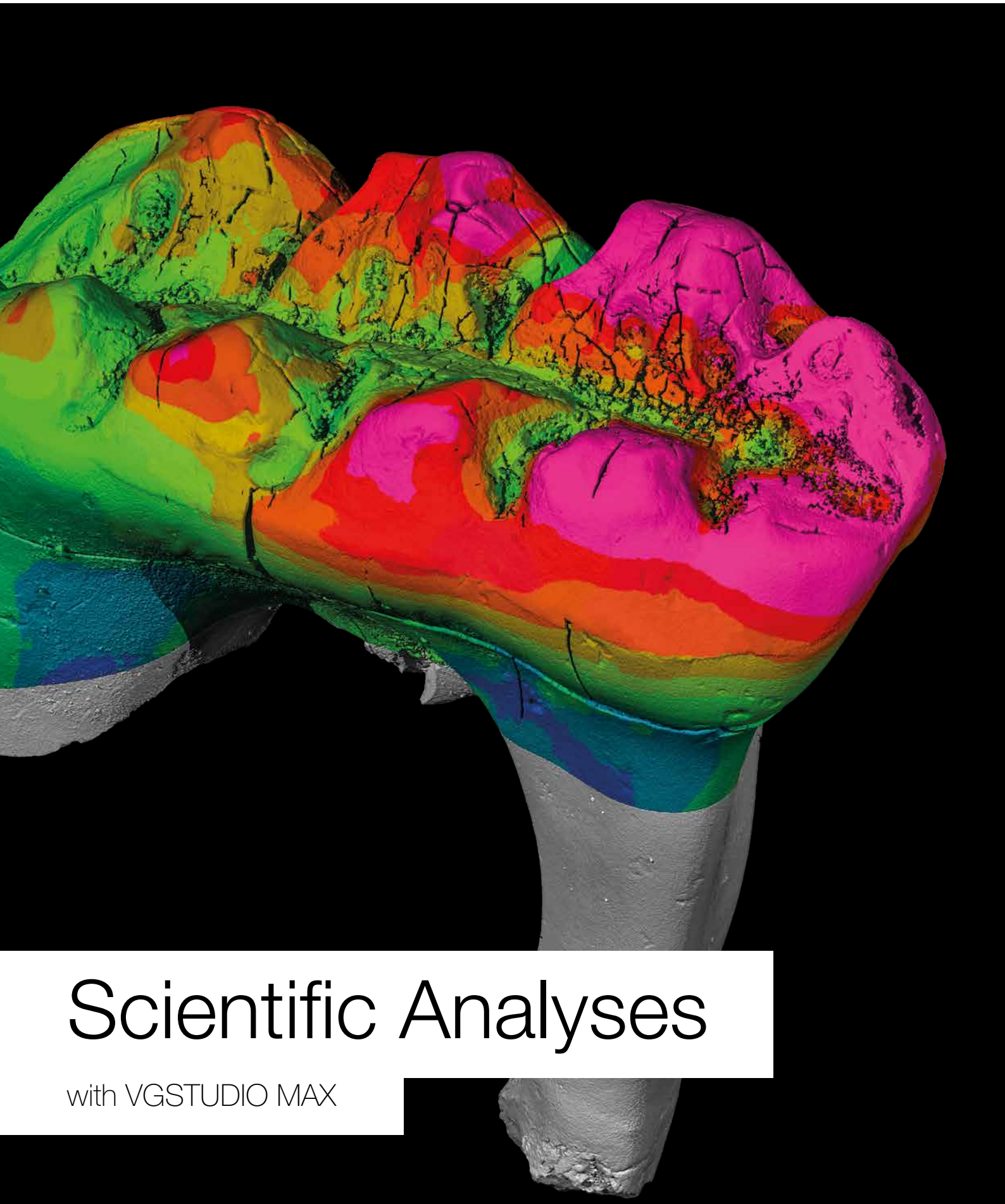
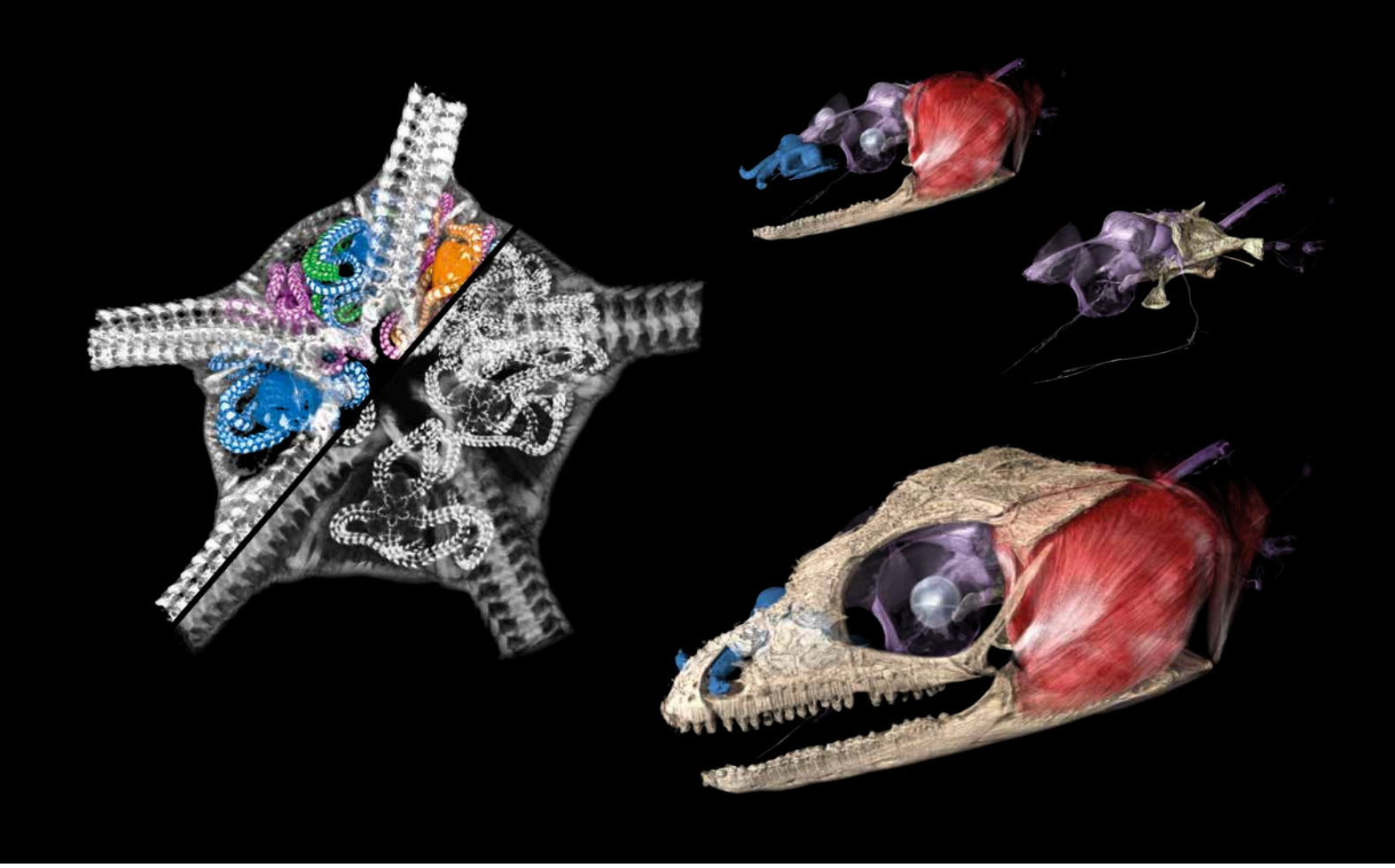
VOLUME GRAPHICS
Enabling better products



Scientific Analyses

with VGSTUDIO MAX



[1] *Ophioderma wahlbergii*, segmented rendering (left) and unsegmented X-ray rendering (right)
[2] *Karusasaurus polyzonus*, segmented muscle system, bones, and nervous tissue

Finding the Right Software Is No Longer a Science

Whether you work in archeology, biology, geology, paleontology, or medical research, VGSTUDIO MAX is the only software you'll need for the analysis and visualization of volume data. No matter which technique was used for acquiring the image stacks; our software works equally well on data, e.g., from X-ray CT, synchrotron tomography, neutron tomography, or MRI. Some of the following functions are standard features of our software, some are optional add-on modules.
For further information, visit us at: www.volumegraphics.com.

Visualization

Volume Graphics software makes it easy to create revealing and stunningly photorealistic visualizations and animations.* Use powerful clipping features to look inside the visualized object without physically dissecting it.

Uses in Biology

> *Ophioderma wahlbergii* [1]: VGSTUDIO MAX was used to visualize the segmented juveniles inside the brood pouches of the South African brittle star.
> This discovery gave scientists new insight into the brooding behavior of the brittle star.

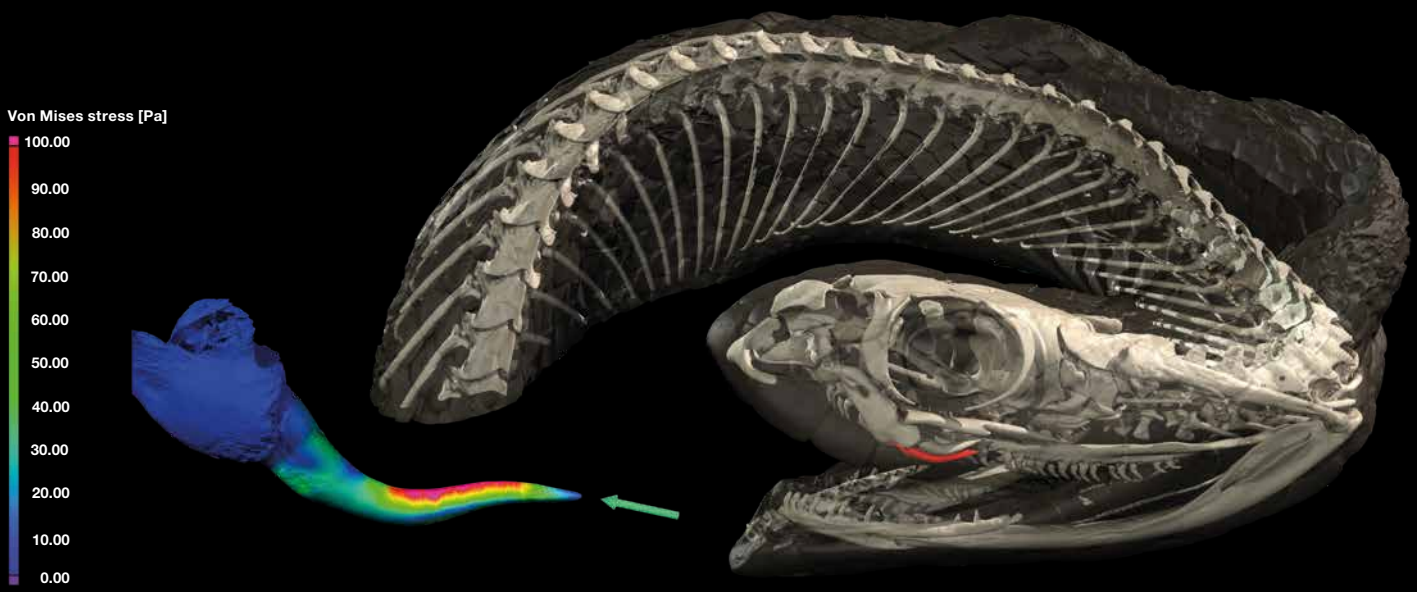
Segmentation

Volume Graphics software offers you powerful yet easy-to-use segmentation tools for defining different components, materials, etc.

Uses in Biology

> *Karusasaurus polyzonus* [2]: The head of the extant lizard was segmented into muscle system, bones, and nervous tissue based on the gray values of the different structures by using the built-in features of VGSTUDIO MAX.
> Without the conventional thin-sectioning or dissection of the extant lizard, the different structures were clearly separated in the segmented volume data set for a detailed anatomical description.

* Don't have time to create impressive animations yourself? Contact us for a quote for a professional video production and visit our website and YouTube channel for examples of our work: youtube.com/VolumeGraphics



[3] *Causus rhombeatus*, visualized force lines showing the simulated bite force

Structural Mechanics Simulation

With the Structural Mechanics Simulation Module for VGSTUDIO MAX, you can perform virtual stress tests directly on your scanned object. Calculate and visualize force lines, local displacements, and failure-related variables such as von Mises stress.

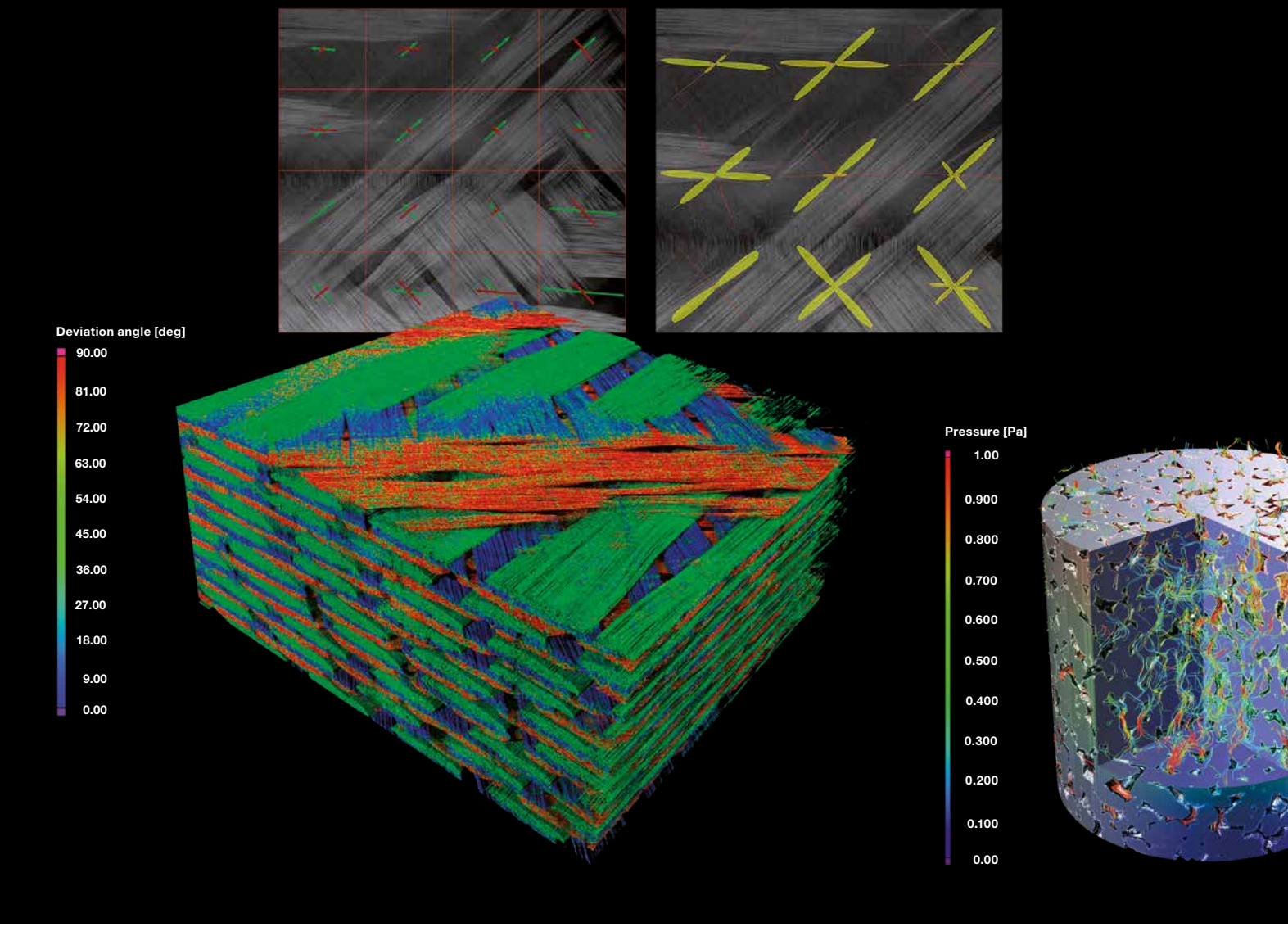
Uses in Biology

> *Causus rhombeatus* [3]: The Structural Mechanics Simulation Module was used to simulate the bite force on different tooth types of the venomous viper from sub-Saharan Africa. In the simulation, direct force was applied to the tip of the fang. The measured von Mises stress of a fang was notably lower than when the same force is applied to a standard tooth. This leads to the conclusion that the much larger fangs can withstand a significantly higher load.

> This type of analysis helps scientists to understand how fang morphology adapts to withstand bite forces, how this differs between fang types, and whether it relates to the feeding behaviors of the respective snakes.

References

[1]: Data from J. Landschoff and C. G. Griffiths 2015, '3D visualisation of brooding behaviour in two distantly-related brittle stars from South African waters' and J. Landschoff, A. du Plessis, C. G. Griffiths 2015, 'A dataset describing brooding in three species of South African brittle stars, comprising seven high-resolution, micro X-ray computed tomography scans'
[2]: Data from E. Stanley and D. Blackburn 2015 (California Academy of Sciences), Scan by: E. Stanley and M. Faillace at GE Inspection Technologies, LP Technical Solutions Center in San Carlos, CA
[3]: Data from du Plessis, A., le Roux, S. G., & Broeckhoven, C. (2016), Scan by: Stellenbosch CT Scanner Facility
[4]: Data from ITCF Denkendorf
[5]: Data from W. B. Lindquist, A. Venkatarangan, J. Dunsmuir, T.-F. Wong 2000, 'Pore and throat size distributions measured from synchrotron X-ray tomographic images of Fontainebleau sandstones' in Journal of Geophysical Research: Solid Earth (105, 21509)
[6]: Data from J. Schultz 2015 (University of Chicago), Synchrotron Scan by: F. Fusseis, X. Xiao, R. Hoffmann
[7]: Data from R. Hoffmann 2015 (Ruhr-Universität Bochum), Scan by: TPW Prüfzentrum GmbH
[8]: Data from Volume Graphics GmbH, Scan by: GE Munich
[9]: Data from S. le Roux and A. du Plessis (Stellenbosch University), Scan by: Stellenbosch CT Scanner Facility
[10]: Data from Volume Graphics GmbH, Scan by: Fraunhofer-Zentrum HTL
[11]: Data from Volume Graphics GmbH



[4] Multi-layered fabric with color-coded orientations, main directions, and orientation distribution
[5] Fontainebleau sandstone with simulated fluid flow

Fiber Composite Material Analysis

The Fiber Composite Material Analysis Module for VGSTUDIO MAX enables you to process both small and large volume data sets of fiber materials. See individual fibers in small-dimension material samples and larger structures such as fabrics or rovings in large-scale volume data sets.

Uses in Archaeology

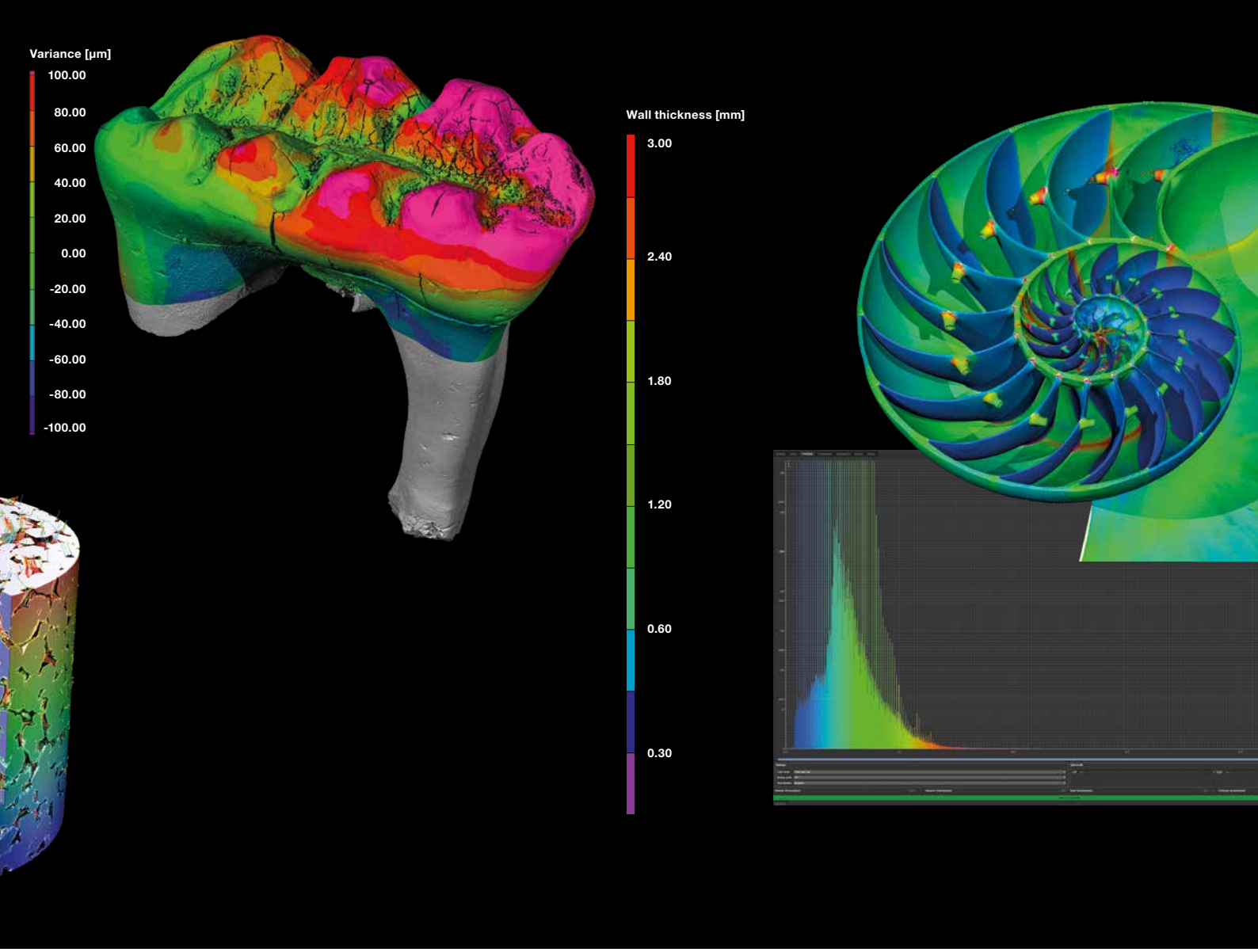
> Multi-layered fabric [4]: VGSTUDIO MAX was used to examine a multi-layered fabric sample.
> Because the fabrics and textile industry is one of the oldest in the world, archaeological textile studies often provide revealing answers to anthropological questions.

Transport Phenomena

The Transport Phenomena Module for VGSTUDIO MAX allows you to perform pore-scale simulations on real-world data such as CT scans of soil and rock samples or other porous or multi-component materials. Calculate homogenized material properties like absolute permeability, tortuosity, formation factor, molecular diffusivity, electrical resistivity, thermal conductivity, or porosity based on virtual flow and diffusion experiments.

Uses in Geology

> Sandstone [5]: The Transport Phenomena Module was used to simulate fluid flow on a pore scale and derive the absolute permeability of the sandstone sample from the French region of Fontainebleau.
> By performing virtual experiments like this directly on voxel data, geologists can get an in-depth look into the material properties of rock samples.



[6] Nominal/actual comparison of a fossil cheek tooth of *Ptilodus sp.*, an early mammal. The less worn tooth is compared to a more worn one.
[7] *Allonautilus scrobiculatus* with color-coded wall thickness and related histogram

Nominal/Actual Comparison

The Nominal/Actual Comparison Module for VGSTUDIO MAX makes it possible to directly compare two sets of volume data. Statistically evaluate these sets and color-code the differences and deviations in the visualization.

Uses in Paleontology

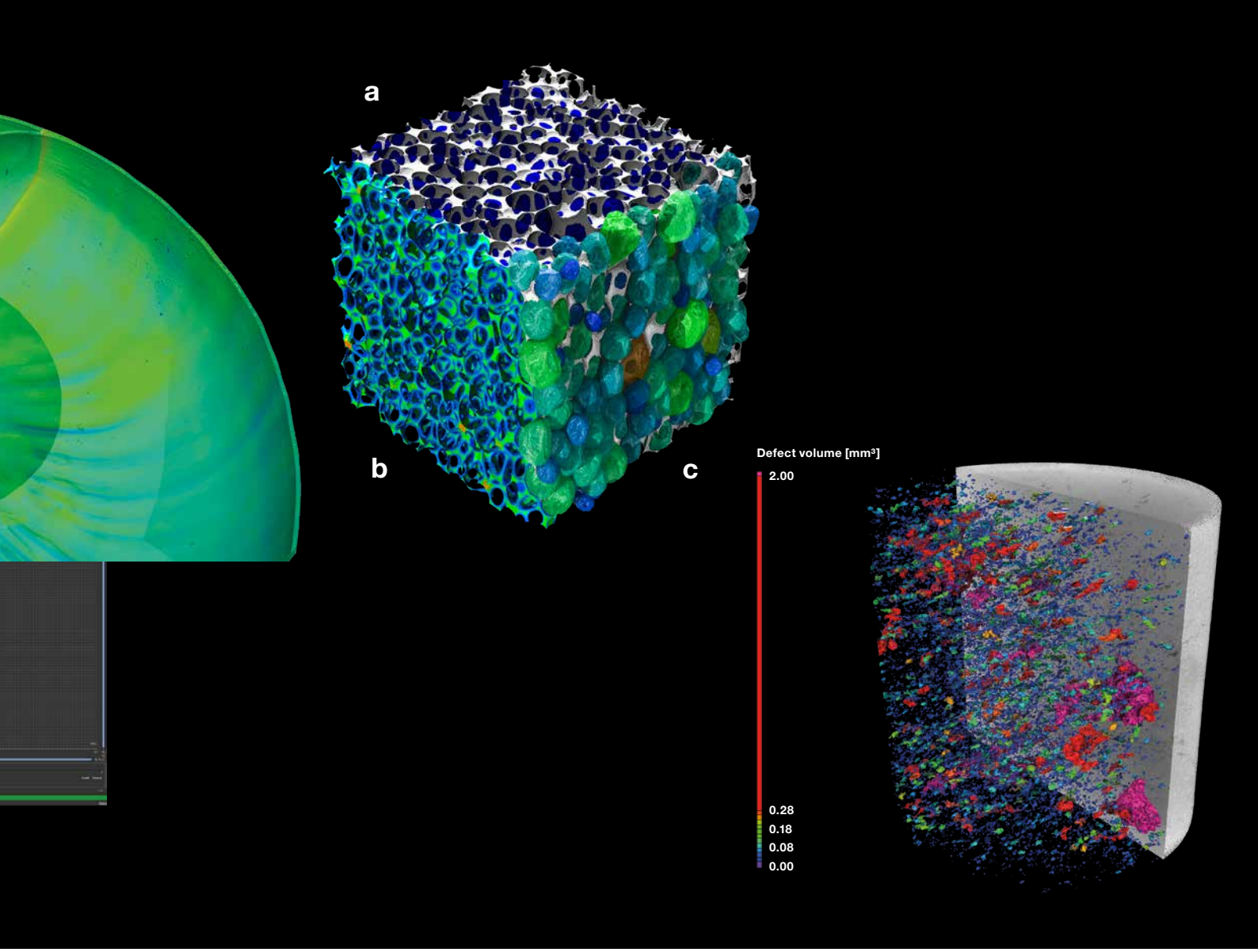
> *Ptilodus sp.* [6]: The Nominal/Actual Comparison Module was used to compare a less worn fossil cheek tooth of the early mammal (living approximately 60 million years ago) to a more worn one, whereby red and pink indicate where the worn areas differ most.
> By comparing the different wear stages of the teeth, paleontologists can gain valuable insights into the diet of the extinct animals and their way of life.

Wall Thickness Analysis

The Wall Thickness Analysis Module for VGSTUDIO MAX can be used to easily determine the wall thickness of objects made of organic or inorganic materials directly within the volume data set.

Uses in Biology

> Marine *Allonautilus scrobiculatus* [7]: The Wall Thickness Analysis Module was used to examine the wall thickness of the shell of the extant cephalopod, with blue indicating thin parts of the shell in the color-coded 3D rendering.
> By analyzing the wall thickness, biologists can find out more about how the species adapts to different water depths.



[8] Pumice rock, visualization of faces (a), strut thickness (b), and cell surface (c)
[9] Visualization of the ilmenite and related minerals in a granite drill

Foam Structure Analysis

The Foam Structure Analysis Module for VGSTUDIO MAX makes it possible to determine cell structures in any cellular material, ranging from synthetically manufactured materials to naturally occurring foam structures. Segment the volume data into cells, struts, and contact surfaces and get numerous statistical values for further analysis.

Uses in Geology

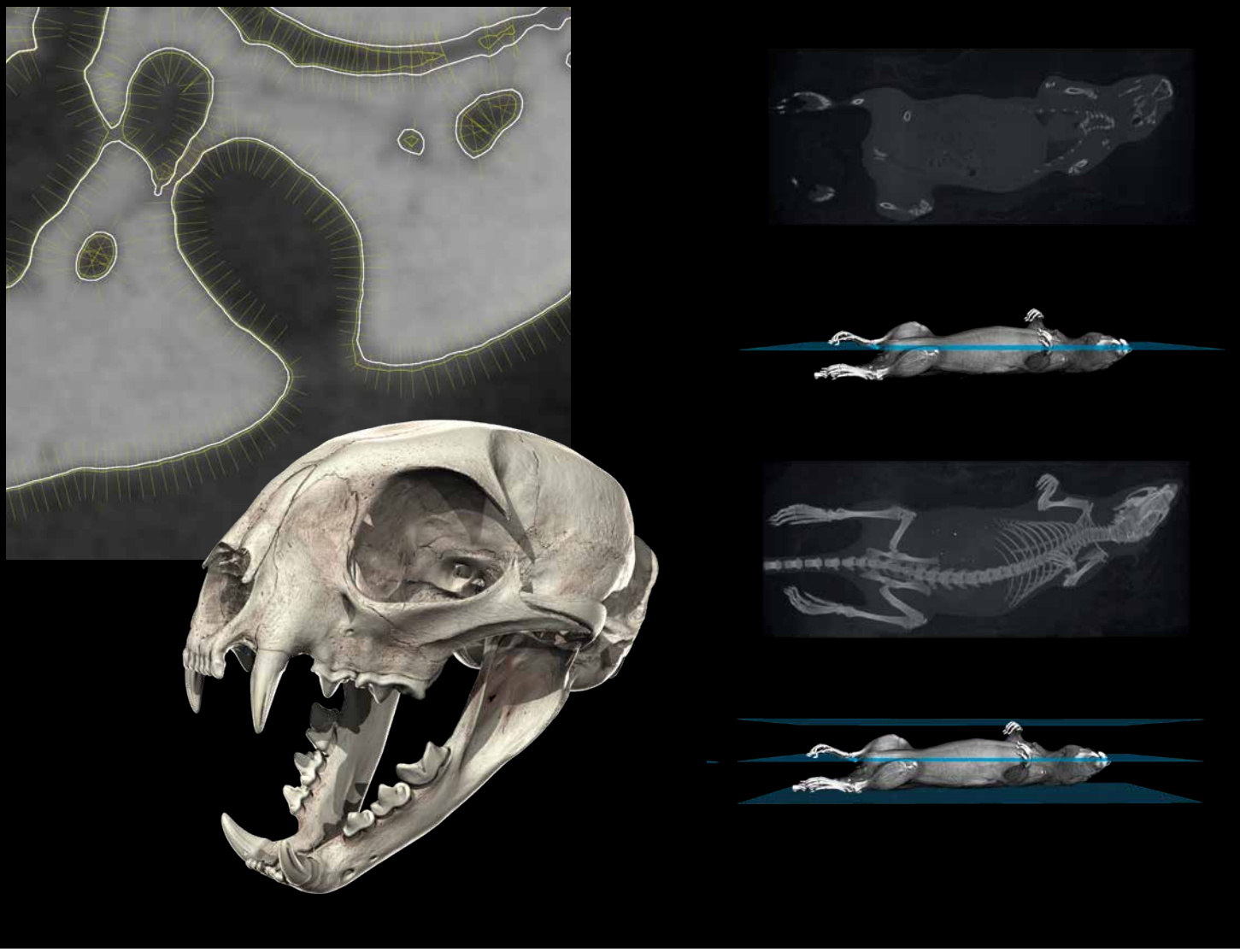
> Pumice [8]: The combined visualization of this highly porous volcanic rock shows the segmented struts, wall thicknesses, and the volume data.
> Taken as a whole, these analyses explain how a light-weight pumice rock with an average porosity of 90 % can still be highly stable due to its foam structure.

Porosity/Inclusion Analysis

With the Porosity/Inclusion Analysis Module for VGSTUDIO MAX, you can detect, analyze, and visualize specific material structures in solid materials. Color-code pores, holes, and inclusions according to their volume, diameter, shape, etc. Calculate and visualize various parameters (position, sphericity/compactness, size and geometry, gap closest to other structures, distance of each structure to a reference surface, etc.).

Uses in Geology

> Granite drill core [9]: The Porosity/Inclusion Analysis Module was used to automatically detect and then color-code dense particles such as ilmenite according to their size.
> In this case, exploration geologists used CT and volume data to non-destructively uncover information about the inside of the rock as a basis for further analysis.



[10] Skull of a *Puma concolor* with a locally adaptive surface determination (white line in 2D slice image)
[11] *Rattus norwegicus*, slice image (top picture) and thick slab view with complete skeleton visible (bottom picture)

Advanced Surface Determination*

With the Advanced Surface Determination of VGSTUDIO MAX, you can make every detail visible – even those that are smaller than a voxel. Gray values of individual voxels are processed depending on the gray values of the surrounding voxels, giving you a smoother and more realistic surface. This locally adaptive surface determination reduces the influence of artifacts while minimizing user influence.

Uses in Biology

> *Puma concolor* [10]: The locally adaptive surface determination was used to prepare the skull of the small cat for highly precise anatomical measurements and accurate visualization.
> Precise measurements of anatomical structures can be used for comparative morphological studies.

Thick Slab Option and Non-Planar Views

VGSTUDIO MAX can be used to visualize structures that are distributed across several slices of the image stack and to view bent structures. Combine consecutive slices into one 2D view with the thick slab option. 'Unroll' objects or flatten a dented surface with the non-planar view function and define and illustrate bent structures such as inscriptions, adornments, bones, or vessels on or within a specimen.

Uses in Biology

> *Rattus norwegicus* [11]: The thick slab mode was used to visualize the entire skeleton of the common rat in one summarizing 2D view.
> By doing this, the inner bone structures – originally situated in different slices of the image stack – became visible at a glance and could therefore be easily followed.

*Part of the Coordinate Measurement Module

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VG-075-EN-v07_B | 08.2018