identity card		
Name:	Lime3-8_LSM_50x075_s...in non-measured points	
Created on:	9/14/2020 10:17:46 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	20820	nm
Size:	428496	digits
Spacing:	0.04859	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	2975	nm
Ssk	-0.519	
Sku	3.749	
Sp	9714	nm
Sv	11106	nm
Sz	20820	nm
Sa	2321	nm
Functional parameters		
Smr	0.4048	%
Smc	3214	nm
Sxp	7132	nm
Spatial parameters		
Sal	19.67	µm
Str	0.6979	
Std	94.01	°
Hybrid parameters		
Sdq	0.7623	
Sdr	21.27	%
Functional parameters (Volume)		
Vm	0.1303	µm³/µm²
Vv	3.344	µm³/µm²
Vmp	0.1303	µm³/µm²
Vmc	2.621	µm³/µm²
Vvc	2.902	µm³/µm²
Vvv	0.4429	µm³/µm²

Analyses:

ISO 25178 8.

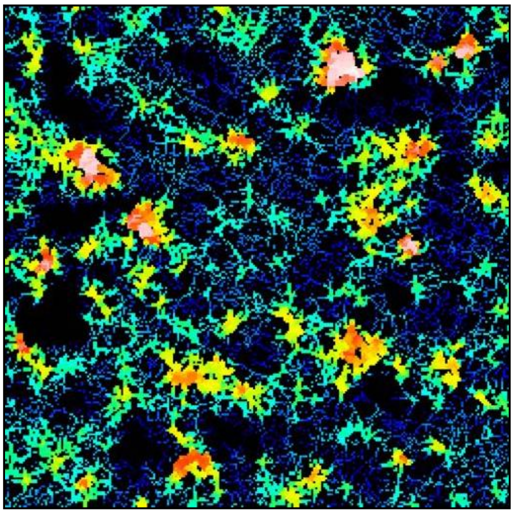
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

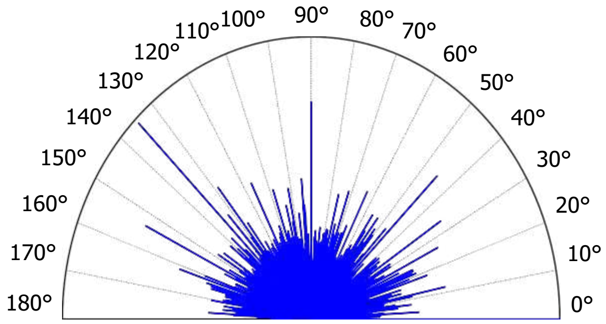
9. Furrow analysis on surface #7



All furrows are shown.

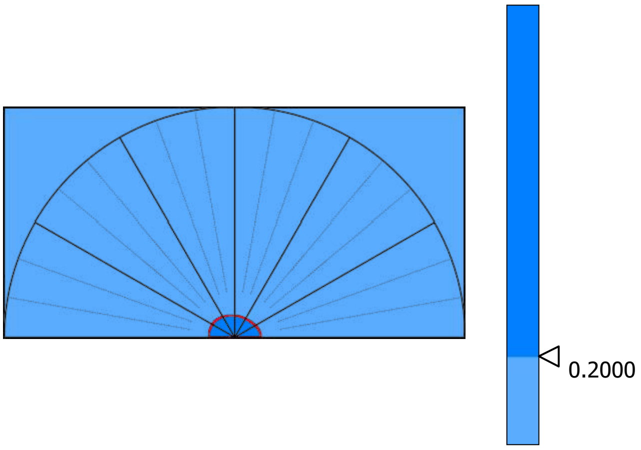
Parameters	Value	Unit
Maximum depth of furrows	12503	nm
Mean depth of furrows	3417	nm
Mean density of furrows	2298	cm/cm2

10. Texture direction on surface #7



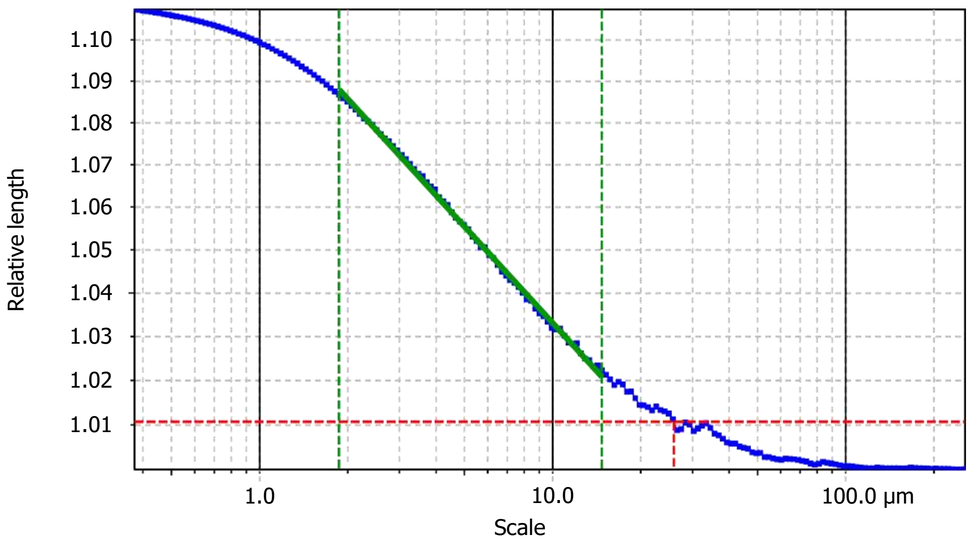
Parameters	Value	Unit
First direction	0.008114	°
Second direction	135.0	°
Third direction	90.01	°

11. Texture isotropy on surface #7



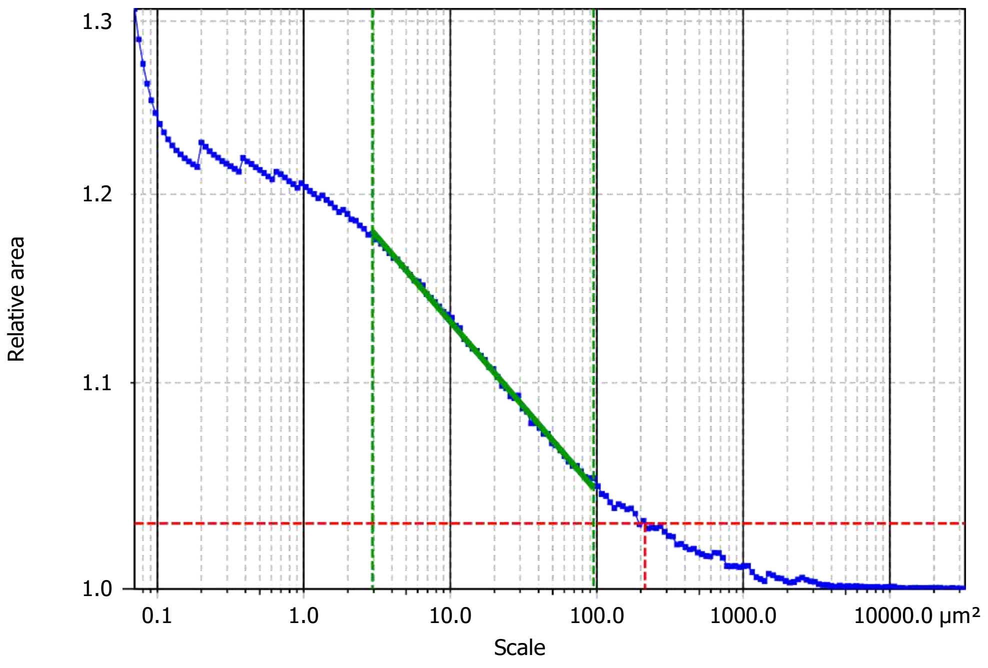
Parameters	Value	Unit
Isotropy	81.12	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0005954		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01777		*Length-scale anisotropy (1.8 µm, 5°)*

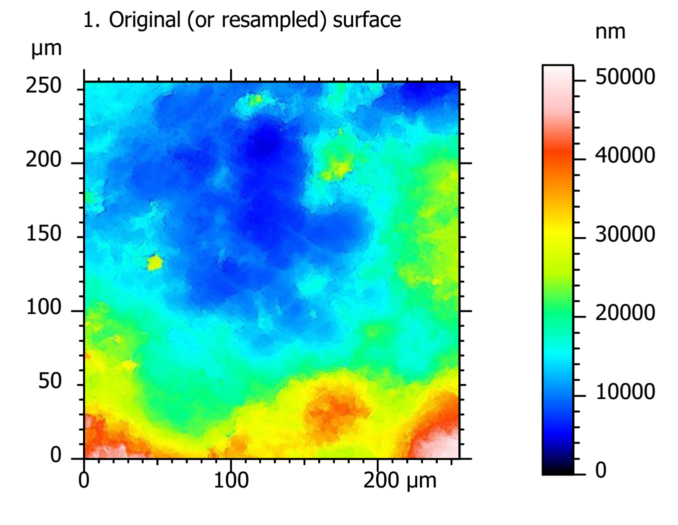


Information	
Method	Area-scale (four corners)

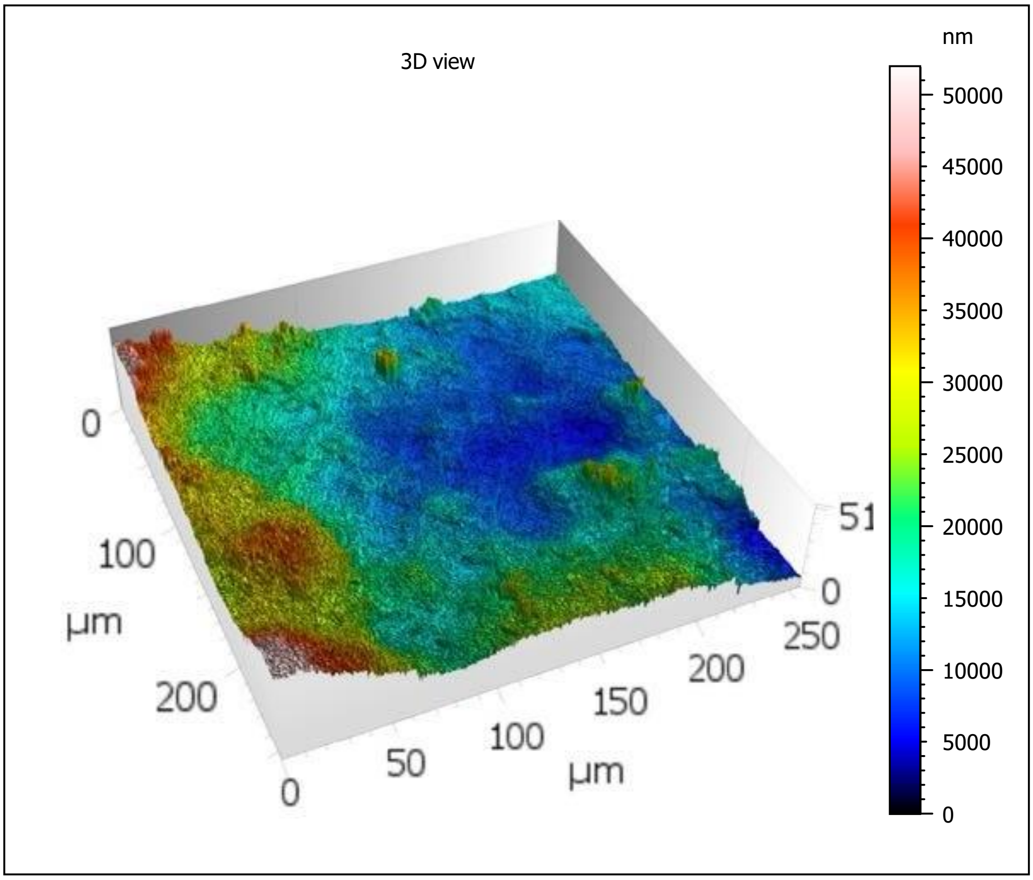
Parameters	Value	Unit	Comment
Asfc	34.10		*Fractal complexity*
Smfc	18.47	µm²	*Scale of max complexity*
HAsfc9	0.2418		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.4123		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

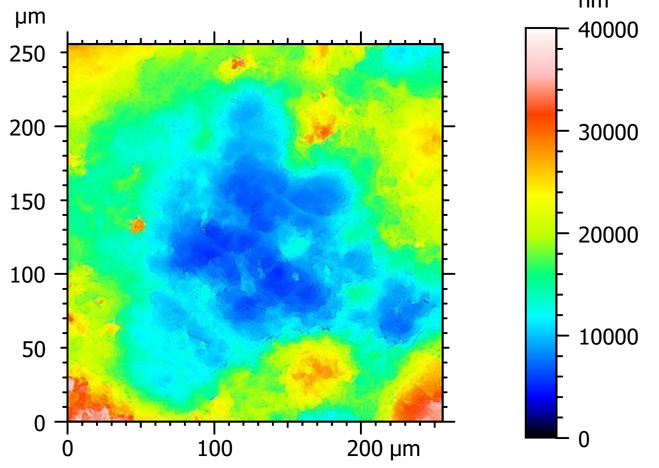
Processing



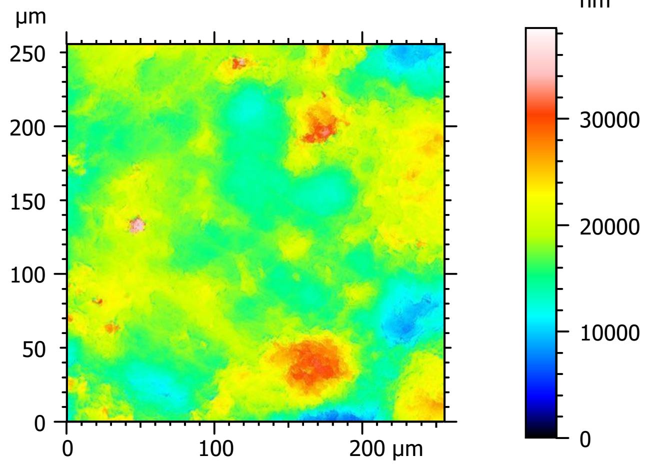
Identity card		
Name:	Lime3-9_LSM_50x075_suf1_Topo	
Created on:	6/24/2020 2:04:50 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	51977	nm
Size:	65531	digits
Spacing:	0.7932	nm
NM-points ratio:	0.000 % (0 Pts)	



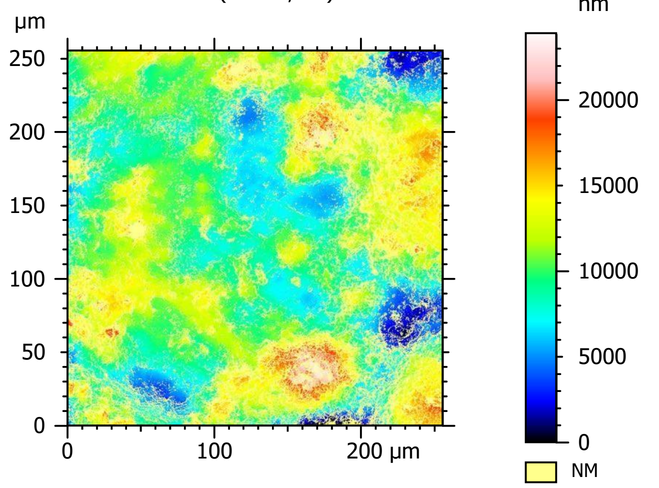
2. Leveled surface (least squares plane, substraction)



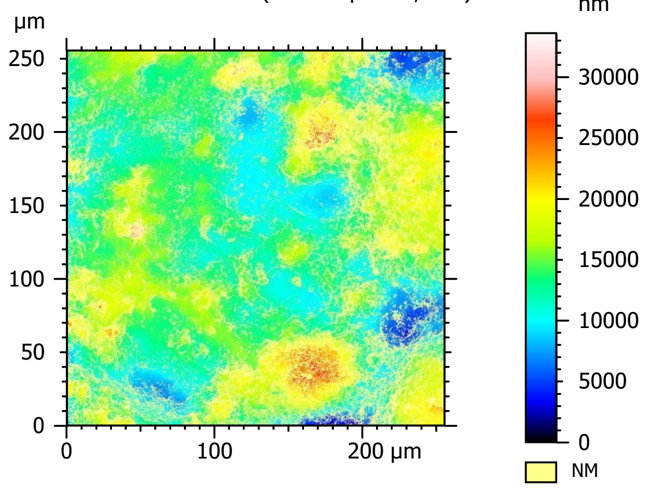
3. Form removed (polynomial degree 3)

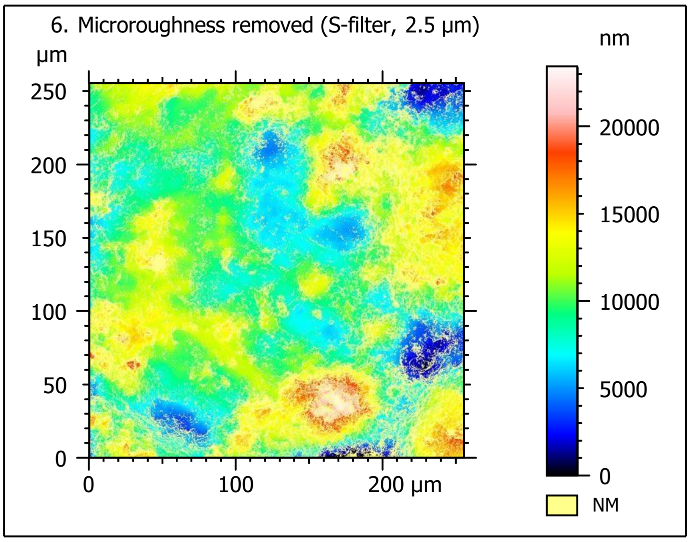


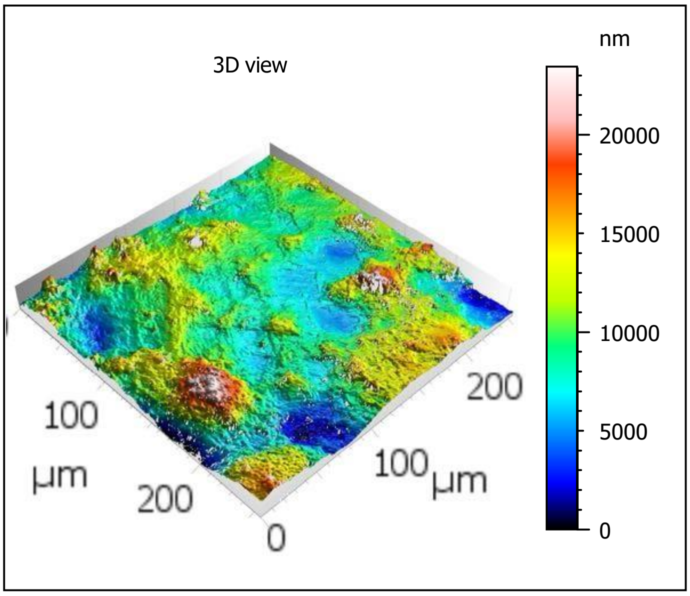
5. Thresholded (0.1-99,9%)



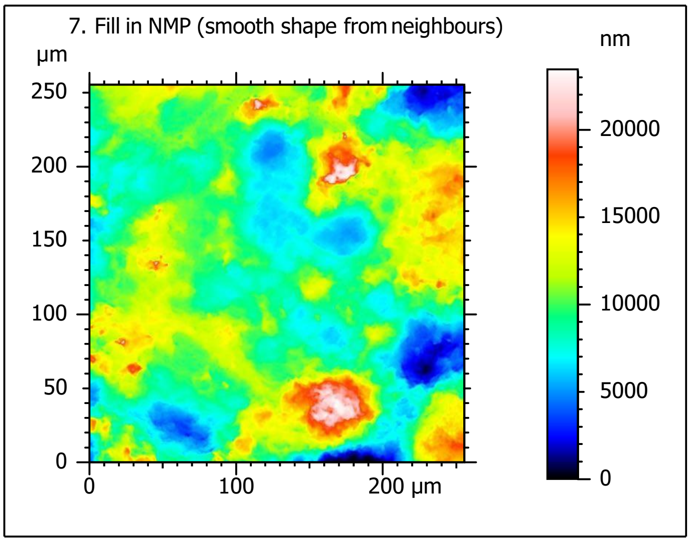
4. Outliers removed (max. slope 80°, soft)

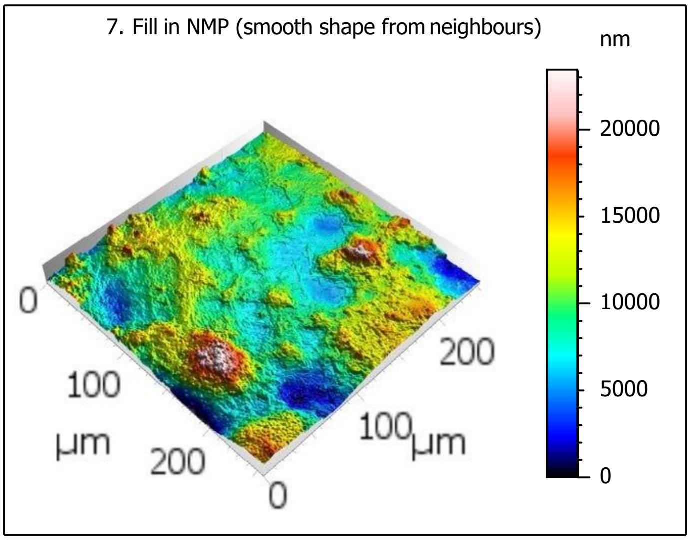






Identity card		
Name:	Lime3-9_LSM_50x075…filtered (λs 2.500 µm)	
File path:	C:\Us…\Lime3-9_LSM_50x075_suf1_Topo.sur	
Created on:	6/24/2020 2:04:50 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	Z	
Layer type:	Topography	
Length:	23446	nm
Min:	-9982	nm
Max:	13463	nm
Size:	295597	digits
Spacing:	0.07932	nm
NM-points ratio:	33.03 % (2973150 Pts)	



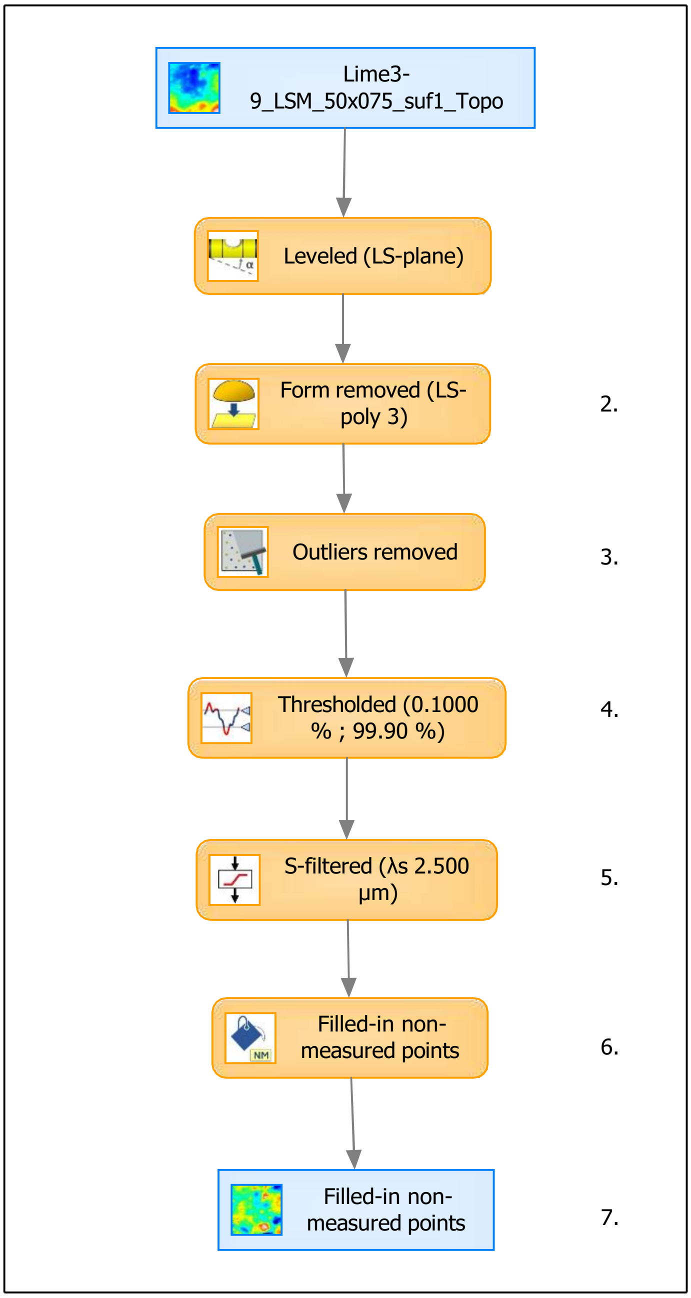


Identity card		
Name:	Lime3-9_LSM_50x075_s...in non-measured points	
Created on:	6/24/2020 2:04:50 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	23446	nm
Size:	295597	digits
Spacing:	0.07932	nm
NM-points ratio:	0.000 % (0 Pts)	

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	3339	nm
Ssk	0.3839	
Sku	4.024	
Sp	13358	nm
Sv	10087	nm
Sz	23446	nm
Sa	2548	nm
Functional parameters		
Smr	0.1444	%
Smc	4106	nm
Sxp	6420	nm
Spatial parameters		
Sal	25.29	µm
Str	0.8510	
Std	39.26	°
Hybrid parameters		
Sdq	0.7598	
Sdr	18.82	%
Functional parameters (Volume)		
Vm	0.2247	µm³/µm²
Vv	4.331	µm³/µm²
Vmp	0.2247	µm³/µm²
Vmc	2.714	µm³/µm²
Vvc	3.973	µm³/µm²
Vvv	0.3578	µm³/µm²



Analyses:

ISO 25178 8.

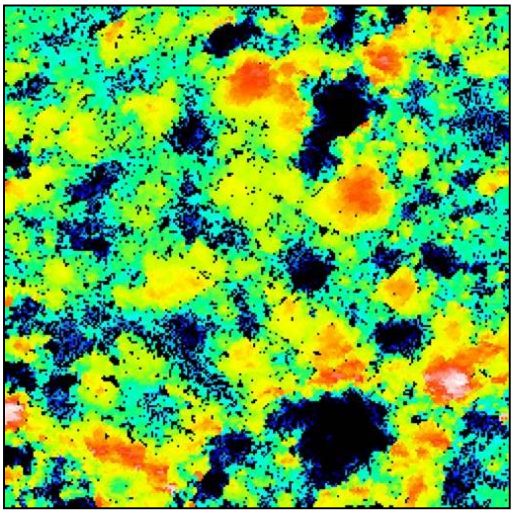
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

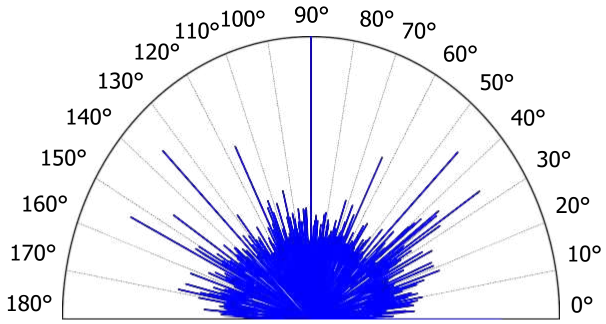
9. Furrow analysis on surface #7



All furrows are shown.

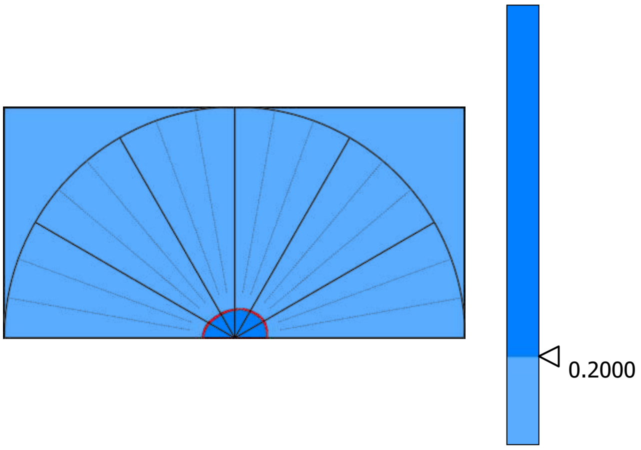
Parameters	Value	Unit	
Maximum depth of furrows	8684	nm	
Mean depth of furrows	3671	nm	
Mean density of furrows	4492	cm/cm2	

10. Texture direction on surface #7



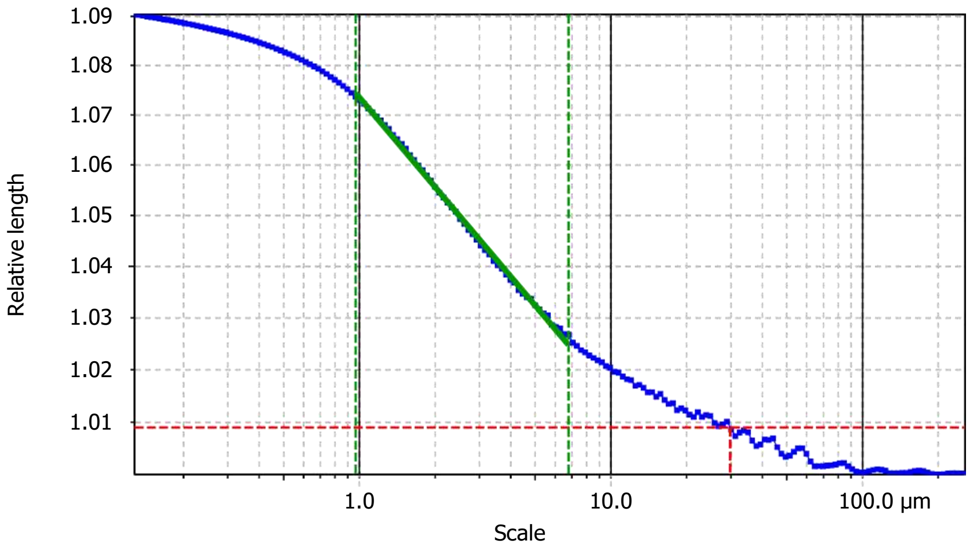
Parameters	Value	Unit	
First direction	90.00	°	
Second direction	135.0	°	
Third direction	44.98	°	

11. Texture isotropy on surface #7



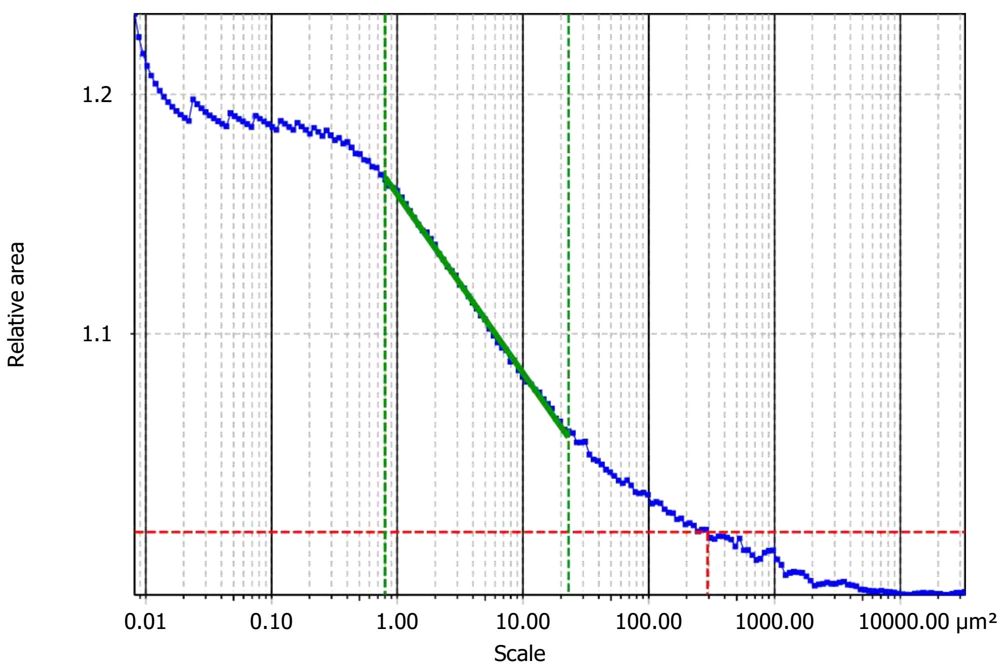
Parameters	Value	Unit	
Isotropy	82.29	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.002506		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01835		*Length-scale anisotropy (1.8 µm, 5°)*

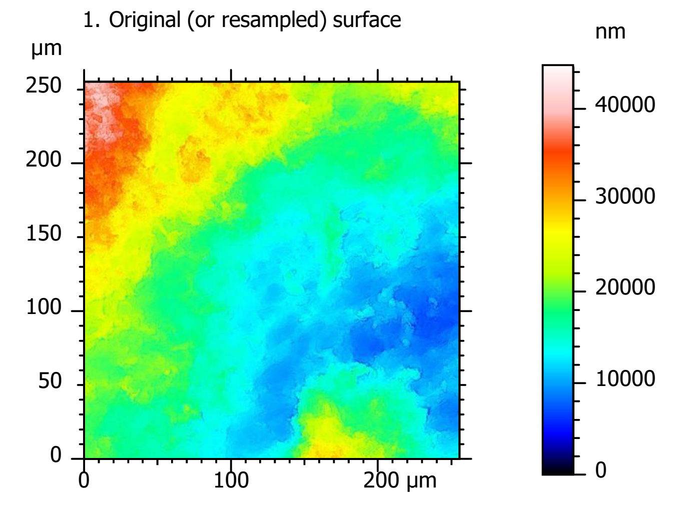


Information	
Method	Area-scale (four corners)

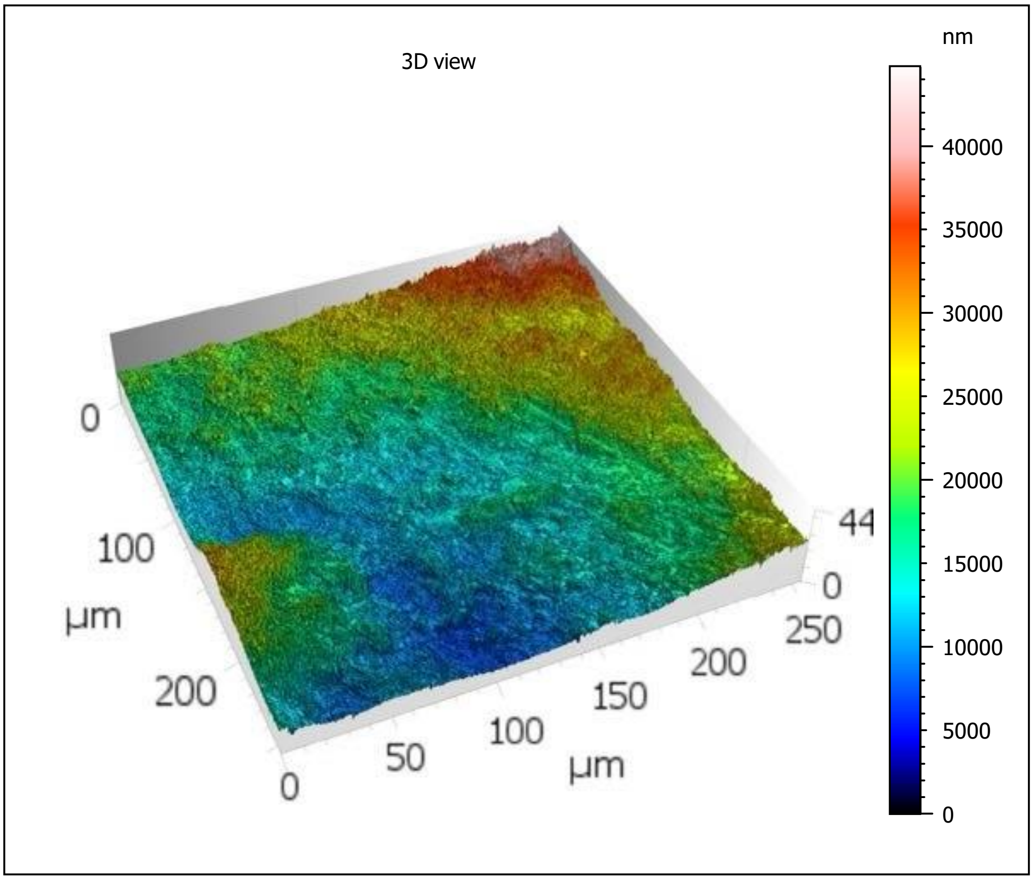
Parameters	Value	Unit	Comment
Asfc	28.14		*Fractal complexity*
Smfc	3.159	µm²	*Scale of max complexity*
HAsfc9	0.2990		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.6150		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

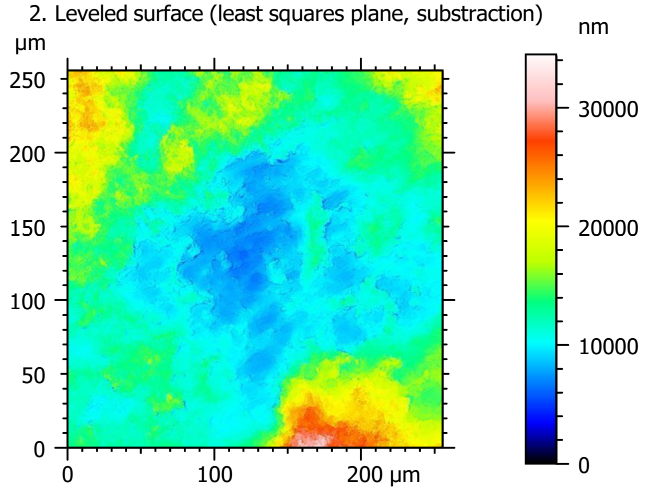
Processing



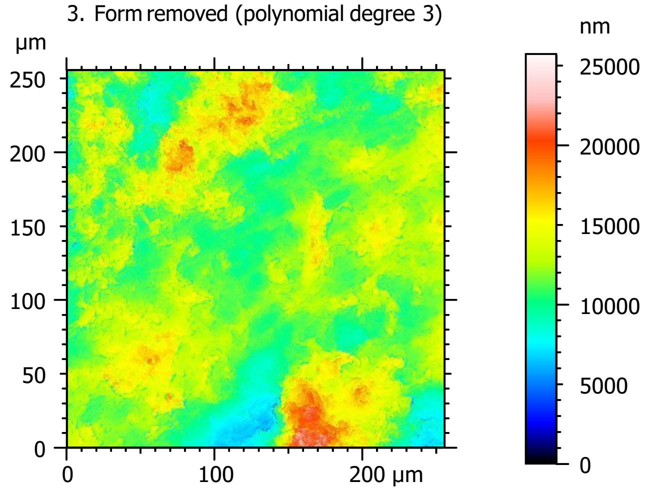
Identity card		
Name:	Lime3-9_LSM_50x075_suf2_Topo	
Created on:	6/24/2020 2:22:16 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	44786	nm
Size:	65532	digits
Spacing:	0.6834	nm
NM-points ratio:	0.000 % (0 Pts)	



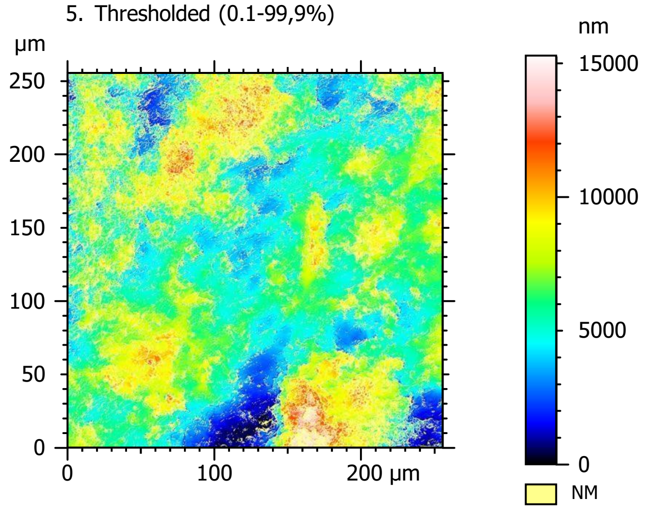
2. Leveled surface (least squares plane, substraction)



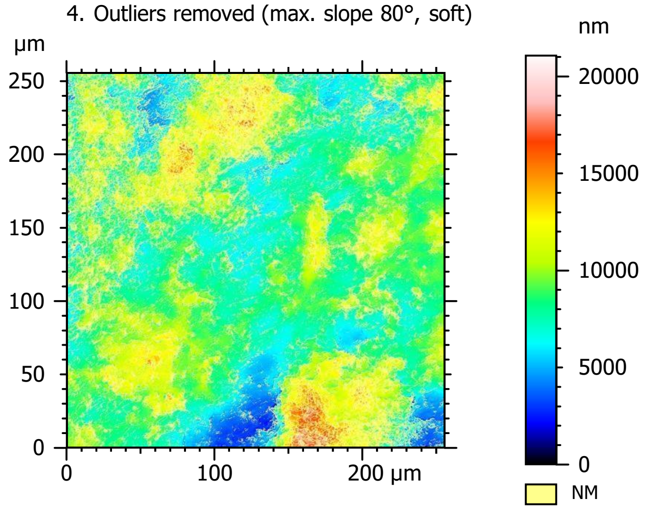
3. Form removed (polynomial degree 3)

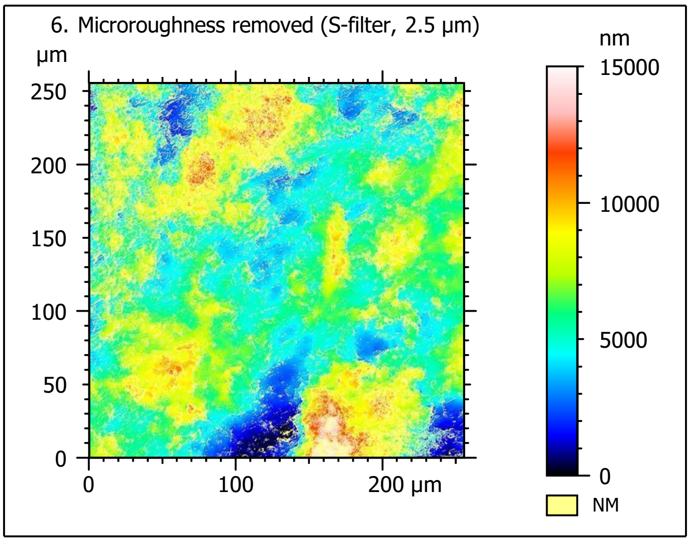


5. Thresholded (0.1-99,9%)

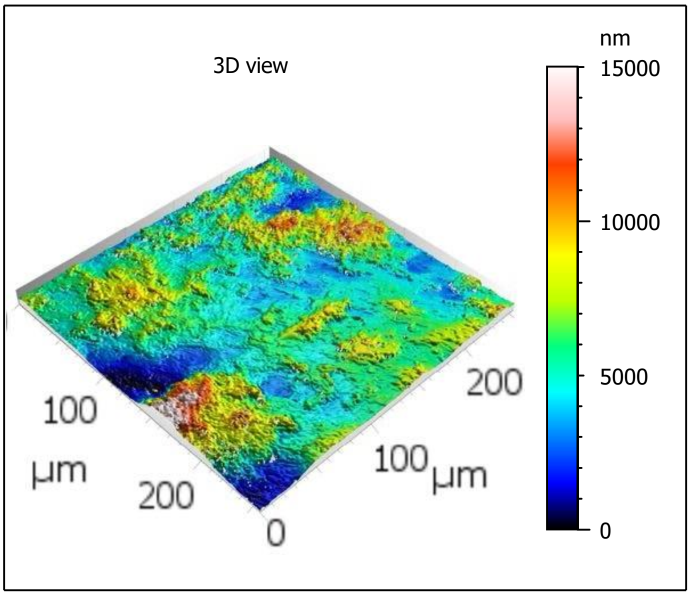


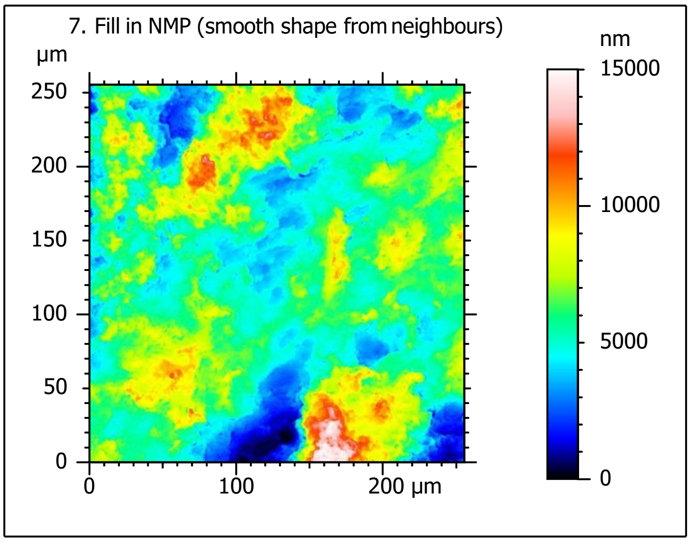
4. Outliers removed (max. slope 80°, soft)

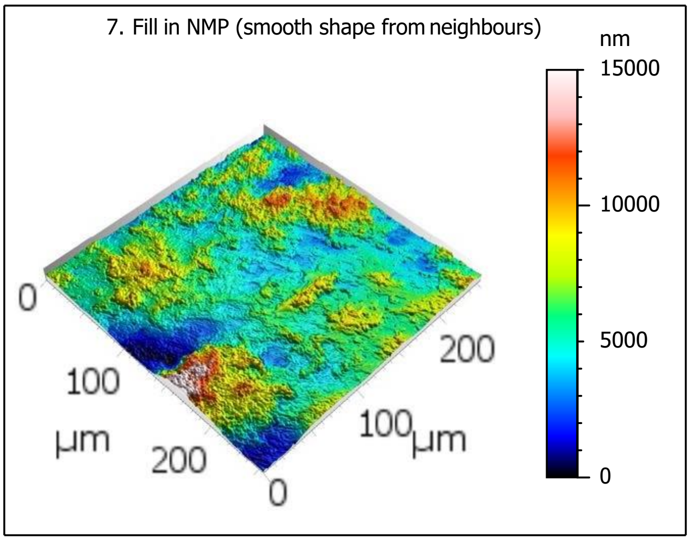




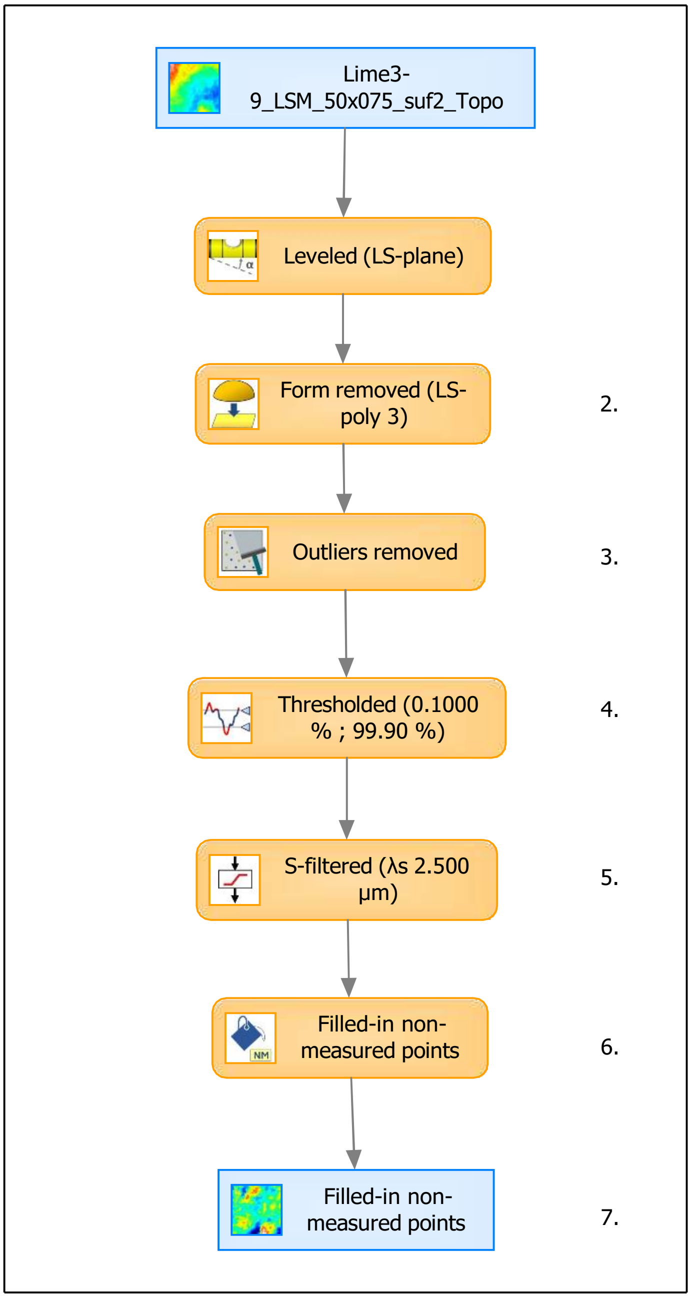
Identity card		
Name:	Lime3-9_LSM_50x075…filtered (λs 2.500 µm)	
File path:	C:\Us…\Lime3-9_LSM_50x075_suf2_Topo.sur	
Created on:	6/24/2020 2:22:16 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	Z	
Layer type:	Topography	
Length:	15003	nm
Min:	-5915	nm
Max:	9088	nm
Size:	219525	digits
Spacing:	0.06834	nm
NM-points ratio:	28.12 % (2530730 Pts)	







Identity card		
Name:	Lime3-9_LSM_50x075_s...in non-measured points	
Created on:	6/24/2020 2:22:16 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	15003	nm
Size:	219525	digits
Spacing:	0.06834	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	2114	nm
Ssk	0.5340	
Sku	4.361	
Sp	9032	nm
Sv	5971	nm
Sz	15003	nm
Sa	1597	nm
Functional parameters		
Smr	0.3638	%
Smc	2645	nm
Sxp	3958	nm
Spatial parameters		
Sal	21.26	µm
Str	0.3001	
Std	39.50	°
Hybrid parameters		
Sdq	0.6772	
Sdr	16.77	%
Functional parameters (Volume)		
Vm	0.1485	µm³/µm²
Vv	2.793	µm³/µm²
Vmp	0.1485	µm³/µm²
Vmc	1.651	µm³/µm²
Vvc	2.569	µm³/µm²
Vvv	0.2241	µm³/µm²

Analyses:

ISO 25178 8.

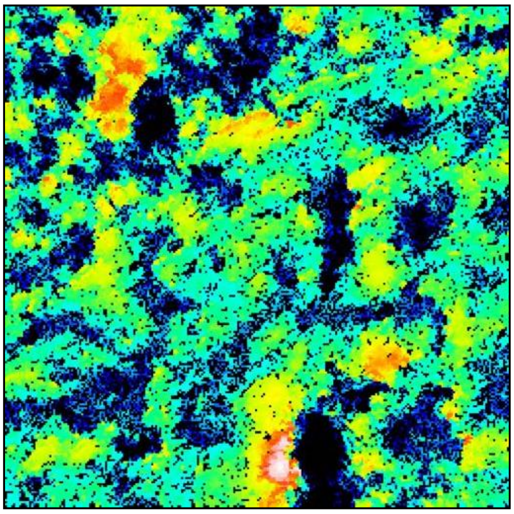
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

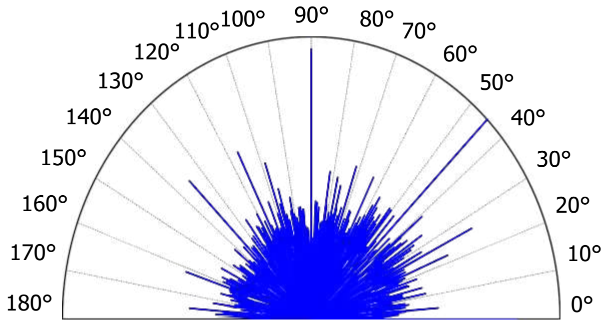
9. Furrow analysis on surface #7



All furrows are shown.

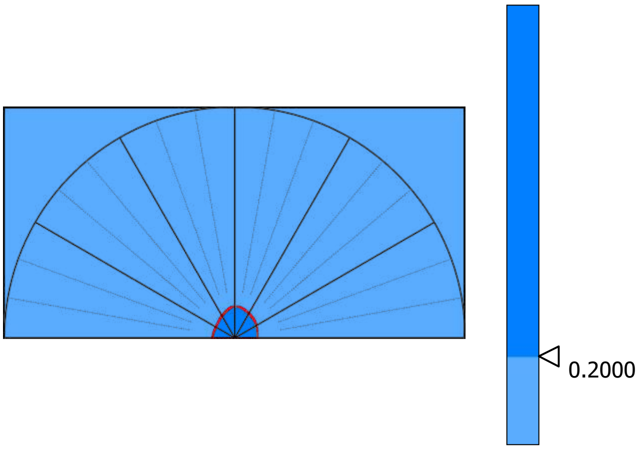
Parameters	Value	Unit	
Maximum depth of furrows	7200	nm	
Mean depth of furrows	2434	nm	
Mean density of furrows	4866	cm/cm2	

10. Texture direction on surface #7



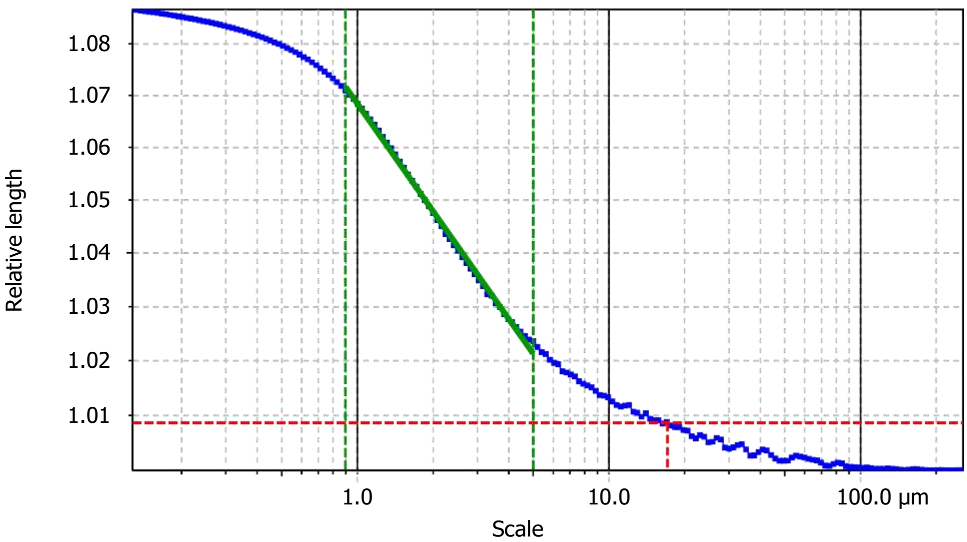
Parameters	Value	Unit	
First direction	45.00	°	
Second direction	89.99	°	
Third direction	0.004873	°	

11. Texture isotropy on surface #7



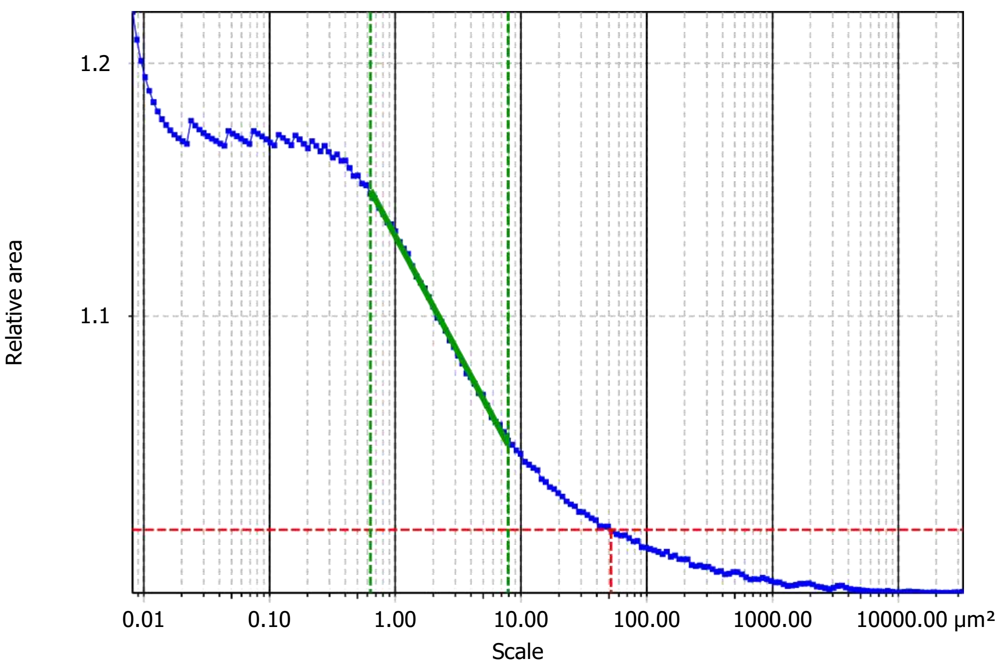
Parameters	Value	Unit	
Isotropy	68.97	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0009469		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.0175		*Length-scale anisotropy (1.8 µm, 5°)*

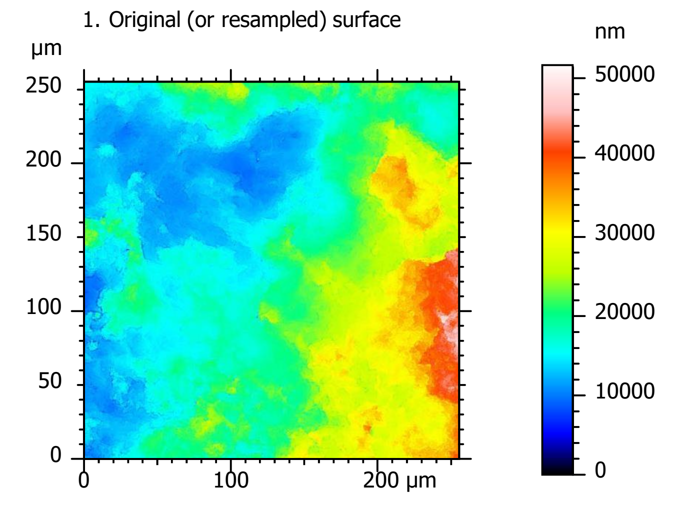


Information	
Method	Area-scale (four corners)

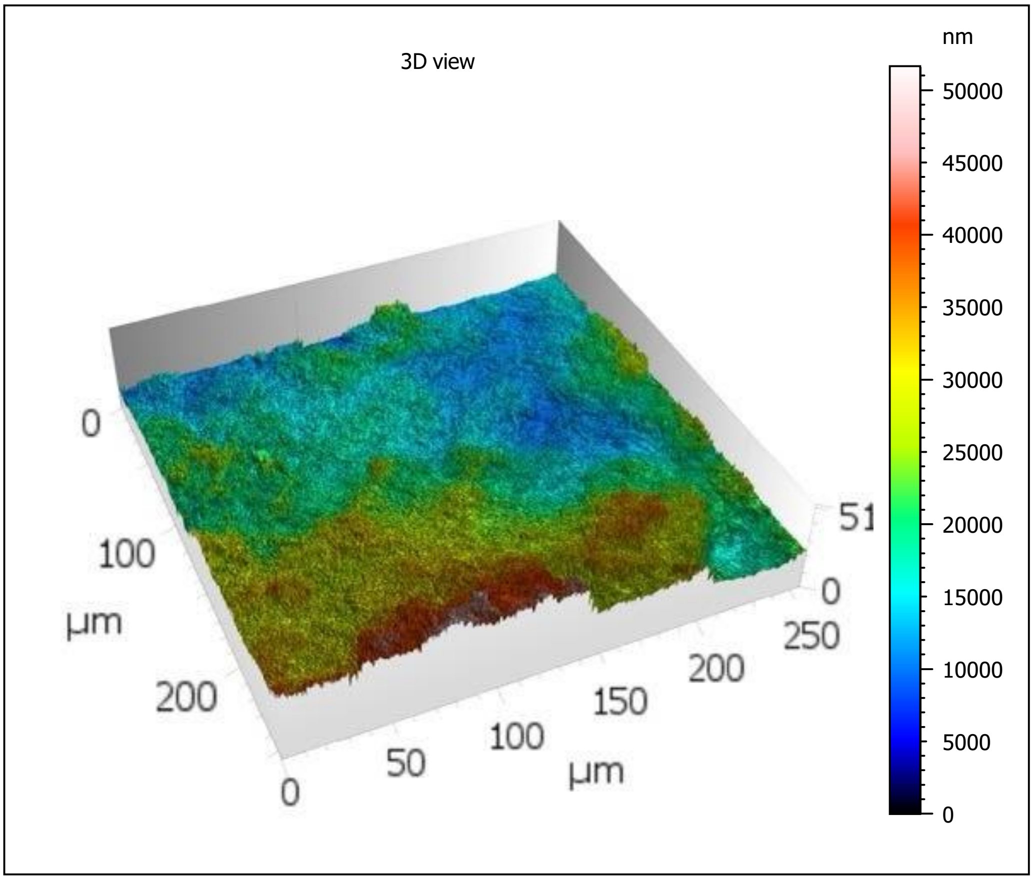
Parameters	Value	Unit	Comment
Asfc	34.74		*Fractal complexity*
Smfc	1.997	µm²	*Scale of max complexity*
HAsfc9	0.3344		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.5175		*Heterogeneity of Asfc (9x9)*

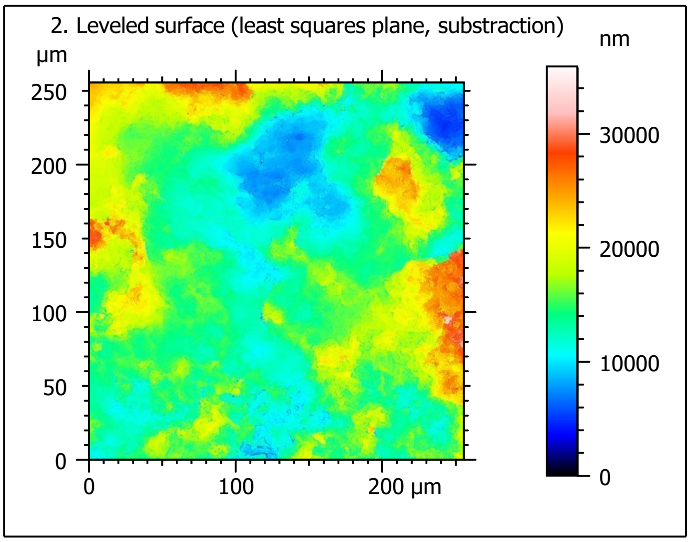
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

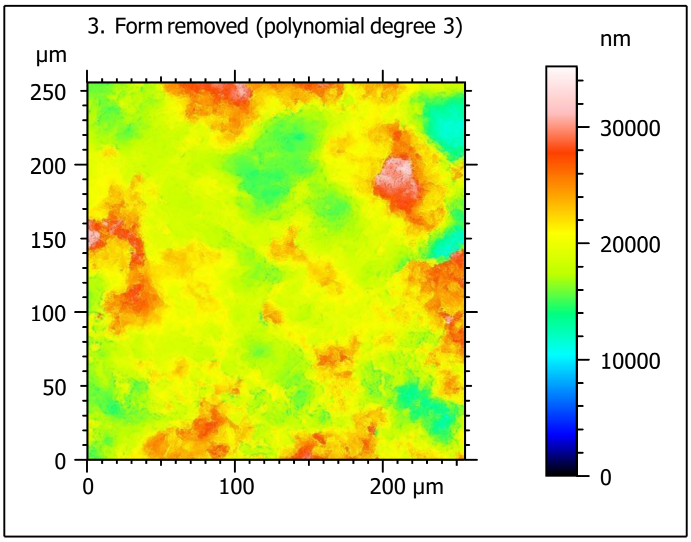
Processing

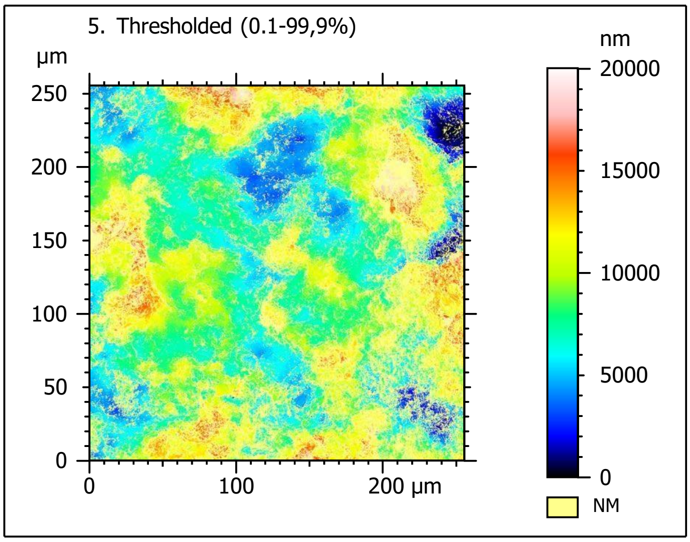


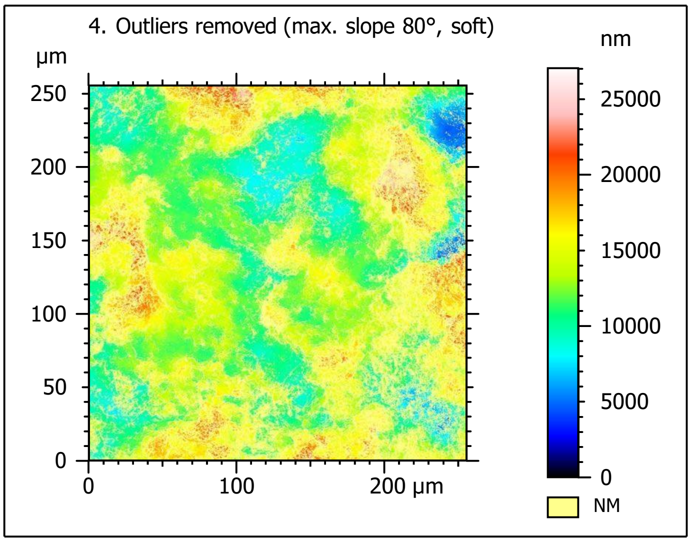
Identity card		
Name:	Lime3-9_LSM_50x075_suf3_Topo	
Created on:	6/24/2020 2:54:34 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	51654	nm
Size:	65531	digits
Spacing:	0.7882	nm
NM-points ratio:	0.000 % (0 Pts)	



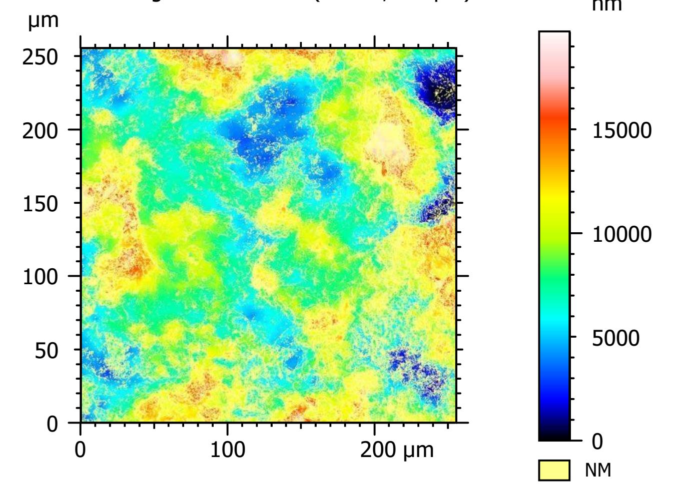

2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
30000
20000
10000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
30000
20000
10000
0

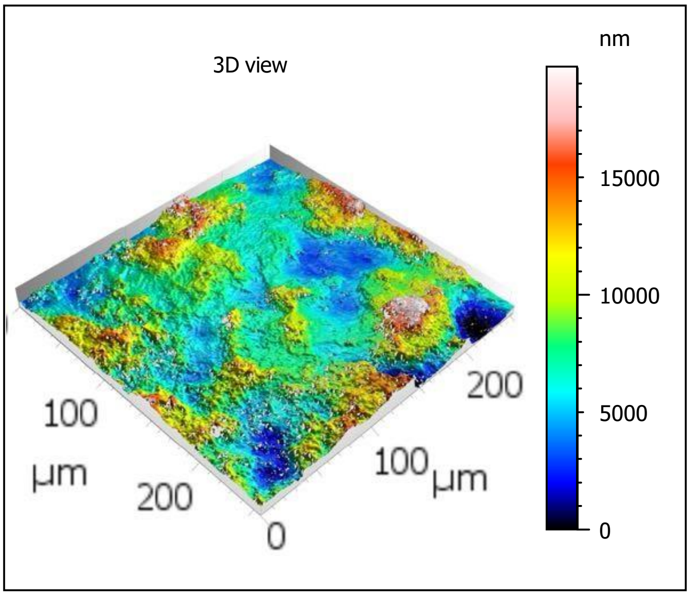

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
20000
15000
10000
5000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
25000
20000
15000
10000
5000
0
NM

6. Microroughness removed (S-filter, 2.5 µm)



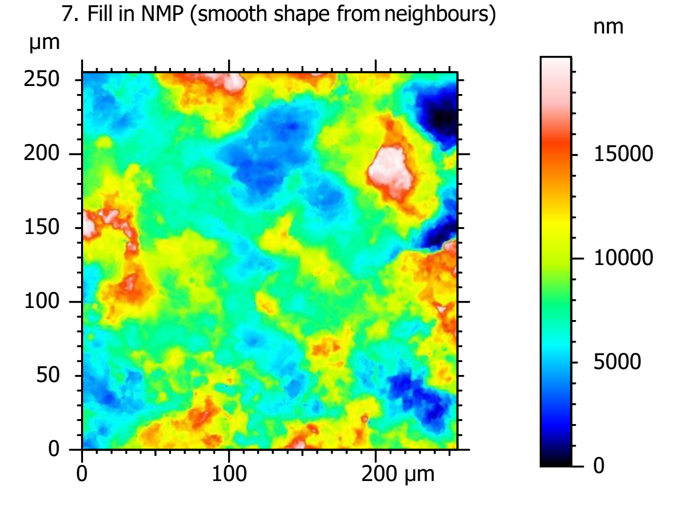
3D view



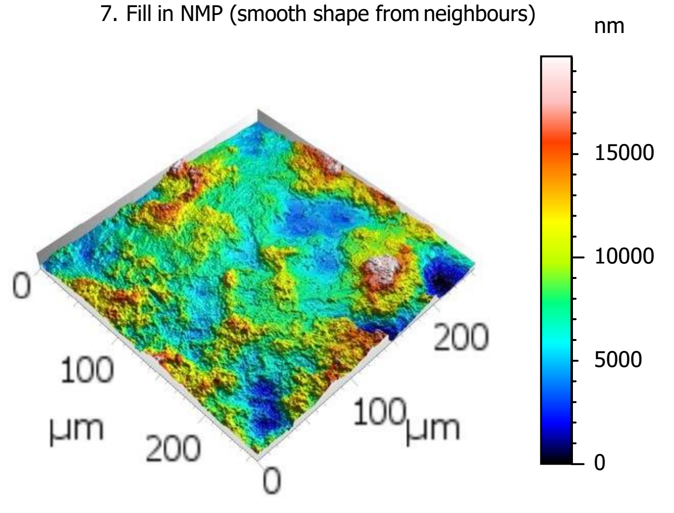
Identity card	

Name:	Lime3-9_LSM_50x075…filtered (λs 2.500 µm)	
File path:	C:\Us…\Lime3-9_LSM_50x075_suf3_Topo.sur	
Created on:	6/24/2020 2:54:34 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Offset:	-255.5	µm
Axis:	Z	
Layer type:	Topography	
Length:	19719	nm
Min:	-8280	nm
Max:	11439	nm
Size:	250172	digits
Spacing:	0.07882	nm
NM-points ratio:	39.75 % (3577236 Pts)	

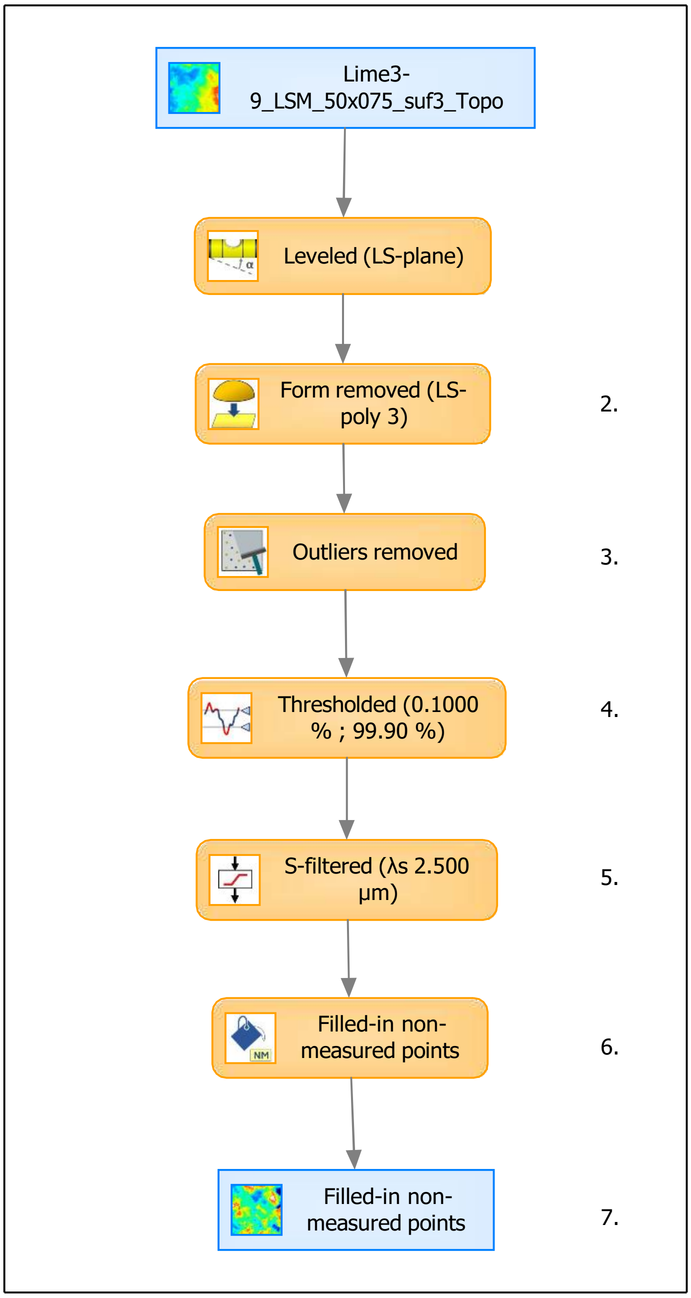
7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card		
Name:	Lime3-9_LSM_50x075_s...in non-measured points	
Created on:	6/24/2020 2:54:34 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	19719	nm
Size:	250172	digits
Spacing:	0.07882	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	3154	nm
Ssk	0.6024	
Sku	3.689	
Sp	11312	nm
Sv	8407	nm
Sz	19719	nm
Sa	2449	nm
Functional parameters		
Smr	0.4690	%
Smc	4211	nm
Sxp	4869	nm
Spatial parameters		
Sal	26.11	µm
Str	0.7232	
Std	163.3	°
Hybrid parameters		
Sdq	0.8406	
Sdr	22.27	%
Functional parameters (Volume)		
Vm	0.2114	µm³/µm²
Vv	4.422	µm³/µm²
Vmp	0.2114	µm³/µm²
Vmc	2.593	µm³/µm²
Vvc	4.144	µm³/µm²
Vvv	0.2787	µm³/µm²

Analyses:

ISO 25178 8.

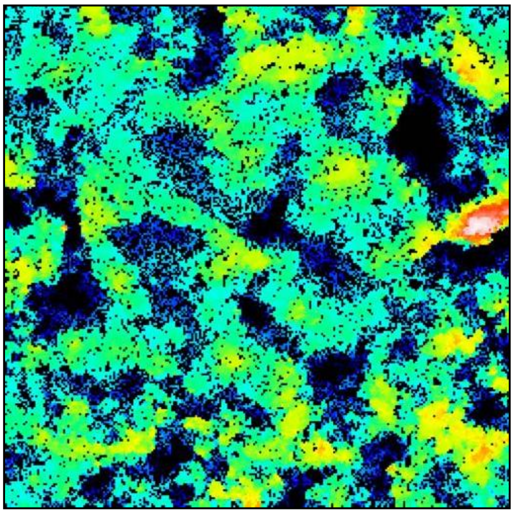
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

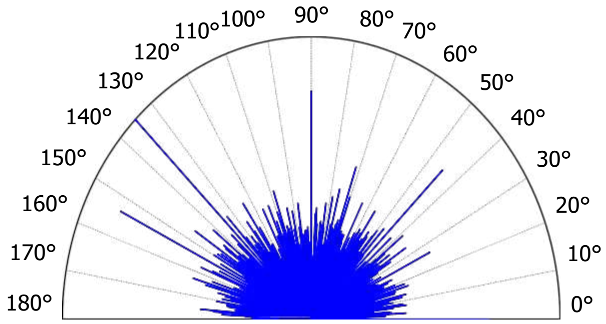
9. Furrow analysis on surface #7



All furrows are shown.

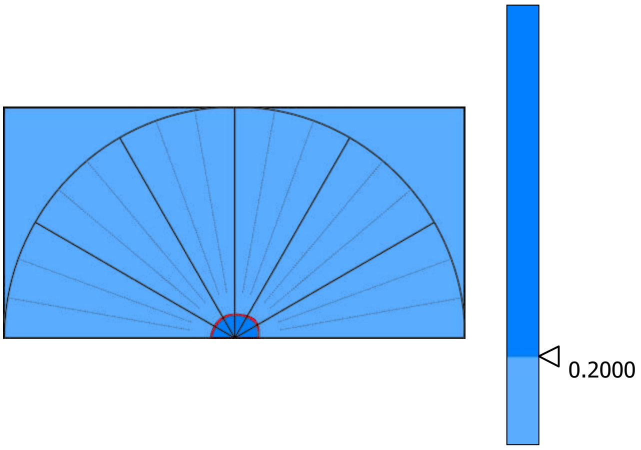
Parameters	Value	Unit
Maximum depth of furrows	12036	nm
Mean depth of furrows	3870	nm
Mean density of furrows	4618	cm/cm2

10. Texture direction on surface #7



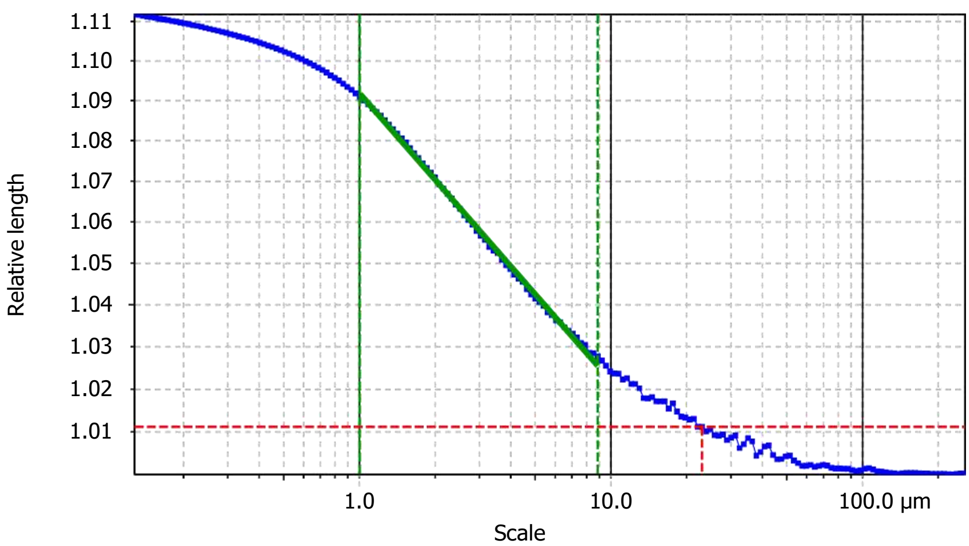
Parameters	Value	Unit
First direction	135.0	°
Second direction	153.5	°
Third direction	90.01	°

11. Texture isotropy on surface #7



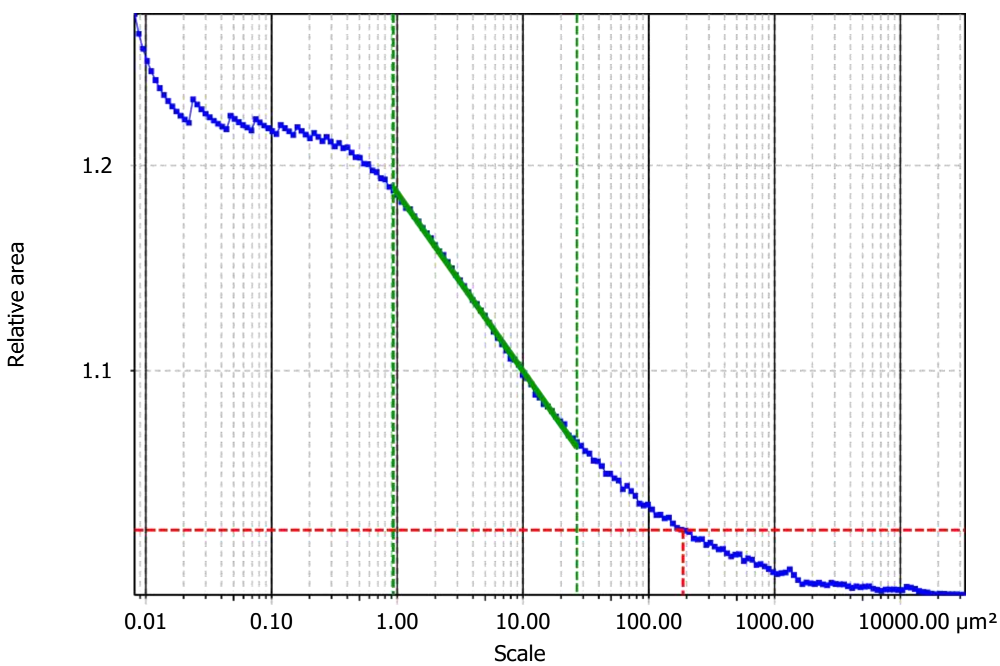
Parameters	Value	Unit
Isotropy	87.77	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0006446		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01795		*Length-scale anisotropy (1.8 µm, 5°)*

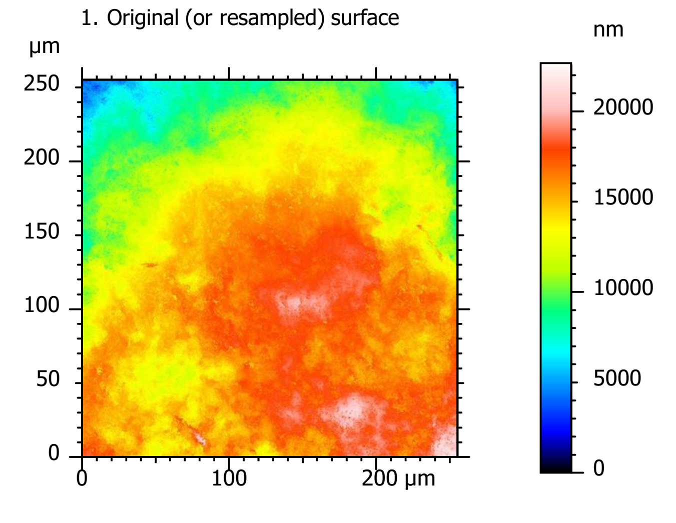


Information	
Method	Area-scale (four corners)

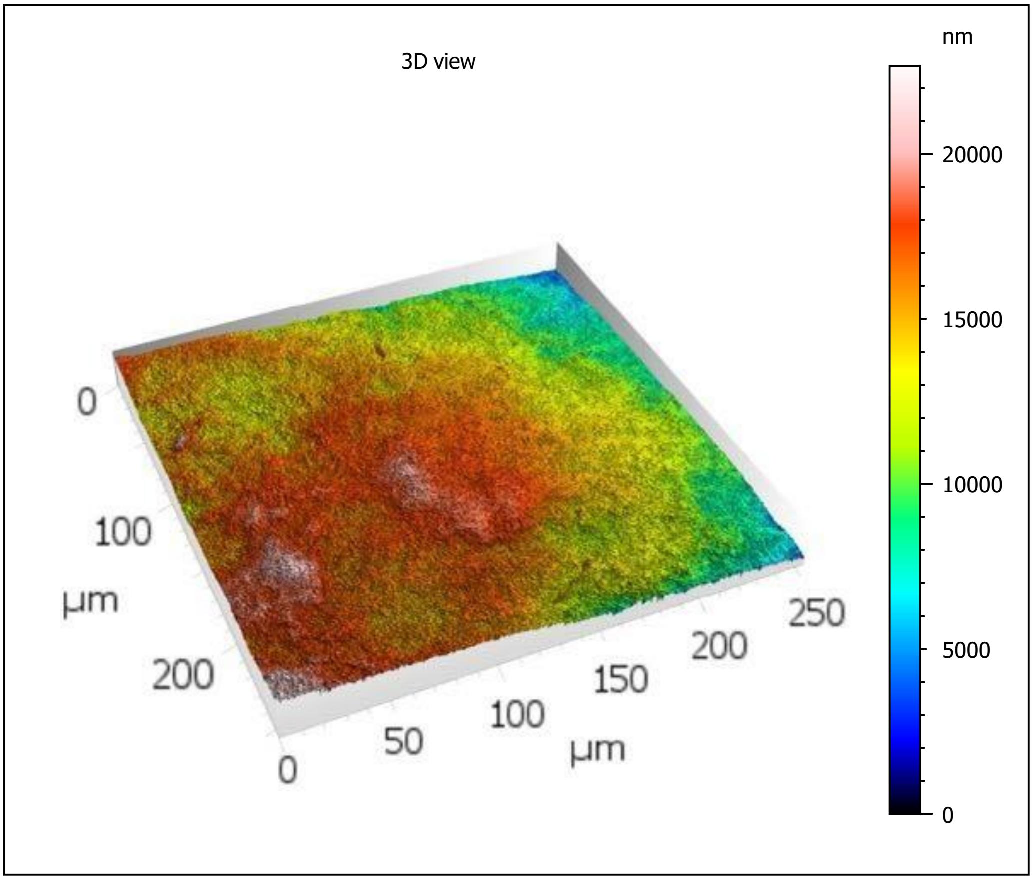
Parameters	Value	Unit	Comment
Asfc	32.87		*Fractal complexity*
Smfc	4.628	µm²	*Scale of max complexity*
HAsfc9	0.2963		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.5723		*Heterogeneity of Asfc (9x9)*

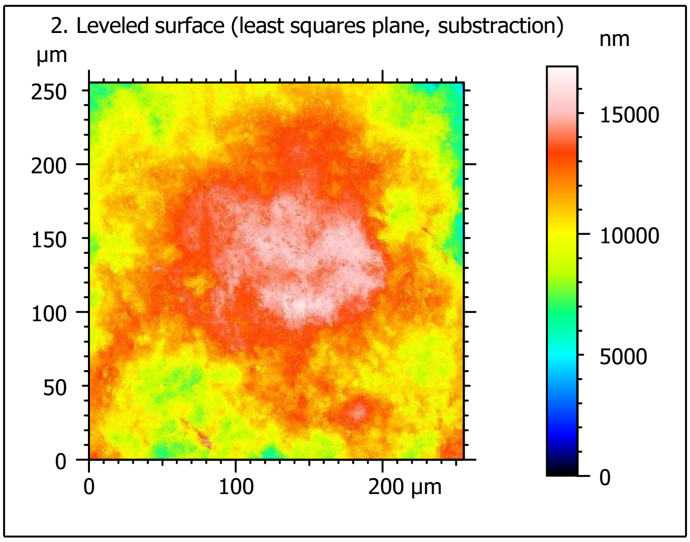
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

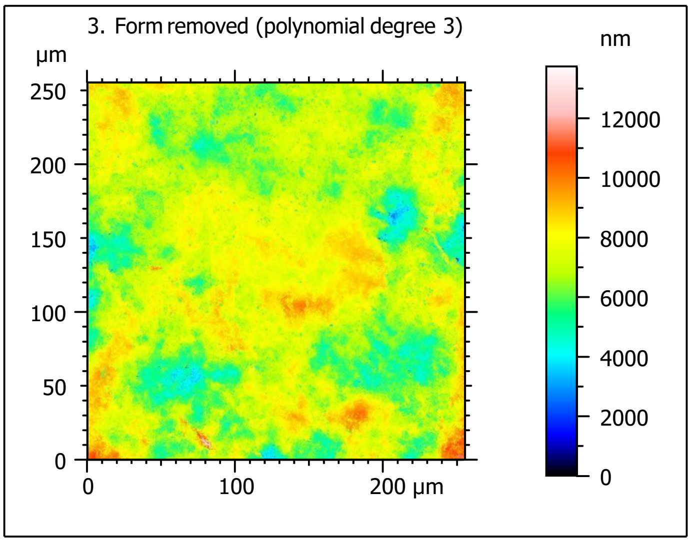
Processing

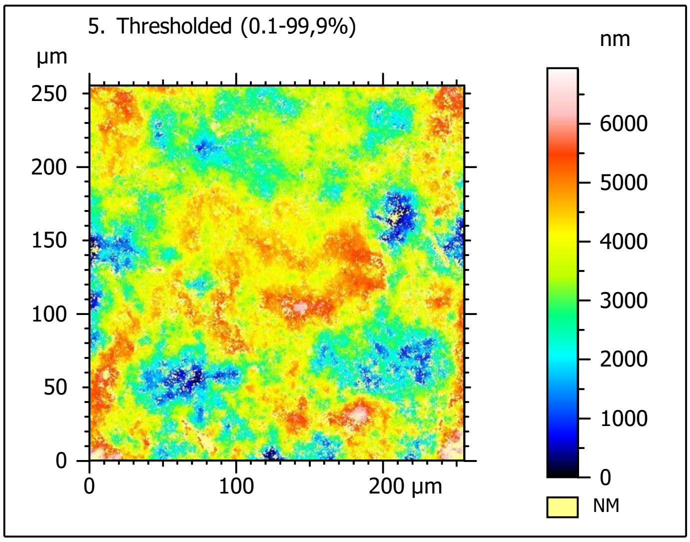


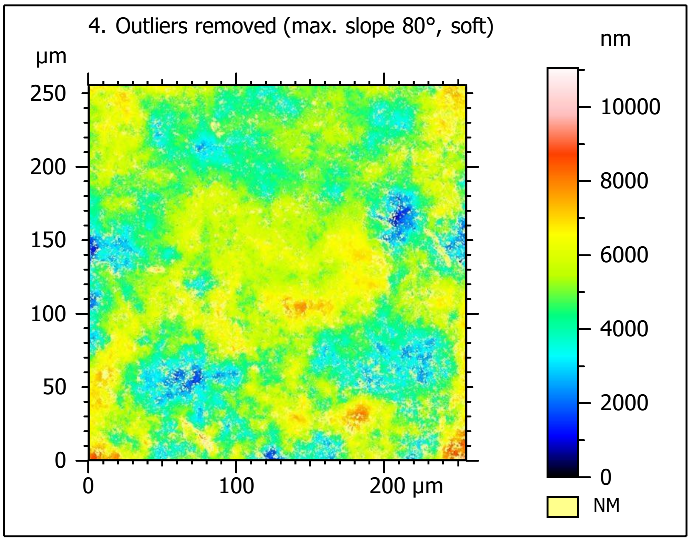
Identity card		
Name:	lime6-1_lsm_50x-0.75_20200914_surf1_Topo	
Created on:	9/14/2020 2:48:35 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	22667	nm
Size:	65532	digits
Spacing:	0.3459	nm
NM-points ratio:	0.000 % (0 Pts)	

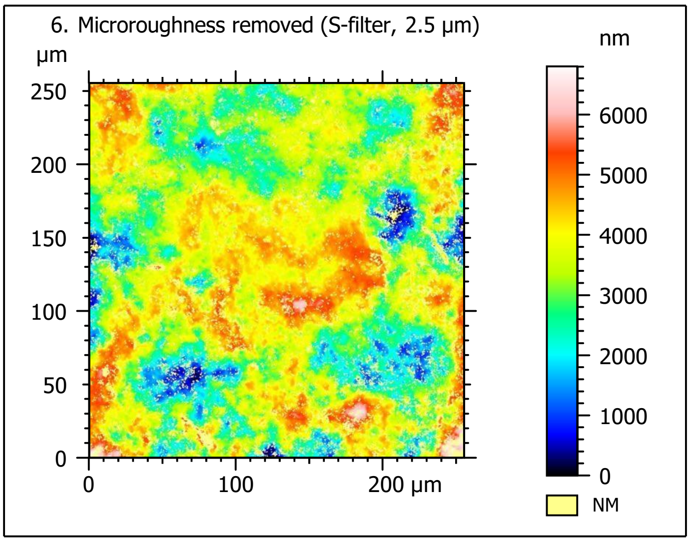



2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
12000
10000
8000
6000
4000
2000
0

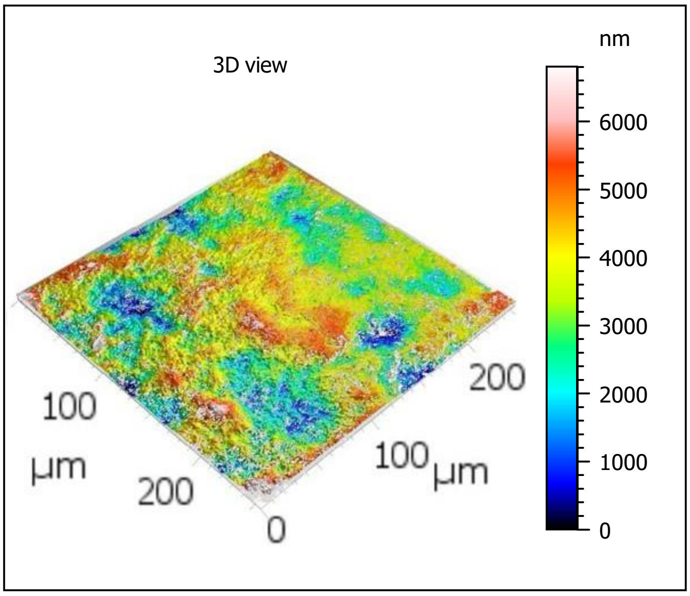

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
6000
5000
4000
3000
2000
1000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
8000
6000
4000
2000
0
NM

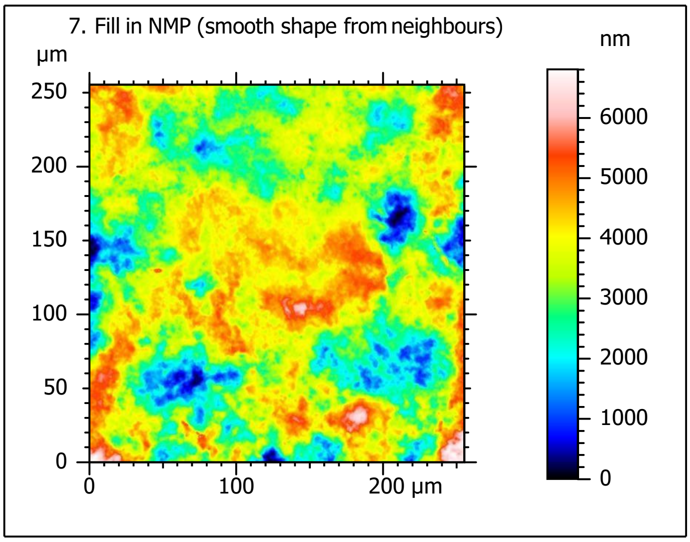


6. Microroughness removed (S-filter, 2.5 µm)

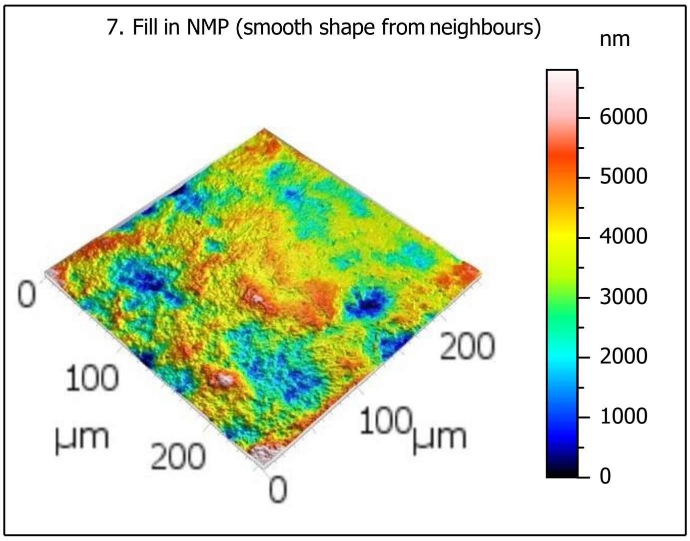
Identity card		
Name:	lime6-1_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…0914_surf1_Topo.sur	
Created on:	9/14/2020 2:48:35 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	6803	nm
Min:	-3389	nm
Max:	3414	nm
Size:	196680	digits
Spacing:	0.03459	nm
NM-points ratio:	15.16 % (158934 Pts)	



3D view

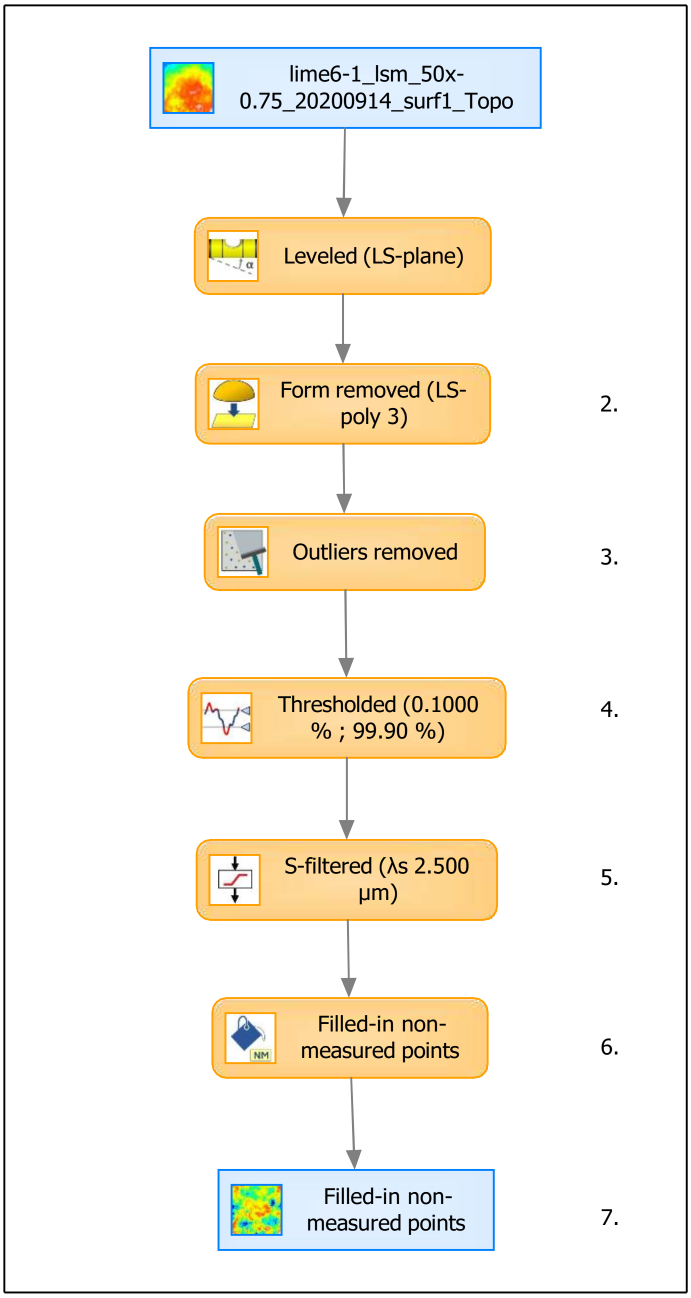


7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)

Identity card		
Name:	lime6-1_lsm_50x-0.75_...in non-measured points	
Created on:	9/14/2020 2:48:35 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	6803	nm
Size:	196680	digits
Spacing:	0.03459	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses:

ISO 25178 8.

Furrow 9.

Texture direction 10.

Texture isotropy 11.

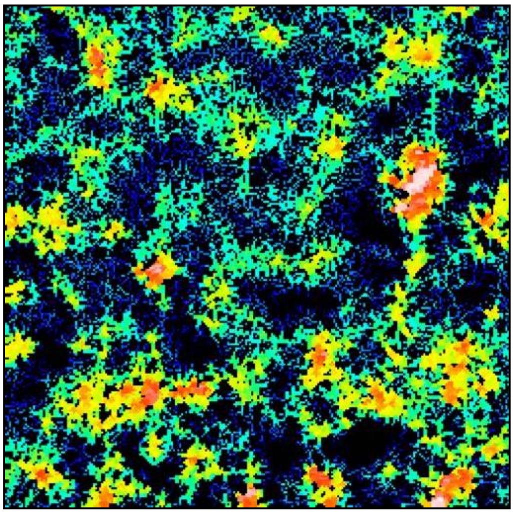
SSFA 12.

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1019	nm
Ssk	-0.2669	
Sku	3.184	
Sp	3376	nm
Sv	3427	nm
Sz	6803	nm
Sa	805.7	nm
Functional parameters		
Smr	0.7713	%
Smc	1234	nm
Sxp	2251	nm
Spatial parameters		
Sal	26.13	µm
Str	0.7948	
Std	86.99	°
Hybrid parameters		
Sdq	0.3030	
Sdr	4.292	%
Functional parameters (Volume)		
Vm	0.04361	µm³/µm²
Vv	1.277	µm³/µm²
Vmp	0.04361	µm³/µm²
Vmc	0.9124	µm³/µm²
Vvc	1.143	µm³/µm²
Vvv	0.1346	µm³/µm²

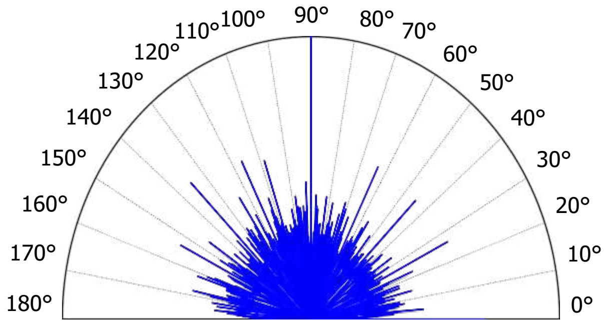
9. Furrow analysis on surface #7



All furrows are shown.

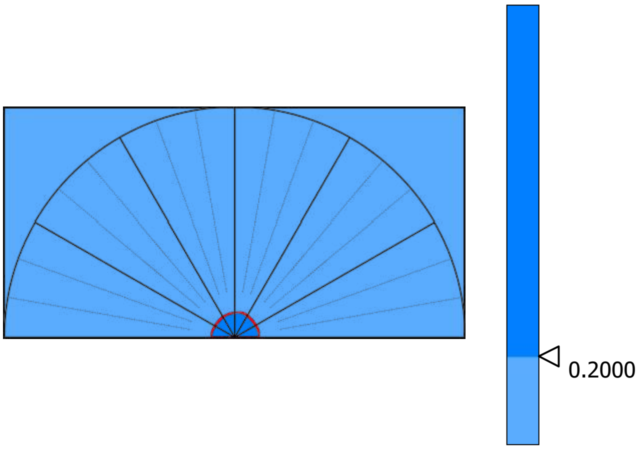
Parameters	Value	Unit
Maximum depth of furrows	3614	nm
Mean depth of furrows	1100	nm
Mean density of furrows	2798	cm/cm2

10. Texture direction on surface #7



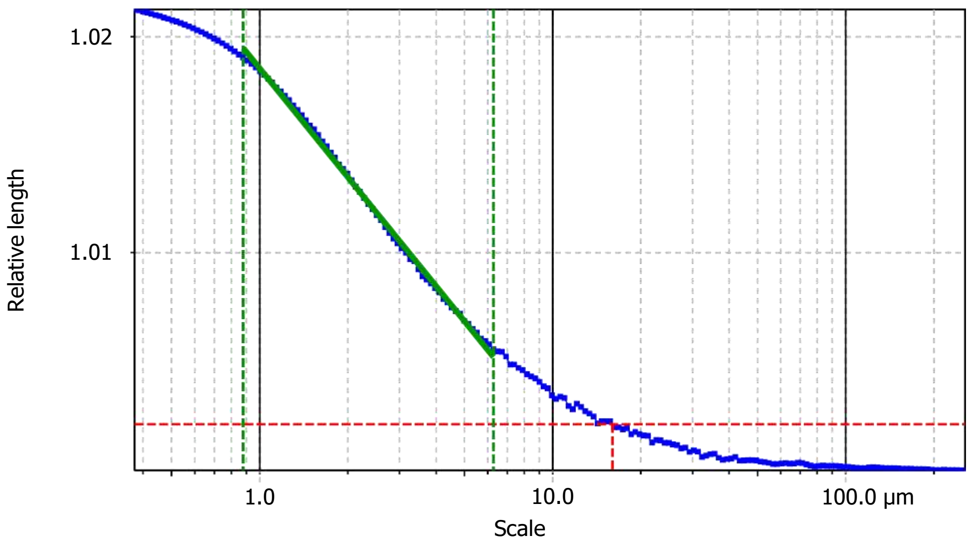
Parameters	Value	Unit
First direction	90.02	°
Second direction	180.0	°
Third direction	135.0	°

11. Texture isotropy on surface #7



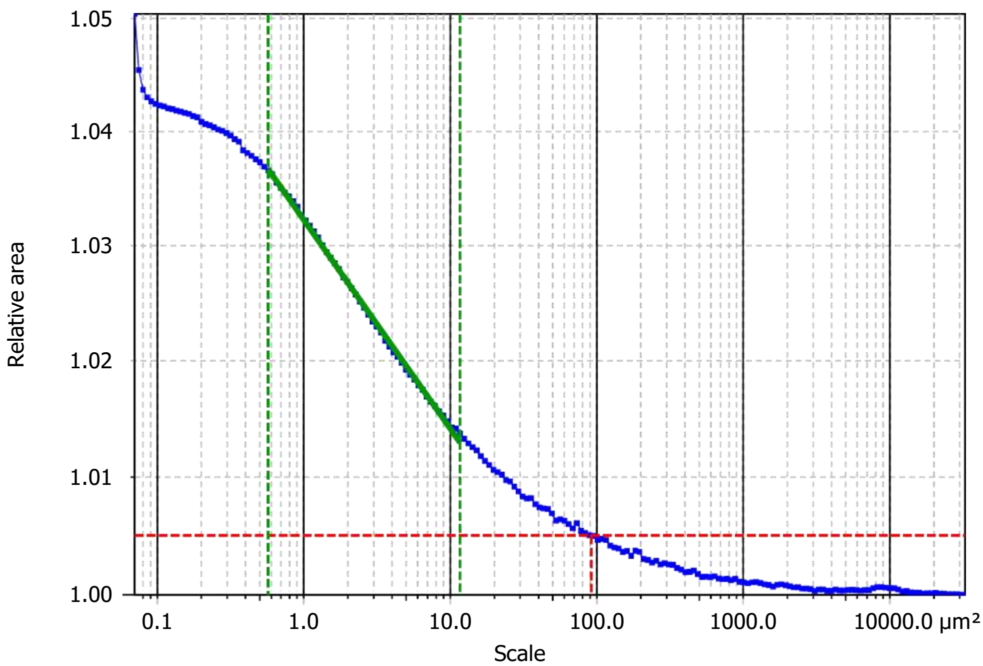
Parameters	Value	Unit
Isotropy	89.58	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0006671		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01742		*Length-scale anisotropy (1.8 µm, 5°)*

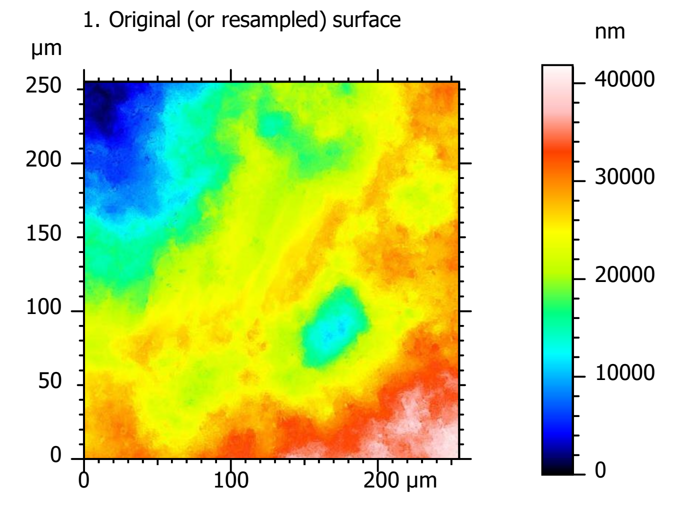


Information	
Method	Area-scale (four corners)

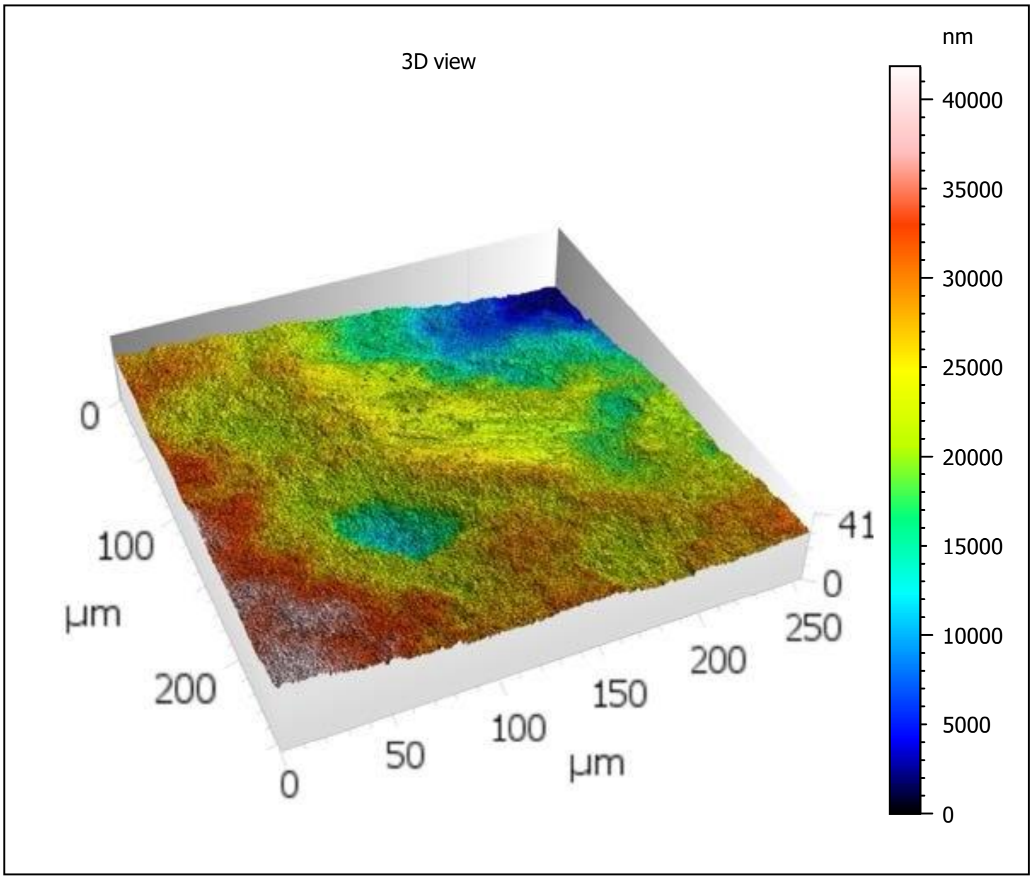
Parameters	Value	Unit	Comment
Asfc	7.679		*Fractal complexity*
Smfc	2.265	µm²	*Scale of max complexity*
HAsfc9	0.1949		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2488		*Heterogeneity of Asfc (9x9)*

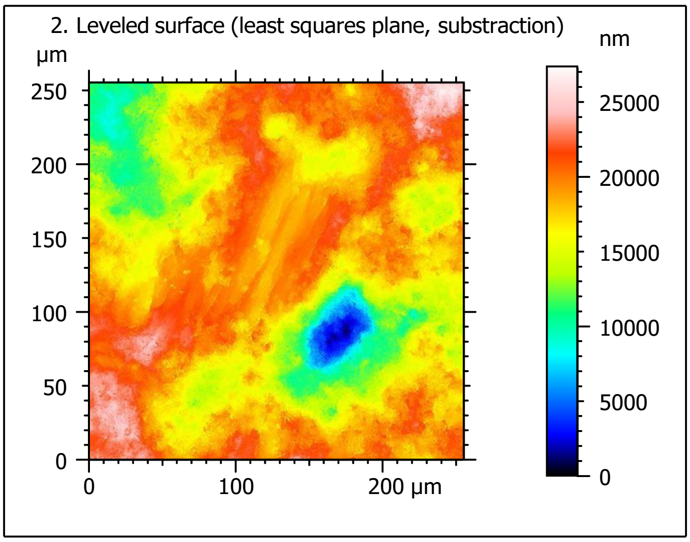
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

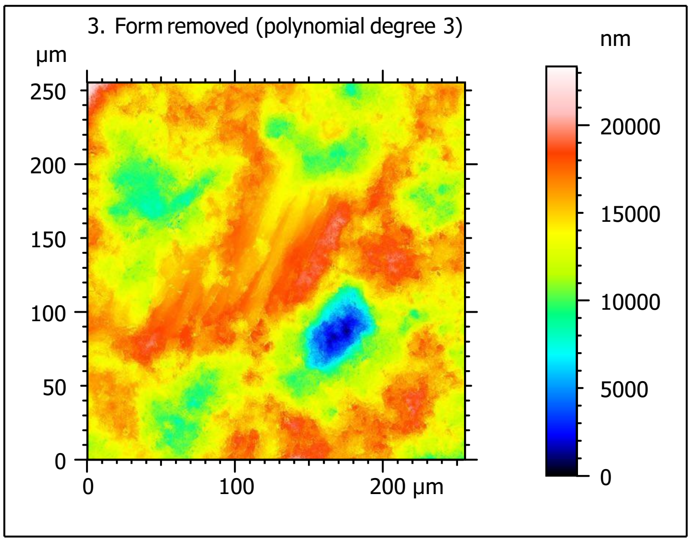
Processing

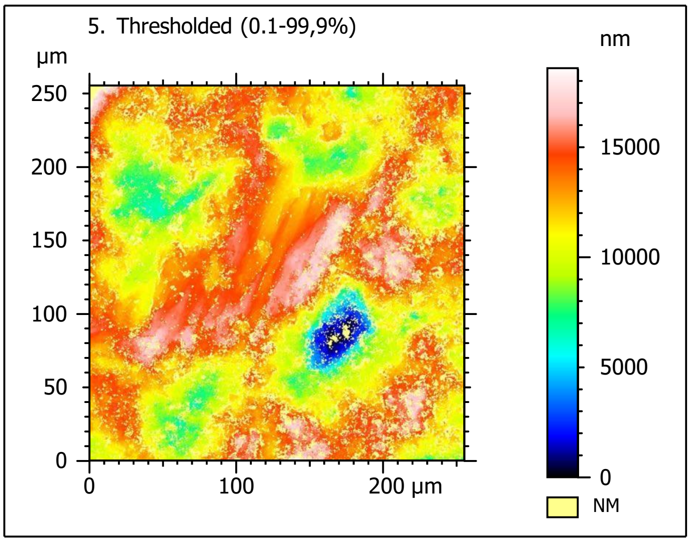


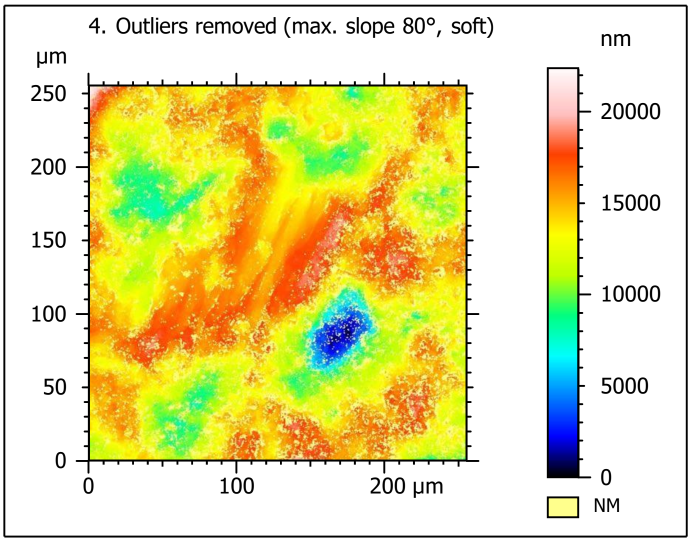
Identity card		
Name:	lime6-1_lsm_50x-0.75_20200914_surf2_Topo	
Created on:	9/14/2020 3:24:30 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	41865	nm
Size:	65532	digits
Spacing:	0.6389	nm
NM-points ratio:	0.000 % (0 Pts)	

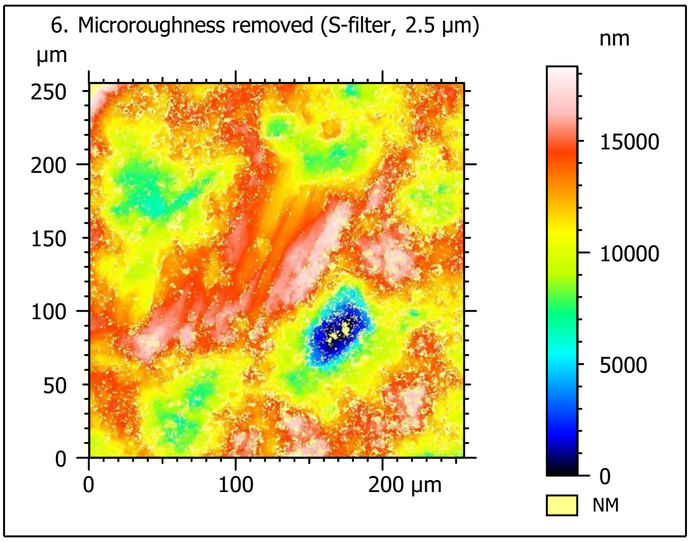



2. Leveled surface (least squares plane, substraction)
µm
nm
250
200
150
100
50
0
0
100
200 µm
25000
20000
15000
10000
5000
0

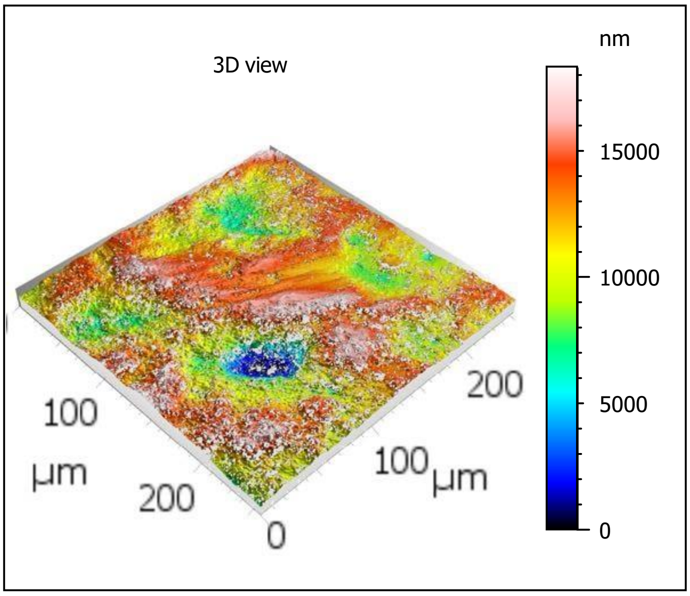

3. Form removed (polynomial degree 3)
µm
nm
250
200
150
100
50
0
0
100
200 µm
20000
15000
10000
5000
0

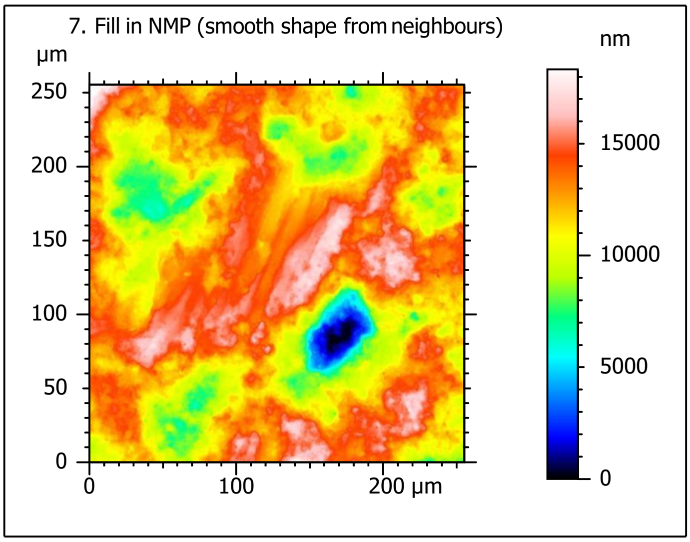

5. Thresholded (0.1-99,9%)
µm
nm
250
200
150
100
50
0
0
100
200 µm
15000
10000
5000
0
NM

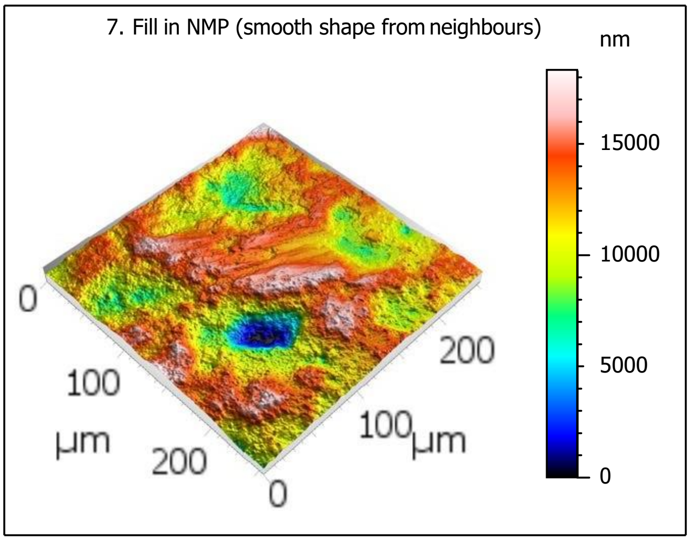

4. Outliers removed (max. slope 80°, soft)
µm
nm
250
200
150
100
50
0
0
100
200 µm
20000
15000
10000
5000
0
NM



Identity card			
Name:	lime6-1_lsm_50x-0.75…filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R…0914_surf2_Topo.sur		
Created on:	9/14/2020 3:24:30 PM		
Studiable type:	Surface		
Axis:	X		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Offset:	0.000	µm	
Axis:	Y		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Offset:	-255.3	µm	
Axis:	Z		
Layer type:	Topography		
Length:	18330	nm	
Min:	-11965	nm	
Max:	6364	nm	
Size:	286917	digits	
Spacing:	0.06389	nm	
NM-points ratio:	20.03 % (210030 Pts)		





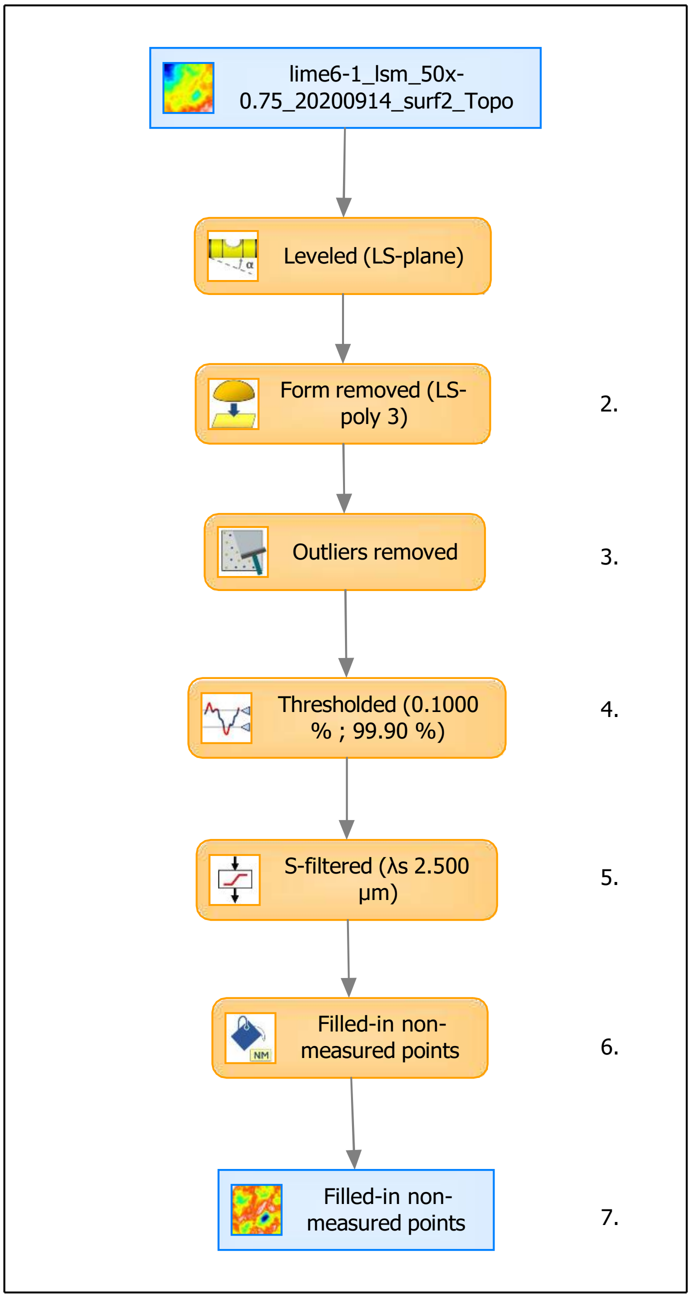


Identity card			
Name:	lime6-1_lsm_50x-0.75_...in non-measured points		
Created on:	9/14/2020 3:24:30 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Axis:	**Y**		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	18330	nm	
Size:	286917	digits	
Spacing:	0.06389	nm	
NM-points ratio:	0.000 % (0 Pts)		

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	2674	nm
Ssk	-0.9445	
Sku	4.888	
Sp	6323	nm
Sv	12007	nm
Sz	18330	nm
Sa	2086	nm
Functional parameters		
Smr	0.2411	%
Smc	3066	nm
Sxp	5968	nm
Spatial parameters		
Sal	26.38	µm
Str	0.5184	
Std	67.25	°
Hybrid parameters		
Sdq	0.4674	
Sdr	9.592	%
Functional parameters (Volume)		
Vm	0.07668	µm³/µm²
Vv	3.142	µm³/µm²
Vmp	0.07668	µm³/µm²
Vmc	2.407	µm³/µm²
Vvc	2.771	µm³/µm²
Vvv	0.3713	µm³/µm²



Analyses:

ISO 25178 8.

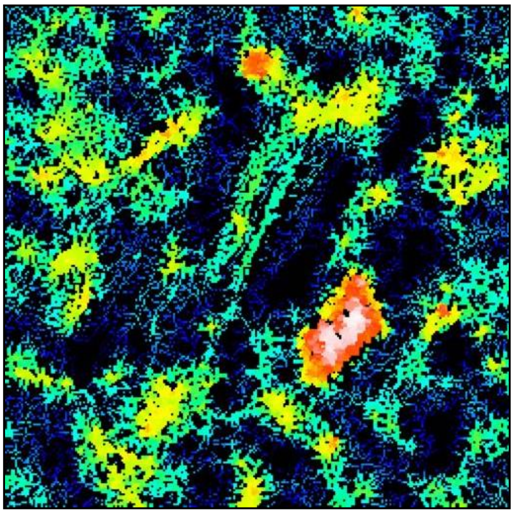
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

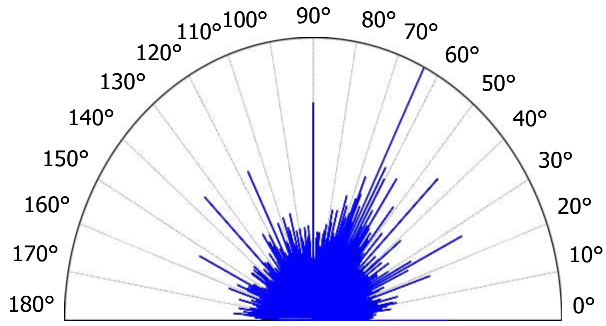
9. Furrow analysis on surface #7



All furrows are shown.

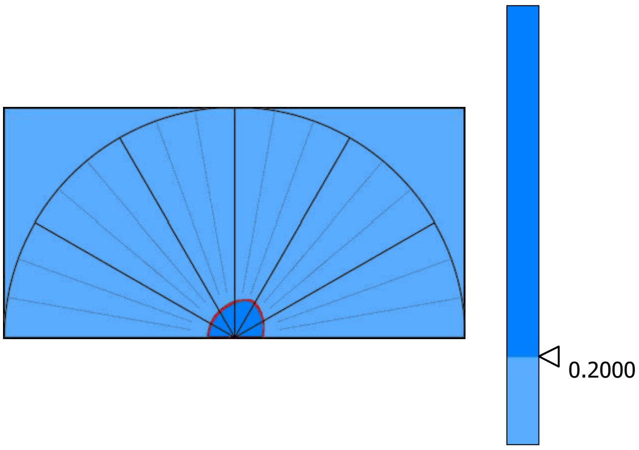
Parameters	Value	Unit	
Maximum depth of furrows	8068	nm	
Mean depth of furrows	2392	nm	
Mean density of furrows	2583	cm/cm2	

10. Texture direction on surface #7



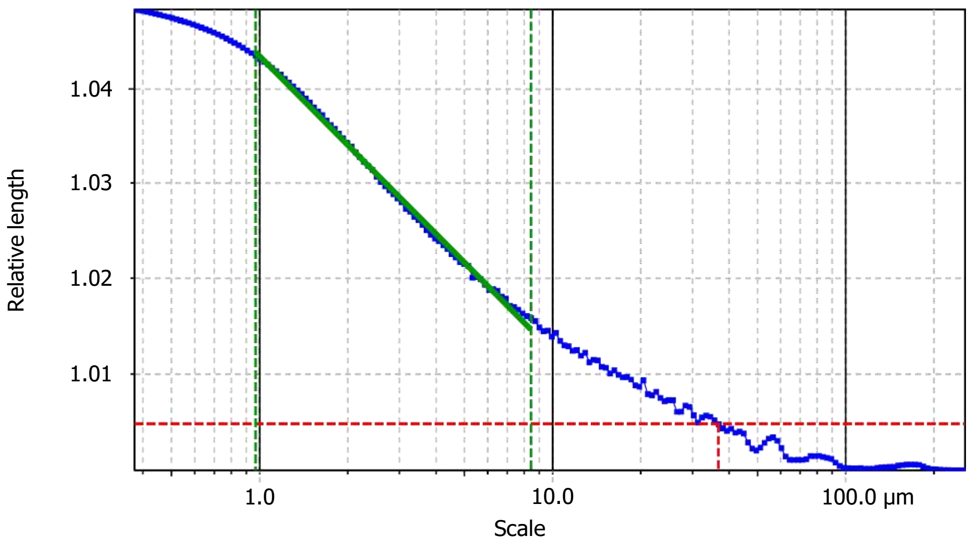
Parameters	Value	Unit	
First direction	63.53	°	
Second direction	90.01	°	
Third direction	45.00	°	

11. Texture isotropy on surface #7



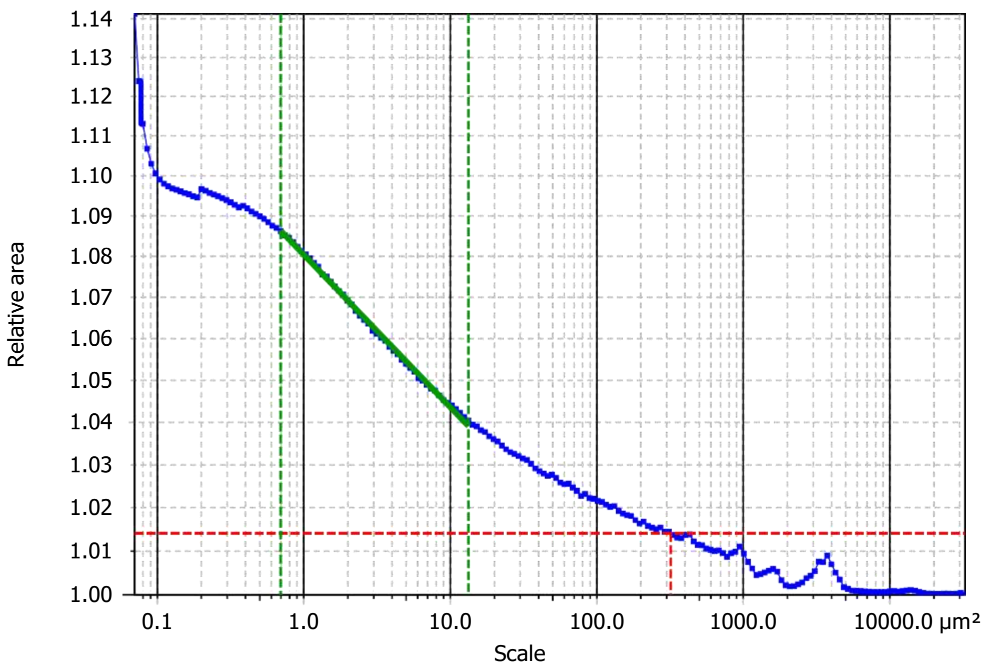
Parameters	Value	Unit	
Isotropy	66.88	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0008065		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01752		*Length-scale anisotropy (1.8 µm, 5°)*

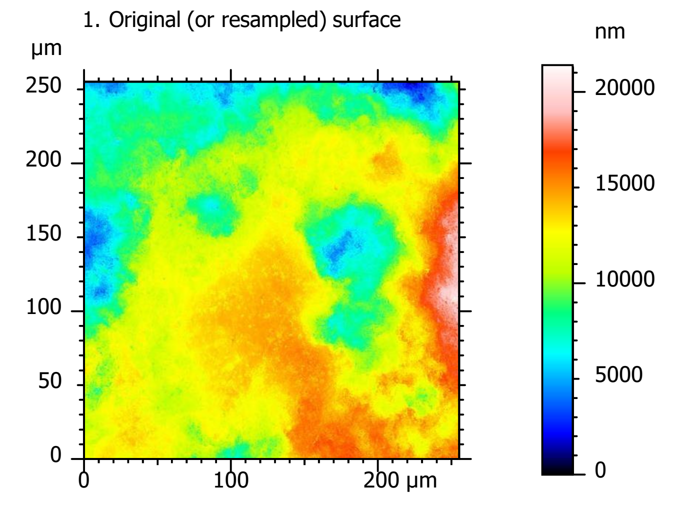


Information	
Method	Area-scale (four corners)

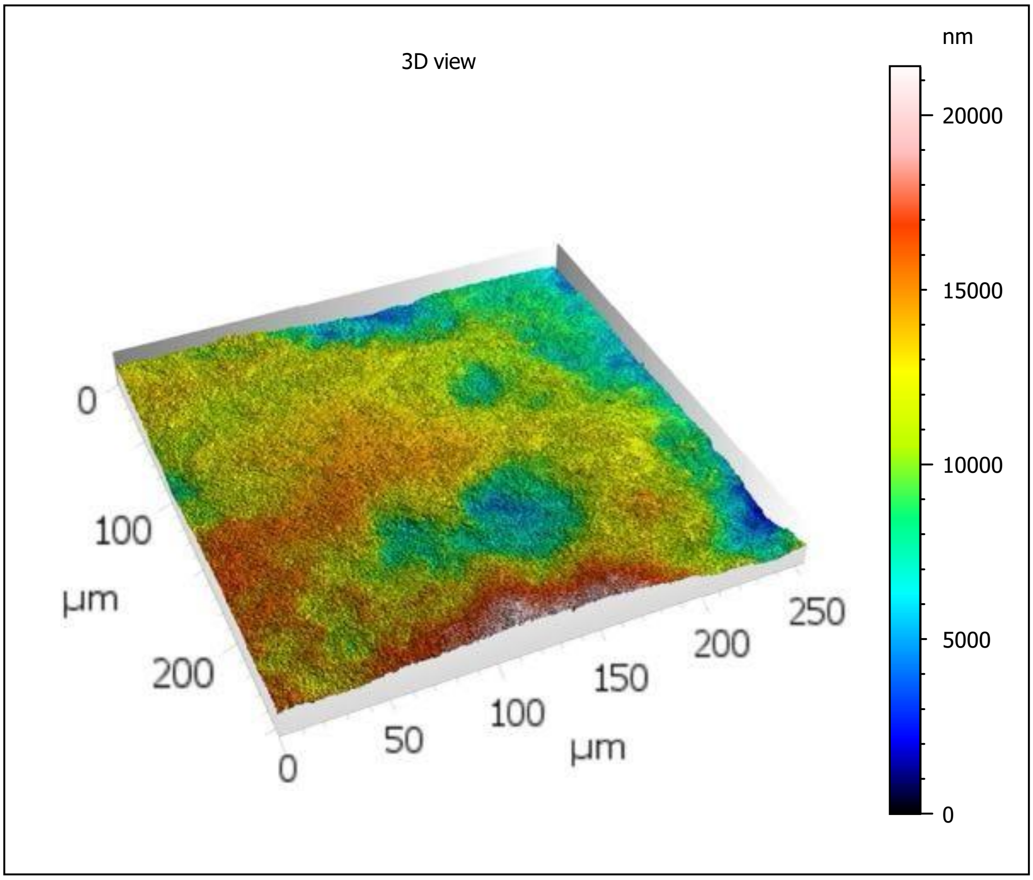
Parameters	Value	Unit	Comment
Asfc	15.07		*Fractal complexity*
Smfc	2.418	µm²	*Scale of max complexity*
HAsfc9	0.1536		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2216		*Heterogeneity of Asfc (9x9)*

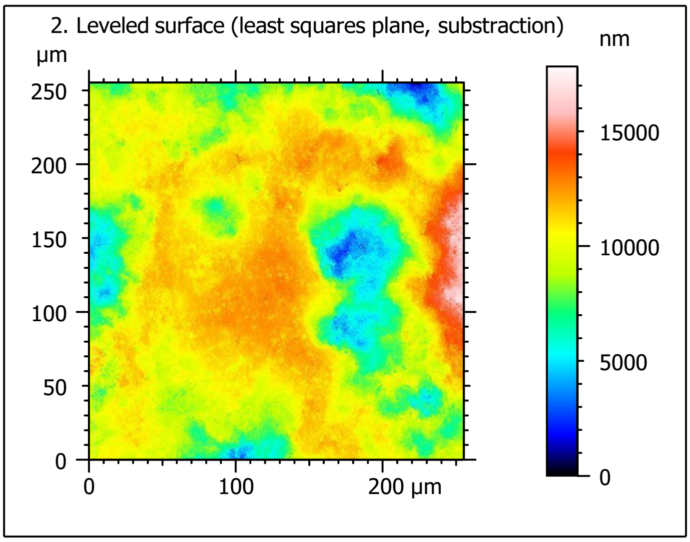
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

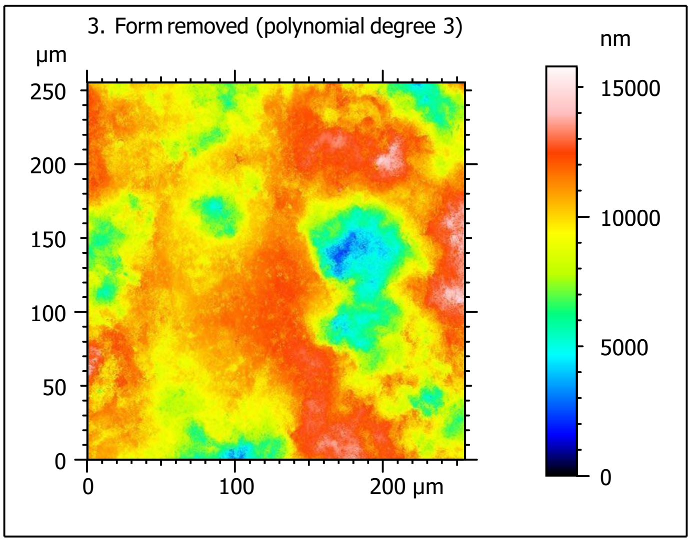
Processing

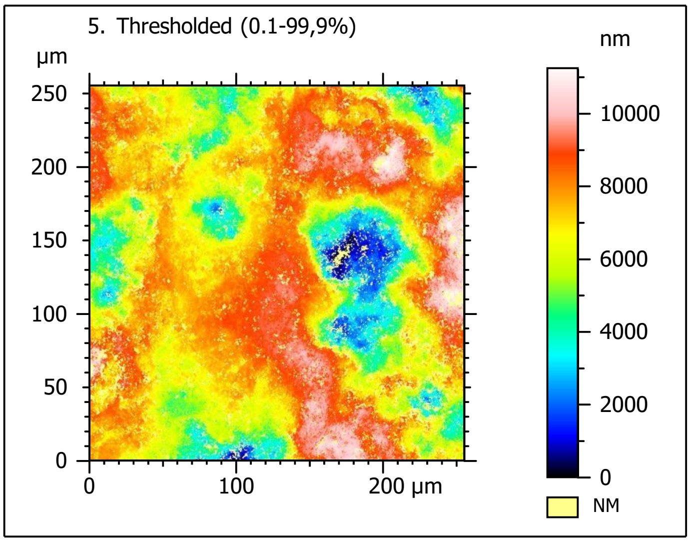


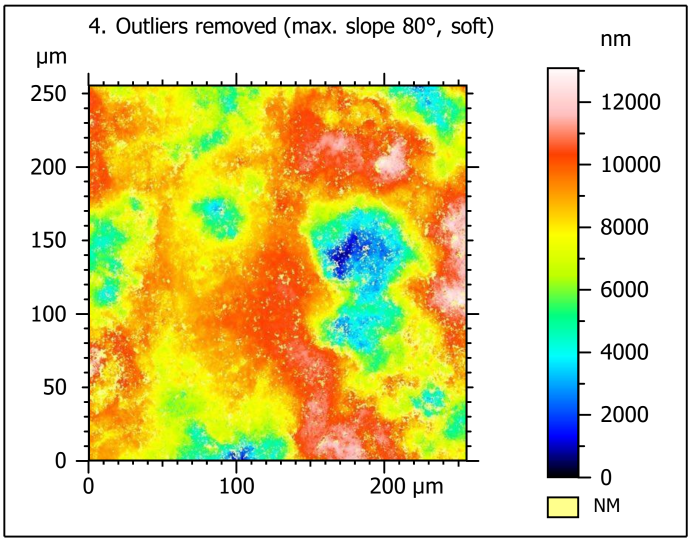
Identity card		
Name:	lime6-1_lsm_50x-0.75_20200914_surf3_Topo	
Created on:	9/14/2020 3:53:22 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	21401	nm
Size:	65532	digits
Spacing:	0.3266	nm
NM-points ratio:	0.000 % (0 Pts)	



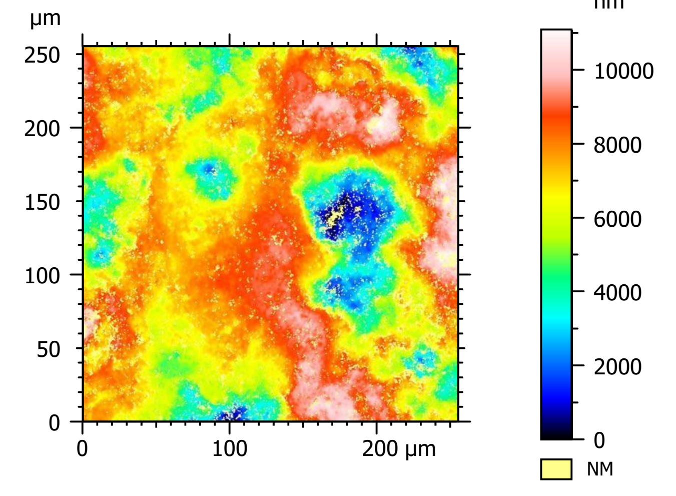

2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0


5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
8000
6000
4000
2000
0
NM

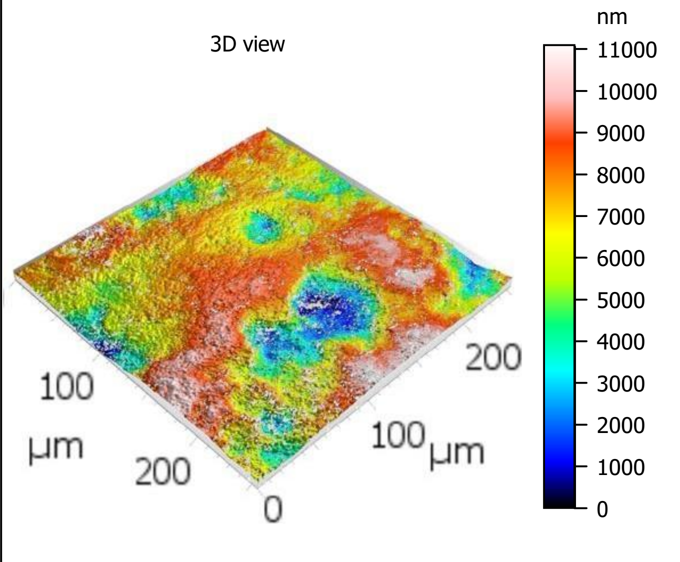

4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
12000
10000
8000
6000
4000
2000
0
NM

6. Microroughness removed (S-filter, 2.5 µm)

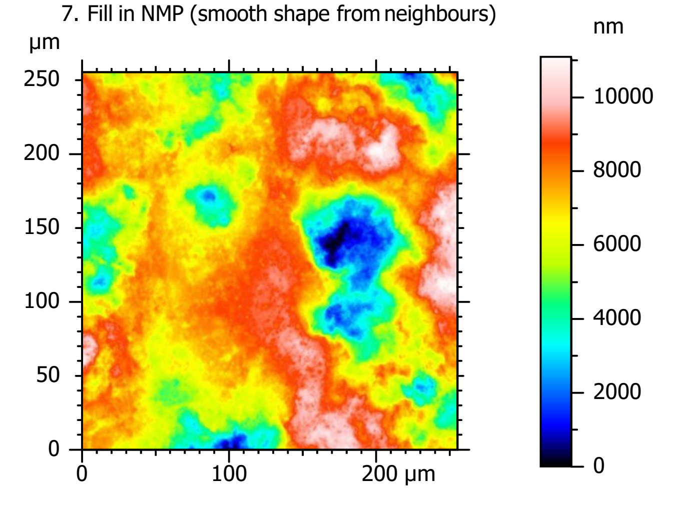


Identity card		
Name:	lime6-1_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…0914_surf3_Topo.sur	
Created on:	9/14/2020 3:53:22 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	11093	nm
Min:	-6768	nm
Max:	4325	nm
Size:	339683	digits
Spacing:	0.03266	nm
NM-points ratio:	11.14 % (116837 Pts)	

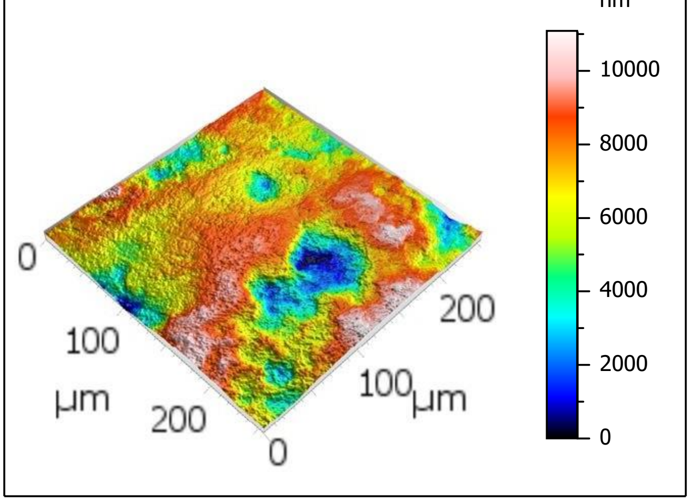
3D view



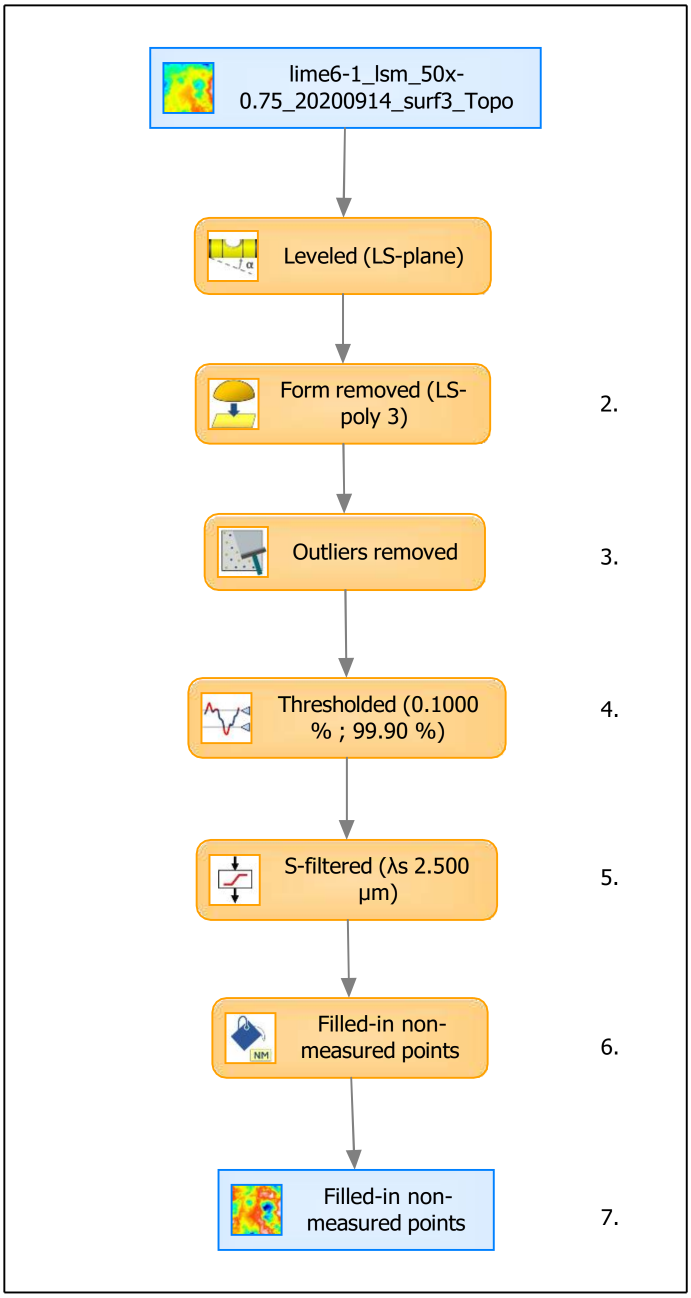
7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card		
Name:	lime6-1_lsm_50x-0.75_...in non-measured points	
Created on:	9/14/2020 3:53:22 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	11093	nm
Size:	339683	digits
Spacing:	0.03266	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1967	nm
Ssk	-0.6892	
Sku	3.236	
Sp	4301	nm
Sv	6792	nm
Sz	11093	nm
Sa	1551	nm
Functional parameters		
Smr	1.717	%
Smc	2276	nm
Sxp	4918	nm
Spatial parameters		
Sal	27.39	µm
Str	0.5385	
Std	109.5	°
Hybrid parameters		
Sdq	0.3529	
Sdr	5.716	%
Functional parameters (Volume)		
Vm	0.05666	µm³/µm²
Vv	2.332	µm³/µm²
Vmp	0.05666	µm³/µm²
Vmc	1.788	µm³/µm²
Vvc	2.022	µm³/µm²
Vvv	0.3105	µm³/µm²

Analyses:

ISO 25178 8.

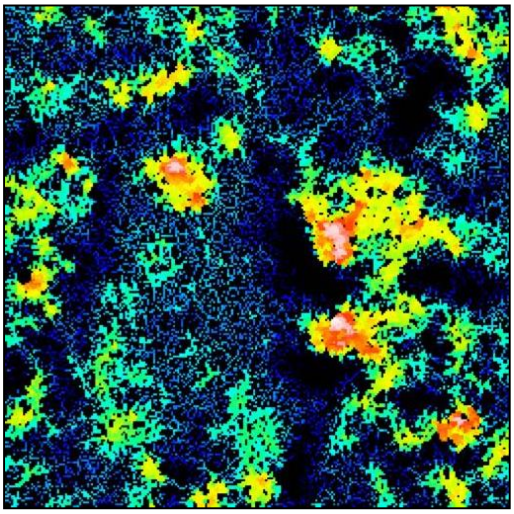
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

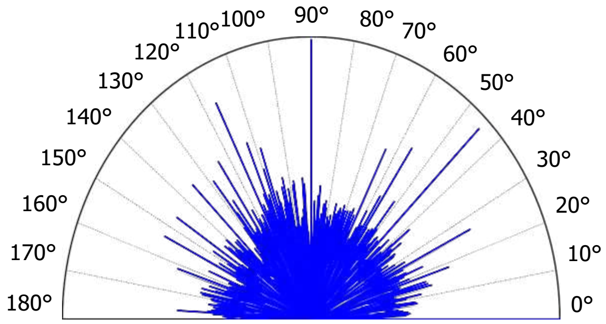
9. Furrow analysis on surface #7



All furrows are shown.

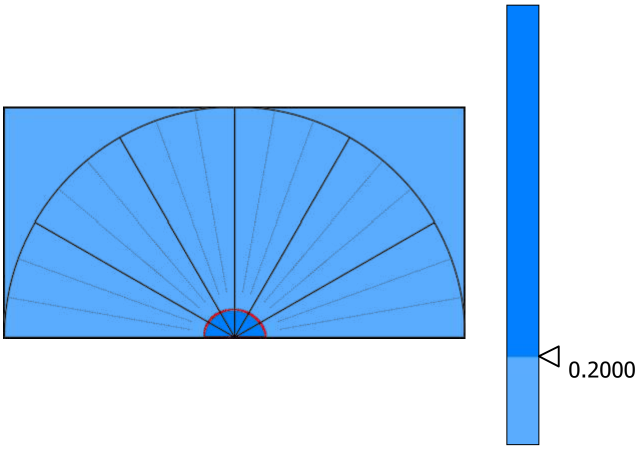
Parameters	Value	Unit
Maximum depth of furrows	5294	nm
Mean depth of furrows	1405	nm
Mean density of furrows	2852	cm/cm2

10. Texture direction on surface #7



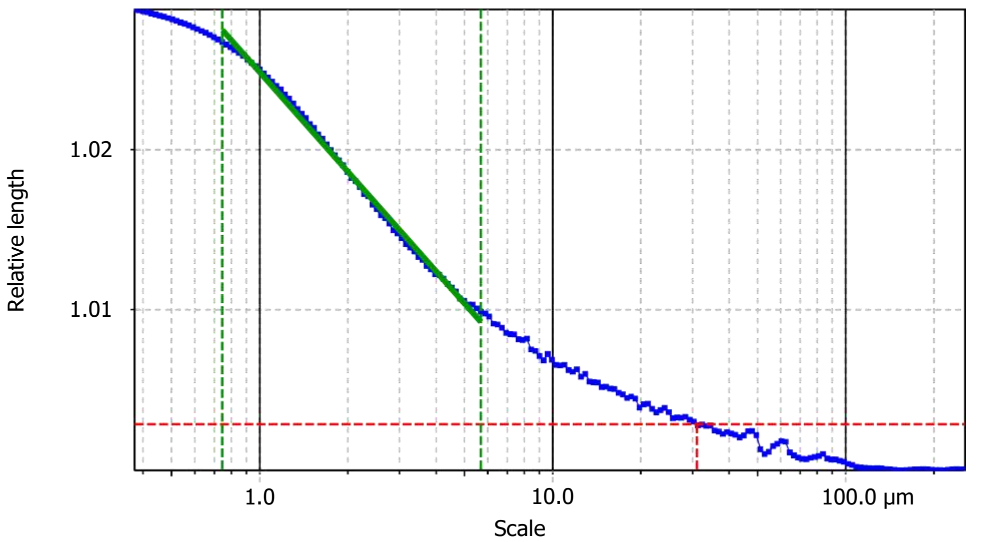
Parameters	Value	Unit
First direction	180.0	°
Second direction	90.00	°
Third direction	45.00	°

11. Texture isotropy on surface #7



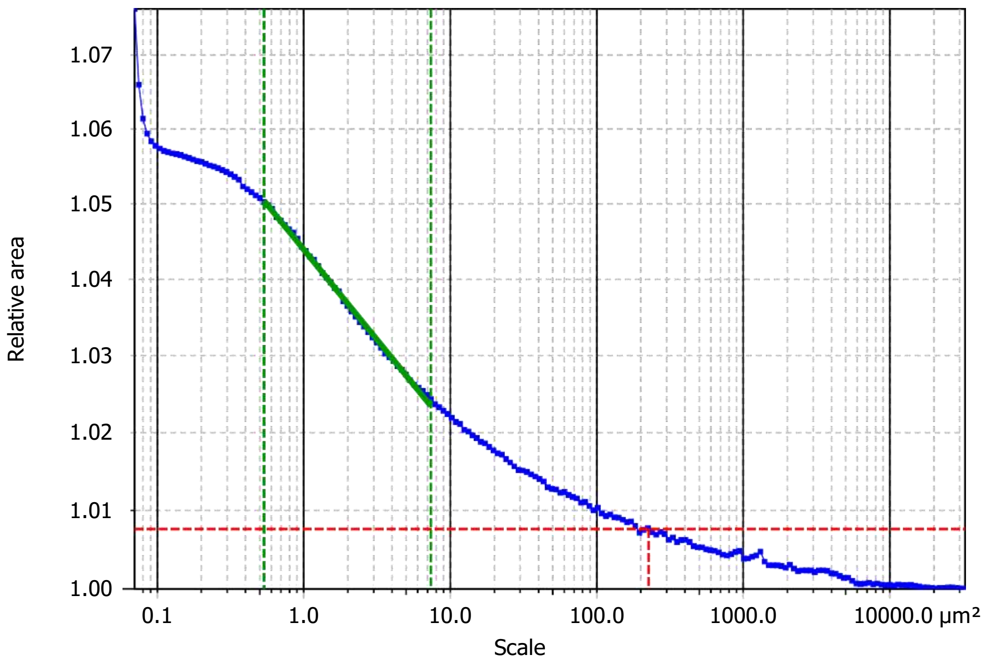
Parameters	Value	Unit
Isotropy	89.39	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001198		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01748		*Length-scale anisotropy (1.8 µm, 5°)*

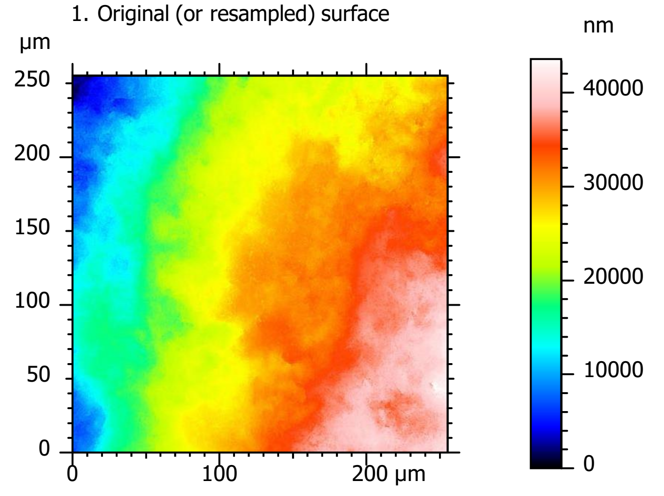


Information	
Method	Area-scale (four corners)

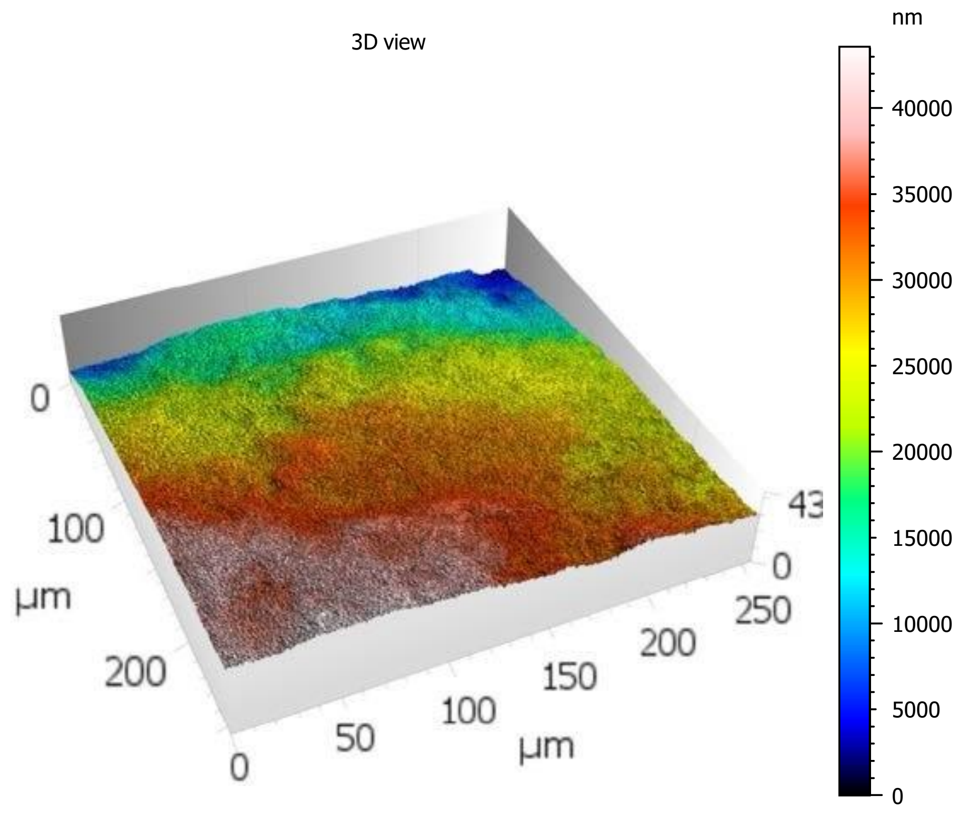
Parameters	Value	Unit	Comment
Asfc	9.914		*Fractal complexity*
Smfc	1.742	µm²	*Scale of max complexity*
HAsfc9	0.09734		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2383		*Heterogeneity of Asfc (9x9)*

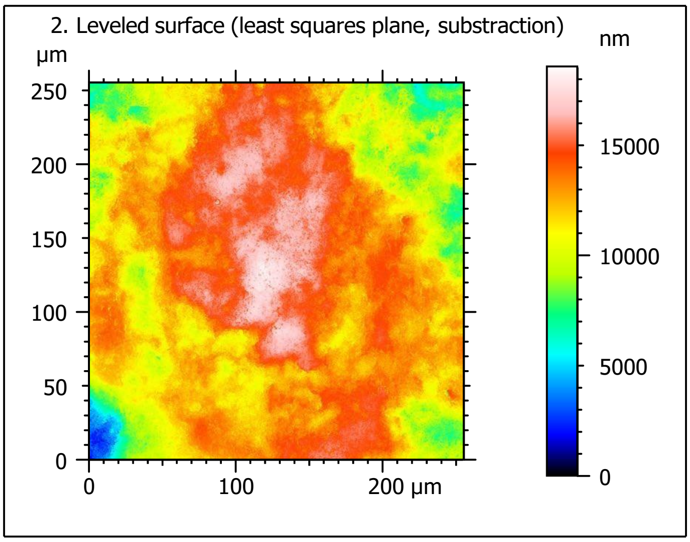
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

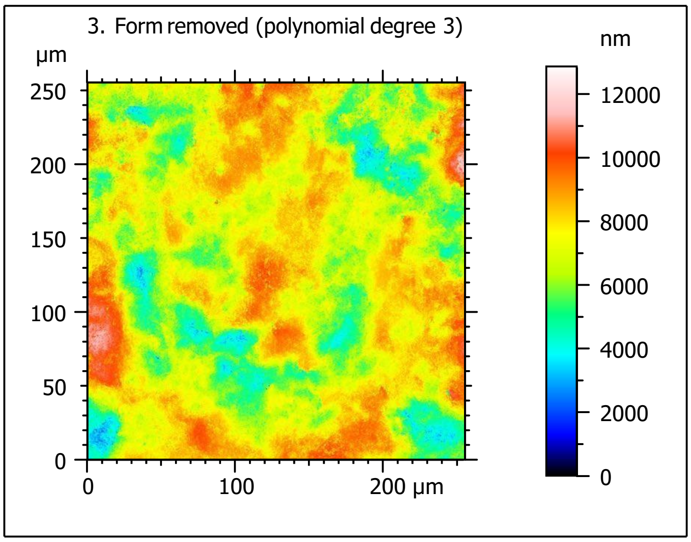
Processing

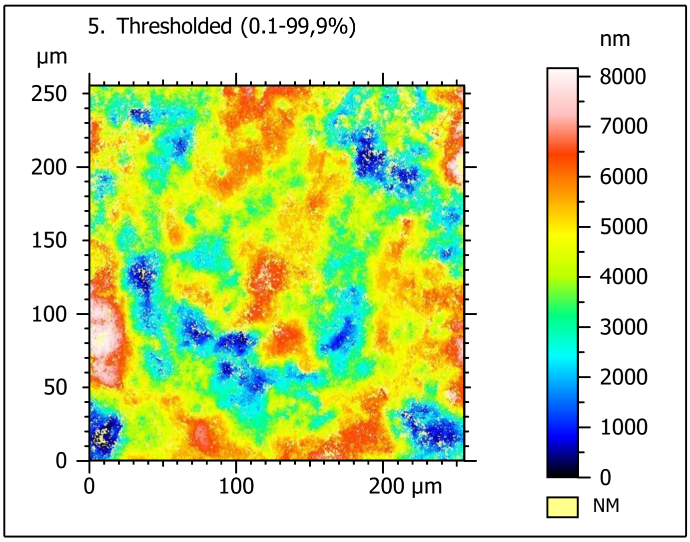


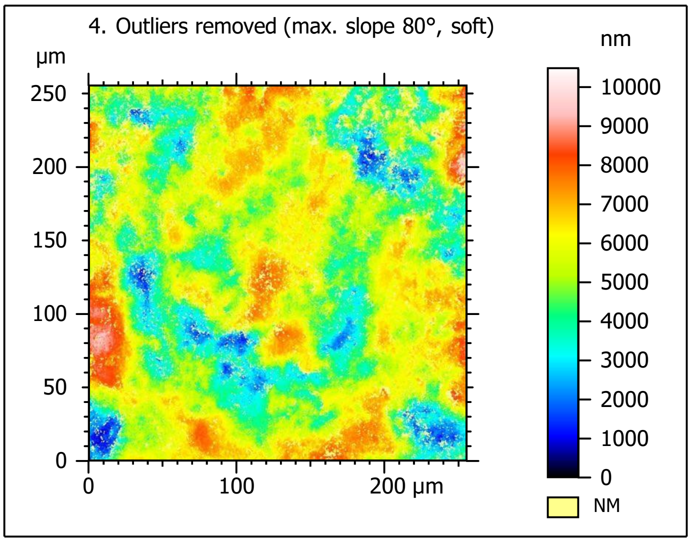
Identity card		
Name:	lime6-1_lsm_50x-0.75_20200914_surf4_Topo	
Created on:	9/14/2020 4:04:46 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	43574	nm
Size:	65532	digits
Spacing:	0.6649	nm
NM-points ratio:	0.000 % (0 Pts)	

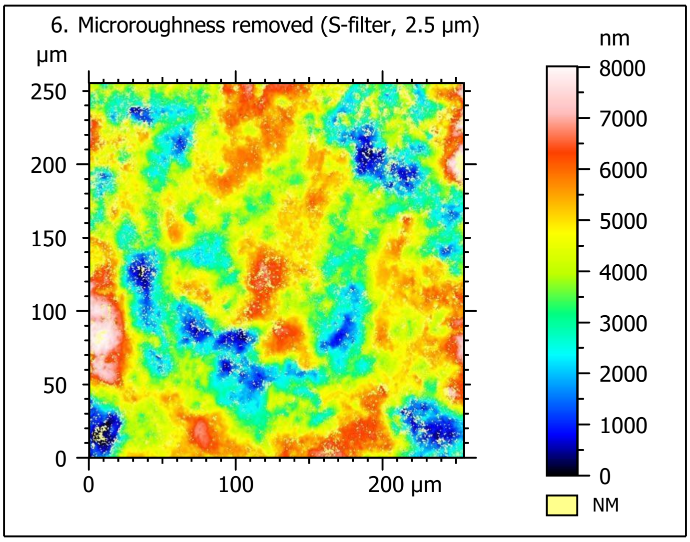


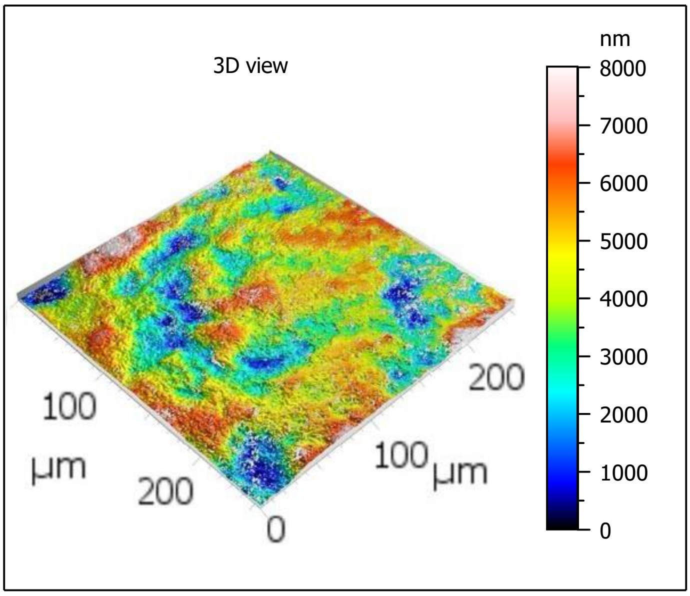

2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
12000
10000
8000
6000
4000
2000
0

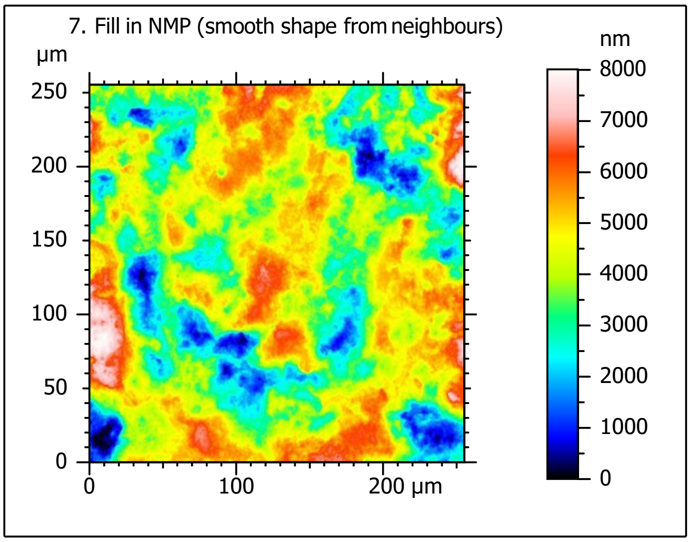

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
8000
7000
6000
5000
4000
3000
2000
1000
0
NM

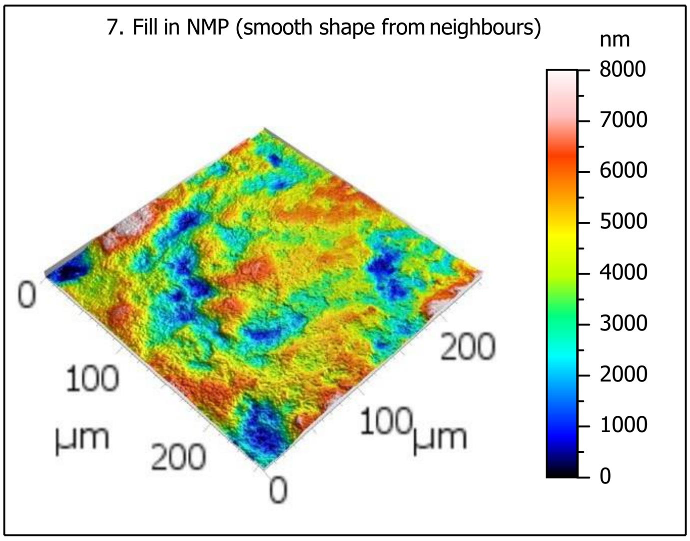

4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
NM





Identity card		
Name:	lime6-1_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…0914_surf4_Topo.sur	
Created on:	9/14/2020 4:04:46 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	8009	nm
Min:	-4019	nm
Max:	3990	nm
Size:	120454	digits
Spacing:	0.06649	nm
NM-points ratio:	10.91 % (114381 Pts)	





Identity card		
Name:	lime6-1_lsm_50x-0.75_...in non-measured points	
Created on:	9/14/2020 4:04:46 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	8009	nm
Size:	120454	digits
Spacing:	0.06649	nm
NM-points ratio:	0.000 % (0 Pts)	

lime6-1_lsm_50x-0.75_20200914_surf4_Topo

Leveled (LS-plane)

Form removed (LS-poly 3) 2.

Outliers removed 3.

Thresholded (0.1000 % ; 99.90 %) 4.

S-filtered (λs 2.500 µm) 5.

Filled-in non-measured points 6.

Filled-in non-measured points 7.

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1406	nm
Ssk	-0.1768	
Sku	2.803	
Sp	3970	nm
Sv	4039	nm
Sz	8009	nm
Sa	1130	nm
Functional parameters		
Smr	1.508	%
Smc	1711	nm
Sxp	3007	nm
Spatial parameters		
Sal	23.05	µm
Str	0.6955	
Std	97.51	°
Hybrid parameters		
Sdq	0.3397	
Sdr	5.360	%
Functional parameters (Volume)		
Vm	0.06179	µm³/µm²
Vv	1.772	µm³/µm²
Vmp	0.06179	µm³/µm²
Vmc	1.325	µm³/µm²
Vvc	1.604	µm³/µm²
Vvv	0.1686	µm³/µm²

Analyses:

ISO 25178 8.

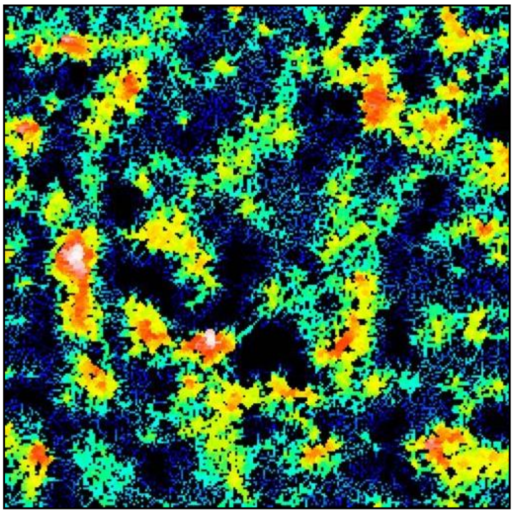
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

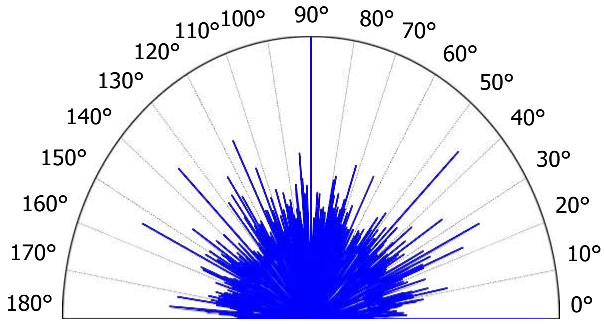
9. Furrow analysis on surface #7



All furrows are shown.

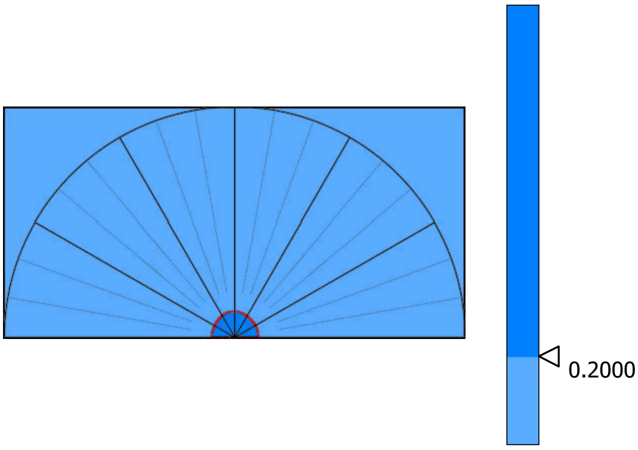
Parameters	Value	Unit
Maximum depth of furrows	4513	nm
Mean depth of furrows	1391	nm
Mean density of furrows	2835	cm/cm2

10. Texture direction on surface #7



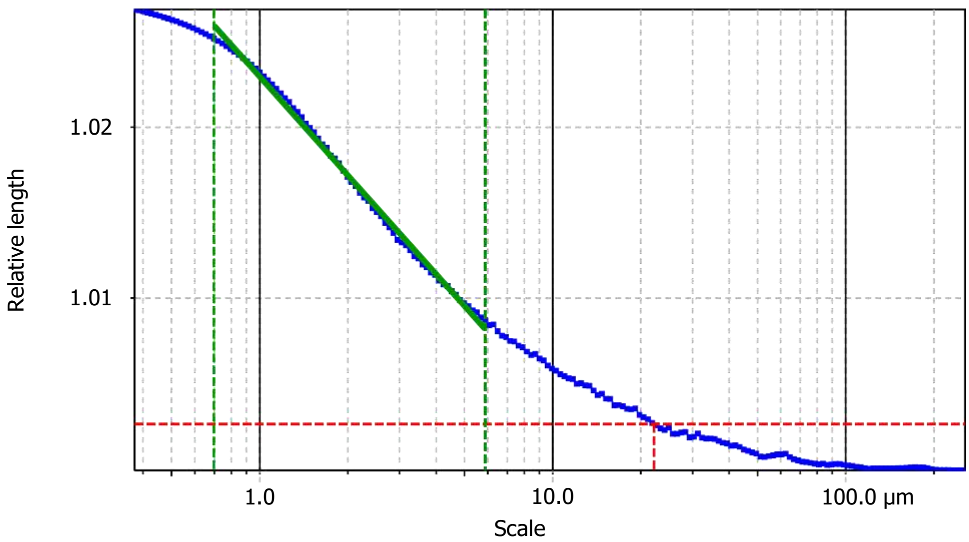
Parameters	Value	Unit
First direction	89.97	°
Second direction	0.003025	°
Third direction	45.00	°

11. Texture isotropy on surface #7



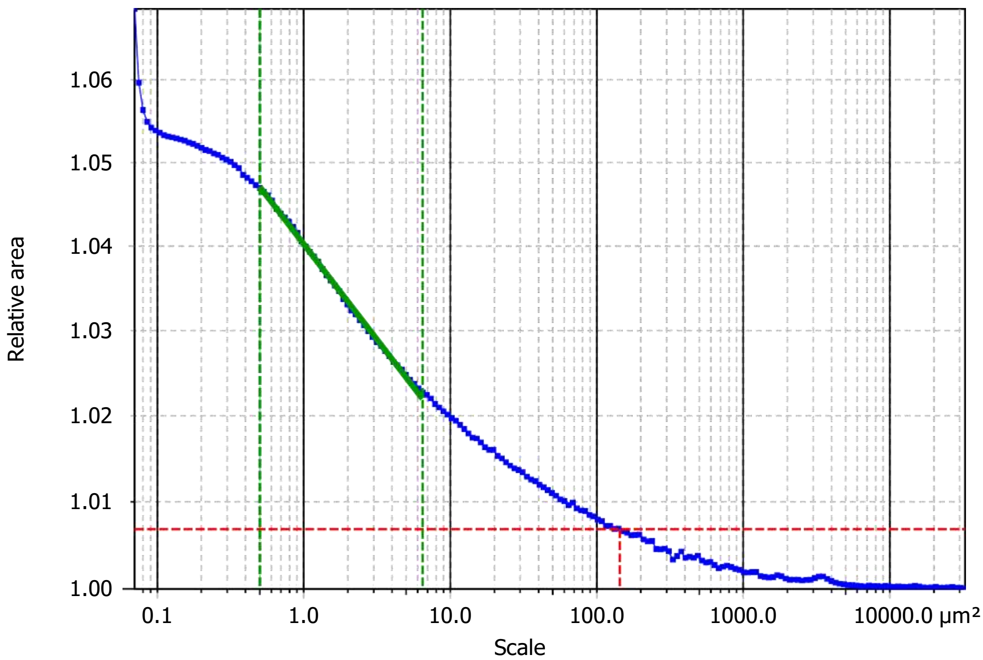
Parameters	Value	Unit
Isotropy	88.54	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0005148		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01758		*Length-scale anisotropy (1.8 µm, 5°)*

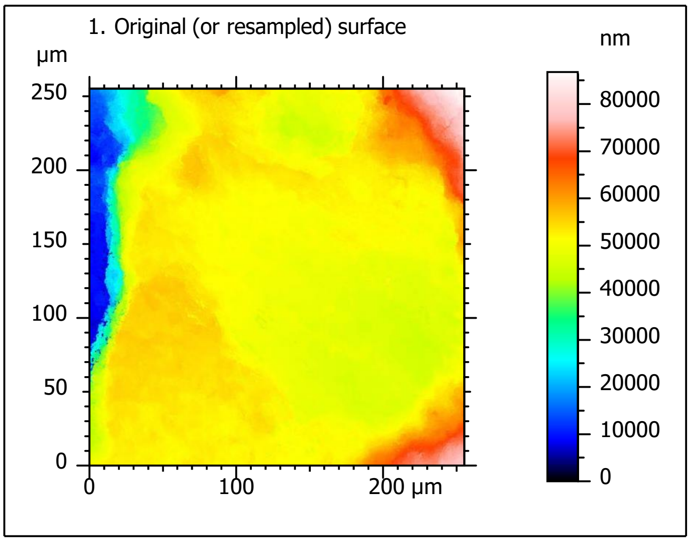


Information	
Method	Area-scale (four corners)

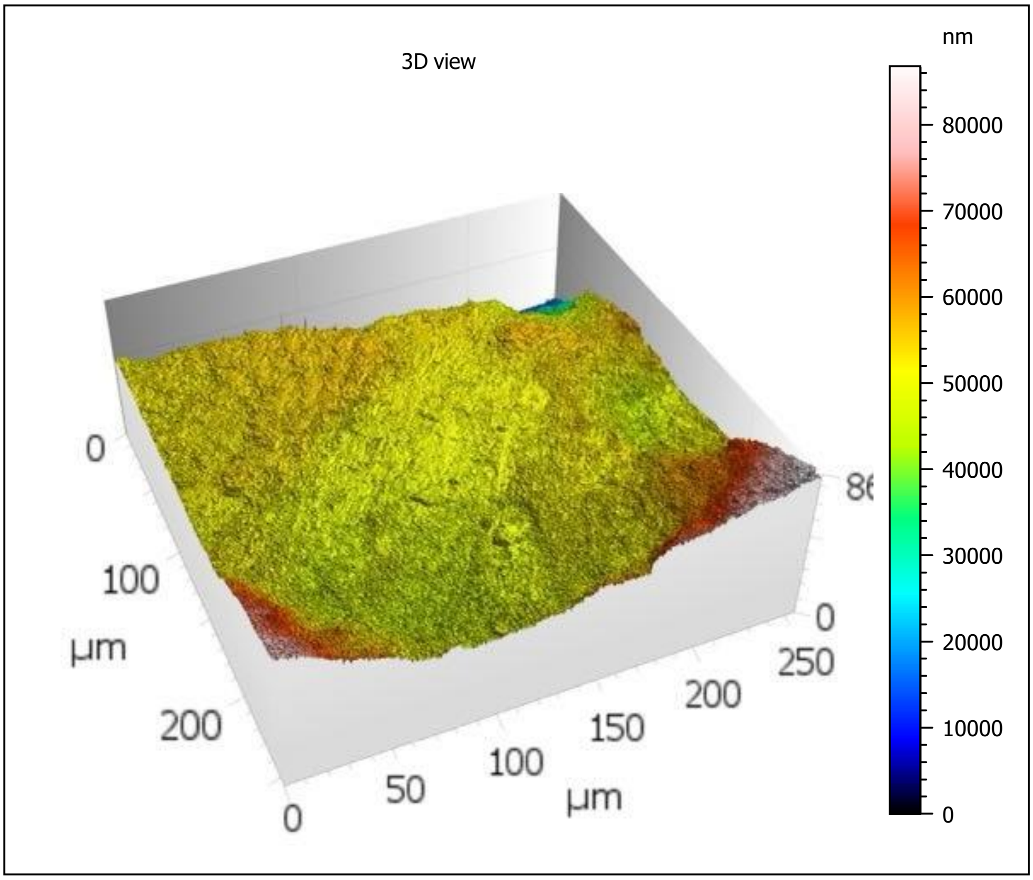
Parameters	Value	Unit	Comment
Asfc	9.477		*Fractal complexity*
Smfc	1.528	µm²	*Scale of max complexity*
HAsfc9	0.1493		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2280		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

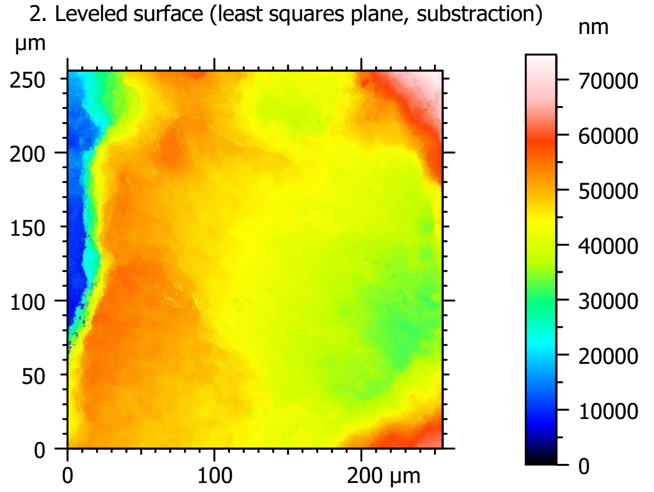
Processing



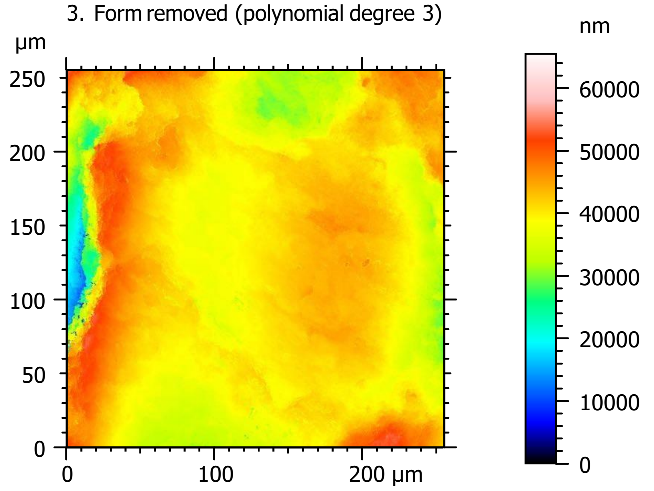
Identity card		
Name:	lime6-3_lsm_50x-0.75_20200915_surf1_Topo	
Created on:	9/15/2020 10:33:03 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	86795	nm
Size:	65531	digits
Spacing:	1.324	nm
NM-points ratio:	0.000 % (0 Pts)	



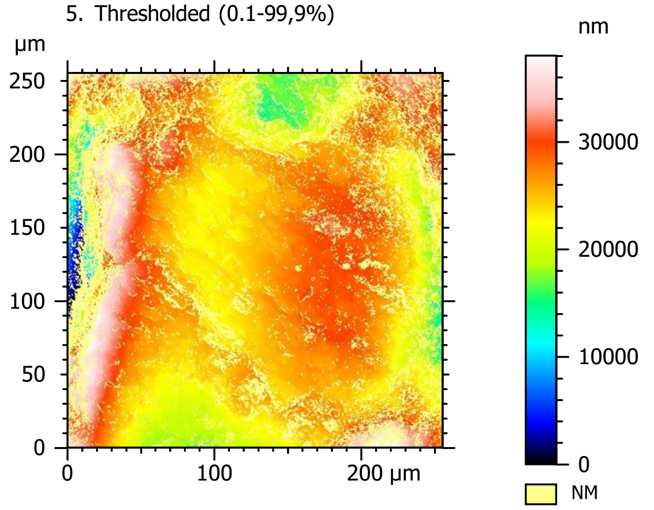
2. Leveled surface (least squares plane, substraction)



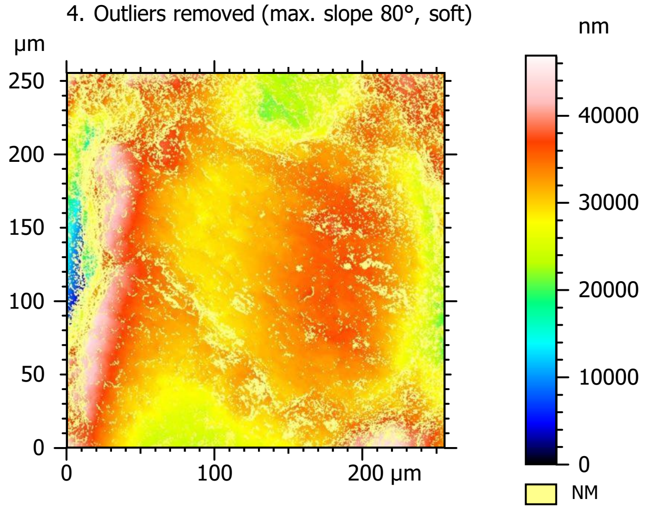
3. Form removed (polynomial degree 3)

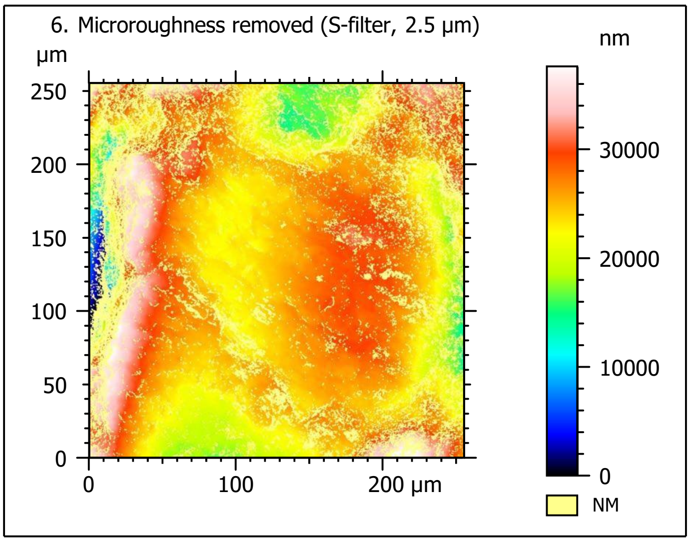


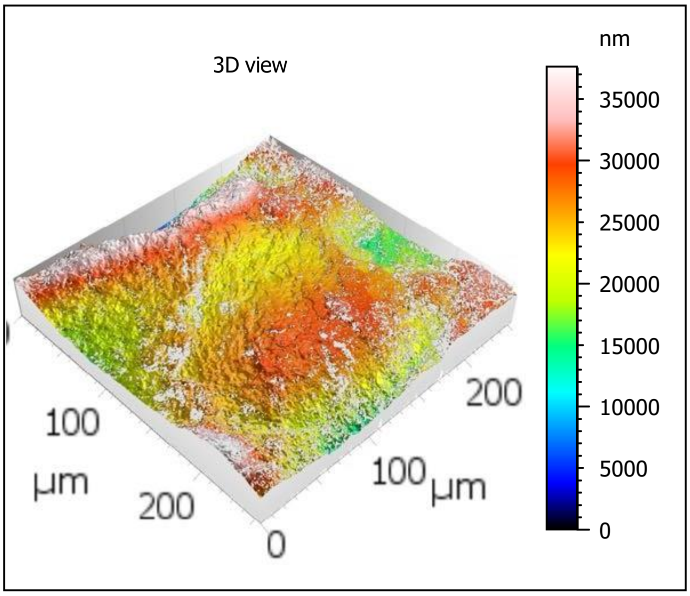
5. Thresholded (0.1-99,9%)



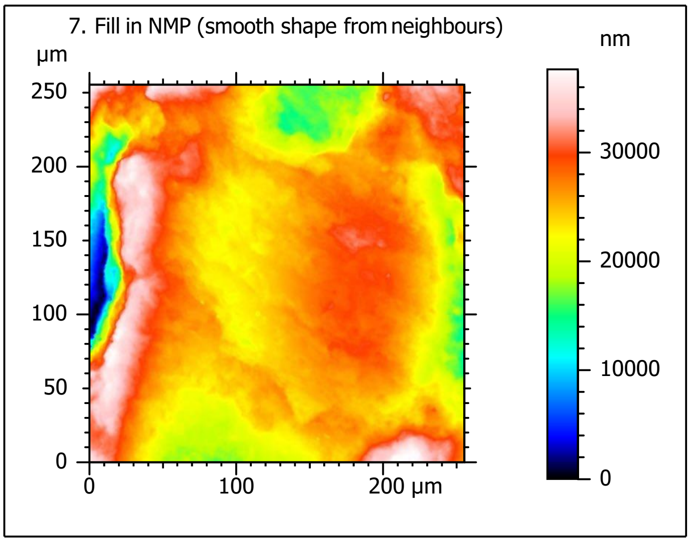
4. Outliers removed (max. slope 80°, soft)

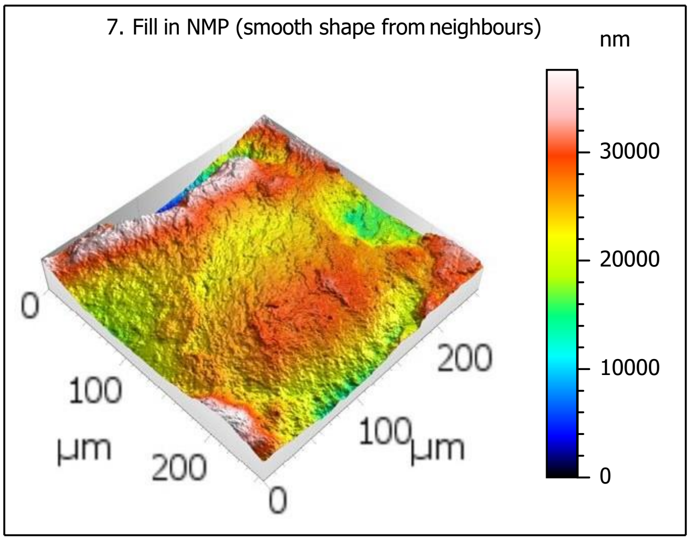




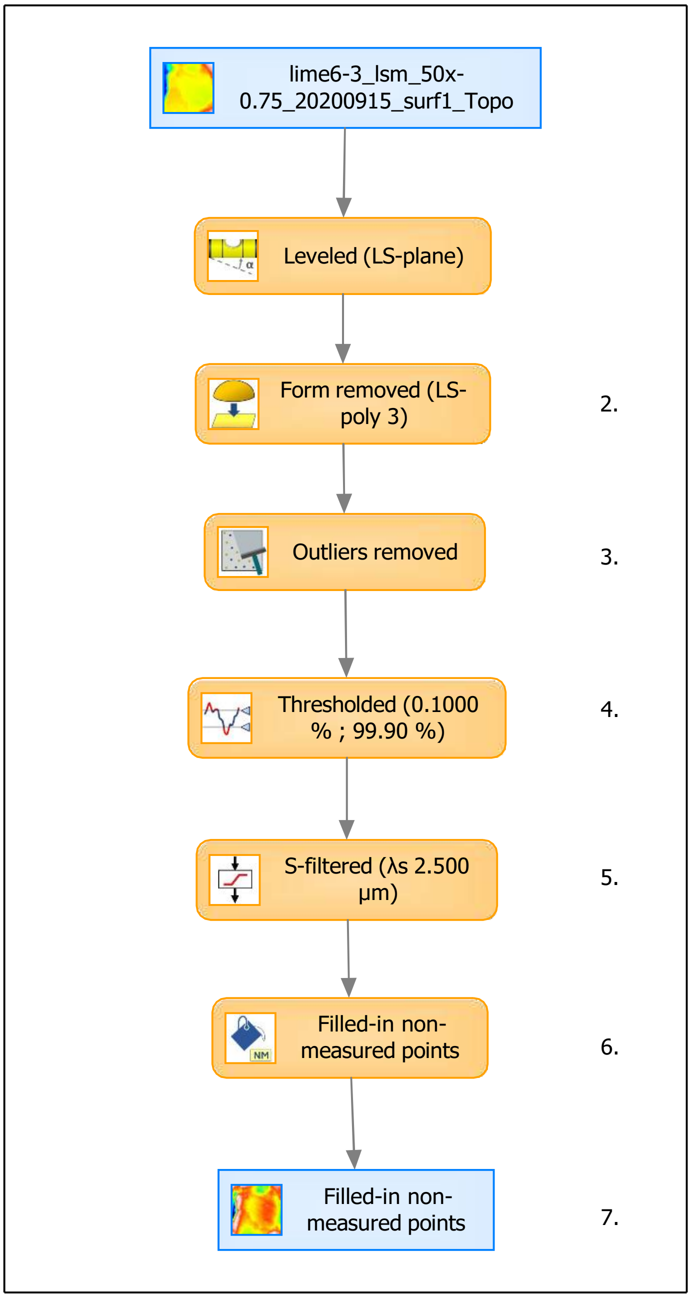


Identity card		
Name:	lime6-3_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…0915_surf1_Topo.sur	
Created on:	9/15/2020 10:33:03 AM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	37624	nm
Min:	-24980	nm
Max:	12644	nm
Size:	284067	digits
Spacing:	0.1324	nm
NM-points ratio:	26.13 % (274036 Pts)	





Identity card		
Name:	lime6-3_lsm_50x-0.75_...in non-measured points	
Created on:	9/15/2020 10:33:03 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	37624	nm
Size:	284067	digits
Spacing:	0.1324	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	5074	nm
Ssk	-0.9159	
Sku	6.044	
Sp	12511	nm
Sv	25113	nm
Sz	37624	nm
Sa	3691	nm
Functional parameters		
Smr	0.4115	%
Smc	5797	nm
Sxp	10651	nm
Spatial parameters		
Sal	21.83	µm
Str	0.3183	
Std	137.7	°
Hybrid parameters		
Sdq	0.6815	
Sdr	14.51	%
Functional parameters (Volume)		
Vm	0.2454	µm³/µm²
Vv	6.042	µm³/µm²
Vmp	0.2454	µm³/µm²
Vmc	3.626	µm³/µm²
Vvc	5.193	µm³/µm²
Vvv	0.8490	µm³/µm²

Analyses:

ISO 25178 8.

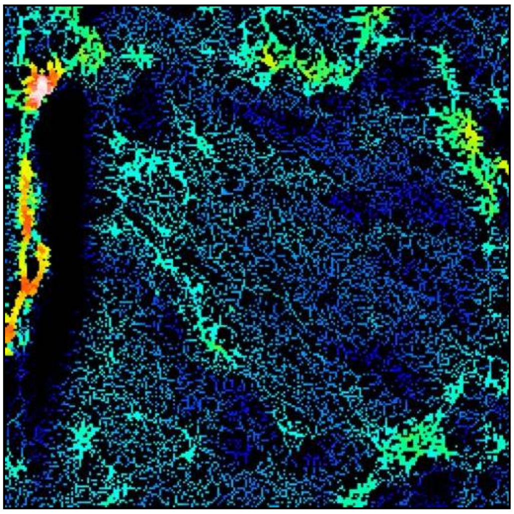
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

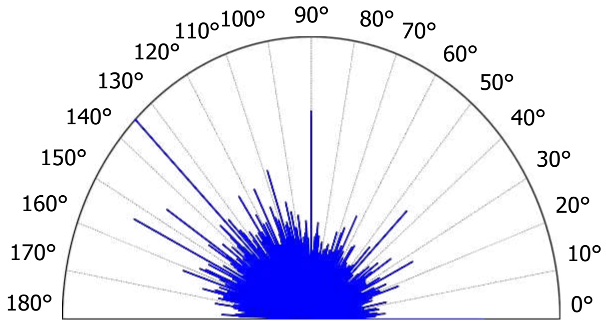
9. Furrow analysis on surface #7



All furrows are shown.

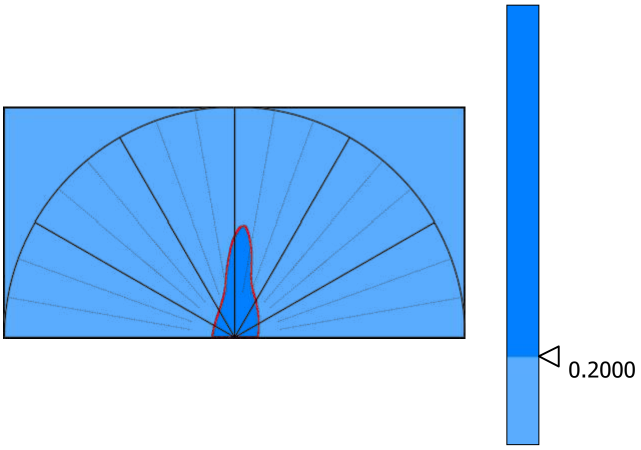
Parameters	Value	Unit	
Maximum depth of furrows	15971	nm	
Mean depth of furrows	3607	nm	
Mean density of furrows	2467	cm/cm2	

10. Texture direction on surface #7



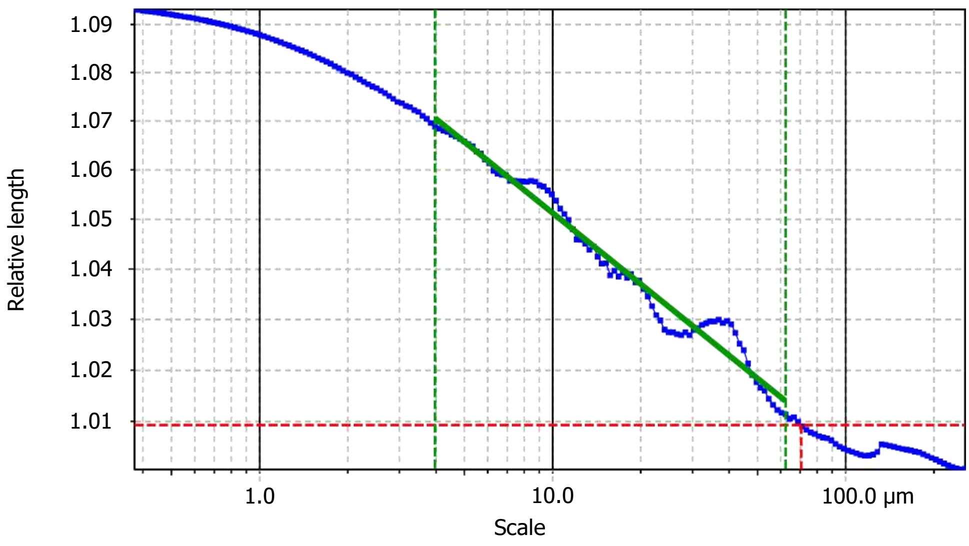
Parameters	Value	Unit	
First direction	135.0	°	
Second direction	153.5	°	
Third direction	90.03	°	

11. Texture isotropy on surface #7



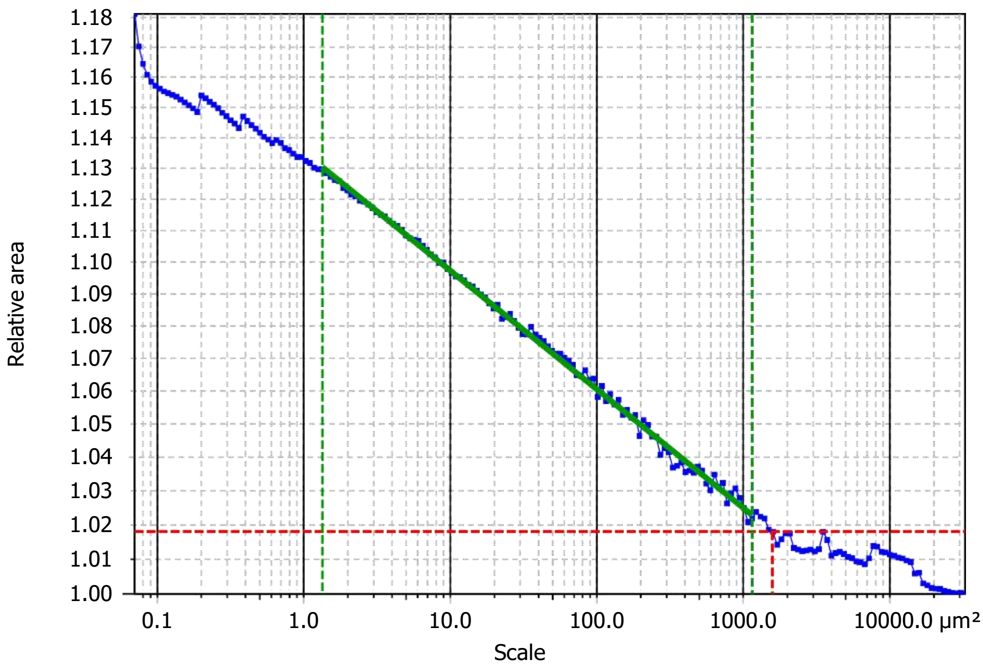
Parameters	Value	Unit	
Isotropy	20.07	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.003002		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01646		*Length-scale anisotropy (1.8 µm, 5°)*

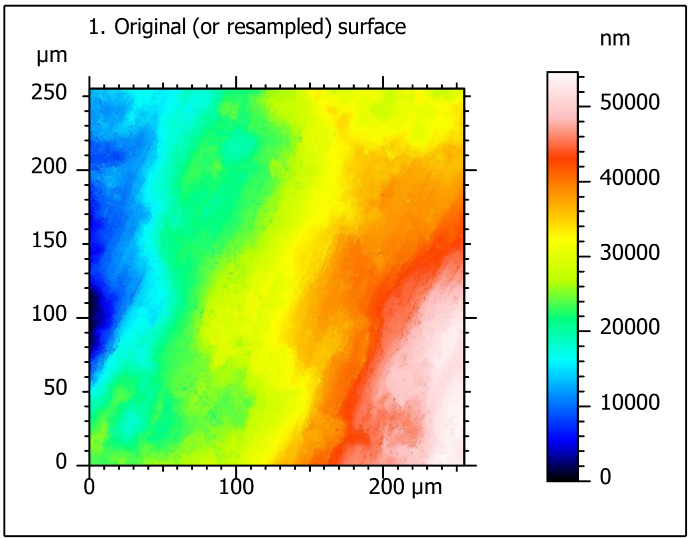


Information	
Method	Area-scale (four corners)

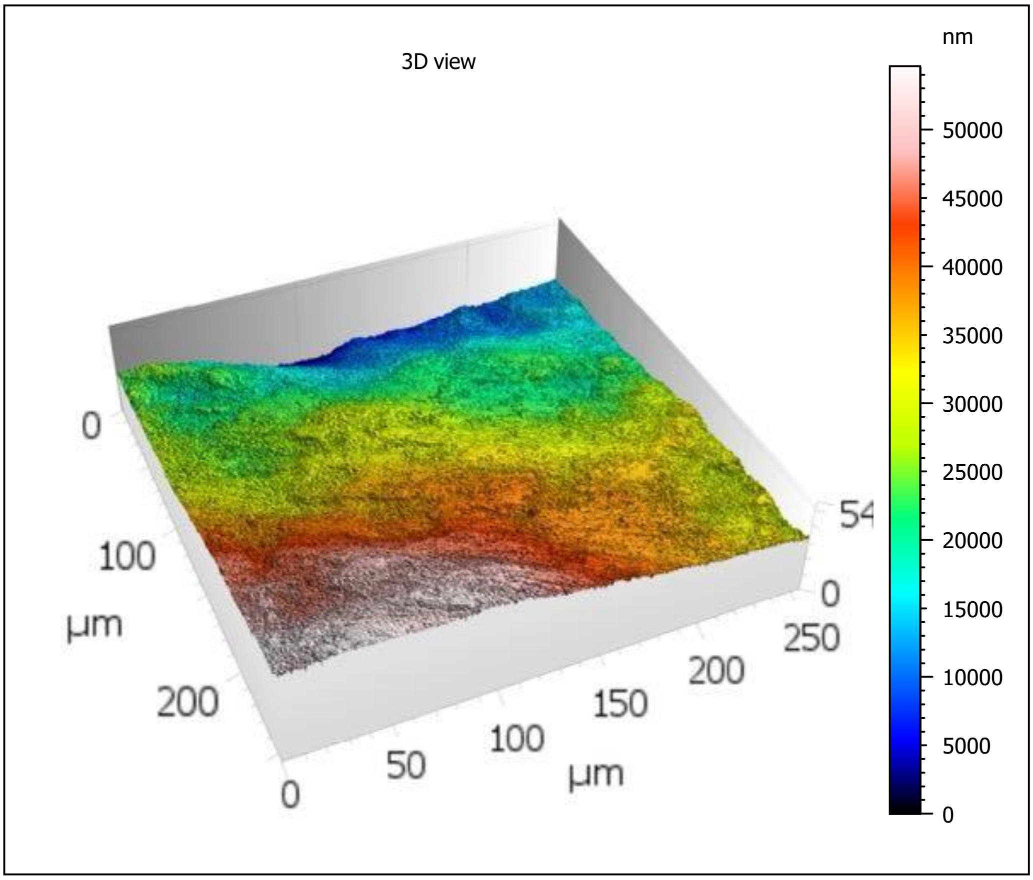
Parameters	Value	Unit	Comment
Asfc	14.81		*Fractal complexity*
Smfc	150.6	µm²	*Scale of max complexity*
HAsfc9	1.108		*Heterogeneity of Asfc (3x3)*
HAsfc81	1.561		*Heterogeneity of Asfc (9x9)*

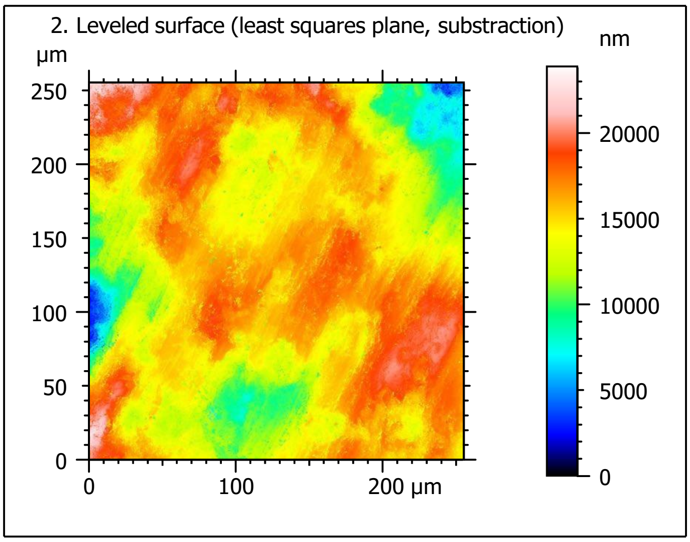
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

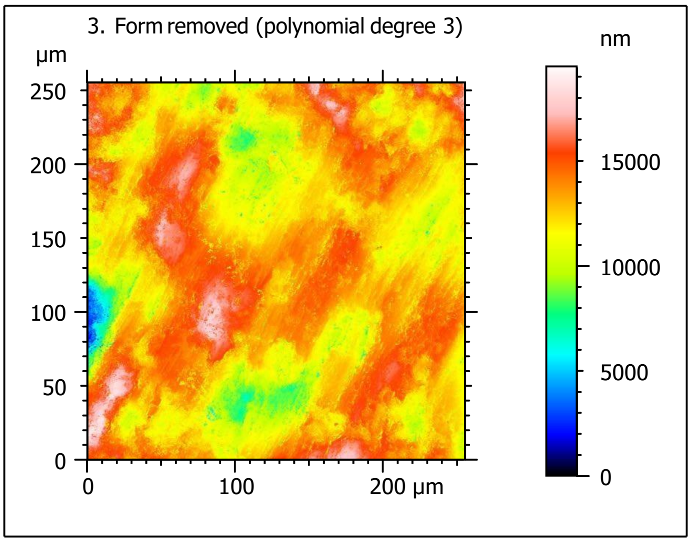
Processing

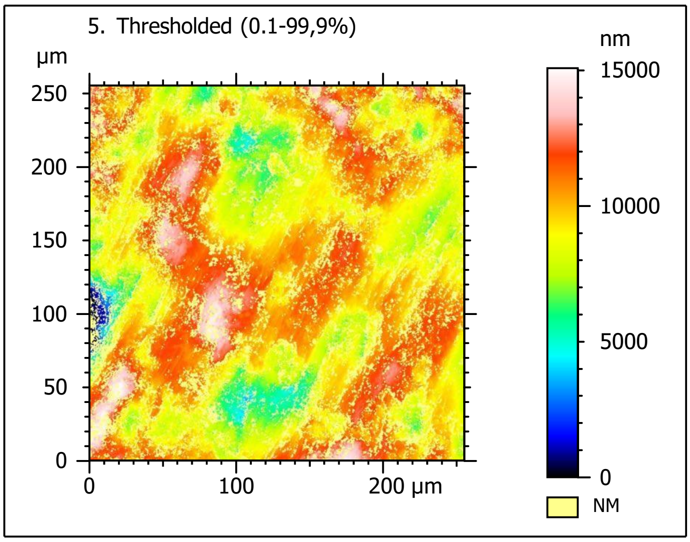


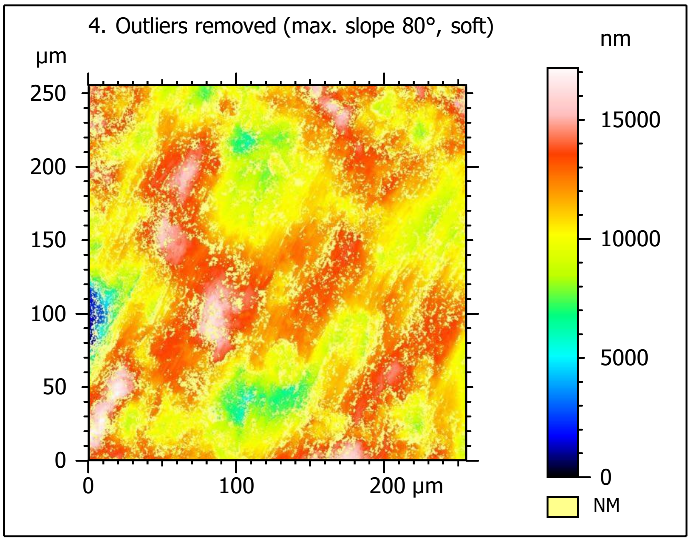
Identity card		
Name:	lime6-3_lsm_50x-0.75_20200915_surf2_Topo	
Created on:	9/15/2020 11:11:26 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	54626	nm
Size:	65532	digits
Spacing:	0.8336	nm
NM-points ratio:	0.000 % (0 Pts)	

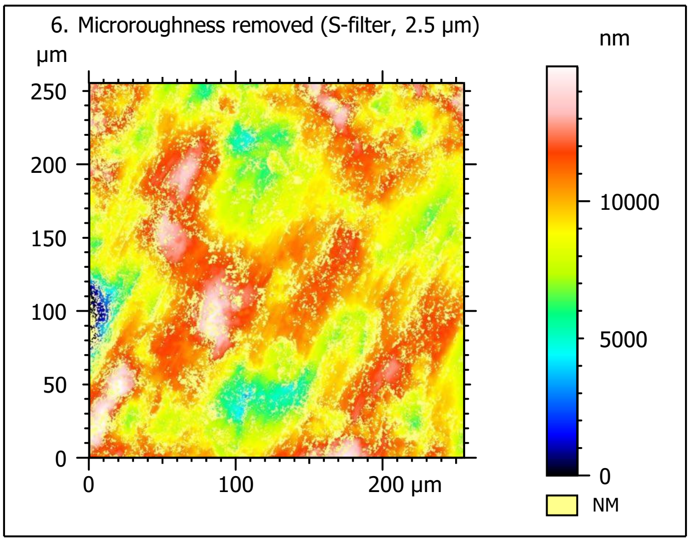



2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
20000
15000
10000
5000
0

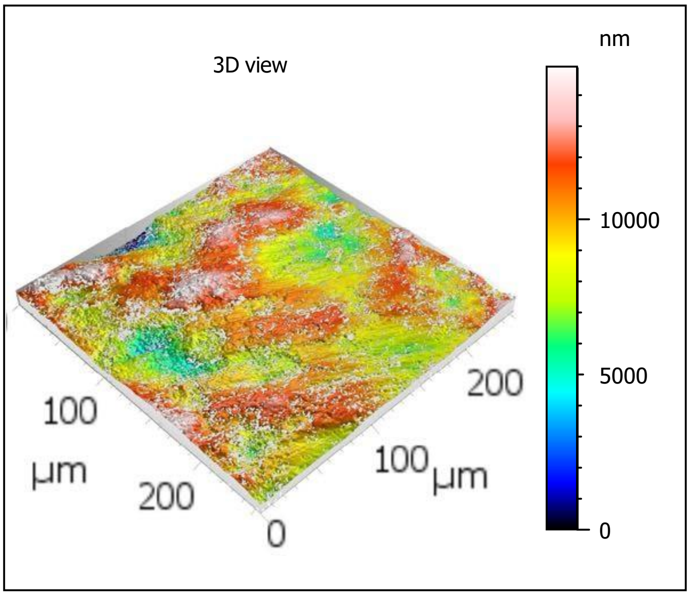

3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0

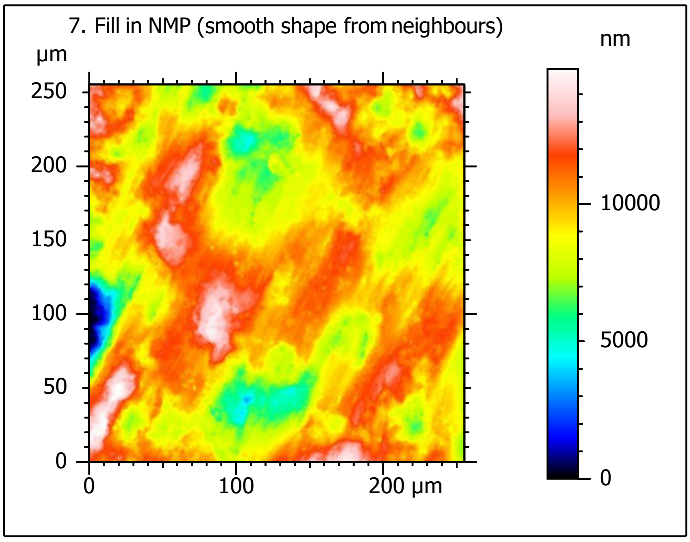

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0
NM

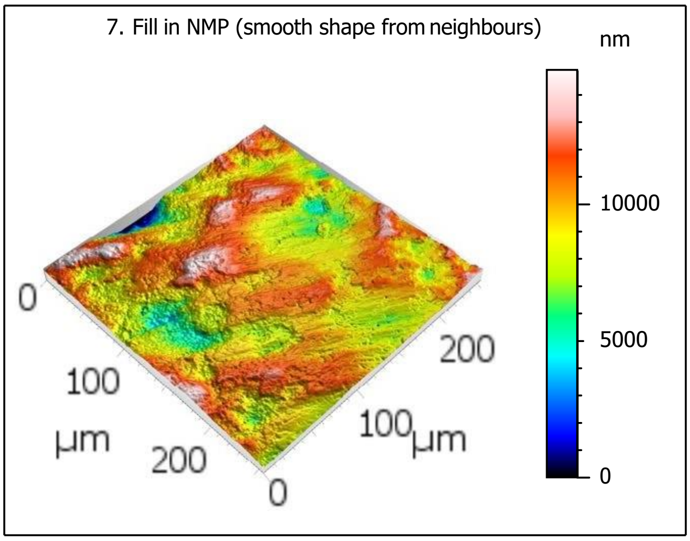

4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
15000
10000
5000
0
NM



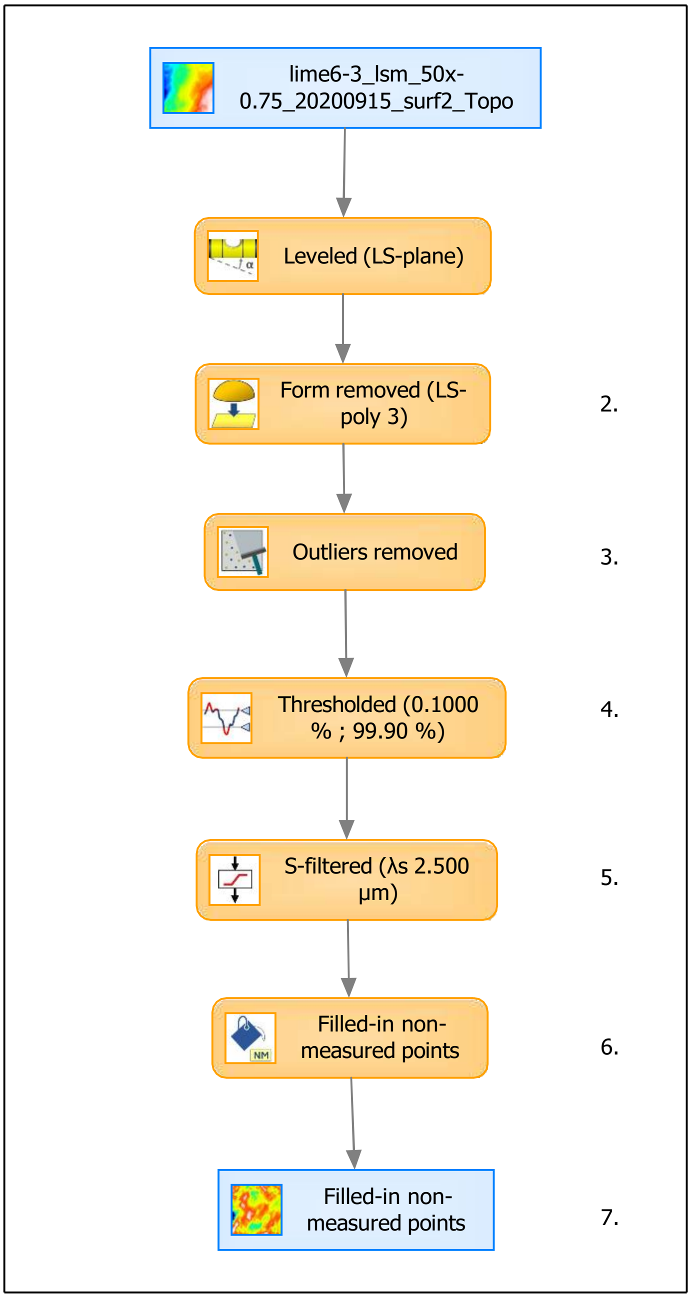
Identity card		
Name:	lime6-3_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…0915_surf2_Topo.sur	
Created on:	9/15/2020 11:11:26 AM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	14917	nm
Min:	-9443	nm
Max:	5474	nm
Size:	178946	digits
Spacing:	0.08336	nm
NM-points ratio:	24.35 % (255378 Pts)	







Identity card		
Name:	lime6-3_lsm_50x-0.75_...in non-measured points	
Created on:	9/15/2020 11:11:26 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	14917	nm
Size:	178946	digits
Spacing:	0.08336	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1942	nm
Ssk	-0.5512	
Sku	4.671	
Sp	5376	nm
Sv	9540	nm
Sz	14917	nm
Sa	1510	nm
Functional parameters		
Smr	0.8498	%
Smc	2264	nm
Sxp	4016	nm
Spatial parameters		
Sal	24.39	µm
Str	0.5603	
Std	64.75	°
Hybrid parameters		
Sdq	0.3606	
Sdr	5.875	%
Functional parameters (Volume)		
Vm	0.09096	µm³/µm²
Vv	2.355	µm³/µm²
Vmp	0.09096	µm³/µm²
Vmc	1.668	µm³/µm²
Vvc	2.109	µm³/µm²
Vvv	0.2464	µm³/µm²

Analyses:

ISO 25178 8.

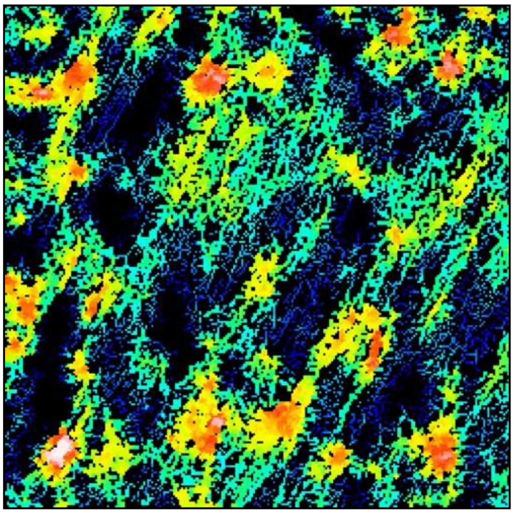
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

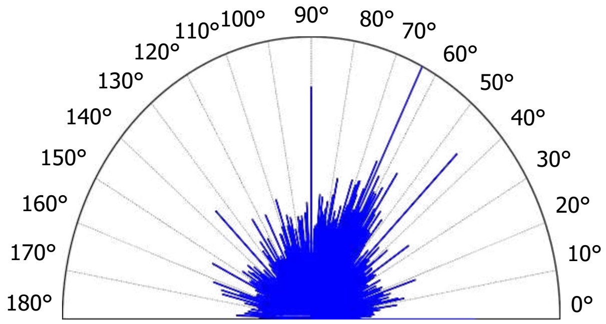
9. Furrow analysis on surface #7



All furrows are shown.

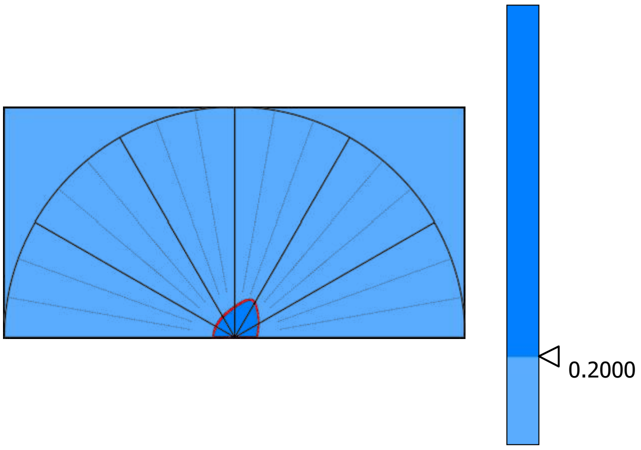
Parameters	Value	Unit
Maximum depth of furrows	5426	nm
Mean depth of furrows	1815	nm
Mean density of furrows	2516	cm/cm2

10. Texture direction on surface #7



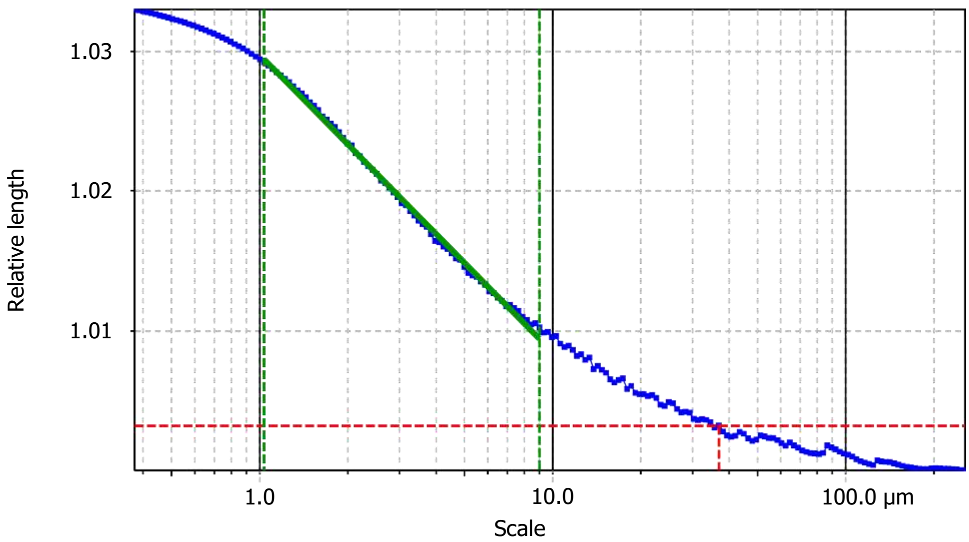
Parameters	Value	Unit
First direction	63.52	°
Second direction	45.01	°
Third direction	90.01	°

11. Texture isotropy on surface #7



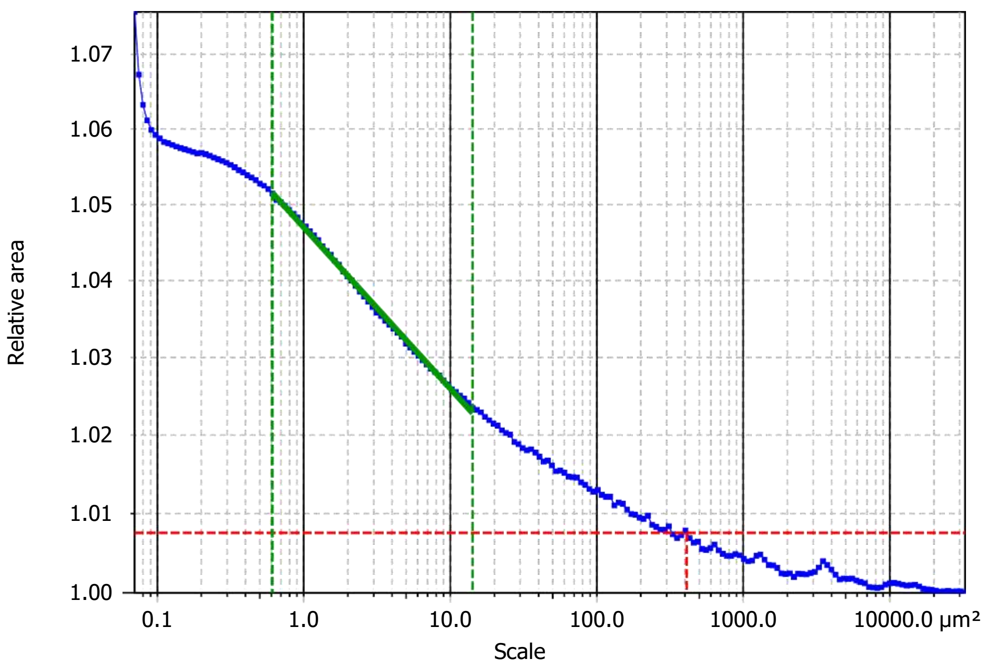
Parameters	Value	Unit
Isotropy	52.22	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.003875		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01714		*Length-scale anisotropy (1.8 µm, 5°)*

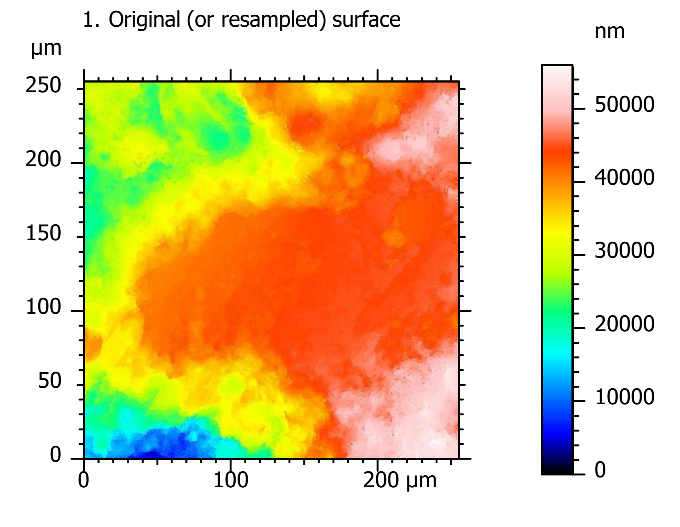


Information	
Method	Area-scale (four corners)

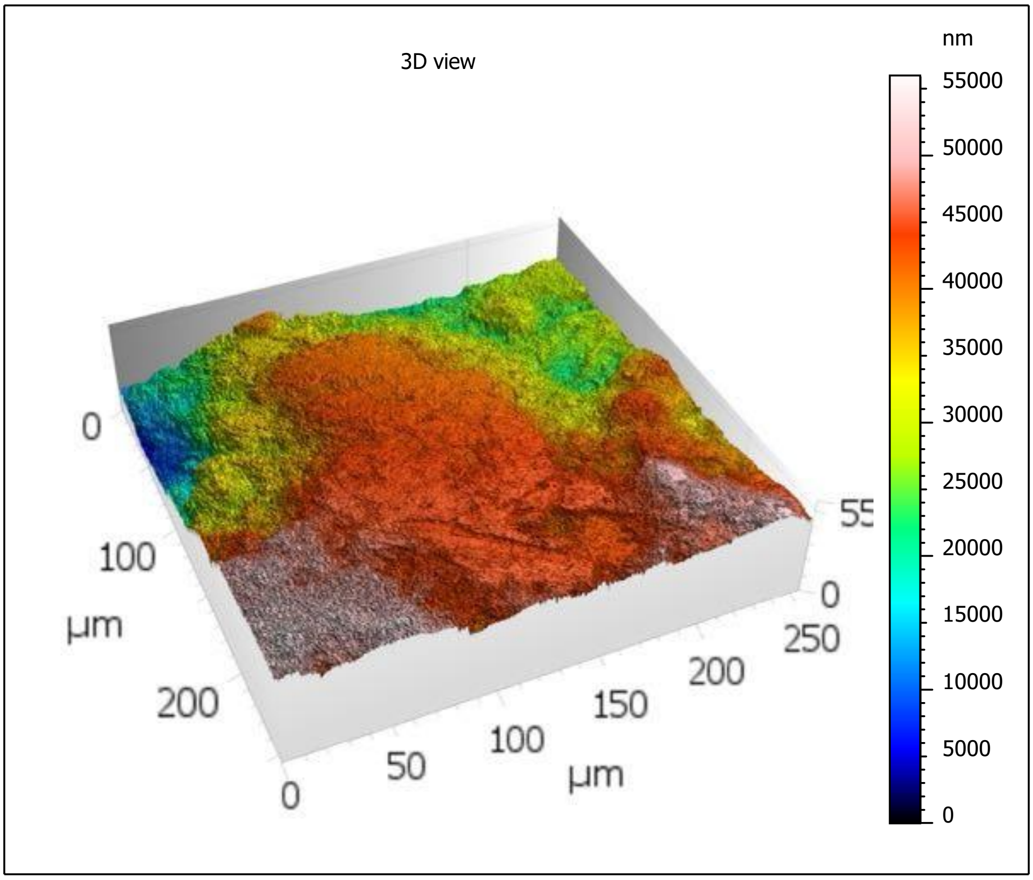
Parameters	Value	Unit	Comment
Asfc	8.799		*Fractal complexity*
Smfc	2.265	µm²	*Scale of max complexity*
HAsfc9	0.1482		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2828		*Heterogeneity of Asfc (9x9)*

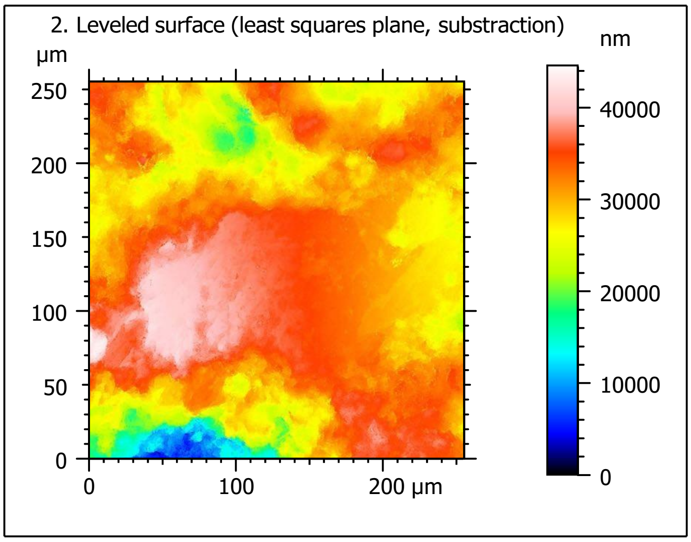
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

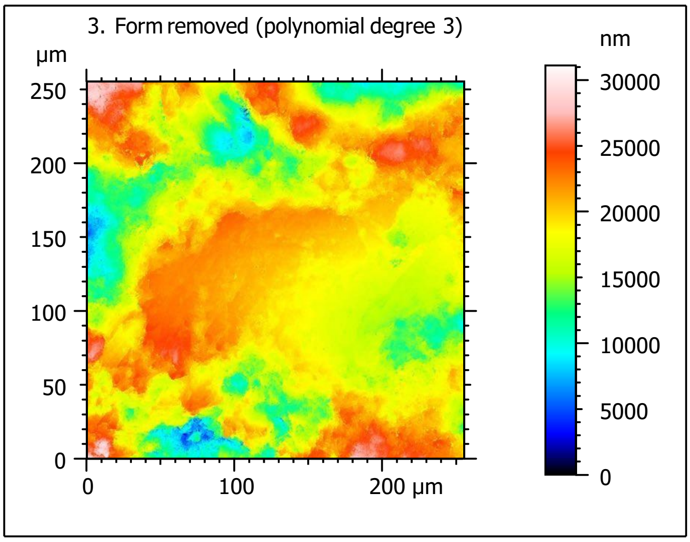
Processing

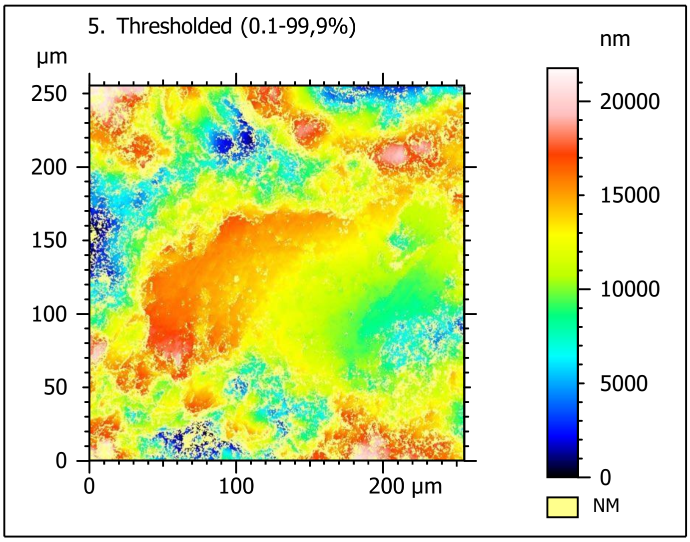


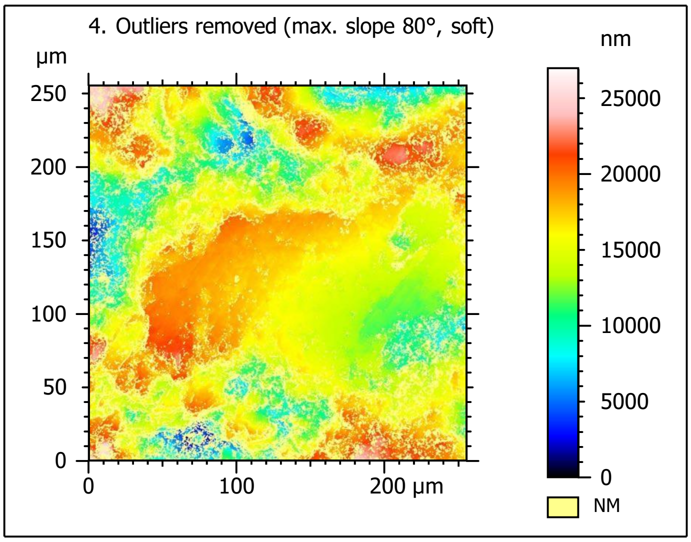
Identity card		
Name:	lime6-3_lsm_50x-0.75_20200915_surf3_Topo	
Created on:	9/15/2020 11:57:48 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	55991	nm
Size:	65532	digits
Spacing:	0.8544	nm
NM-points ratio:	0.000 % (0 Pts)	

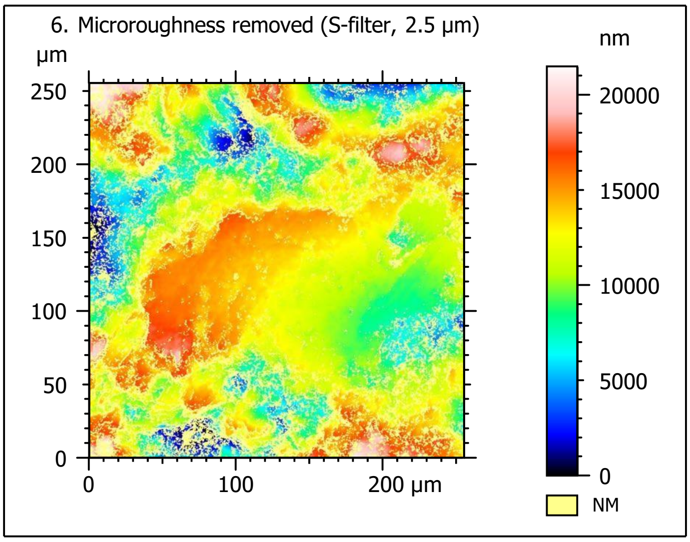


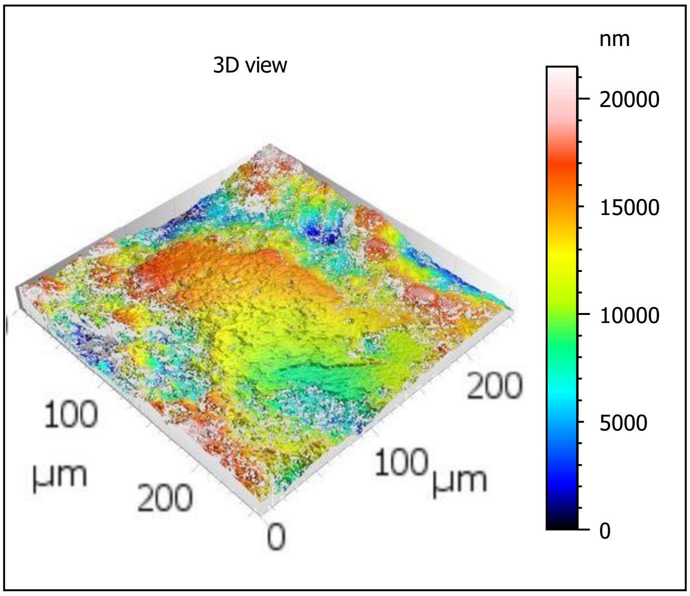

2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
40000
30000
20000
10000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
30000
25000
20000
15000
10000
5000
0

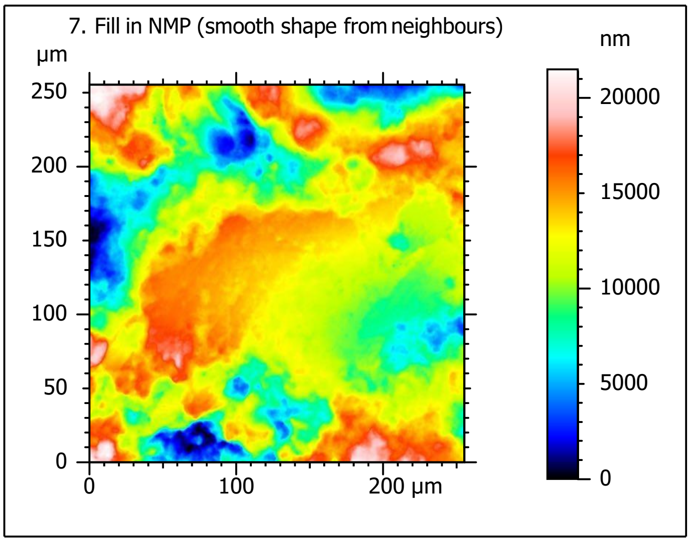

5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
20000
15000
10000
5000
0
NM

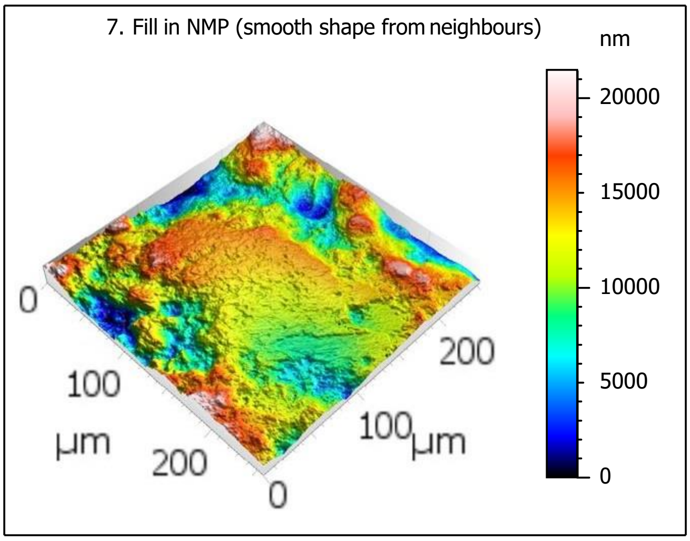

4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
25000
20000
15000
10000
5000
0
NM





Identity card		
Name:	lime6-3_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…0915_surf3_Topo.sur	
Created on:	9/15/2020 11:57:48 AM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	21489	nm
Min:	-11289	nm
Max:	10200	nm
Size:	251511	digits
Spacing:	0.08544	nm
NM-points ratio:	28.47 % (298535 Pts)	



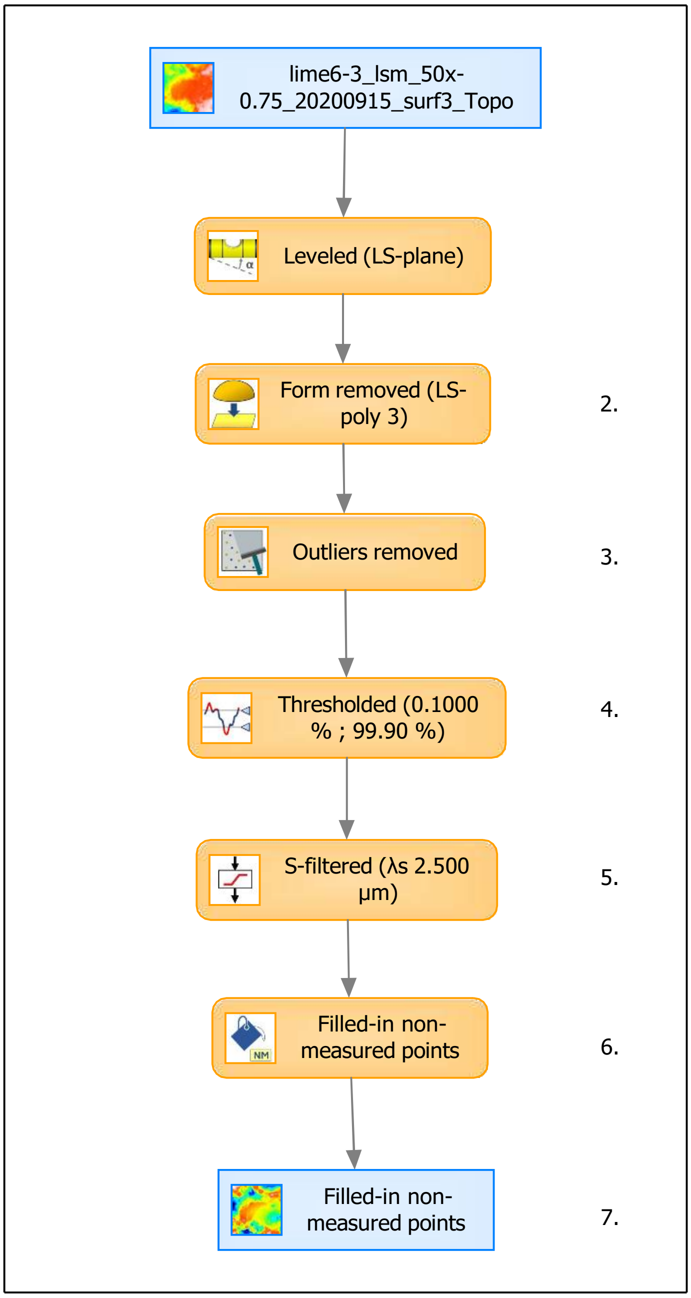


Identity card		
Name:	lime6-3_lsm_50x-0.75_...in non-measured points	
Created on:	9/15/2020 11:57:48 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	21489	nm
Size:	251511	digits
Spacing:	0.08544	nm
NM-points ratio:	0.000 % (0 Pts)	

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	3735	nm
Ssk	-0.3439	
Sku	2.936	
Sp	10092	nm
Sv	11397	nm
Sz	21489	nm
Sa	2977	nm
Functional parameters		
Smr	0.3952	%
Smc	4405	nm
Sxp	8371	nm
Spatial parameters		
Sal	27.69	µm
Str	0.7049	
Std	51.01	°
Hybrid parameters		
Sdq	0.5773	
Sdr	12.97	%
Functional parameters (Volume)		
Vm	0.1513	µm³/µm²
Vv	4.556	µm³/µm²
Vmp	0.1513	µm³/µm²
Vmc	3.411	µm³/µm²
Vvc	4.048	µm³/µm²
Vvv	0.5076	µm³/µm²



Analyses:

ISO 25178 8.

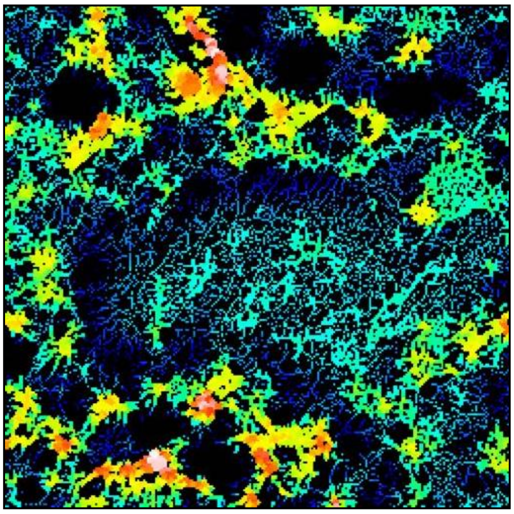
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

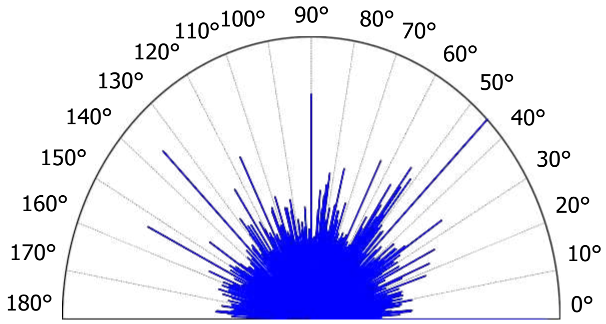
9. Furrow analysis on surface #7



All furrows are shown.

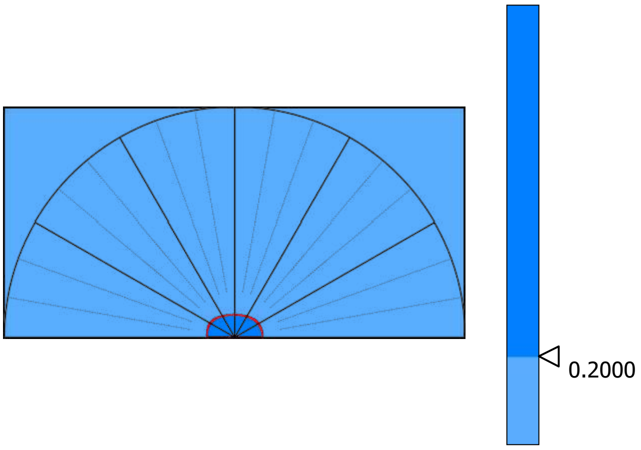
Parameters	Value	Unit	
Maximum depth of furrows	10157	nm	
Mean depth of furrows	3102	nm	
Mean density of furrows	2322	cm/cm2	

10. Texture direction on surface #7



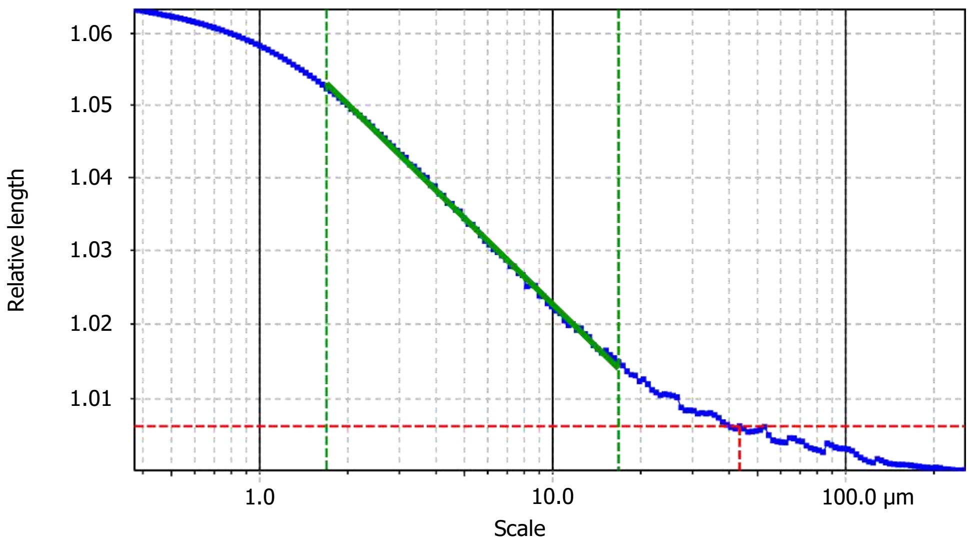
Parameters	Value	Unit	
First direction	44.99	°	
Second direction	0.01839	°	
Third direction	135.0	°	

11. Texture isotropy on surface #7



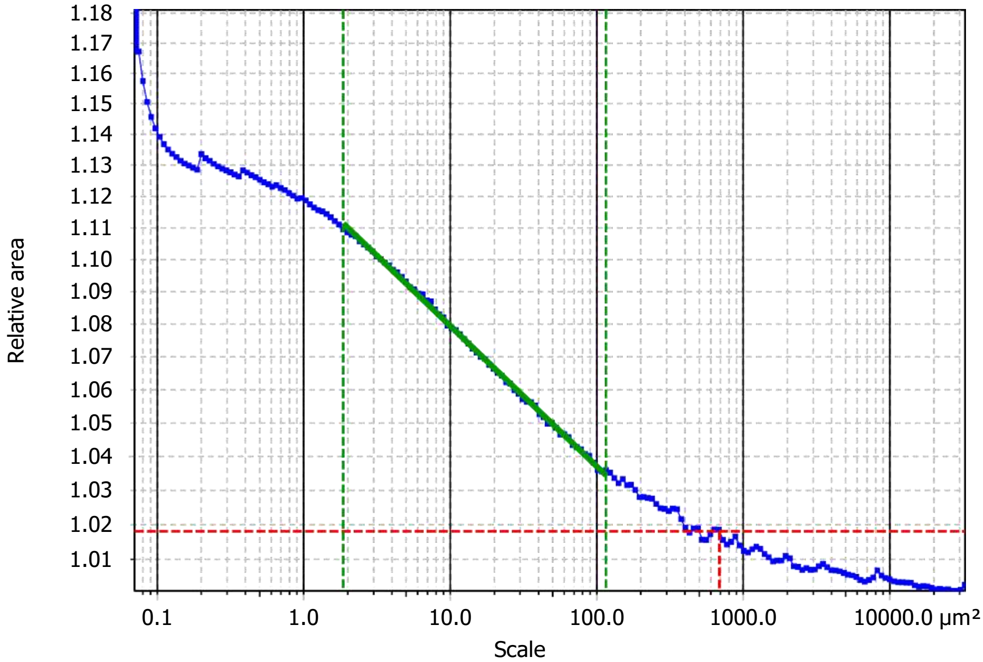
Parameters	Value	Unit	
Isotropy	78.76	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0015		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01805		*Length-scale anisotropy (1.8 µm, 5°)*

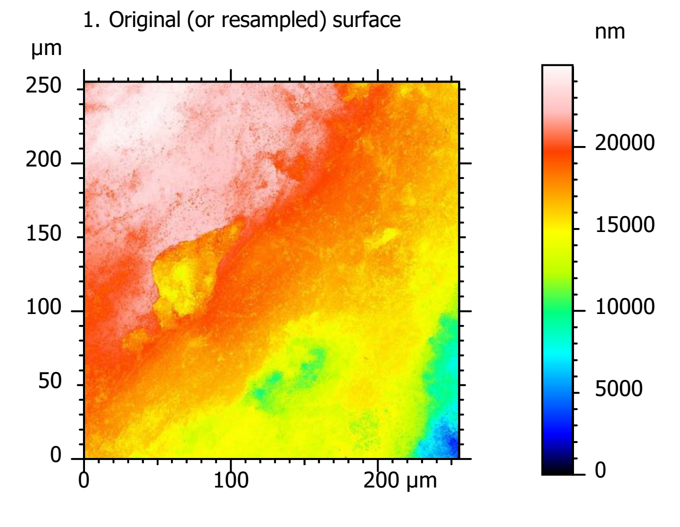


Information	
Method	Area-scale (four corners)

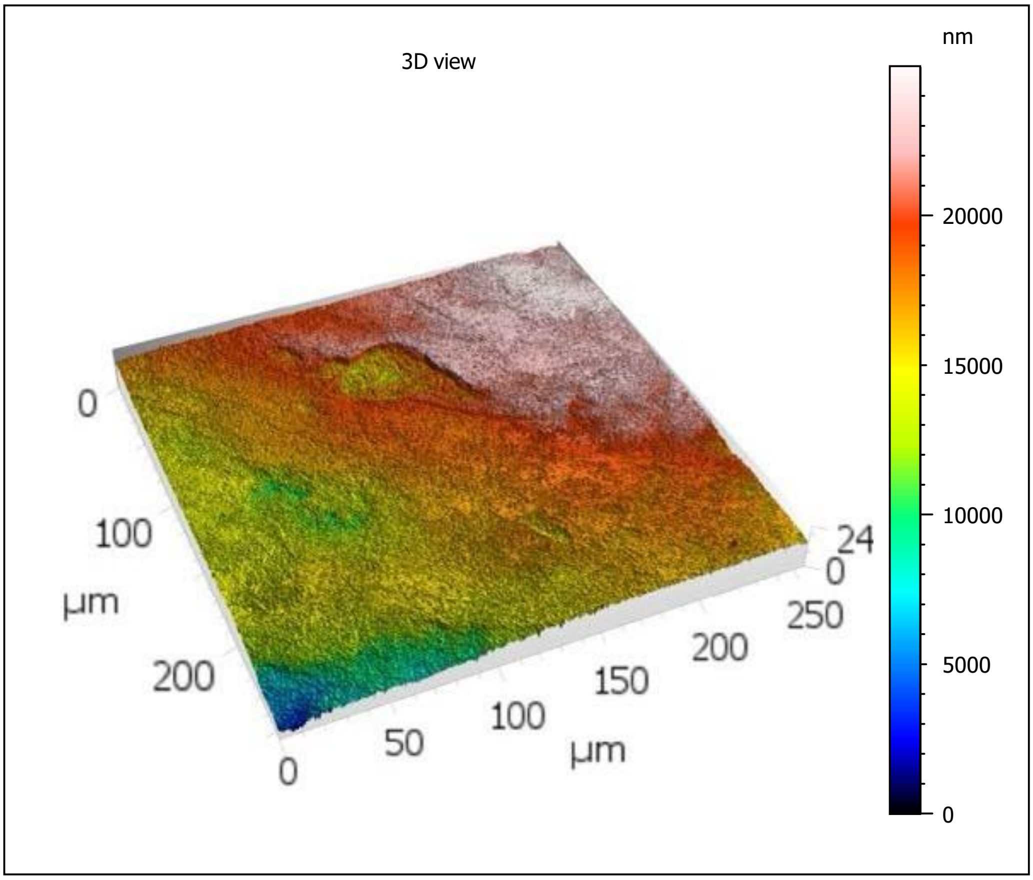
Parameters	Value	Unit	Comment
Asfc	17.36		*Fractal complexity*
Smfc	10.93	µm²	*Scale of max complexity*
HAsfc9	0.7092		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.7387		*Heterogeneity of Asfc (9x9)*

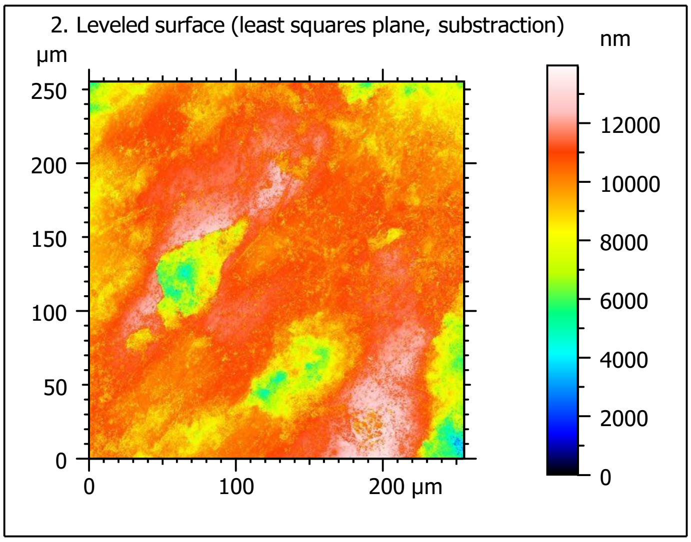
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

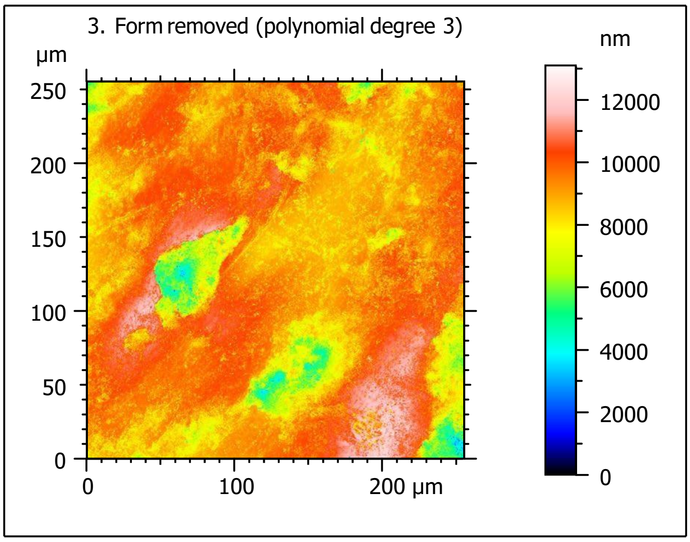
Processing

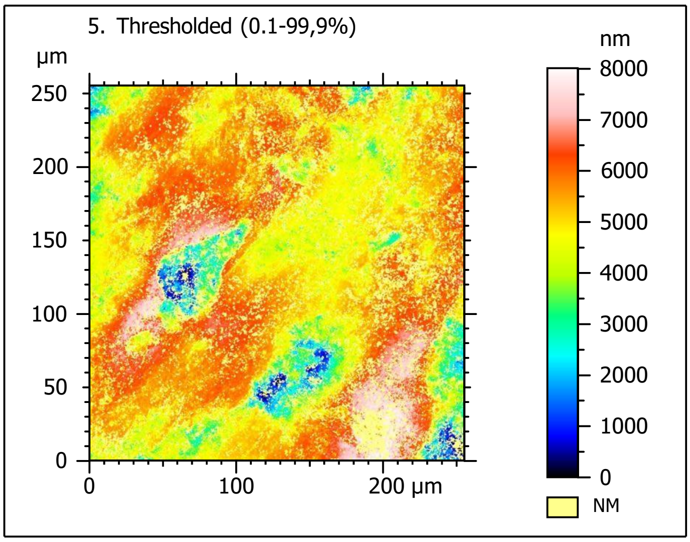


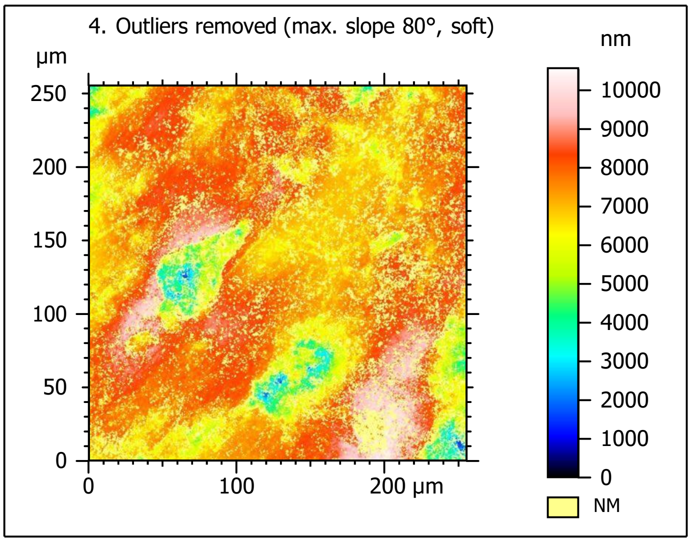
Identity card		
Name:	lime6-6_lsm_50x-0.75_...11_1000rot_surf1_Topo	
Created on:	9/11/2020 1:38:11 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	24999	nm
Size:	65531	digits
Spacing:	0.3815	nm
NM-points ratio:	0.000 % (0 Pts)	



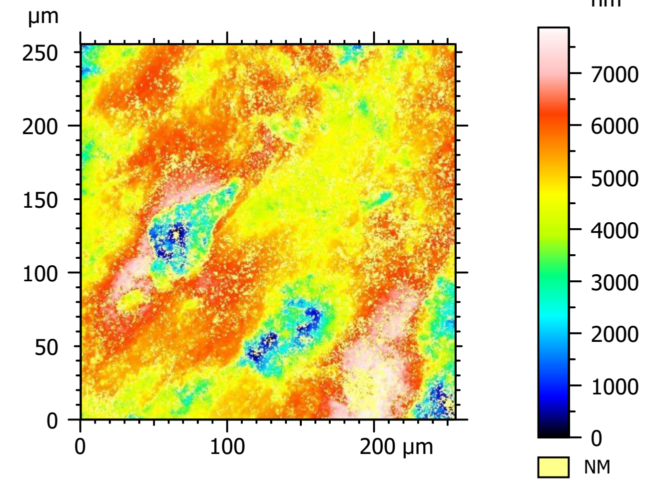

2. Leveled surface (least squares plane, substraction)
µm
250
200
150
100
50
0
0
100
200 µm
nm
12000
10000
8000
6000
4000
2000
0


3. Form removed (polynomial degree 3)
µm
250
200
150
100
50
0
0
100
200 µm
nm
12000
10000
8000
6000
4000
2000
0


5. Thresholded (0.1-99,9%)
µm
250
200
150
100
50
0
0
100
200 µm
nm
8000
7000
6000
5000
4000
3000
2000
1000
0
NM

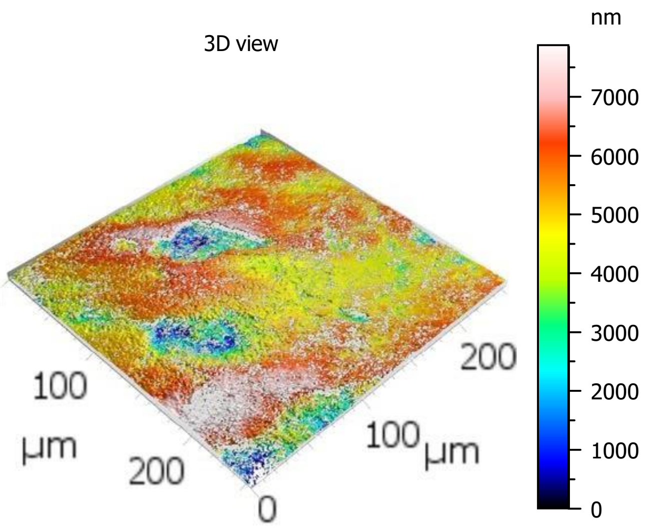

4. Outliers removed (max. slope 80°, soft)
µm
250
200
150
100
50
0
0
100
200 µm
nm
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
NM

6. Microroughness removed (S-filter, 2.5 µm)

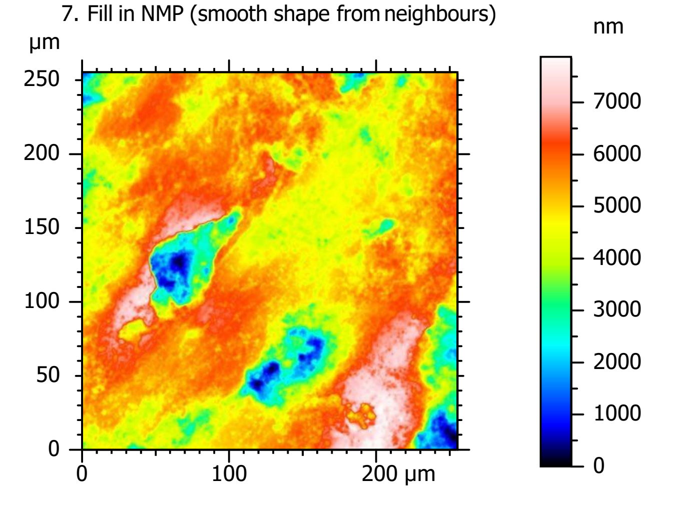


Identity card		
Name:	lime6-6_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…00rot_surf1_Topo.sur	
Created on:	9/11/2020 1:38:11 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	7877	nm
Min:	-4904	nm
Max:	2973	nm
Size:	206488	digits
Spacing:	0.03815	nm
NM-points ratio:	23.33 % (244631 Pts)	

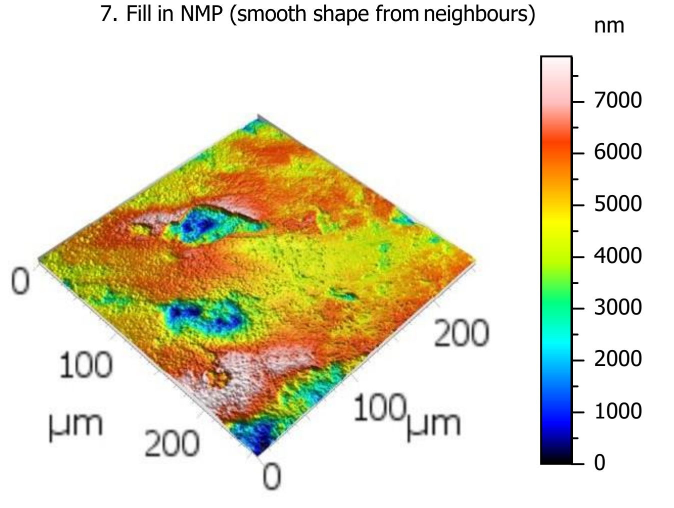
3D view



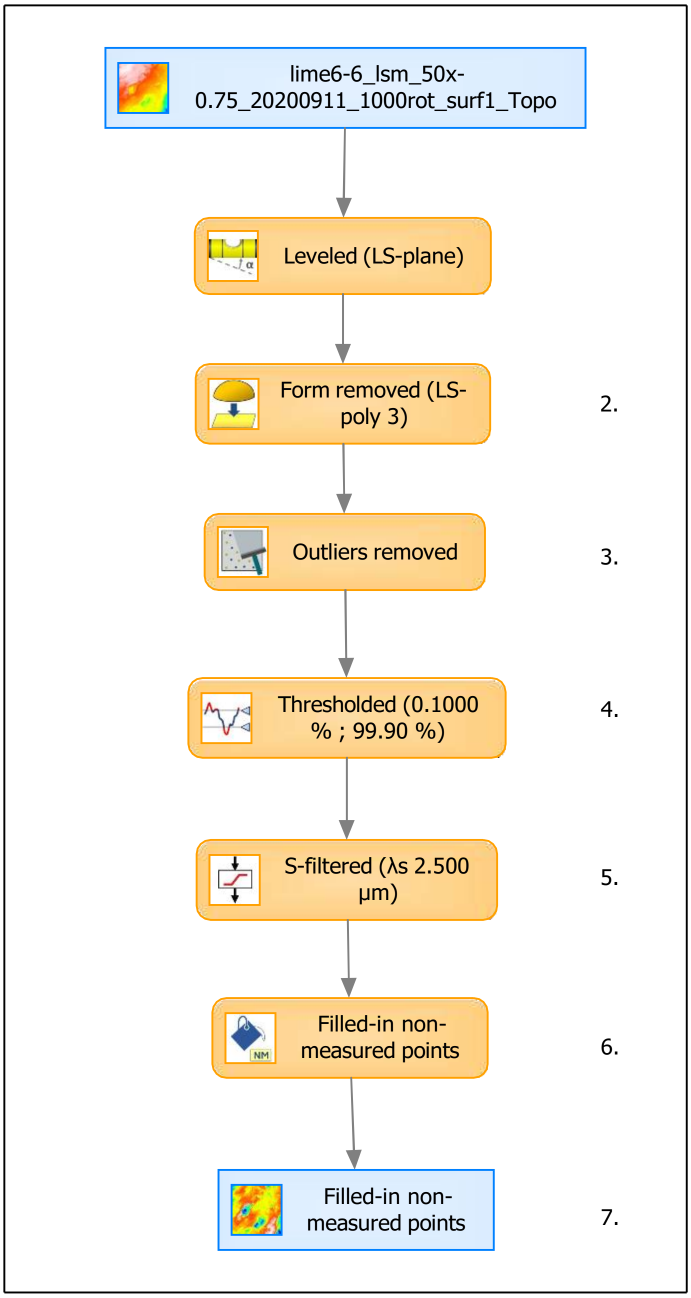
7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card		
Name:	lime6-6_lsm_50x-0.75_...in non-measured points	
Created on:	9/11/2020 1:38:11 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	7877	nm
Size:	206488	digits
Spacing:	0.03815	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses:

ISO 25178 8.

Furrow 9.

Texture direction 10.

Texture isotropy 11.

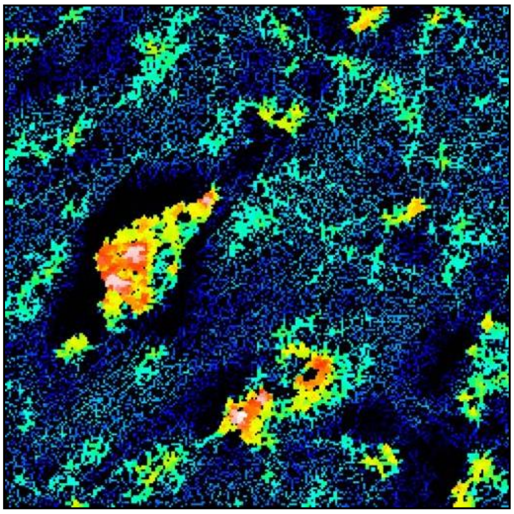
SSFA 12.

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1172	nm
Ssk	-0.8975	
Sku	4.711	
Sp	2902	nm
Sv	4975	nm
Sz	7877	nm
Sa	870.1	nm
Functional parameters		
Smr	3.687	%
Smc	1240	nm
Sxp	3218	nm
Spatial parameters		
Sal	19.19	µm
Str	0.5389	
Std	23.25	°
Hybrid parameters		
Sdq	0.3265	
Sdr	4.685	%
Functional parameters (Volume)		
Vm	0.05547	µm³/µm²
Vv	1.295	µm³/µm²
Vmp	0.05547	µm³/µm²
Vmc	0.8639	µm³/µm²
Vvc	1.087	µm³/µm²
Vvv	0.2081	µm³/µm²

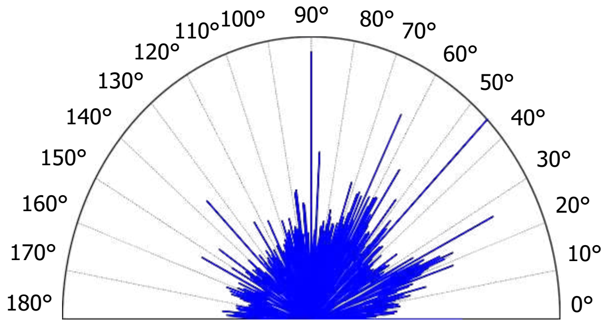
9. Furrow analysis on surface #7



All furrows are shown.

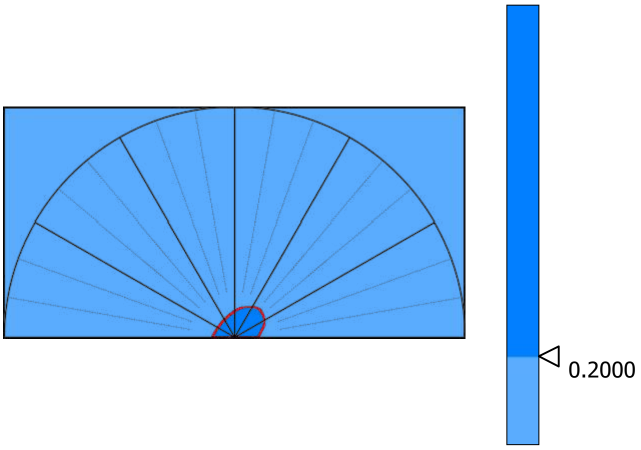
Parameters	Value	Unit
Maximum depth of furrows	4852	nm
Mean depth of furrows	1062	nm
Mean density of furrows	2978	cm/cm2

10. Texture direction on surface #7



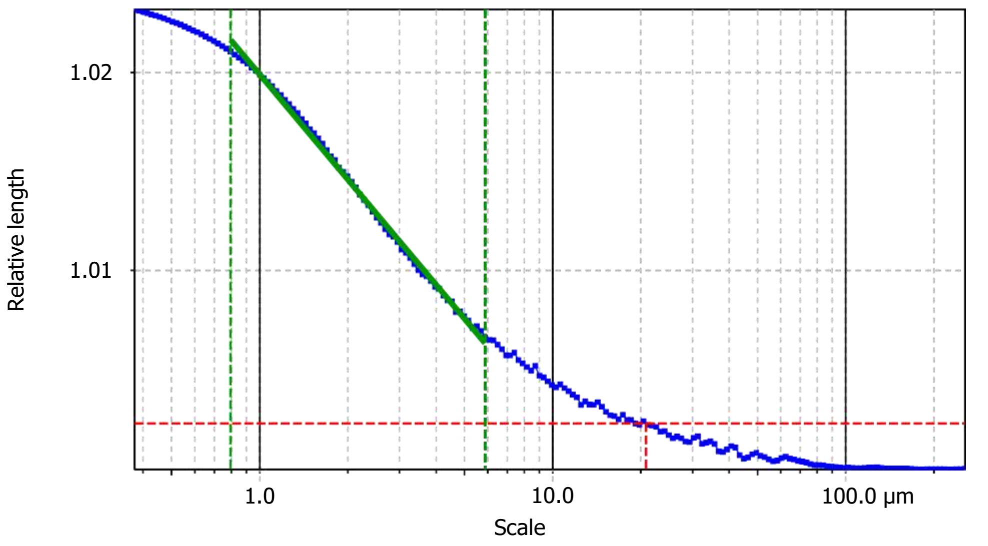
Parameters	Value	Unit
First direction	44.99	°
Second direction	90.01	°
Third direction	26.43	°

11. Texture isotropy on surface #7



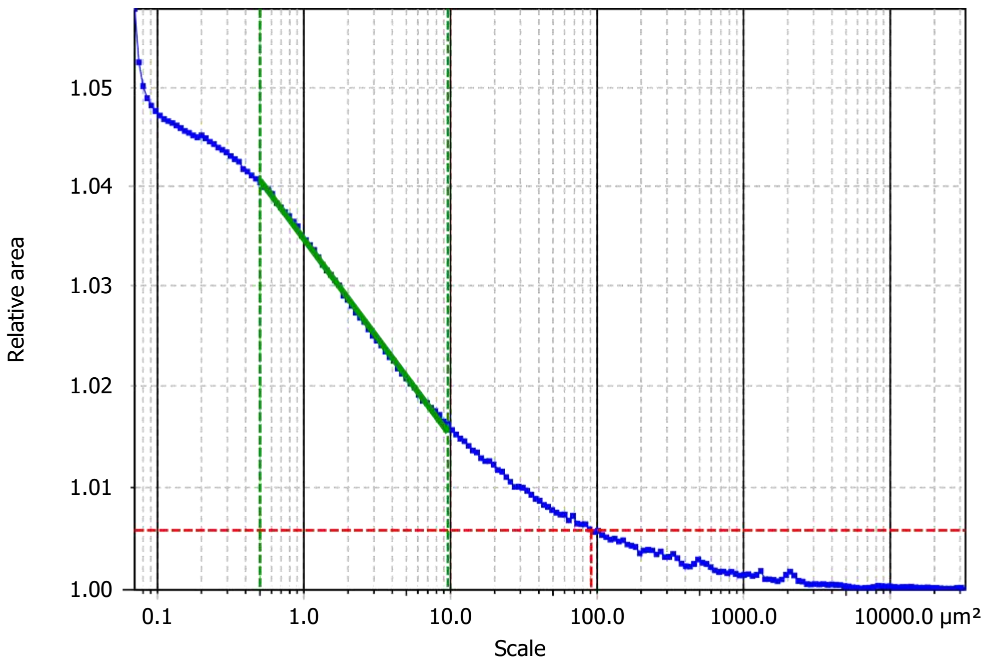
Parameters	Value	Unit
Isotropy	52.60	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001283		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01747		*Length-scale anisotropy (1.8 µm, 5°)*

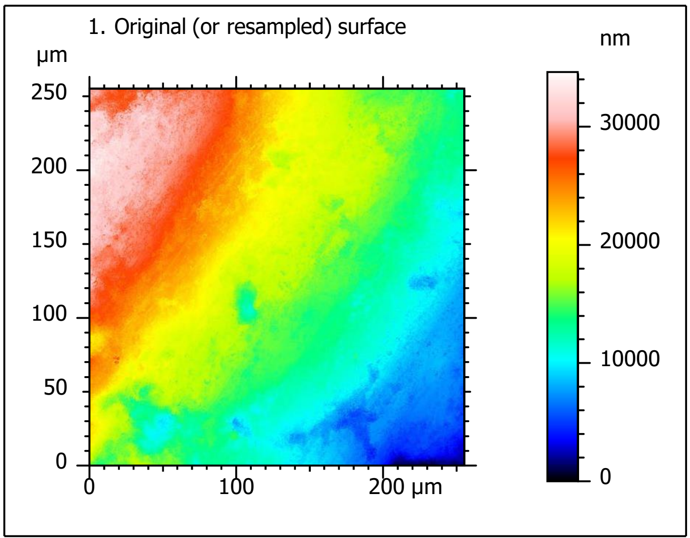


Information	
Method	Area-scale (four corners)

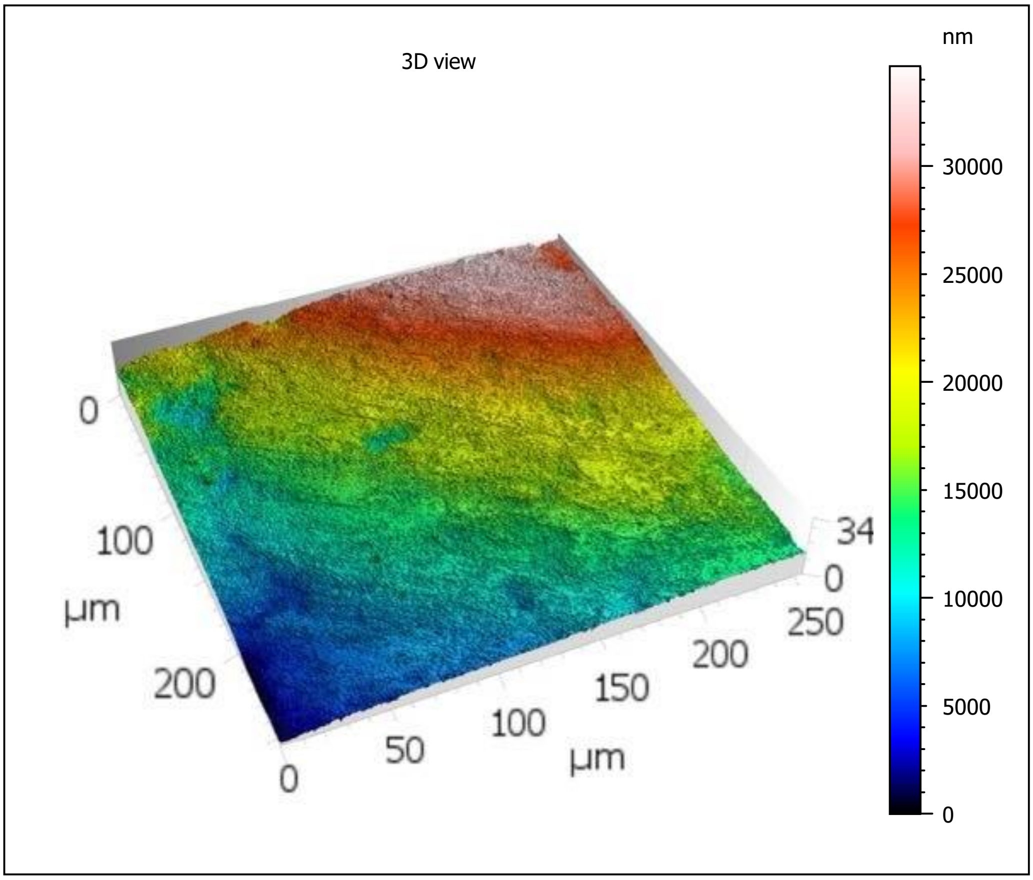
Parameters	Value	Unit	Comment
Asfc	8.312		*Fractal complexity*
Smfc	1.742	µm²	*Scale of max complexity*
HAsfc9	0.1504		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.3153		*Heterogeneity of Asfc (9x9)*

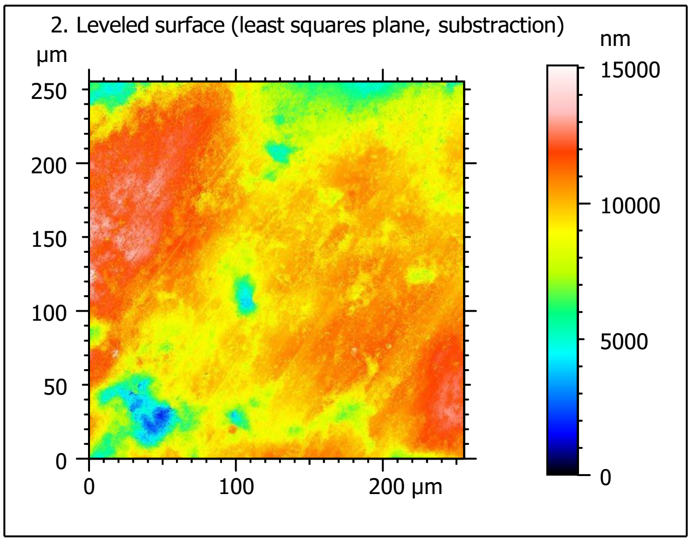
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

Processing

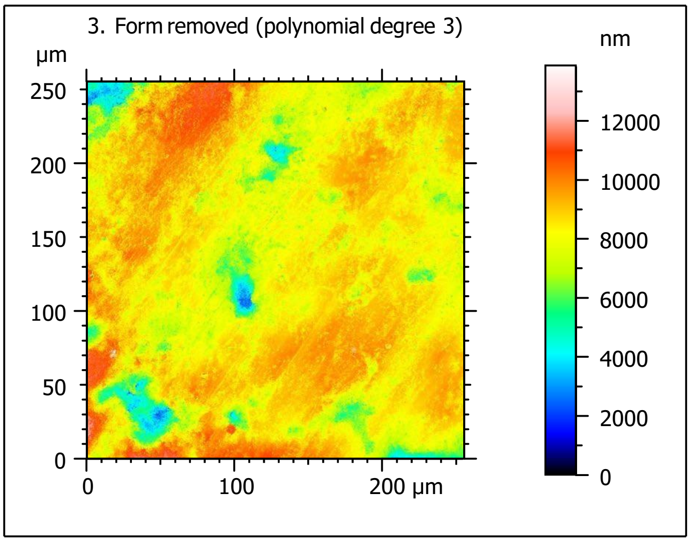


Identity card		
Name:	lime6-6_lsm_50x-0.75_...11_1000rot_surf2_Topo	
Created on:	9/11/2020 10:44:50 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	34629	nm
Size:	65532	digits
Spacing:	0.5284	nm
NM-points ratio:	0.000 % (0 Pts)	

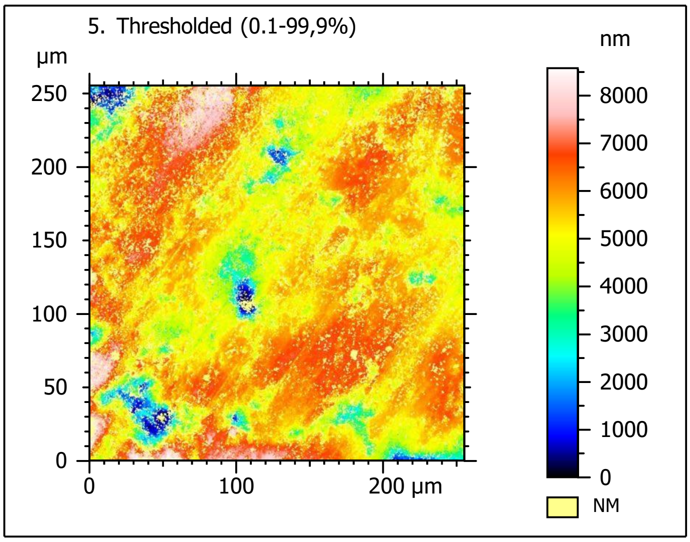




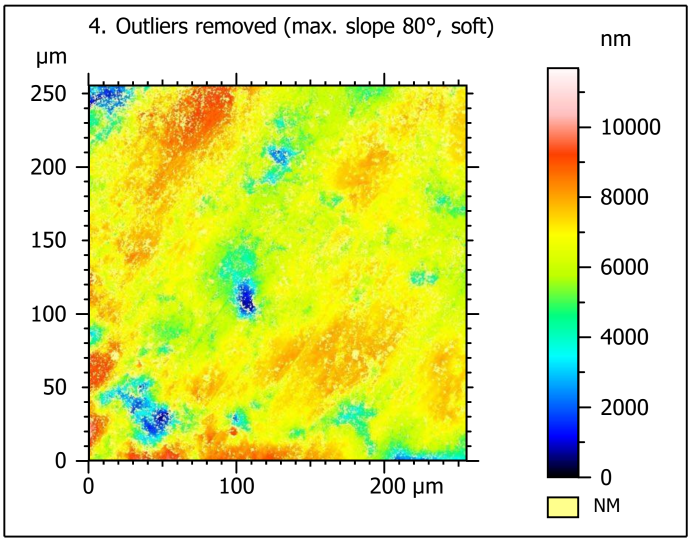
2. Leveled surface (least squares plane, substraction)



3. Form removed (polynomial degree 3)

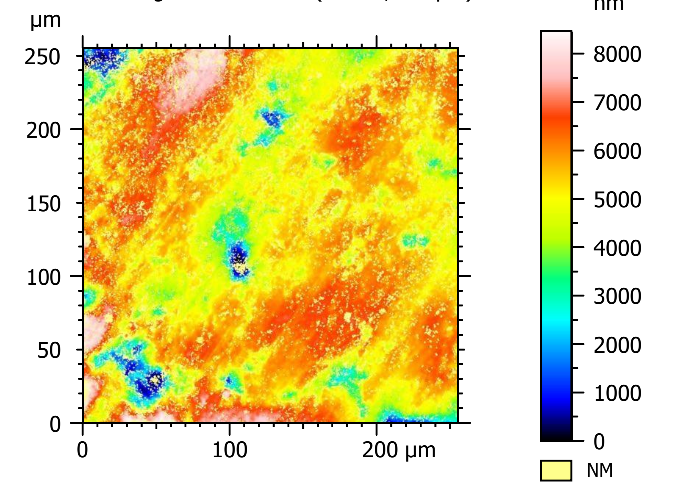


5. Thresholded (0.1-99,9%)

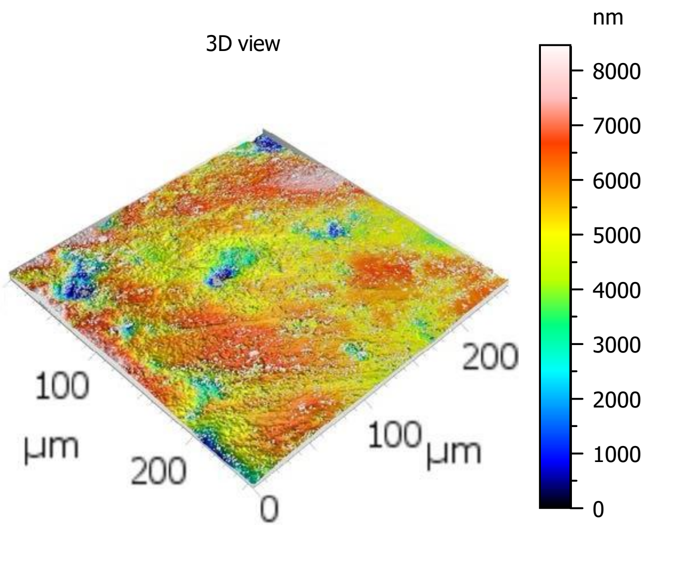


4. Outliers removed (max. slope 80°, soft)

6. Microroughness removed (S-filter, 2.5 µm)

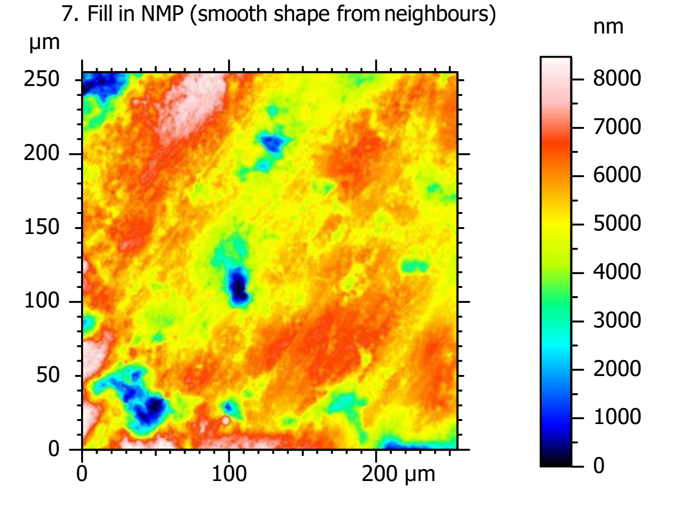


3D view

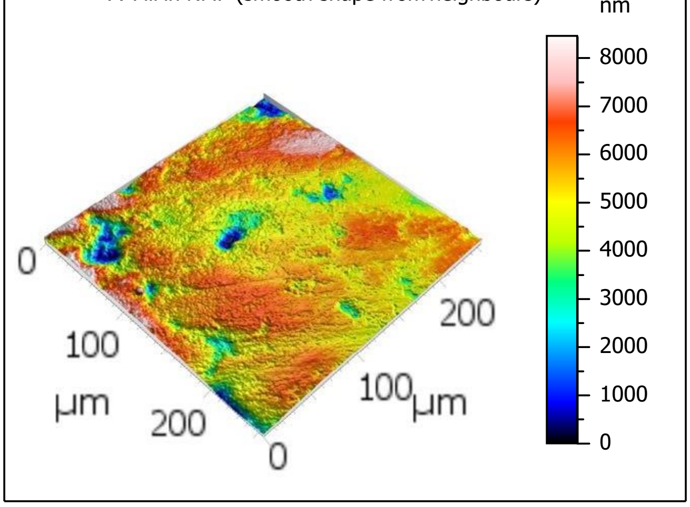


Identity card		
Name:	lime6-6_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…00rot_surf2_Topo.sur	
Created on:	9/11/2020 10:44:50 AM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	8463	nm
Min:	-5283	nm
Max:	3180	nm
Size:	160158	digits
Spacing:	0.05284	nm
NM-points ratio:	16.79 % (176059 Pts)	

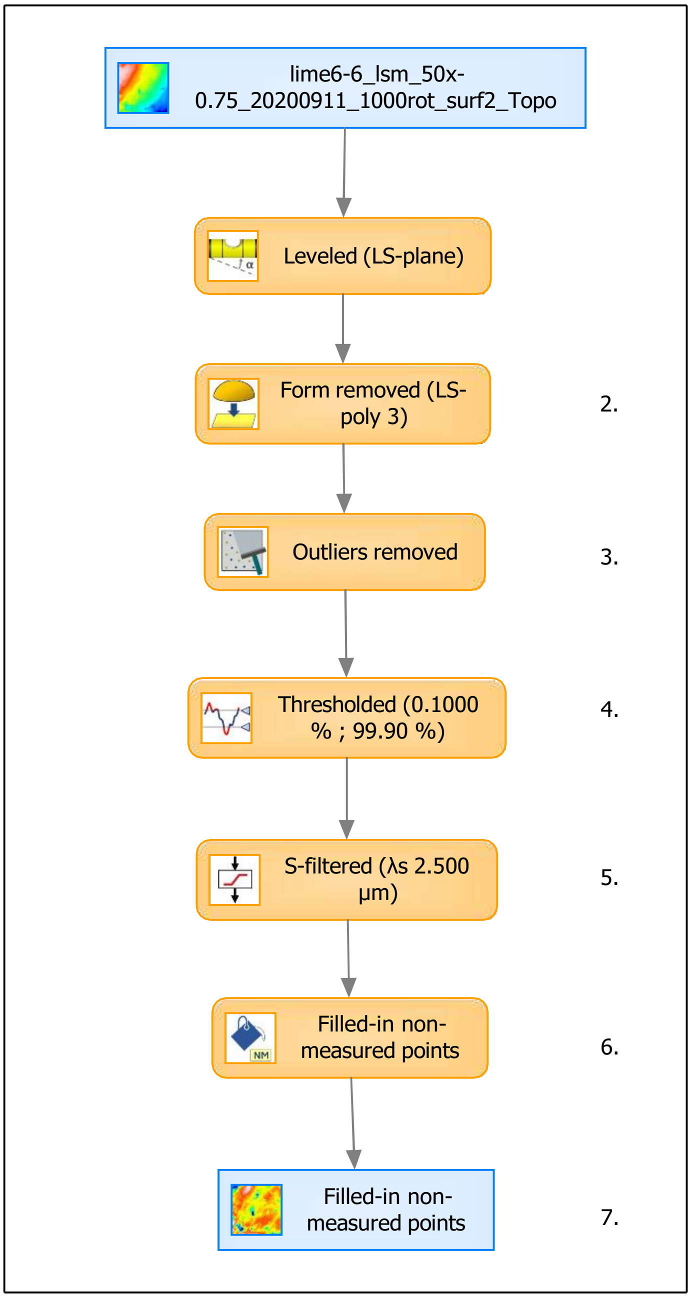
7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card		
Name:	lime6-6_lsm_50x-0.75_...in non-measured points	
Created on:	9/11/2020 10:44:50 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	8463	nm
Size:	160158	digits
Spacing:	0.05284	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses:

ISO 25178 8.

Furrow 9.

Texture direction 10.

Texture isotropy 11.

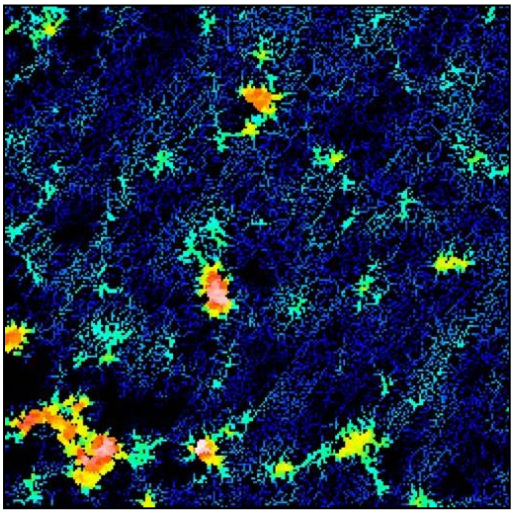
SSFA 12.

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1144	nm
Ssk	-1.116	
Sku	6.062	
Sp	3140	nm
Sv	5323	nm
Sz	8463	nm
Sa	820.9	nm
Functional parameters		
Smr	2.082	%
Smc	1182	nm
Sxp	3256	nm
Spatial parameters		
Sal	23.95	µm
Str	0.3454	
Std	51.25	°
Hybrid parameters		
Sdq	0.3108	
Sdr	4.465	%
Functional parameters (Volume)		
Vm	0.0537	µm³/µm²
Vv	1.236	µm³/µm²
Vmp	0.0537	µm³/µm²
Vmc	0.8125	µm³/µm²
Vvc	1.037	µm³/µm²
Vvv	0.1989	µm³/µm²

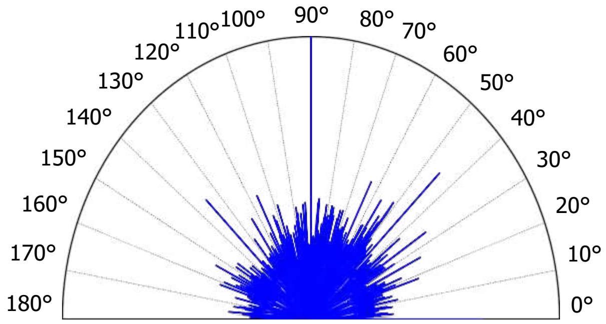
9. Furrow analysis on surface #7



All furrows are shown.

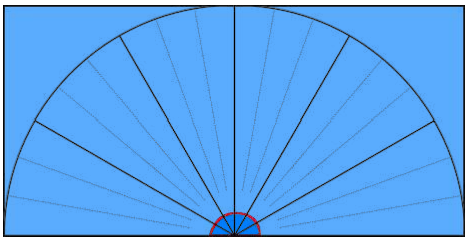
Parameters	Value	Unit	
Maximum depth of furrows	5337	nm	
Mean depth of furrows	873.3	nm	
Mean density of furrows	2938	cm/cm2	

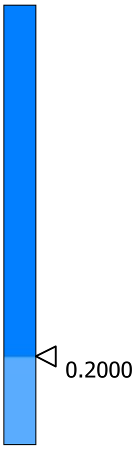
10. Texture direction on surface #7



Parameters	Value	Unit	
First direction	89.99	°	
Second direction	45.01	°	
Third direction	180.0	°	

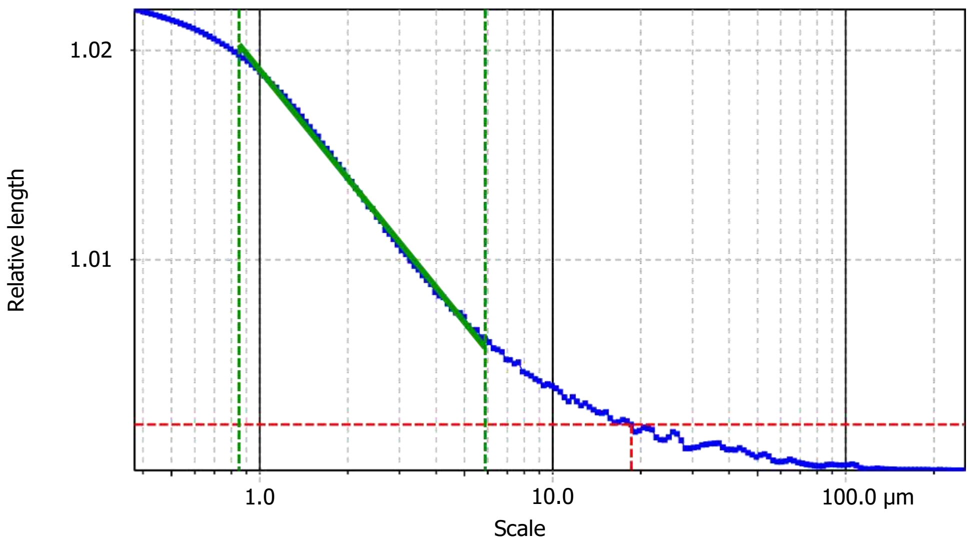
11. Texture isotropy on surface #7





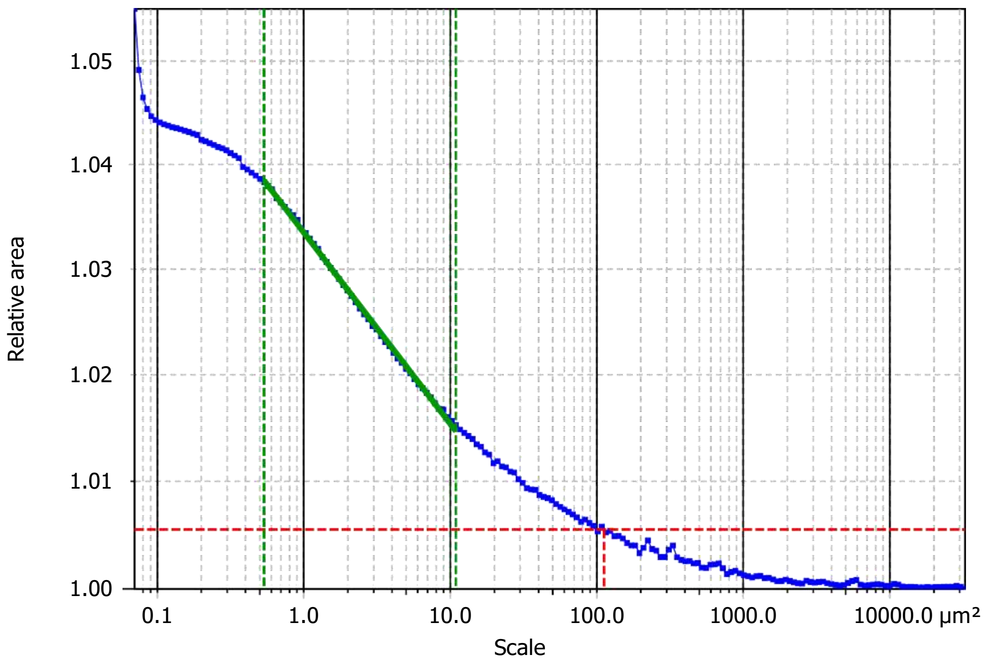
Parameters	Value	Unit	
Isotropy	87.98	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.002668		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01793		*Length-scale anisotropy (1.8 µm, 5°)*

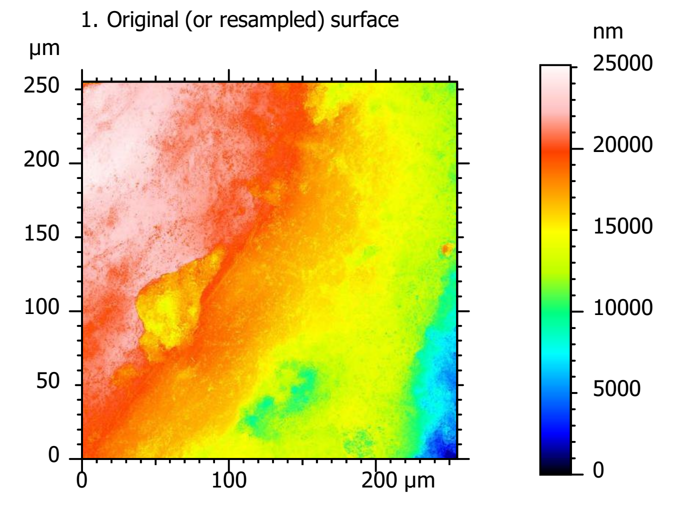


Information	
Method	Area-scale (four corners)

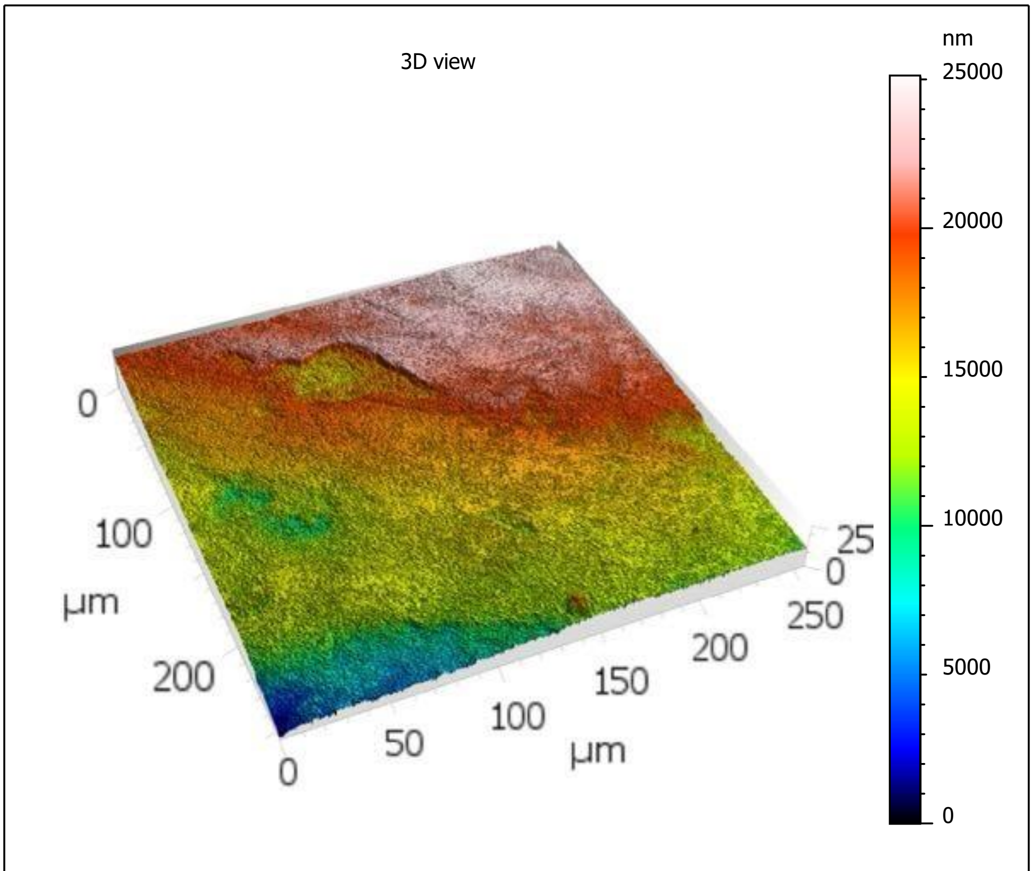
Parameters	Value	Unit	Comment
Asfc	7.689		*Fractal complexity*
Smfc	1.860	µm²	*Scale of max complexity*
HAsfc9	0.2266		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2827		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

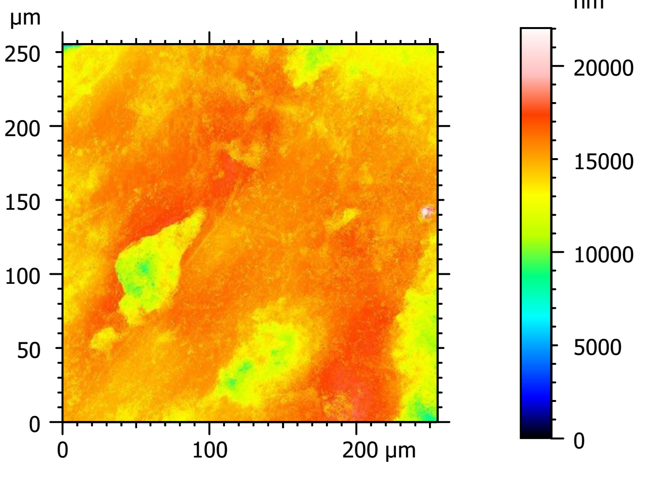
Processing



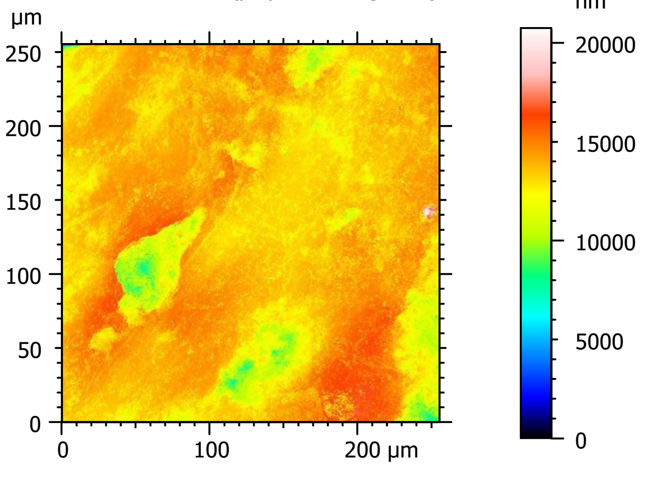
Identity card		
Name:	lime6-6_lsm_50x-0.75_...11_1000rot_surf3_Topo	
Created on:	9/11/2020 11:43:27 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	25135	nm
Size:	65532	digits
Spacing:	0.3836	nm
NM-points ratio:	0.000 % (0 Pts)	



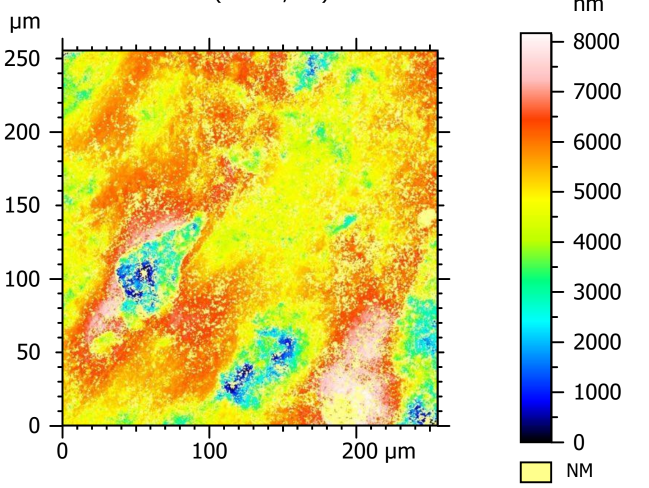
2. Leveled surface (least squares plane, substraction)



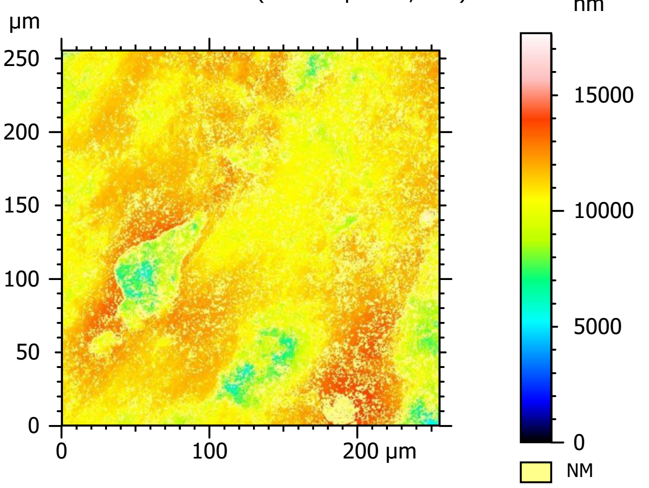
3. Form removed (polynomial degree 3)

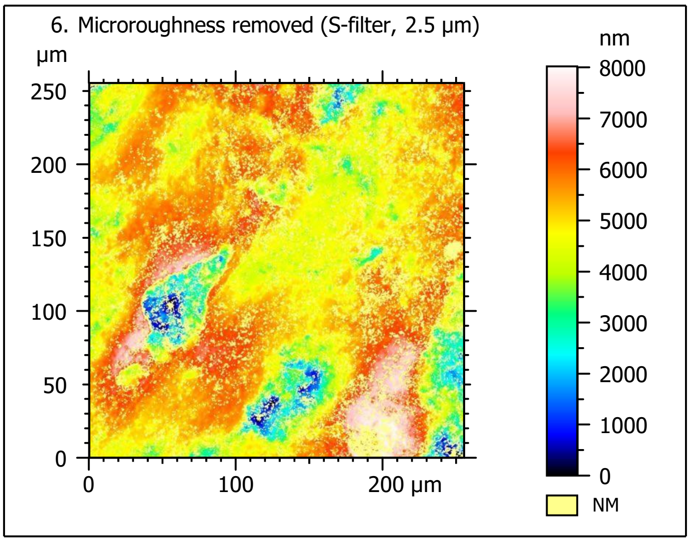


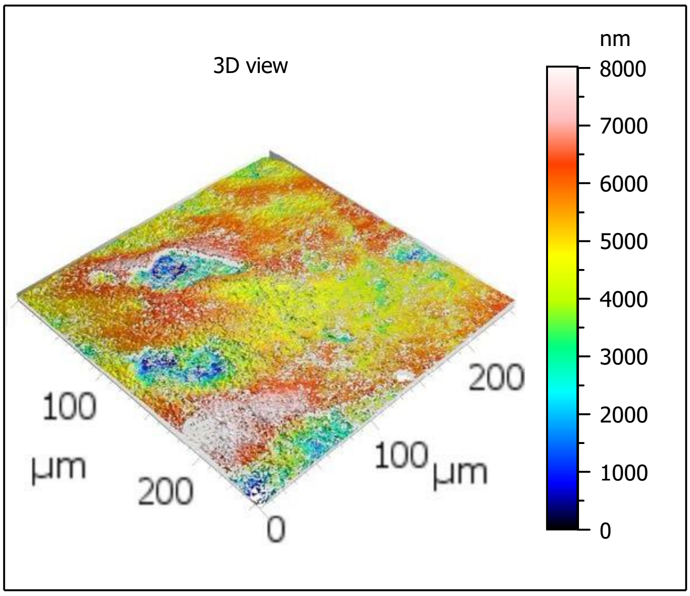
5. Thresholded (0.1-99,9%)



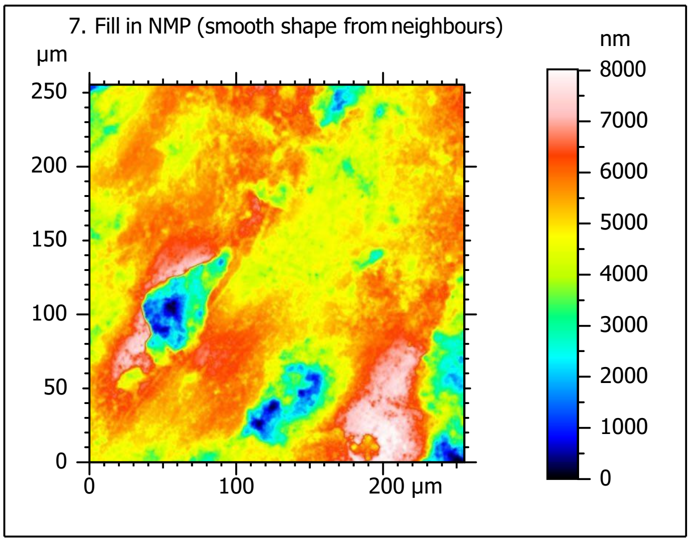
4. Outliers removed (max. slope 80°, soft)

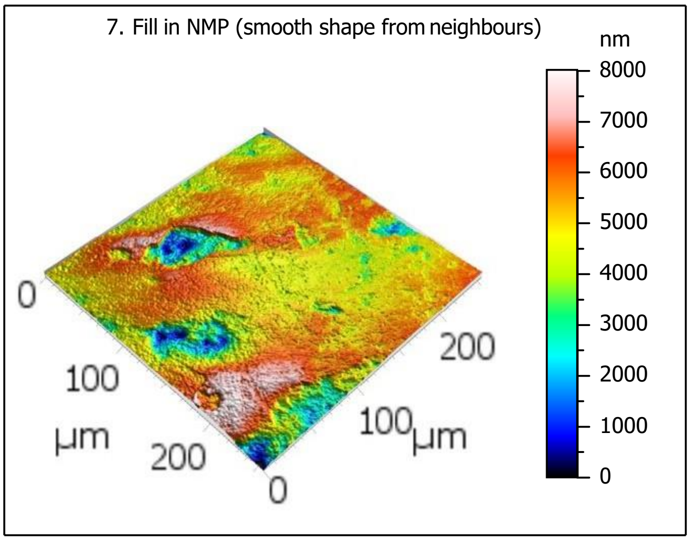






Identity card		
Name:	lime6-6_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…00rot_surf3_Topo.sur	
Created on:	9/11/2020 11:43:27 AM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	8019	nm
Min:	-4907	nm
Max:	3112	nm
Size:	209070	digits
Spacing:	0.03836	nm
NM-points ratio:	24.09 % (252571 Pts)	



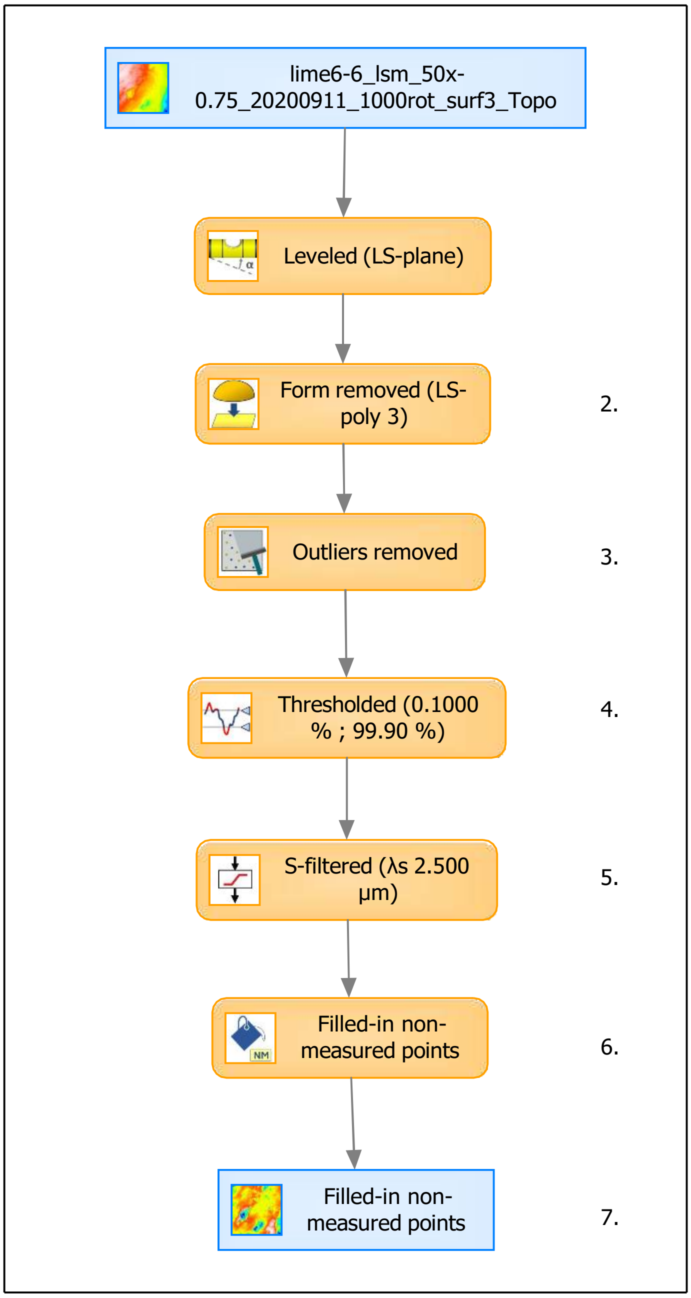


Identity card		
Name:	lime6-6_lsm_50x-0.75_...in non-measured points	
Created on:	9/11/2020 11:43:27 AM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	8019	nm
Size:	209070	digits
Spacing:	0.03836	nm
NM-points ratio:	0.000 % (0 Pts)	

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1155	nm
Ssk	-0.8254	
Sku	4.705	
Sp	3043	nm
Sv	4976	nm
Sz	8019	nm
Sa	852.3	nm
Functional parameters		
Smr	2.924	%
Smc	1223	nm
Sxp	3079	nm
Spatial parameters		
Sal	19.05	µm
Str	0.5719	
Std	28.01	°
Hybrid parameters		
Sdq	0.3285	
Sdr	4.732	%
Functional parameters (Volume)		
Vm	0.05839	µm³/µm²
Vv	1.282	µm³/µm²
Vmp	0.05839	µm³/µm²
Vmc	0.8338	µm³/µm²
Vvc	1.075	µm³/µm²
Vvv	0.2063	µm³/µm²



Analyses:

ISO 25178 8.

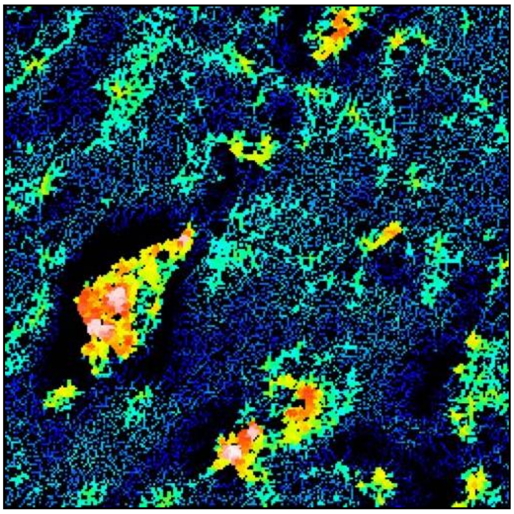
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

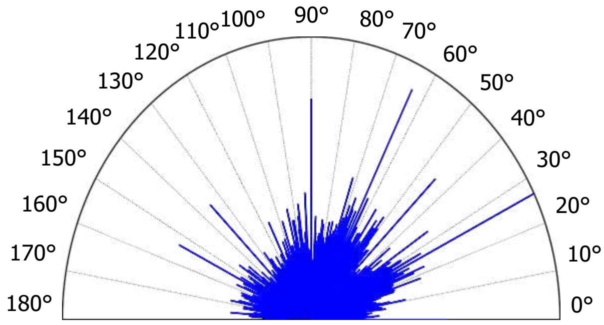
9. Furrow analysis on surface #7



All furrows are shown.

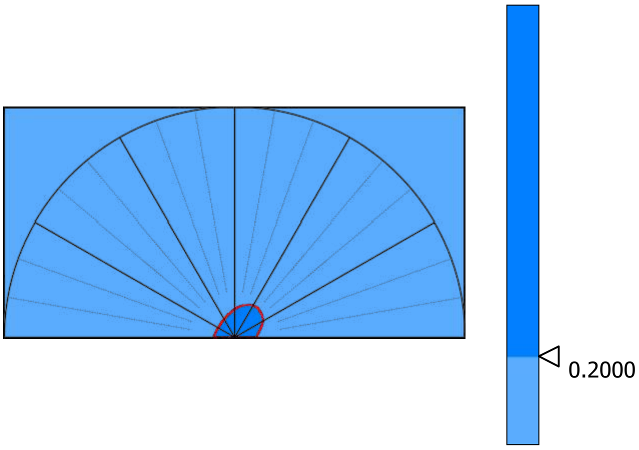
Parameters	Value	Unit	
Maximum depth of furrows	4777	nm	
Mean depth of furrows	1092	nm	
Mean density of furrows	2973	cm/cm2	

10. Texture direction on surface #7



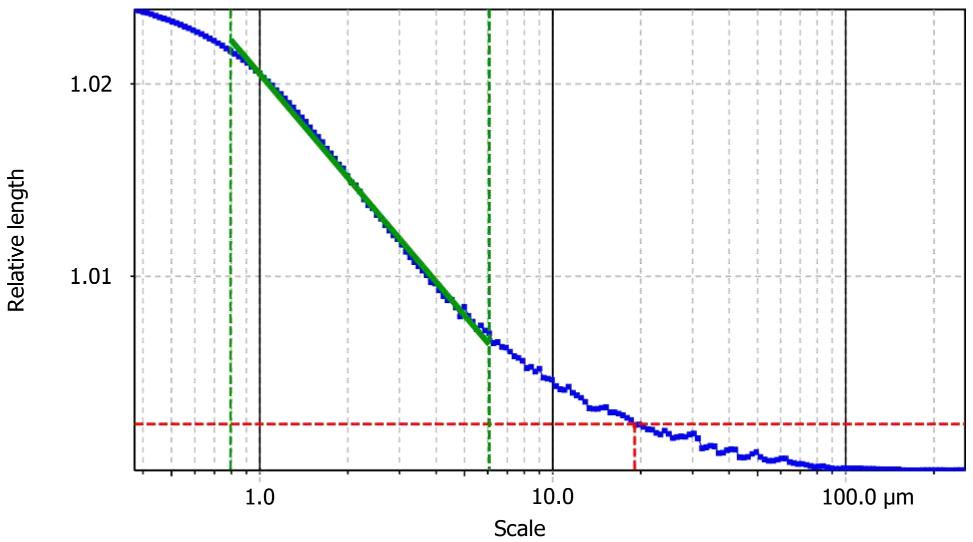
Parameters	Value	Unit	
First direction	26.46	°	
Second direction	63.51	°	
Third direction	90.01	°	

11. Texture isotropy on surface #7



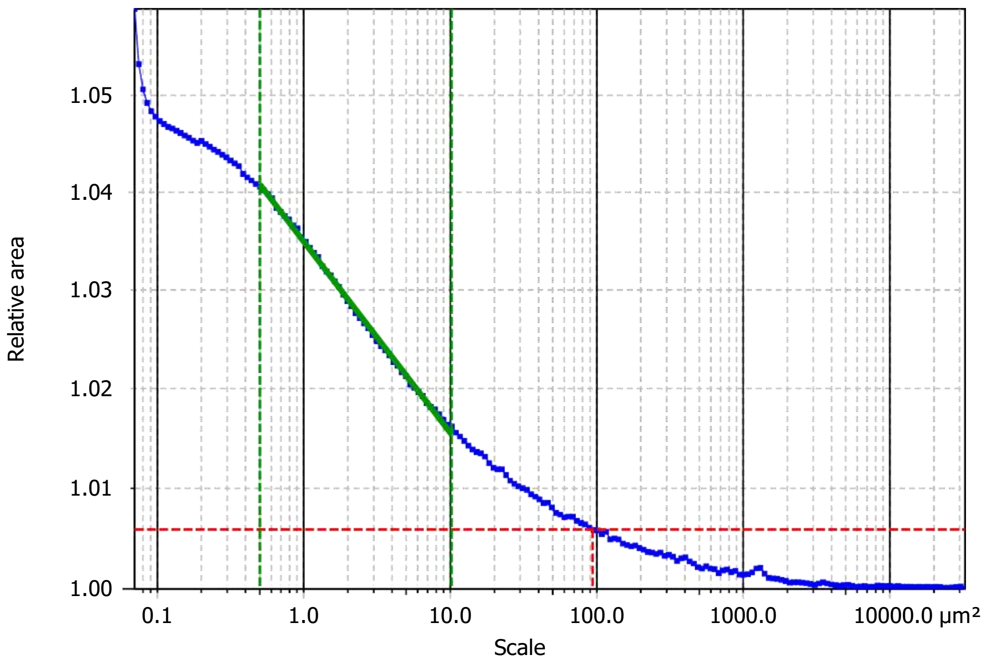
Parameters	Value	Unit	
Isotropy	51.86	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001015		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01734		*Length-scale anisotropy (1.8 µm, 5°)*

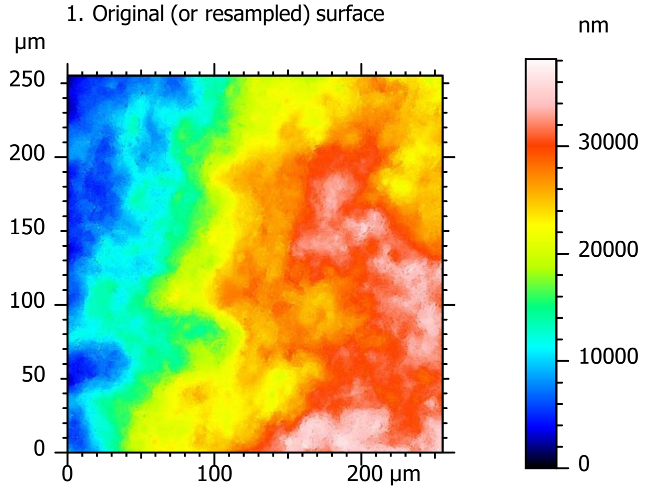


Information	
Method	Area-scale (four corners)

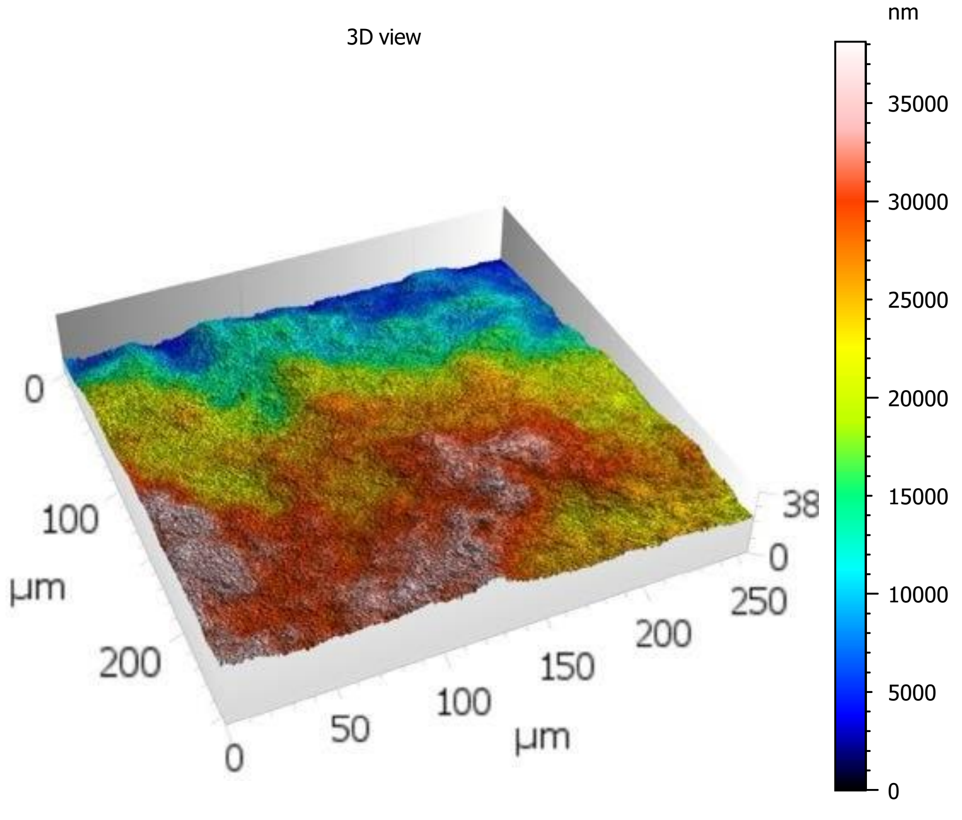
Parameters	Value	Unit	Comment
Asfc	8.213		*Fractal complexity*
Smfc	1.742	µm²	*Scale of max complexity*
HAsfc9	0.1575		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.3187		*Heterogeneity of Asfc (9x9)*

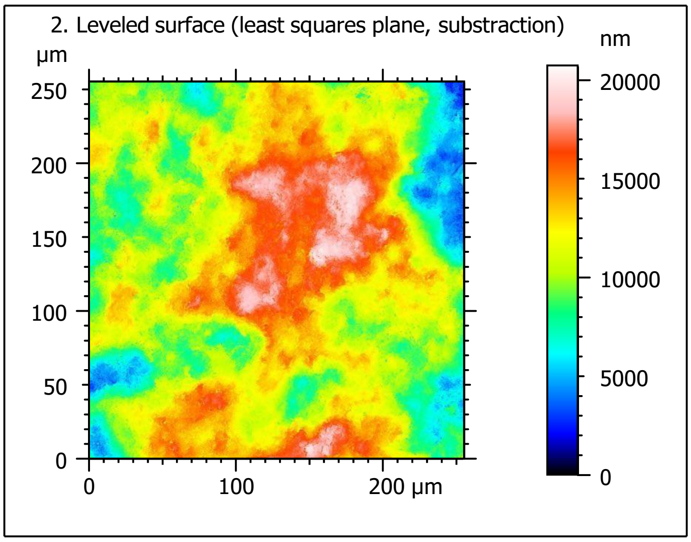
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

Processing

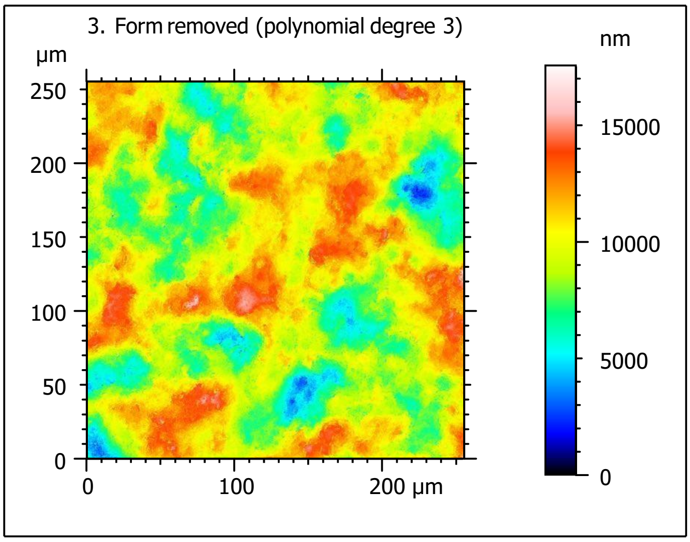


Identity card		
Name:	lime6-7_lsm_50x-0.75_...10_1000rot_surf1_Topo	
Created on:	9/10/2020 12:50:56 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	38142	nm
Size:	65532	digits
Spacing:	0.5820	nm
NM-points ratio:	0.000 % (0 Pts)	

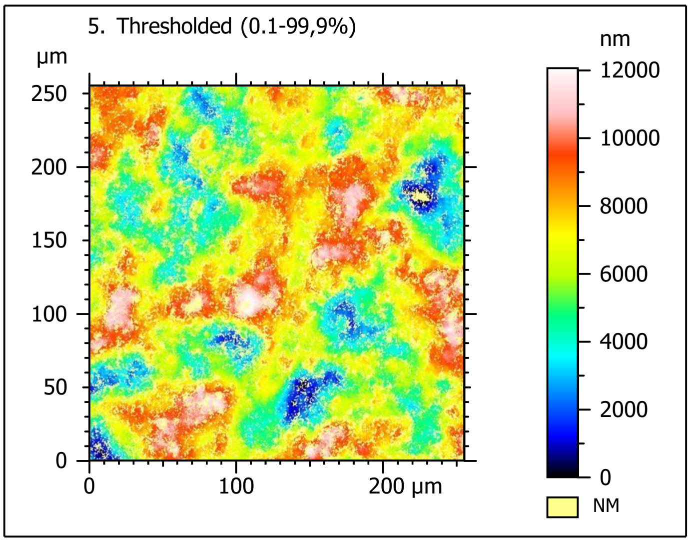




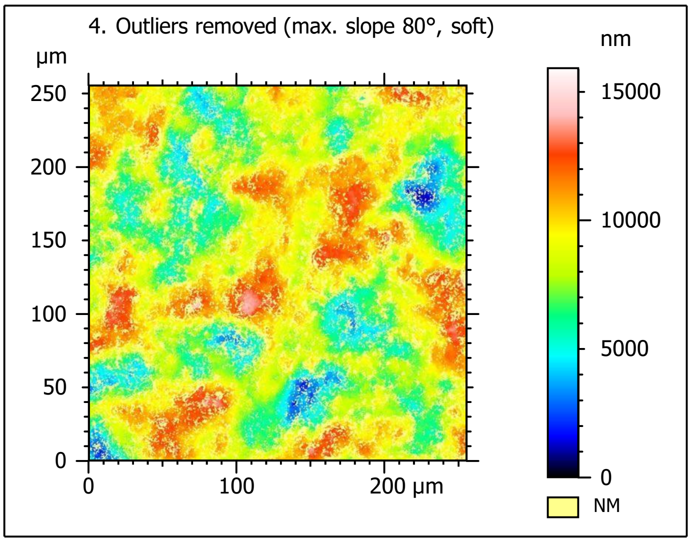
2. Leveled surface (least squares plane, substraction)



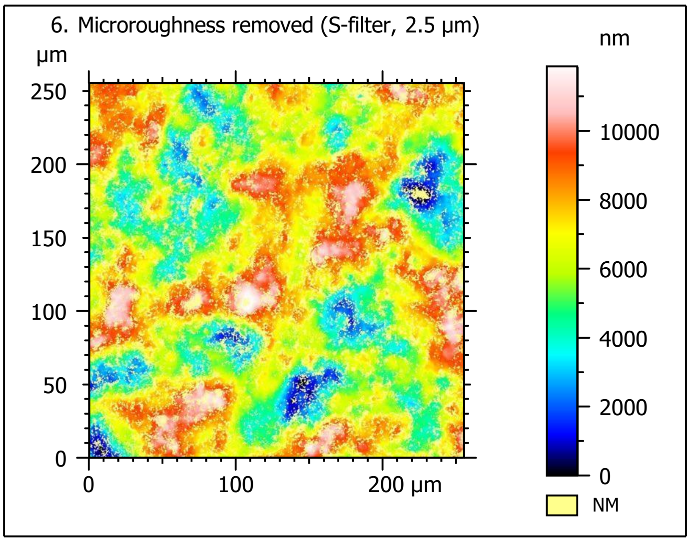
3. Form removed (polynomial degree 3)

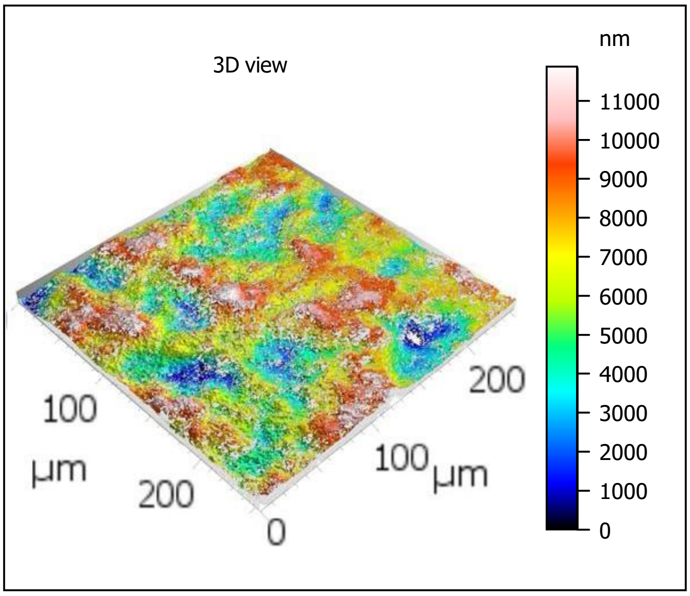


5. Thresholded (0.1-99,9%)

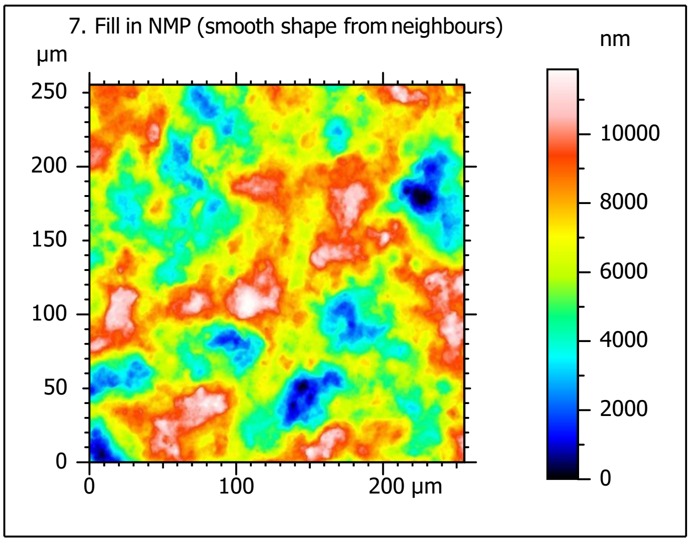


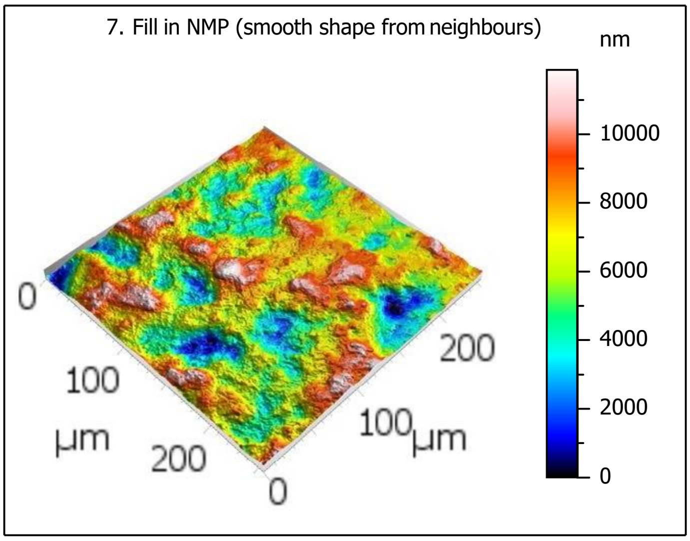
4. Outliers removed (max. slope 80°, soft)



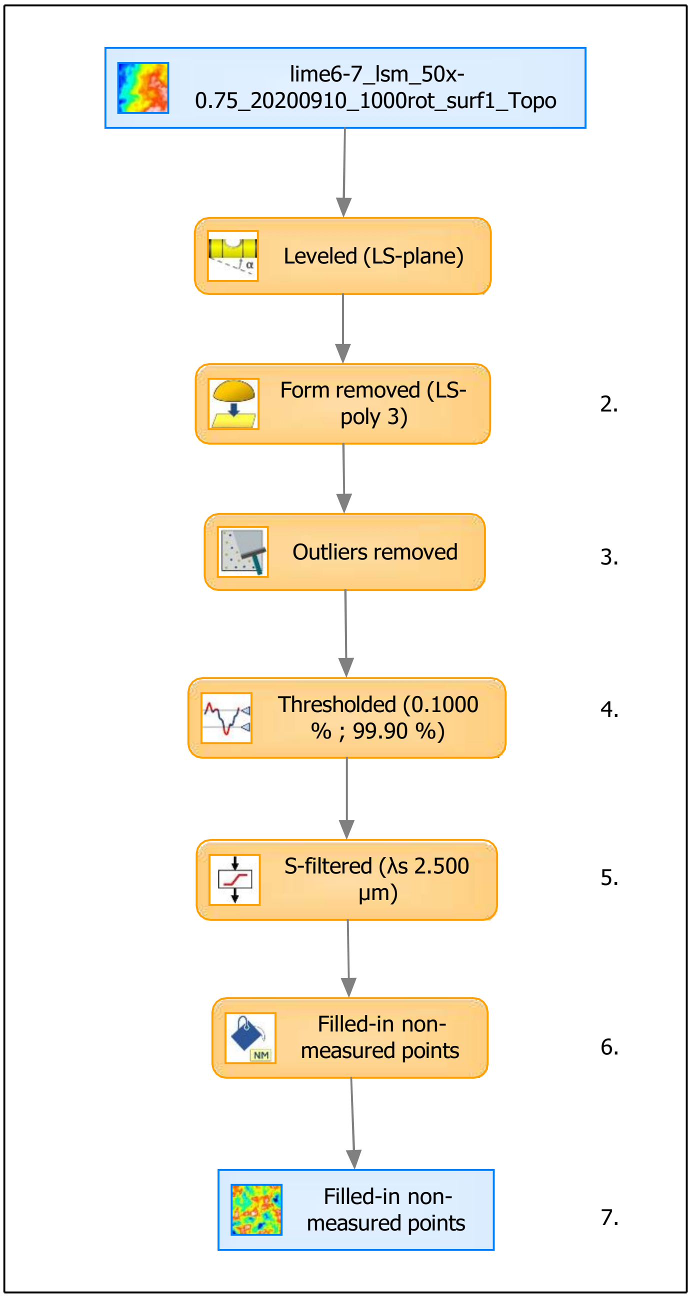


Identity card			
Name:	lime6-7_lsm_50x-0.75…filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R…00rot_surf1_Topo.sur		
Created on:	9/10/2020 12:50:56 PM		
Studiable type:	Surface		
Axis:	X		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Offset:	0.000	µm	
Axis:	Y		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Offset:	-255.3	µm	
Axis:	Z		
Layer type:	Topography		
Length:	11875	nm	
Min:	-6465	nm	
Max:	5411	nm	
Size:	204032	digits	
Spacing:	0.0582	nm	
NM-points ratio:	25.15 % (263761 Pts)		





Identity card		
Name:	lime6-7_lsm_50x-0.75_...in non-measured points	
Created on:	9/10/2020 12:50:56 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	11875	nm
Size:	204032	digits
Spacing:	0.0582	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	2193	nm
Ssk	-0.1488	
Sku	2.569	
Sp	5345	nm
Sv	6530	nm
Sz	11875	nm
Sa	1791	nm
Functional parameters		
Smr	1.256	%
Smc	2878	nm
Sxp	4405	nm
Spatial parameters		
Sal	23.27	µm
Str	0.6687	
Std	73.50	°
Hybrid parameters		
Sdq	0.4170	
Sdr	7.830	%
Functional parameters (Volume)		
Vm	0.07634	µm³/µm²
Vv	2.954	µm³/µm²
Vmp	0.07634	µm³/µm²
Vmc	2.094	µm³/µm²
Vvc	2.712	µm³/µm²
Vvv	0.2429	µm³/µm²

Analyses:

ISO 25178 8.

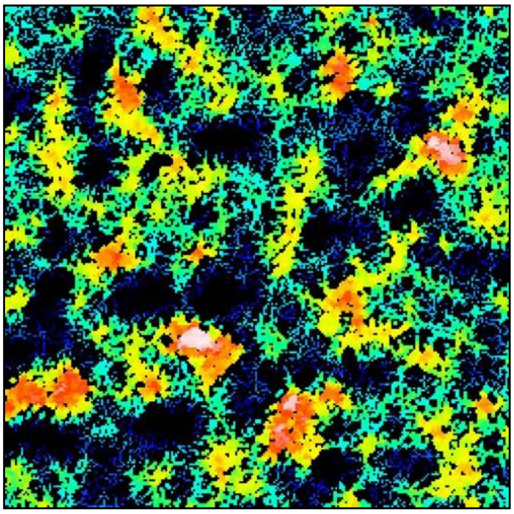
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

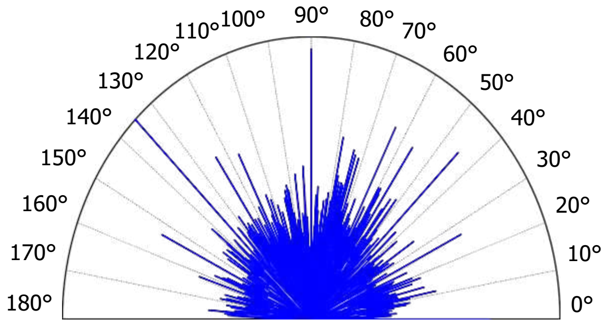
9. Furrow analysis on surface #7



All furrows are shown.

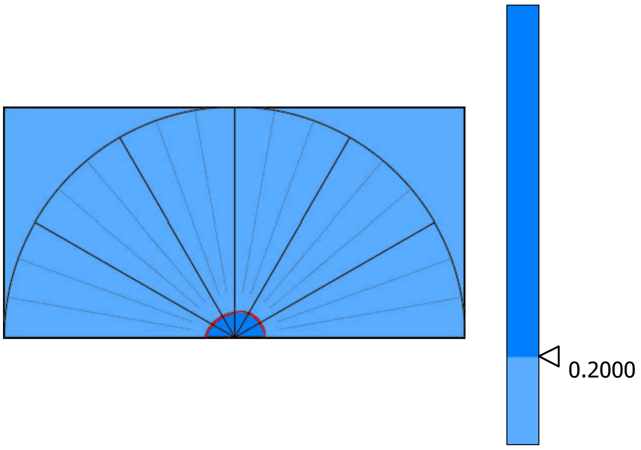
Parameters	Value	Unit
Maximum depth of furrows	6853	nm
Mean depth of furrows	2483	nm
Mean density of furrows	2404	cm/cm2

10. Texture direction on surface #7



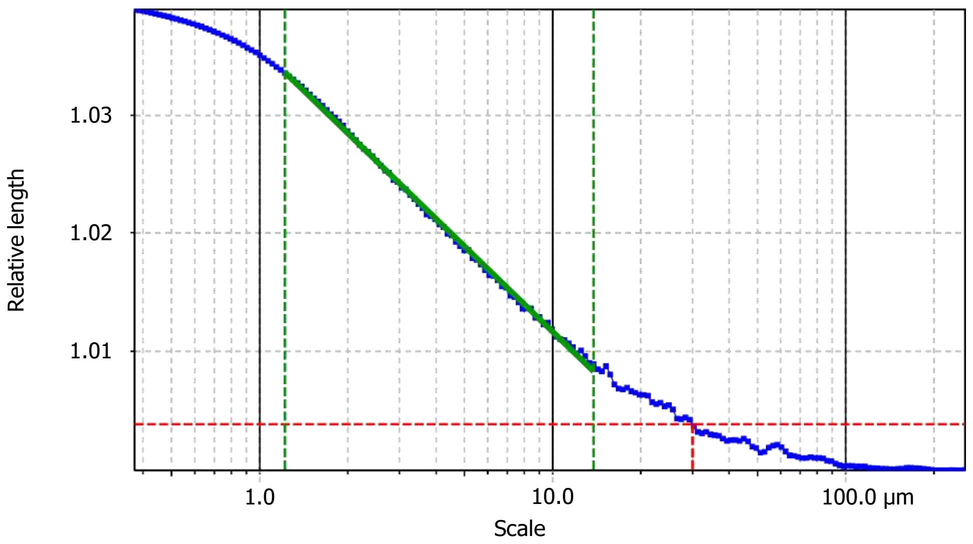
Parameters	Value	Unit
First direction	135.0	°
Second direction	89.99	°
Third direction	45.00	°

11. Texture isotropy on surface #7



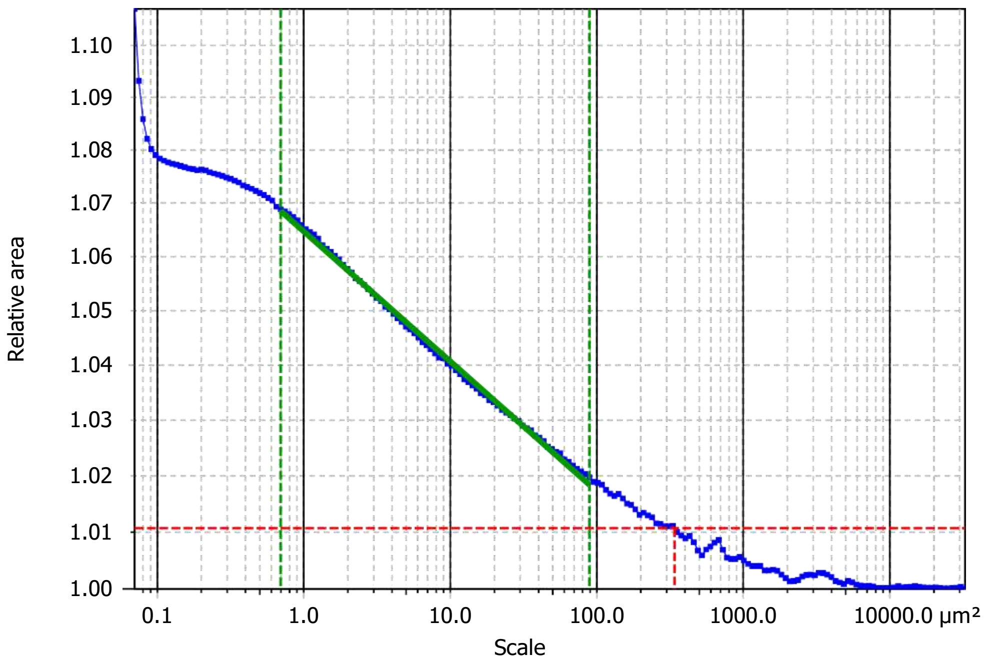
Parameters	Value	Unit
Isotropy	80.19	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0008761		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01758		*Length-scale anisotropy (1.8 µm, 5°)*

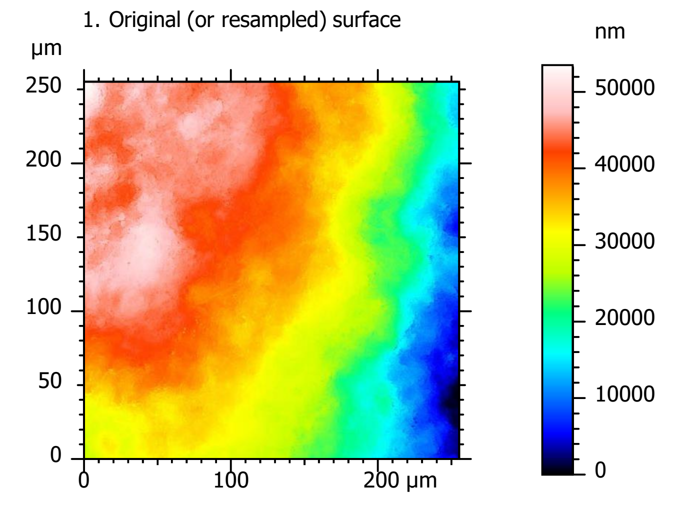


Information	
Method	Area-scale (four corners)

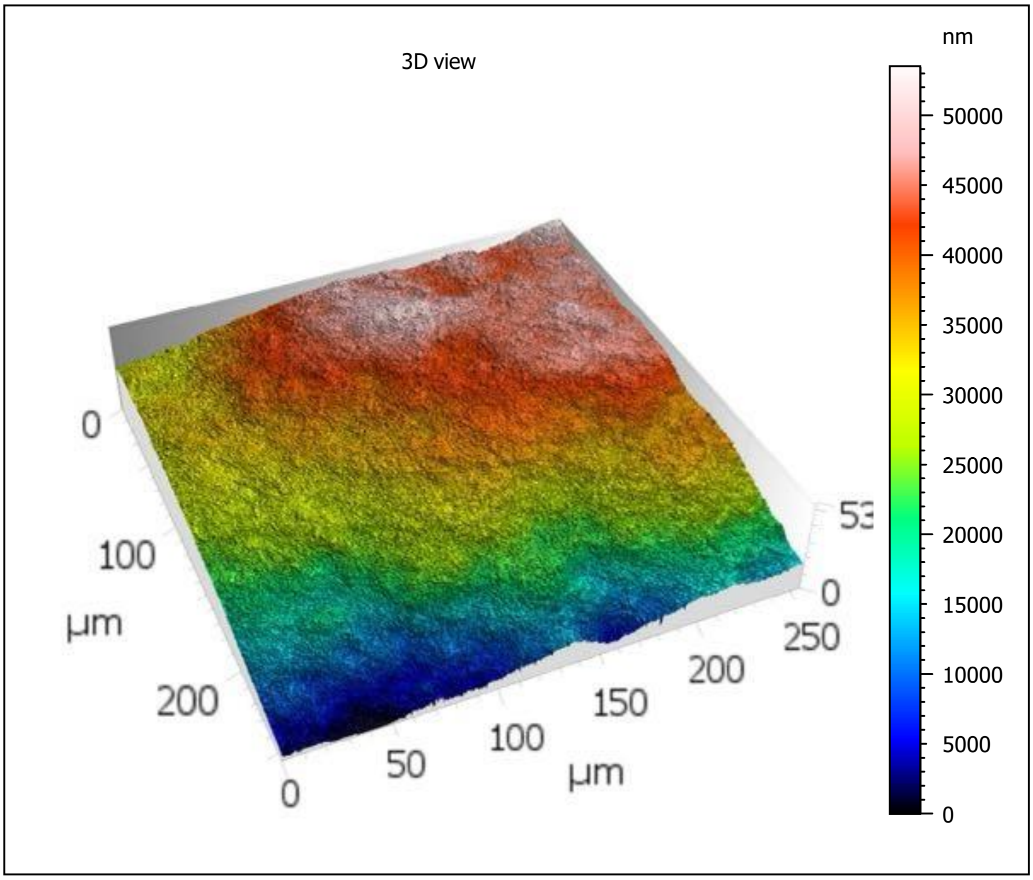
Parameters	Value	Unit	Comment
Asfc	9.905		*Fractal complexity*
Smfc	2.757	µm²	*Scale of max complexity*
HAsfc9	0.06856		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2041		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

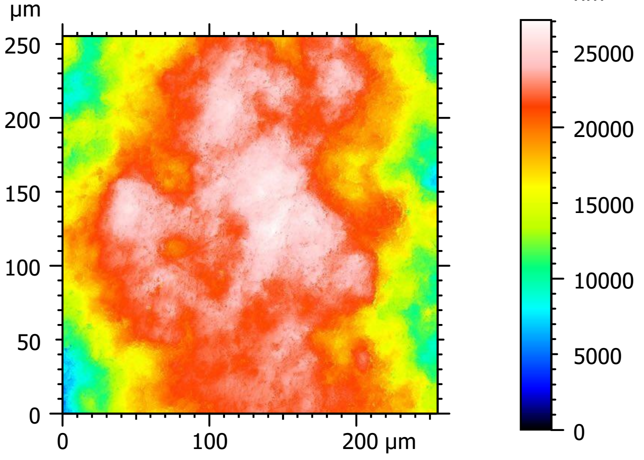
Processing



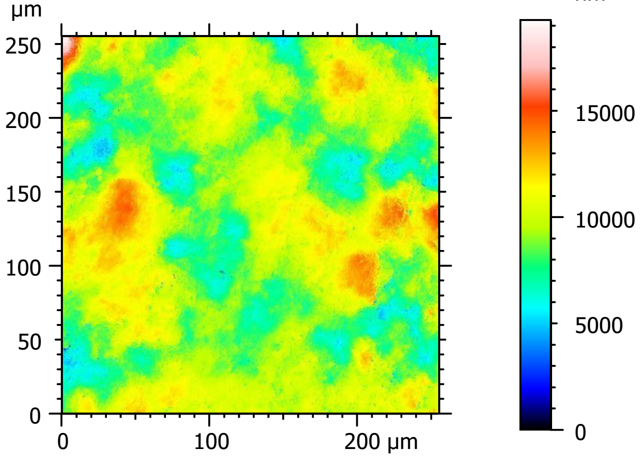
Identity card		
Name:	lime6-7_lsm_50x-0.75_...10_1000rot_surf2_Topo	
Created on:	9/10/2020 3:13:35 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	53528	nm
Size:	65532	digits
Spacing:	0.8168	nm
NM-points ratio:	0.000 % (0 Pts)	



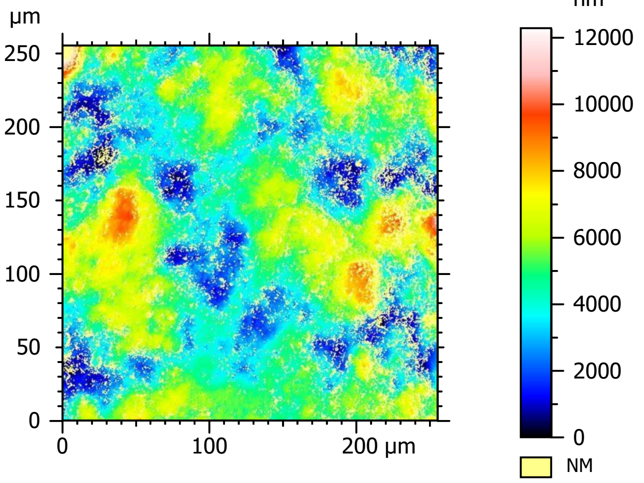
2. Leveled surface (least squares plane, substraction)



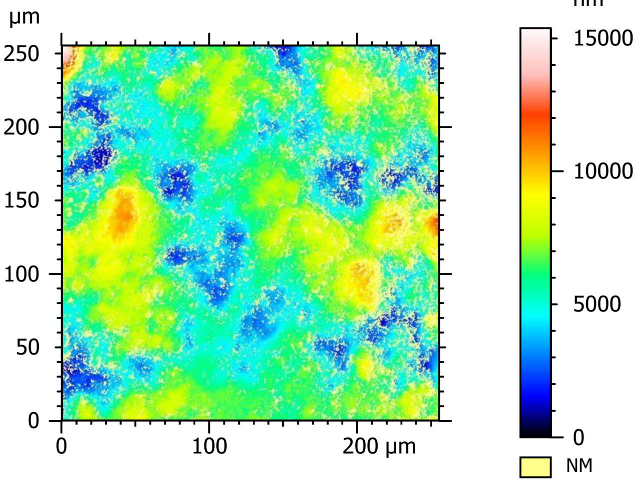
3. Form removed (polynomial degree 3)

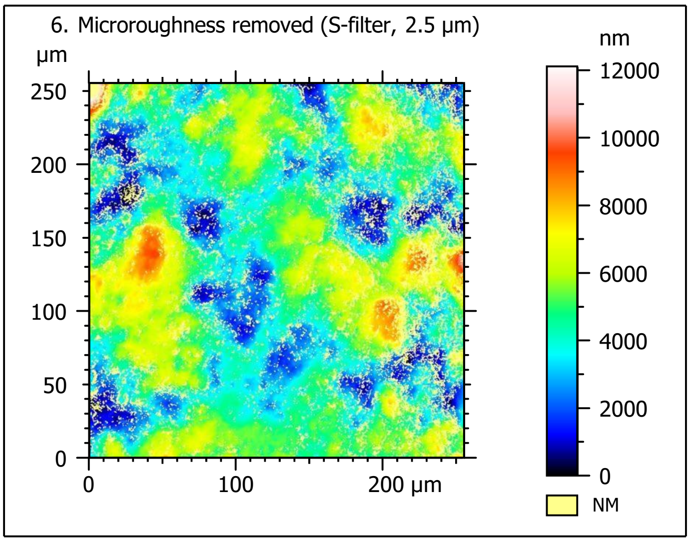


5. Thresholded (0.1-99,9%)

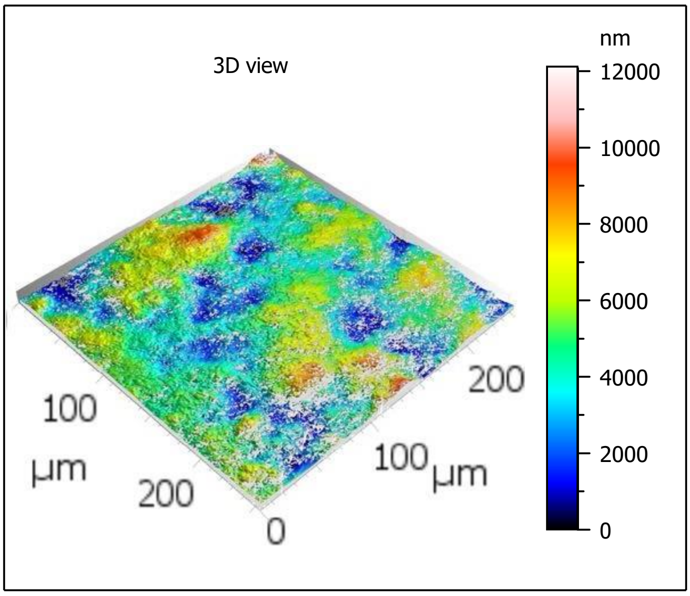


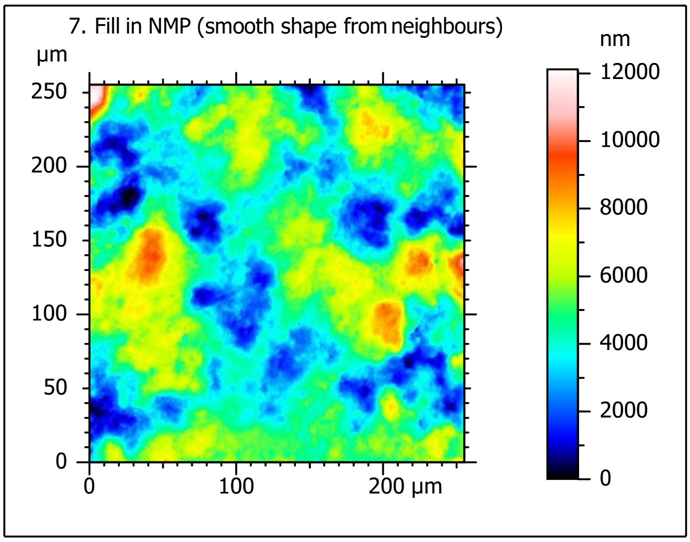
4. Outliers removed (max. slope 80°, soft)

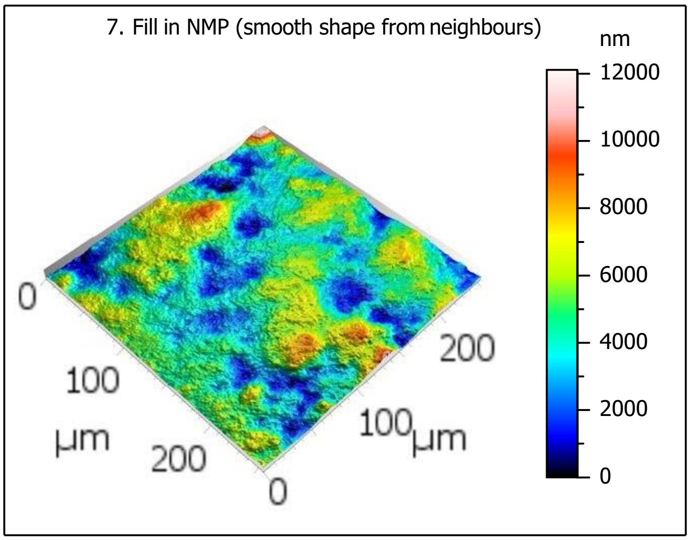




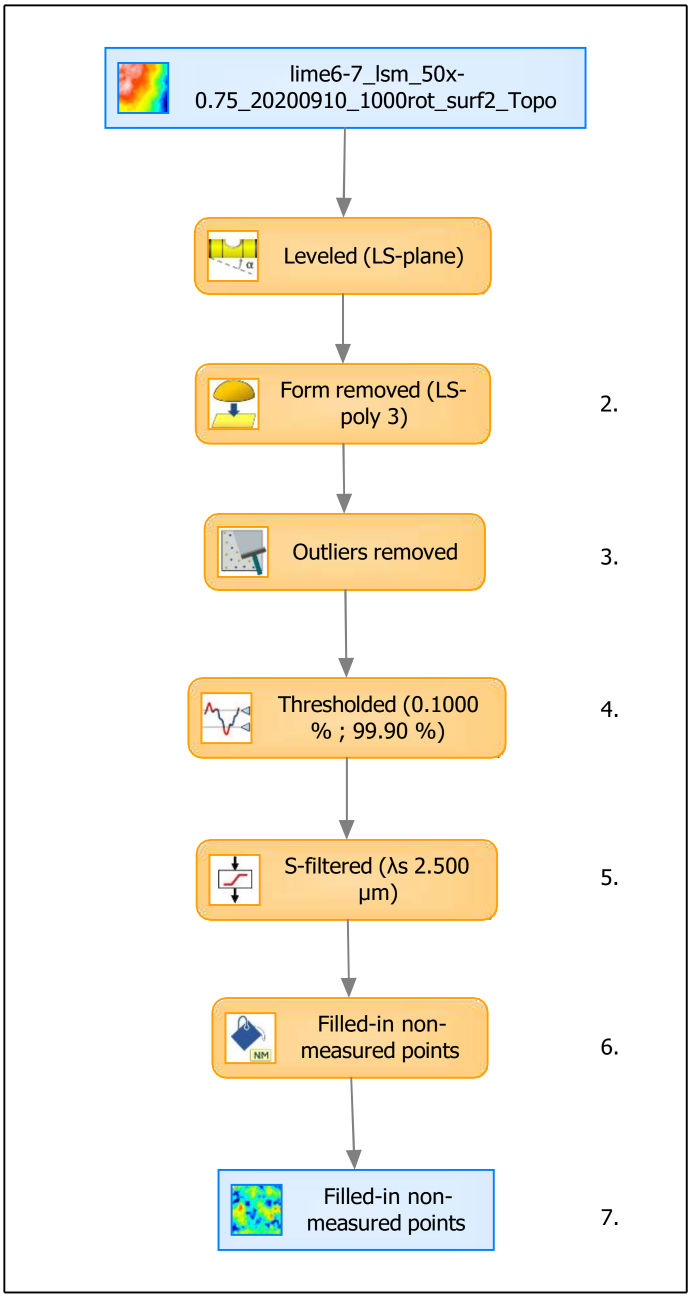
Identity card		
Name:	lime6-7_lsm_50x-0.75…filtered (λs 2.500 µm)	
File path:	C:\Users\marreiros.R…00rot_surf2_Topo.sur	
Created on:	9/10/2020 3:13:35 PM	
Studiable type:	Surface	
Axis:	X	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	0.000	µm
Axis:	Y	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Offset:	-255.3	µm
Axis:	Z	
Layer type:	Topography	
Length:	12115	nm
Min:	-4365	nm
Max:	7751	nm
Size:	148320	digits
Spacing:	0.08168	nm
NM-points ratio:	20.47 % (214631 Pts)	







Identity card		
Name:	lime6-7_lsm_50x-0.75_...in non-measured points	
Created on:	9/10/2020 3:13:35 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	12115	nm
Size:	148320	digits
Spacing:	0.08168	nm
NM-points ratio:	0.000 % (0 Pts)	



Analyses:

ISO 25178 8.

Furrow 9.

Texture direction 10.

Texture isotropy 11.

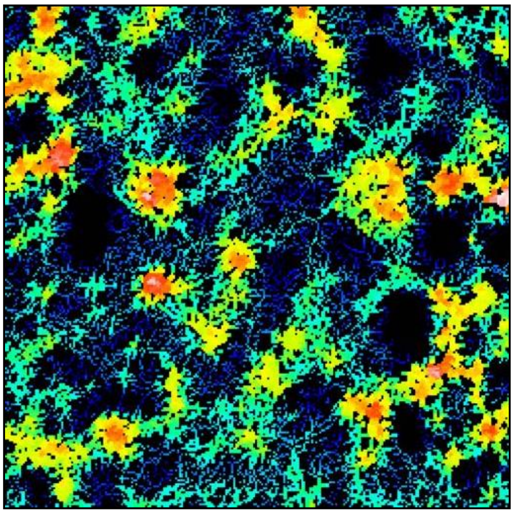
SSFA 12.

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	1701	nm
Ssk	0.1704	
Sku	3.174	
Sp	7691	nm
Sv	4424	nm
Sz	12115	nm
Sa	1368	nm
Functional parameters		
Smr	0.1383	%
Smc	2081	nm
Sxp	3268	nm
Spatial parameters		
Sal	24.30	µm
Str	0.7342	
Std	81.50	°
Hybrid parameters		
Sdq	0.3513	
Sdr	5.662	%
Functional parameters (Volume)		
Vm	0.09106	µm³/µm²
Vv	2.172	µm³/µm²
Vmp	0.09106	µm³/µm²
Vmc	1.548	µm³/µm²
Vvc	1.989	µm³/µm²
Vvv	0.1827	µm³/µm²

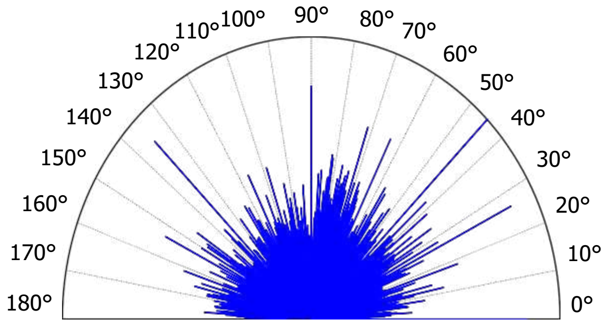
9. Furrow analysis on surface #7



All furrows are shown.

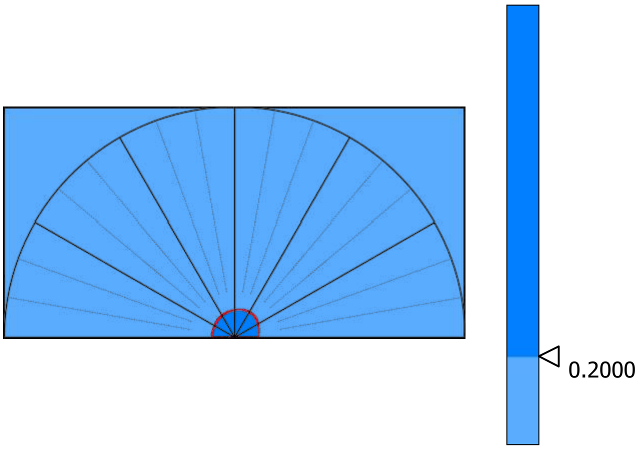
Parameters	Value	Unit
Maximum depth of furrows	5585	nm
Mean depth of furrows	1742	nm
Mean density of furrows	2558	cm/cm2

10. Texture direction on surface #7



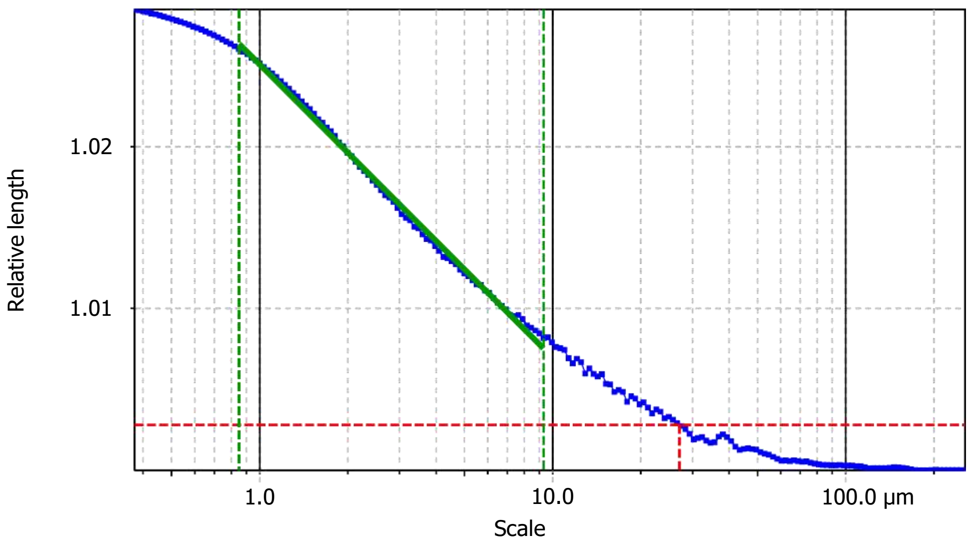
Parameters	Value	Unit
First direction	45.01	°
Second direction	26.45	°
Third direction	135.0	°

11. Texture isotropy on surface #7



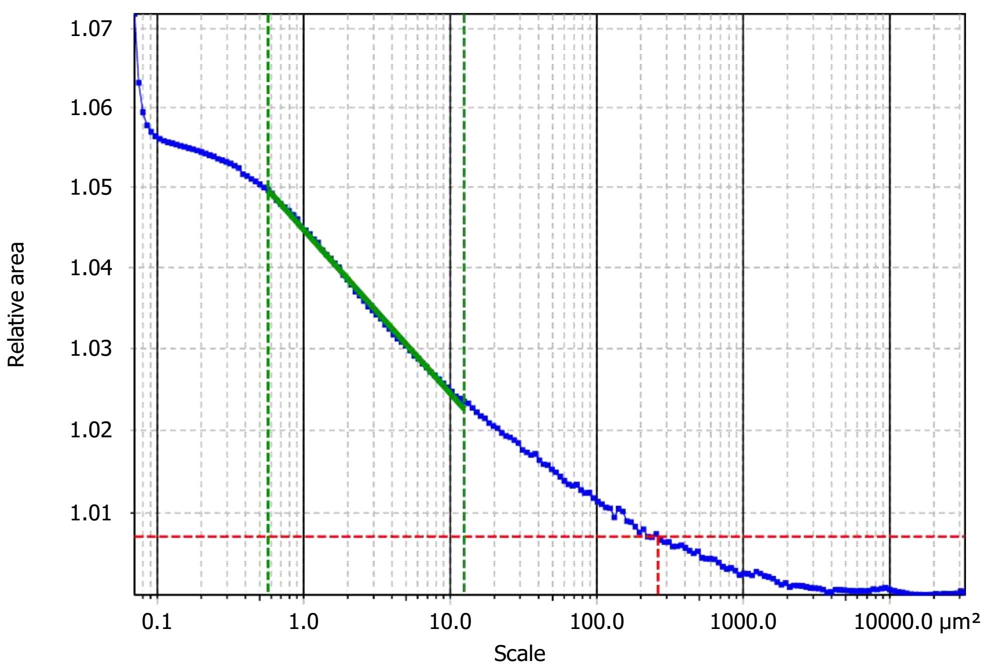
Parameters	Value	Unit
Isotropy	79.36	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.0004216		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01754		*Length-scale anisotropy (1.8 µm, 5°)*

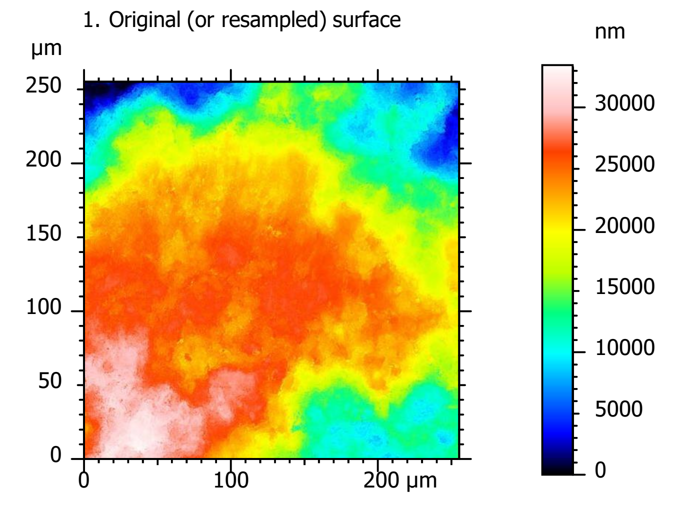


Information	
Method	Area-scale (four corners)

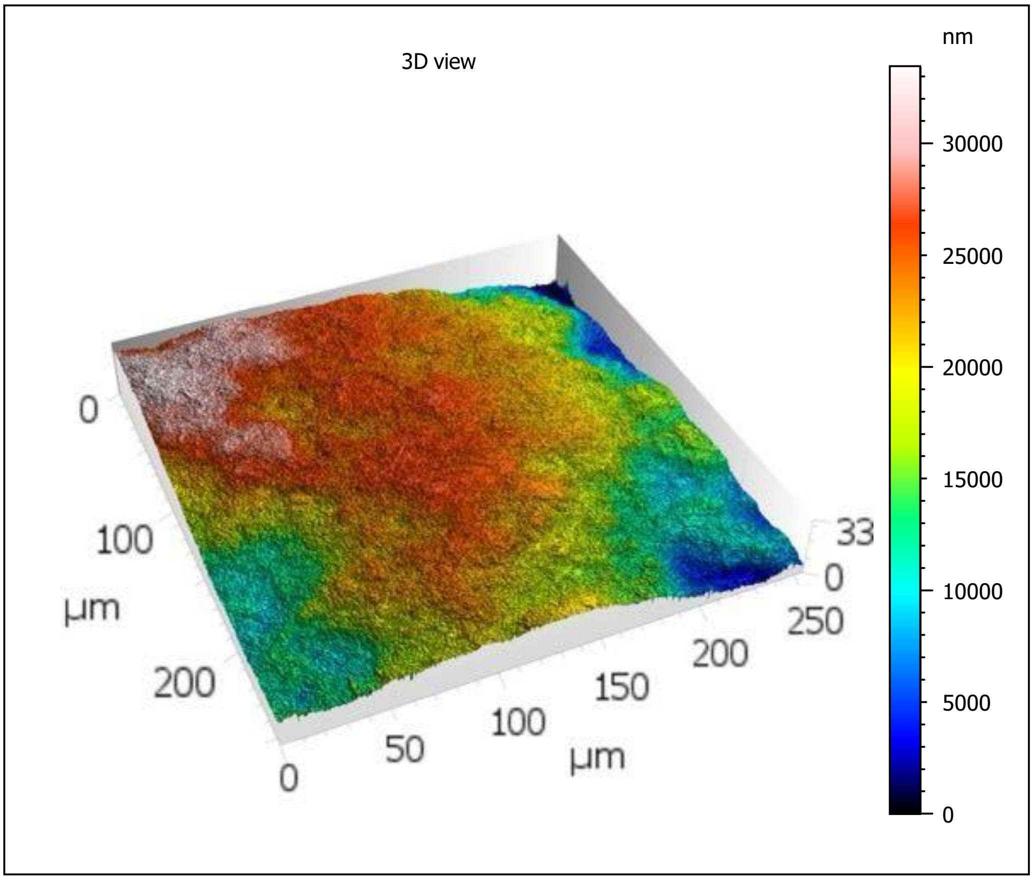
Parameters	Value	Unit	Comment
Asfc	8.466		*Fractal complexity*
Smfc	1.860	µm²	*Scale of max complexity*
HAsfc9	0.1856		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2438		*Heterogeneity of Asfc (9x9)*

Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

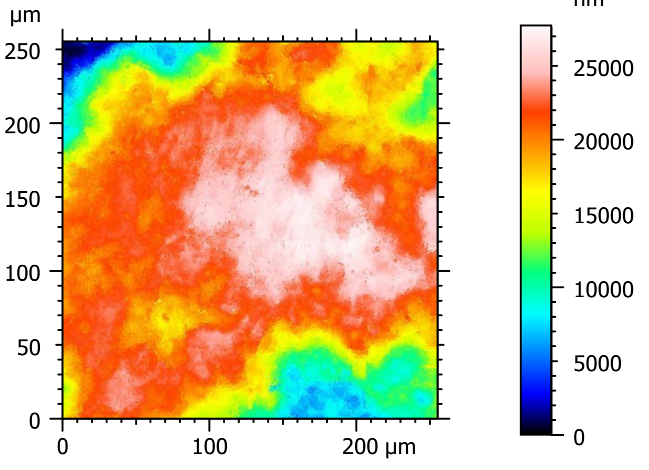
Processing



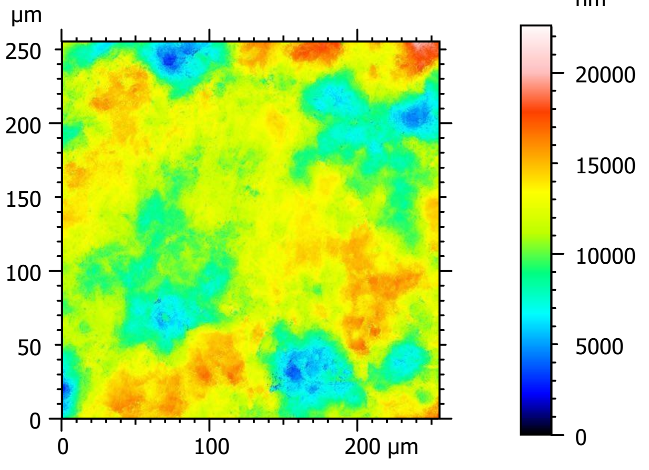
Identity card		
Name:	lime6-7_lsm_50x-0.75_...10_1000rot_surf3_Topo	
Created on:	9/10/2020 4:09:38 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	33458	nm
Size:	65532	digits
Spacing:	0.5106	nm
NM-points ratio:	0.000 % (0 Pts)	



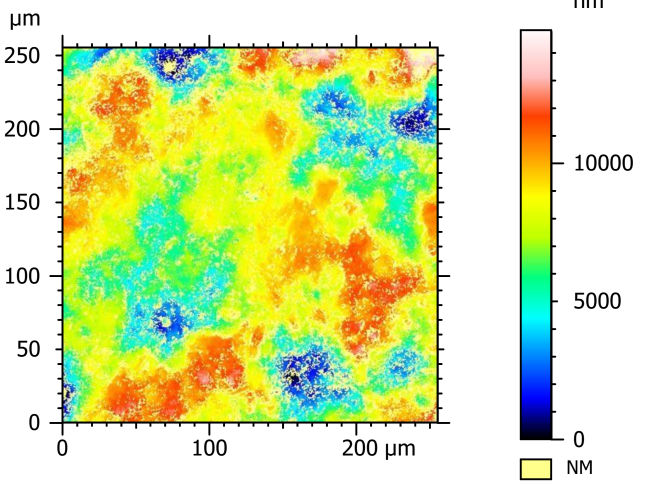
2. Leveled surface (least squares plane, substraction)



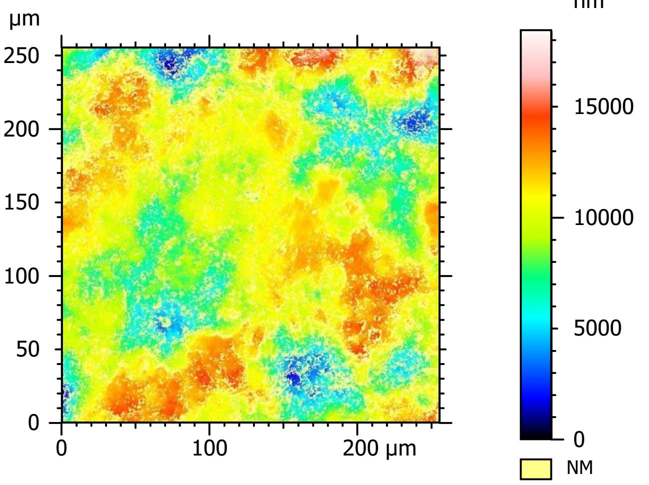
3. Form removed (polynomial degree 3)

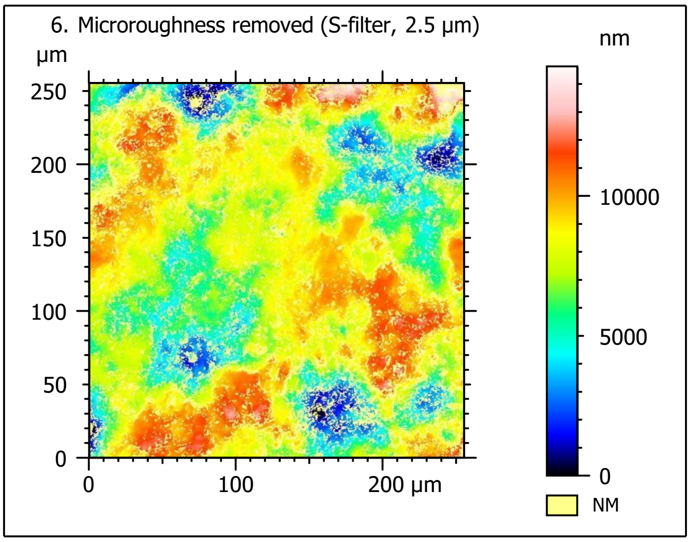


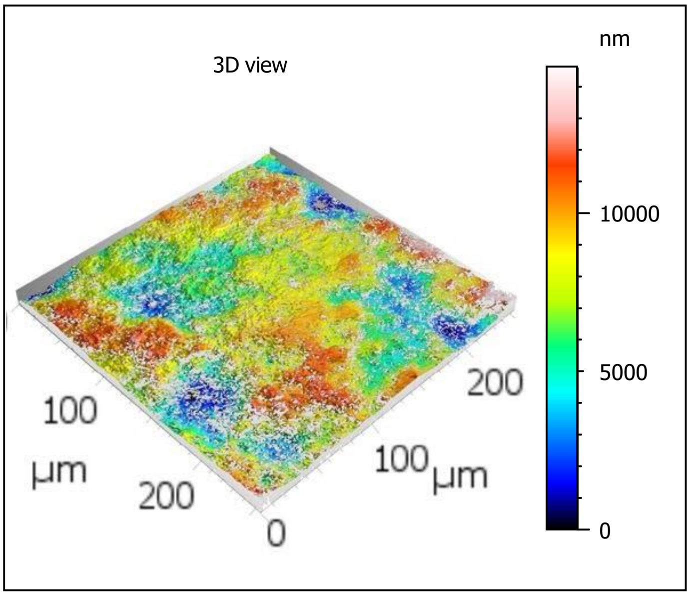
5. Thresholded (0.1-99,9%)



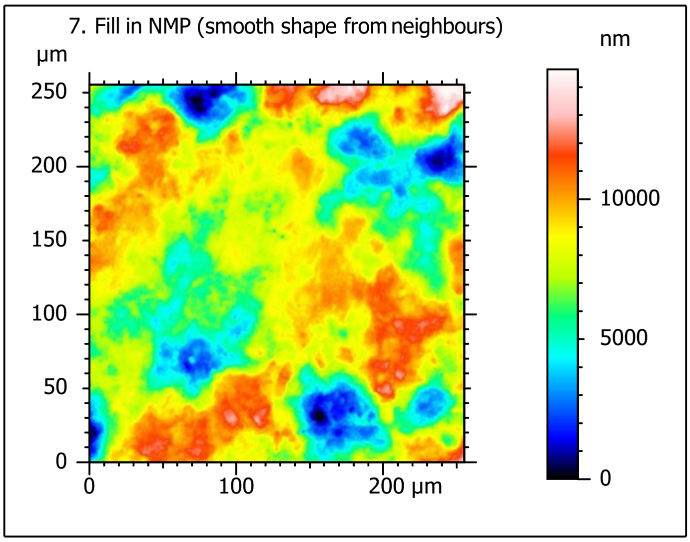
4. Outliers removed (max. slope 80°, soft)

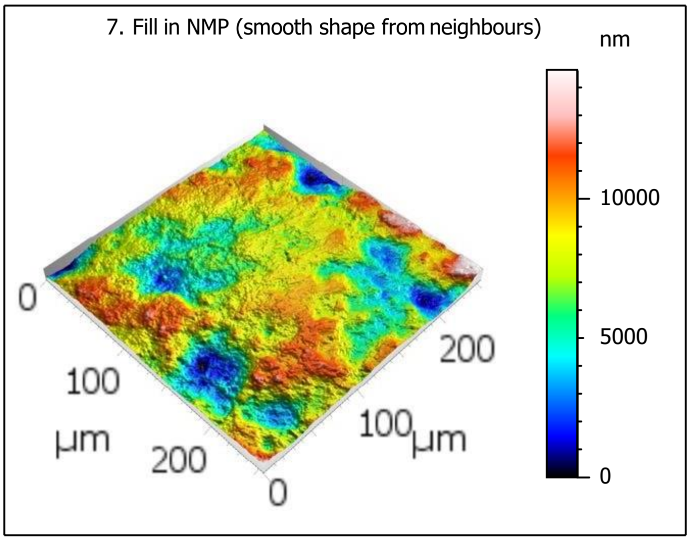






Identity card			
Name:	lime6-7_lsm_50x-0.75…filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R…00rot_surf3_Topo.sur		
Created on:	9/10/2020 4:09:38 PM		
Studiable type:	Surface		
Axis:	X		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Offset:	0.000	µm	
Axis:	Y		
Length:	255.3	µm	
Size:	1024	points	
Spacing:	0.2496	µm	
Offset:	-255.3	µm	
Axis:	Z		
Layer type:	Topography		
Length:	14633	nm	
Min:	-7412	nm	
Max:	7220	nm	
Size:	286602	digits	
Spacing:	0.05106	nm	
NM-points ratio:	27.62 % (289573 Pts)		





Identity card		
Name:	lime6-7_lsm_50x-0.75_...in non-measured points	
Created on:	9/10/2020 4:09:38 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Y**	
Length:	255.3	µm
Size:	1024	points
Spacing:	0.2496	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	14633	nm
Size:	286602	digits
Spacing:	0.05106	nm
NM-points ratio:	0.000 % (0 Pts)	

lime6-7_lsm_50x-0.75_20200910_1000rot_surf3_Topo

Leveled (LS-plane)

Form removed (LS-poly 3) 2.

Outliers removed 3.

Thresholded (0.1000 % ; 99.90 %) 4.

S-filtered (λs 2.500 µm) 5.

Filled-in non-measured points 6.

Filled-in non-measured points 7.

Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface		
F: [Workflow] Form removed (LS-poly 3)		
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)		
Height parameters		
Sq	2435	nm
Ssk	-0.3369	
Sku	2.852	
Sp	7133	nm
Sv	7499	nm
Sz	14633	nm
Sa	1956	nm
Functional parameters		
Smr	0.3642	%
Smc	2962	nm
Sxp	5435	nm
Spatial parameters		
Sal	23.39	µm
Str	0.6891	
Std	67.76	°
Hybrid parameters		
Sdq	0.4159	
Sdr	7.711	%
Functional parameters (Volume)		
Vm	0.08708	µm³/µm²
Vv	3.049	µm³/µm²
Vmp	0.08708	µm³/µm²
Vmc	2.328	µm³/µm²
Vvc	2.737	µm³/µm²
Vvv	0.3122	µm³/µm²

Analyses:

ISO 25178 8.

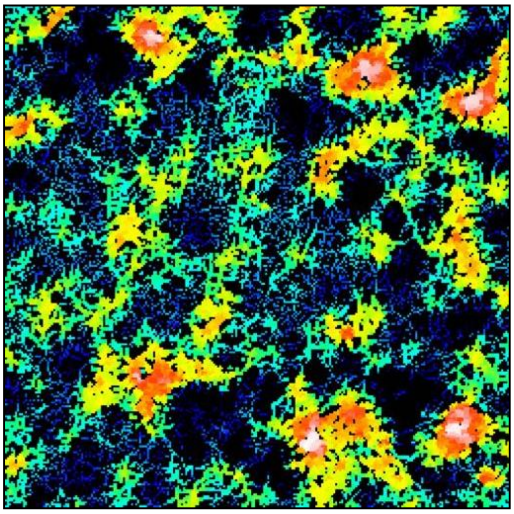
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

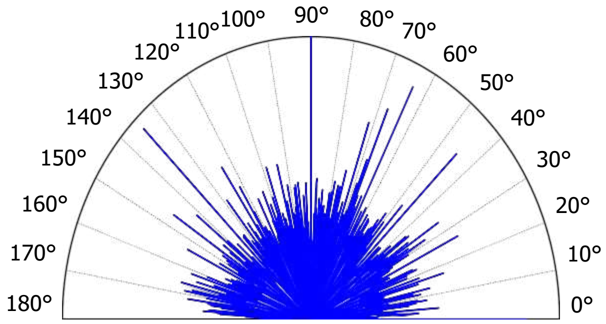
9. Furrow analysis on surface #7



All furrows are shown.

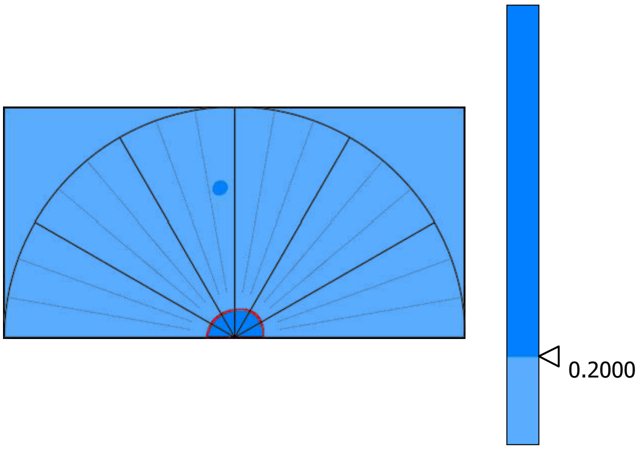
Parameters	Value	Unit
Maximum depth of furrows	6342	nm
Mean depth of furrows	2113	nm
Mean density of furrows	2457	cm/cm2

10. Texture direction on surface #7



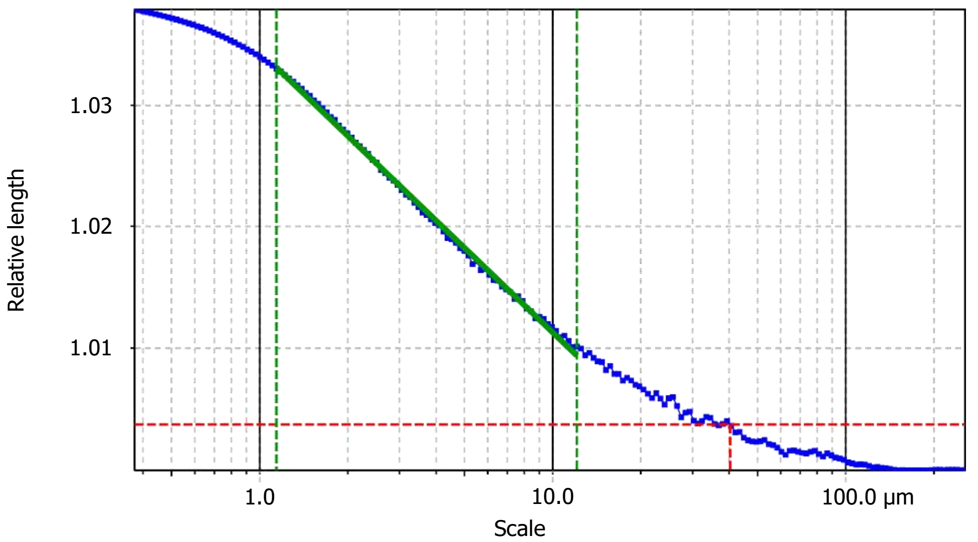
Parameters	Value	Unit
First direction	90.01	°
Second direction	135.0	°
Third direction	63.53	°

11. Texture isotropy on surface #7



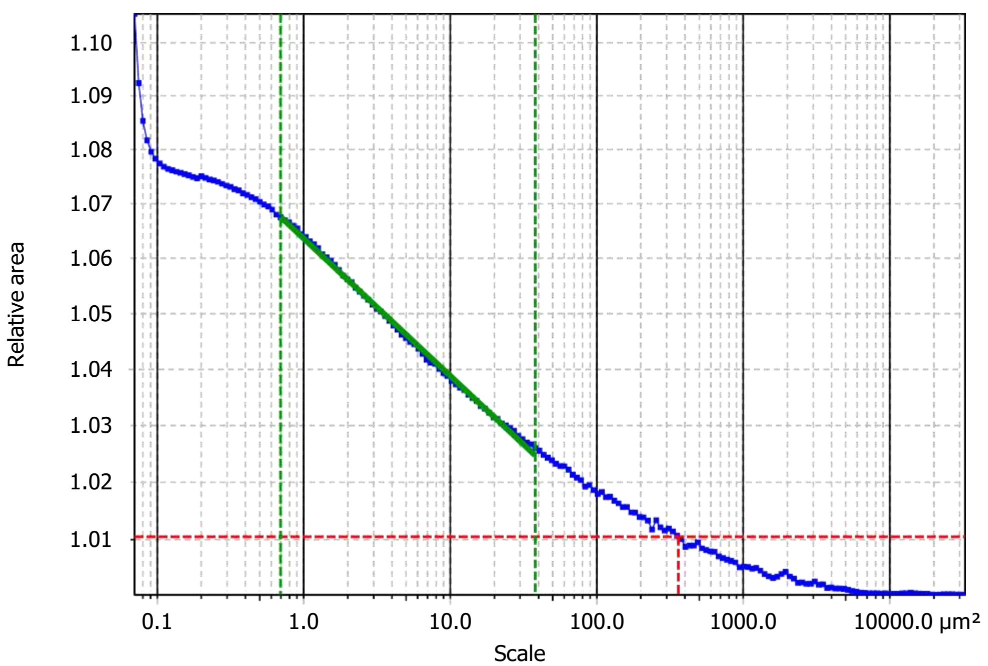
Parameters	Value	Unit
Isotropy	86.68	%

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001545		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01788		*Length-scale anisotropy (1.8 µm, 5°)*

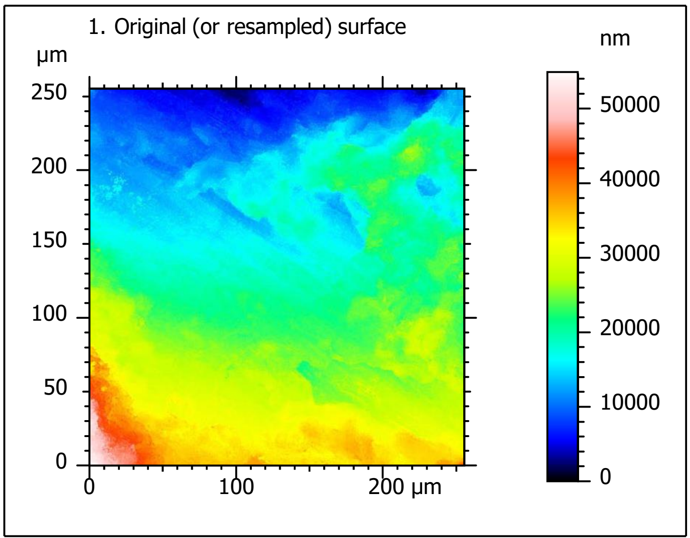


Information	
Method	Area-scale (four corners)

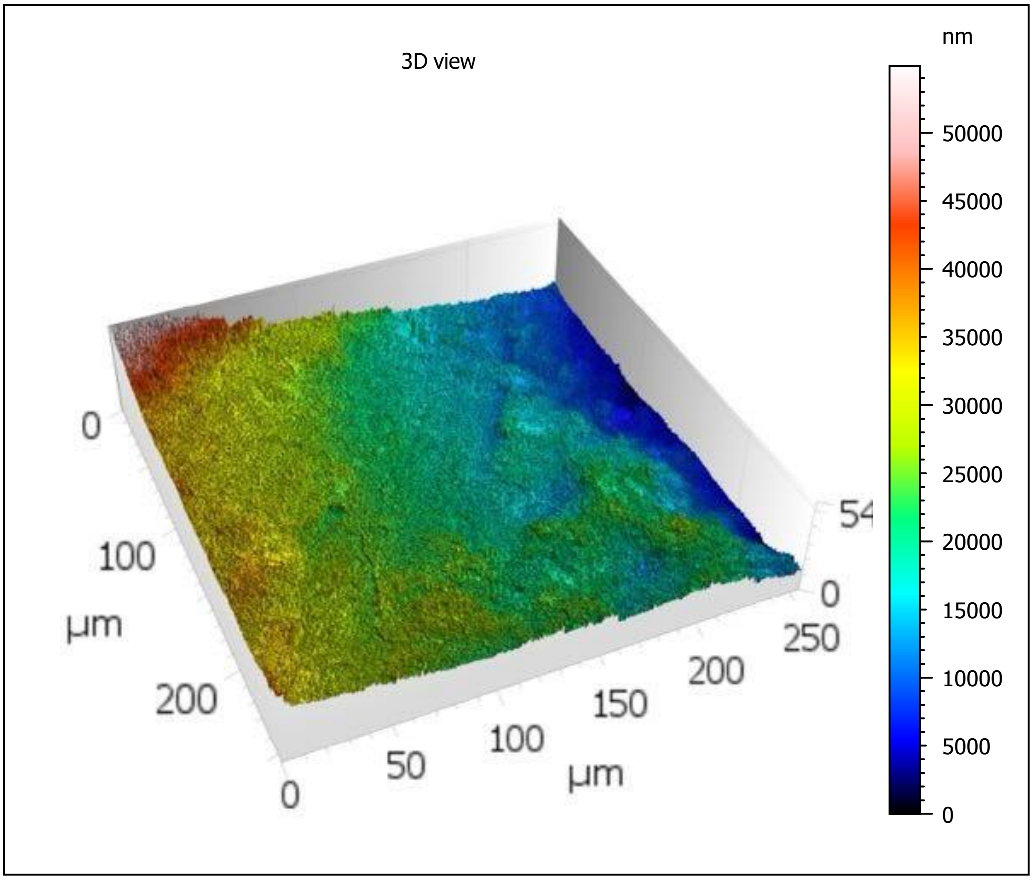
Parameters	Value	Unit	Comment
Asfc	10.25		*Fractal complexity*
Smfc	2.418	µm²	*Scale of max complexity*
HAsfc9	0.1691		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.2661		*Heterogeneity of Asfc (9x9)*

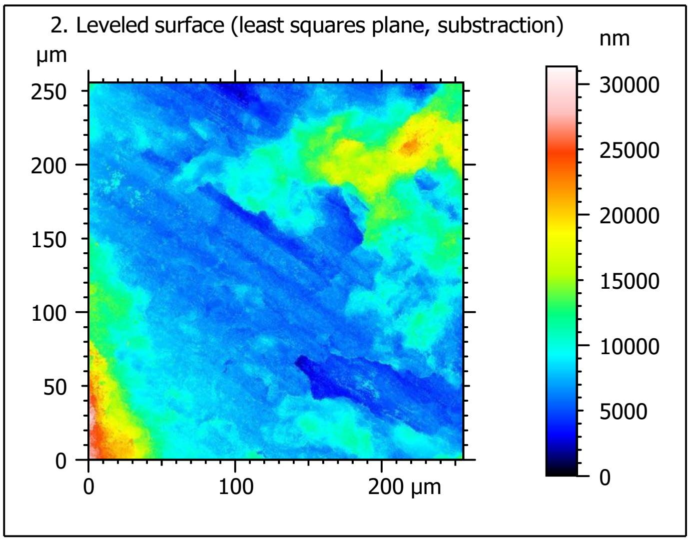
Template - Processing analysis
Template to process all surfaces aquired with the LSM with the 50x/0.75 and 50x/0.95 objectives.

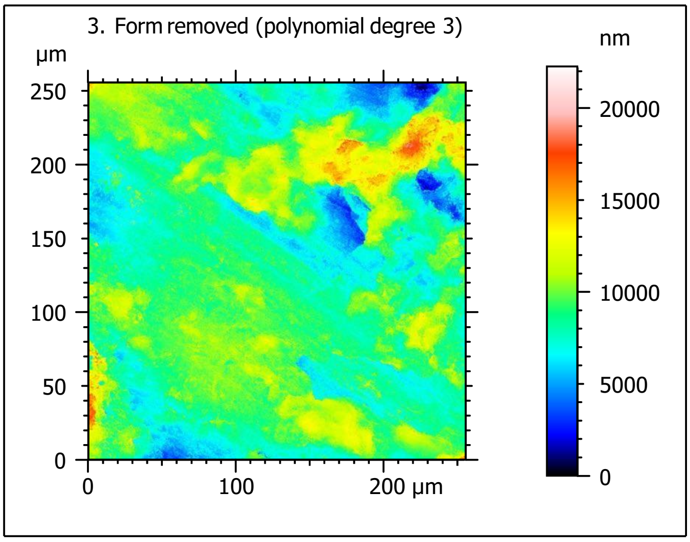
Processing

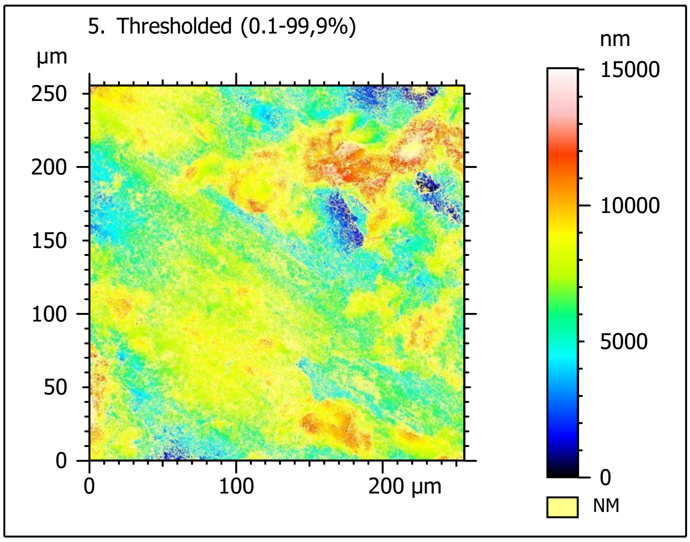


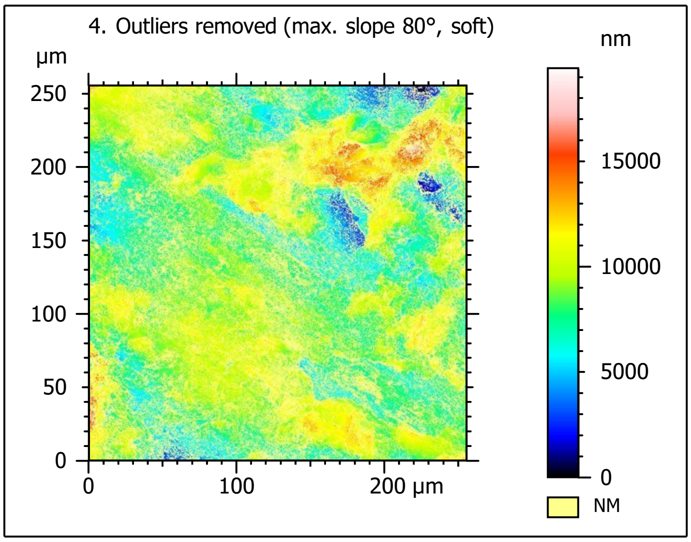
Identity card		
Name:	MirroringSurfaces --- li...0914_surf1_Topo-mold	
Created on:	3/10/2020 4:25:37 PM	
Studiable type:	Surface	
Axis:	**X**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Y**	
Length:	255.5	µm
Size:	3000	points
Spacing:	0.08519	µm
Axis:	**Z**	
Layer type:	Topography	
Length:	54908	nm
Size:	65532	digits
Spacing:	0.8379	nm
NM-points ratio:	0.000 % (0 Pts)	



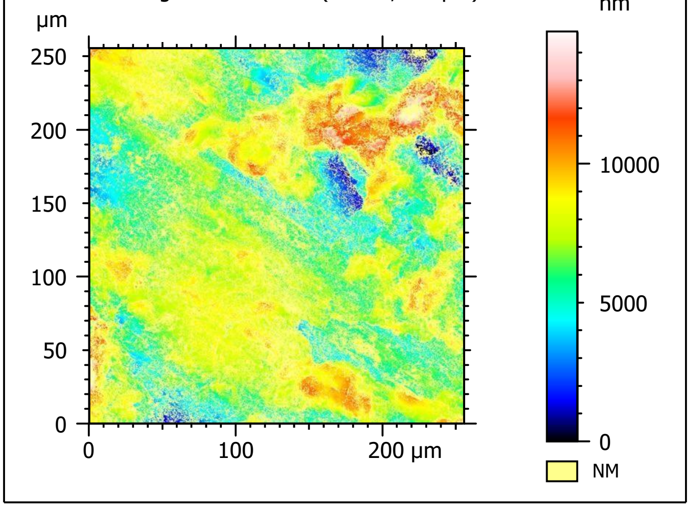

2. Leveled surface (least squares plane, substraction)
µm
nm
250
200
150
100
50
0
0
100
200 µm
30000
25000
20000
15000
10000
5000
0


3. Form removed (polynomial degree 3)
µm
nm
250
200
150
100
50
0
0
100
200 µm
20000
15000
10000
5000
0

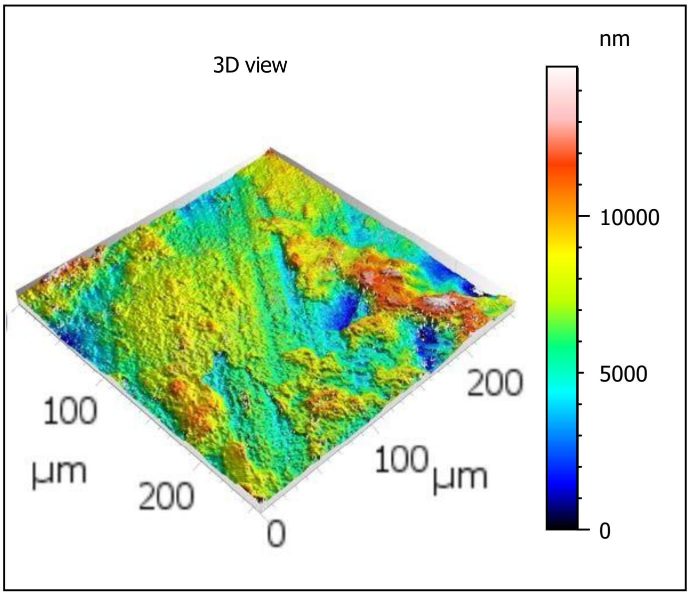

5. Thresholded (0.1-99,9%)
µm
nm
250
200
150
100
50
0
0
100
200 µm
15000
10000
5000
0
NM


4. Outliers removed (max. slope 80°, soft)
µm
nm
250
200
150
100
50
0
0
100
200 µm
15000
10000
5000
0
NM

6. Microroughness removed (S-filter, 2.5 µm)

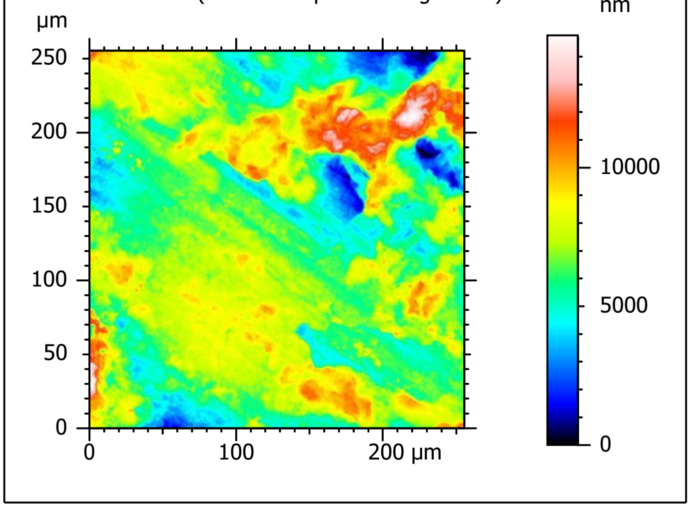


3D view

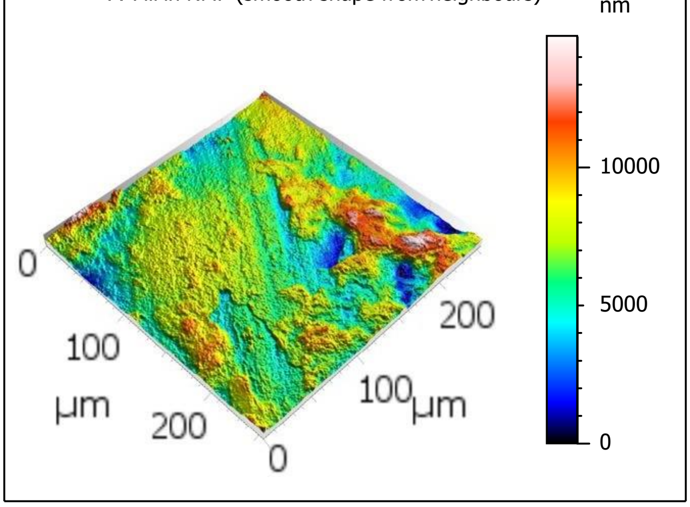


Identity card			
Name:	MirroringSurfaces --- 1…filtered (λs 2.500 µm)		
File path:	C:\Users\marreiros.R…_surf1_Topo-mold.sur		
Created on:	3/10/2020 4:25:37 PM		
Studiable type:	Surface		
Axis:	X		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	0.000	µm	
Axis:	Y		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Offset:	-255.5	µm	
Axis:	Z		
Layer type:	Topography		
Length:	14766	nm	
Min:	-6989	nm	
Max:	7777	nm	
Size:	176229	digits	
Spacing:	0.08379	nm	
NM-points ratio:	42.45 % (3820628 Pts)		

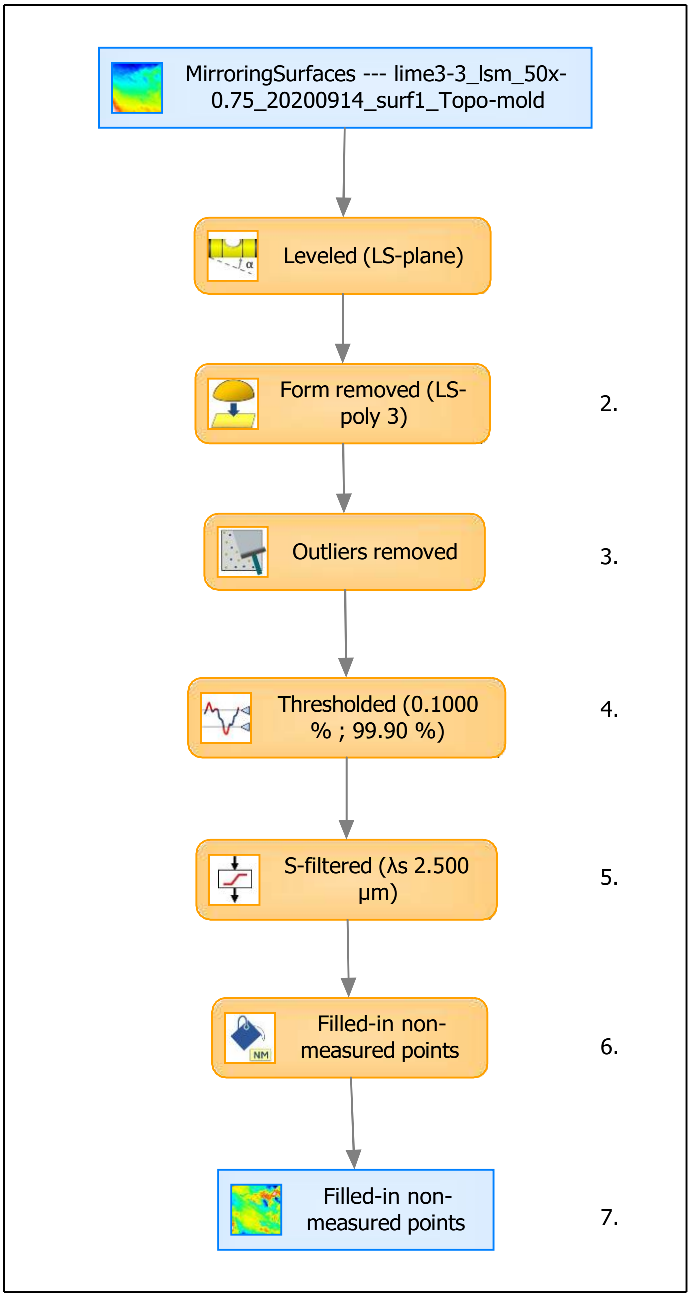
7. Fill in NMP (smooth shape from neighbours)



7. Fill in NMP (smooth shape from neighbours)



Identity card			
Name:	MirroringSurfaces --- li...in non-measured points		
Created on:	3/10/2020 4:25:37 PM		
Studiable type:	Surface		
Axis:	**X**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Y**		
Length:	255.5	µm	
Size:	3000	points	
Spacing:	0.08519	µm	
Axis:	**Z**		
Layer type:	Topography		
Length:	14766	nm	
Size:	176229	digits	
Spacing:	0.08379	nm	
NM-points ratio:	0.000 % (0 Pts)		



Analyses

8. ISO 25178-2 parameters on surface #7

ISO 25178 - Primary surface			
F: [Workflow] Form removed (LS-poly 3)			
S-filter (λs): [Workflow] S-filtered (λs 2.500 µm)			
Height parameters			
Sq	1978	nm	
Ssk	0.1797		
Sku	3.914		
Sp	7859	nm	
Sv	6907	nm	
Sz	14766	nm	
Sa	1507	nm	
Functional parameters			
Smr	0.2124	%	
Smc	2378	nm	
Sxp	4002	nm	
Spatial parameters			
Sal	19.02	µm	
Str	0.4634		
Std	147.5	°	
Hybrid parameters			
Sdq	0.6043		
Sdr	13.49	%	
Functional parameters (Volume)			
Vm	0.1331	µm³/µm²	
Vv	2.511	µm³/µm²	
Vmp	0.1331	µm³/µm²	
Vmc	1.631	µm³/µm²	
Vvc	2.281	µm³/µm²	
Vvv	0.2304	µm³/µm²	

Analyses:

ISO 25178 8.

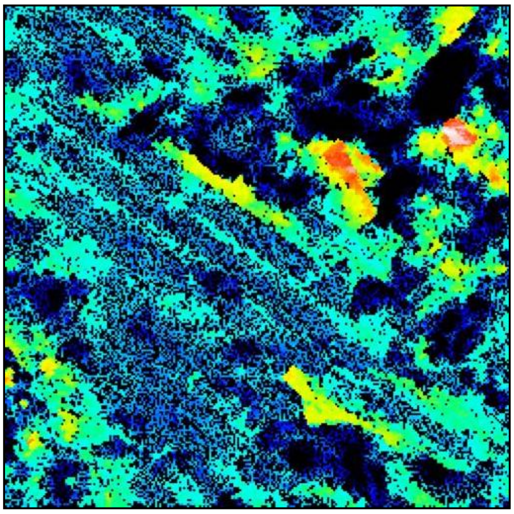
Furrow 9.

Texture direction 10.

Texture isotropy 11.

SSFA 12.

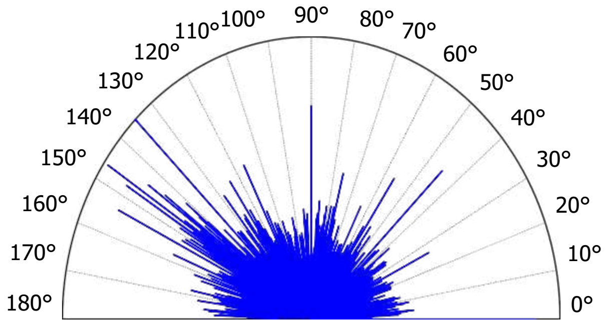
9. Furrow analysis on surface #7



All furrows are shown.

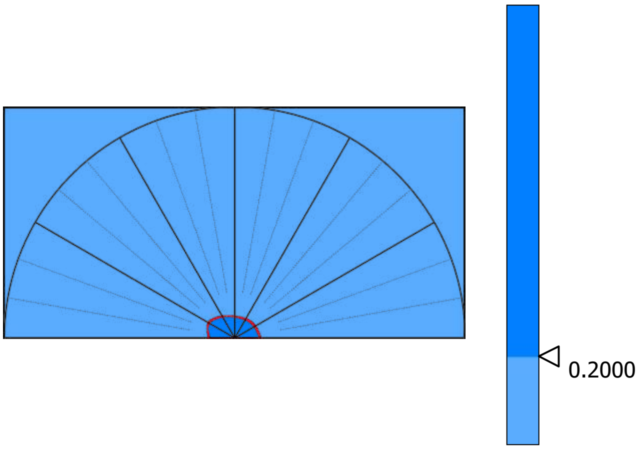
Parameters	Value	Unit	
Maximum depth of furrows	9325	nm	
Mean depth of furrows	2431	nm	
Mean density of furrows	4763	cm/cm2	

10. Texture direction on surface #7



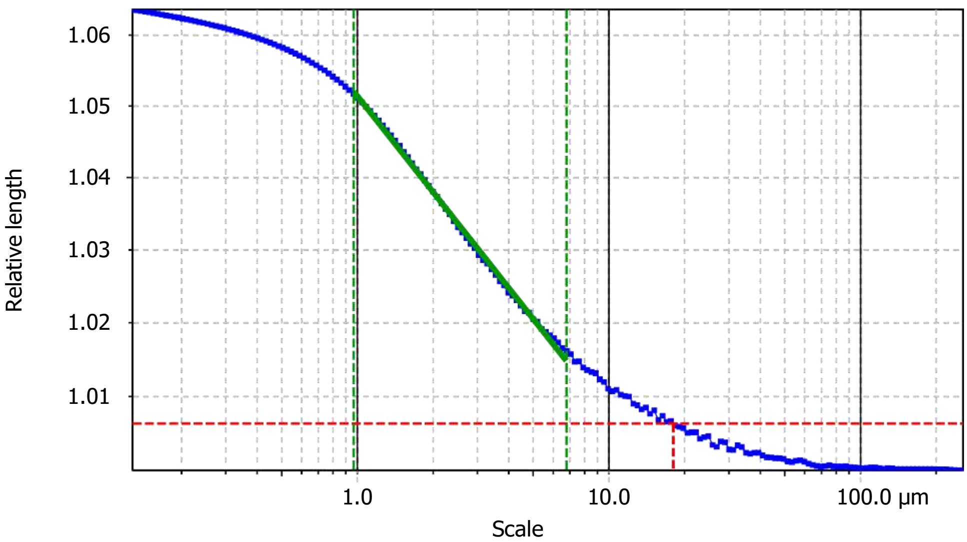
Parameters	Value	Unit	
First direction	135.0	°	
Second direction	146.2	°	
Third direction	0.0149	°	

11. Texture isotropy on surface #7



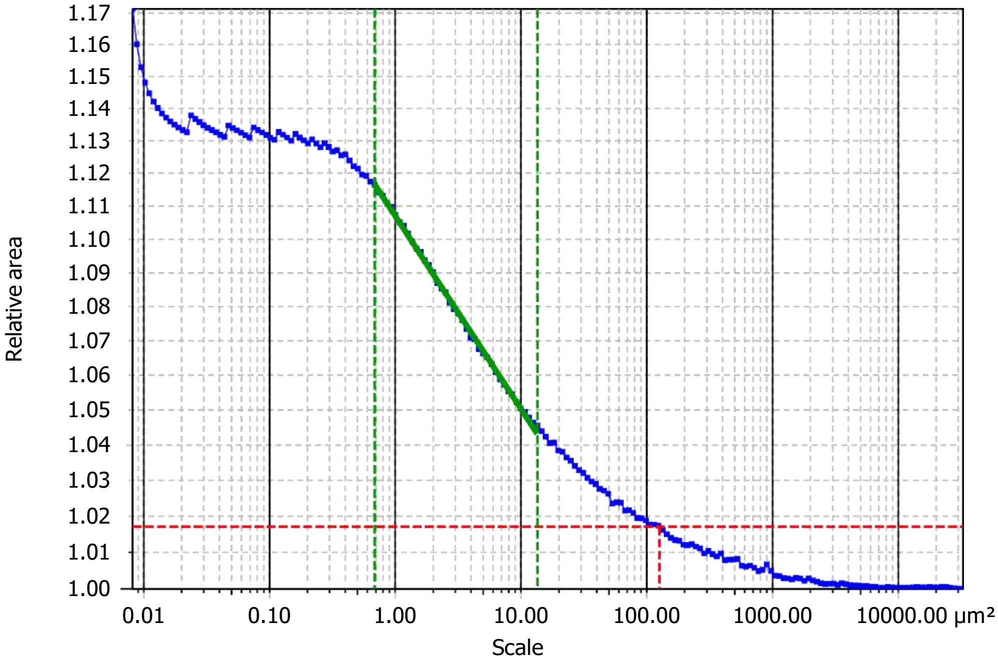
Parameters	Value	Unit	
Isotropy	69.75	%	

12. SSFA on surface #7



Information	
Method	Length-scale (rows)

Parameters	Value	Unit	Comment
epLsar	0.001488		*Length-scale anisotropy (Sfrax) (1.8 µm, 5°)*
NewEplsar	0.01829		*Length-scale anisotropy (1.8 µm, 5°)*



Information	
Method	Area-scale (four corners)

Parameters	Value	Unit	Comment
Asfc	22.83		*Fractal complexity*
Smfc	2.512	µm²	*Scale of max complexity*
HAsfc9	0.2337		*Heterogeneity of Asfc (3x3)*
HAsfc81	0.3674		*Heterogeneity of Asfc (9x9)*