Methods in 3D Modelling of Triassic Ammonites from Turkey (Taurus, FWF P22109-B17)

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Abstract

A case study in 3D modelling on an ammonite mass occurrence, deposited during the Upper Triassic (approx. 225 myr) of Turkey, is presented. Well established 3D visualisation and geometrical modelling techniques are used in a unique palaeontological task of reconstructing the distribution and alignment of ammonites within ammonite abundance beds. The software package GOCAD is used for the 3D reconstruction of ammonites, calcite cement and calcite veins from digitized polished sections and for the visualisation of a 3D surface laser scan data. Expected results of 3D modelling can act as proxy for the environmental activities and biotic crisis during the Carnian time.

1 Introduction

Evidently, the creation of 3D models of palaeontological structures such as fossils (e.g. ammonites, algae etc.), facilitates their interpretation and further permits the generation of mechanical models. 3D models of fossil specimens have become increasingly popular, providing accurate reconstructions of volumes, distribution, orientation and size of fossils in a sample, as well as biostratinomic and diagenetic processes. A multitude of complementary techniques has advanced in recent years, which provide such 3D datasets of palaeontological objects, both from surface and volume scanning methods (e.g. microtomography). Laser scanning (airborne, terrestrial or desktop scanners) of surface morphology, point cloud data generated from digital images, or computed tomography down to a few microns (or even below) of spatial resolution are increasingly employed for geoscientific investigations, using an equally variable range of processing techniques and software packages. Numerous papers from all fields in earth sciences (e.g. MARSCHALLINGER 2001, KETCHAM 2005, LOHR et al. 2008, WYCISK et al. 2008, GARWOOD et al. 2010, MALOOF et al. 2010, KRUTA et al. 2011, RATH et al. in press) demonstrate the great versatility of 3D geometrical models in a wide range of analytical techniques and applications.

2 Material

The abundant, at least 200 million specimens of Upper Triassic ammonites, of the genus *Orthoceltites* are assumed to be a new species. Further topics of investigation are the original position and environmental conditions of the sedimentation area at the Asagiyaylabel section, located in the Taurids. The formation of the ammonite beds is either autochthonous or allochthonous (transported). Expected 3D modelling results will be essential to reach geodynamic, palaeooceanographic and palaeobiological conclusions. This further leads to the question of the original water depth during the formation of this ammonite mass occurrence. As a collaborative project, one aim is to work within different sciences, with the Structural Processes Group at the Departments of Geodynamic and Sedimentology (University of Vienna) and the Geometric Modelling and Industrial Geometry group (3D technology at the Vienna University of Technology). Interdisciplinary collaboration with other scientists is essential in modern times. Statistical analysis of the orientation and relative position (e.g. imbrication) of the ammonite shells can hint to current or transport directions. Different orientation of calcite veins should tell us something about depositional conditions of the mass occurrence. 3D modelling of calcite-cement distribution (representing geopetal structures) and post-diagenetic calcite veins displacing several ammonites will complete the geometrical reconstruction and shed light on the biostratinomic and additional diagentic processes. The combination of analysing different fossil groups, with additional analysis of istotopic, magnetostratigraphic, cyclostratigraphic and geochemical features, will help to extract details of the Upper Triassic history around one of the most severe crisis in the Mesozoic time, the Carnian Crisis. Investigations, undertaken at sections (e.g. Asagiyaylabel) covering this time interval, can work as proxy for the major Upper Triassic Tethyan crisis. Environmental changes as displayed by the sea level and climate can become clearer and the 'motor' behind the demise better understood.

Figure 1: Rock sample of the Triassic ammonite bed with abundant specimens of the genus *Orthoceltites* from Asagiyaylabel. Taurus Mountains in Turkey.

3 Main scope

The creation of a 3D model from the ammonite *Orthoceltites* itself and moreover the reconstruction of a 3D model of the ammonite-occurrence at Asagiyaylabel with the according palaeontological structures and fossils (e.g. ammonites, bivalves, corals, algae etc.), is the main aim of the study herein. Within a 3 years project of the Austrians Science Fund (FWF P22109-B17) volumes, distribution, orientation and size of the ammonites will be used to deduce to the biostratinomic and diagenetic processes at the time of formation. A multitude of complementary techniques will provide surface laser scans of hand specimens from the mass occurrence as well as from single ammonite specimens. Modern techniques will be employed, such as laser scanning of surface morphology, point cloud generating from digital images, or computed tomography down to a few microns using an equally variable range of processing techniques. We want to demonstrate the importance of 3D models in palaeontology, by showing the great versatility and wide range of applications, analytical techniques and possible limitations of 3D models in earth sciences.

4 Methods

Most of the laboratory and analytical work will be performed at the Geological-Palaeontological Department of the Natural History Museum Vienna, Burgring 7, A-1010 Vienna. For analysing the thin sections, equipment for standard and large-size thin sectioning will be provided, along with dissecting microscopes and microscopes. For documentation of the collected materials, various photographic equipment is available (cameras, uclidean ronments, photomicroscope, light scanning device, SEM). For data processing, modern computer equipment with appropriate software is also present. Thin sections and acetate peels will be used to analyze sedimentary structures and textures, components, cements and fossil structures. Digital images will be taken to document outcrops and logs. 3D scans and digital calculations (GOCAD) will be made in cooperation with the Department of Geodynamic and Sedimentology (Structural Processes Group; University of Vienna) and the Geometric Modelling and Industrial Geometry group (3D technology, Vienna University of Technology). Mathematical problems will be solved and mathematical modelling with simulations can be performed at the MathConsult GmbH in Linz.

The test of a 3D model based on computer-tomography (CT; see KETCHAM & CARLSEN 2001) has to be repudiated due to same composition and similar specific mass density of the embedding matrix (about 2.8 g/cm^3) and the ammonite shell (secondary calcite, about 2.6-2.8 g/cm^3) and the infilled matrix (about 2.8 g/cm^3). Garwood et al. 2010 described 2 more possibilities for using CT scans at material of similar density: Scanning them at low x-ray energy would reveal the different phases (Garwood et al. 2010). By using phase contrast holotomography at a synchrotron (an inaccessible tool for palaeontologist in the future) different crystal structures could be visible (Garwood et al. 2010).

4.1 3D Modelling by Combination of 2D Slices

4.1.1 Procedure

A 15 x 8 x 8 cm block, taken from the ammonite mass occurrence, was set into concrete for stabilisation. We recurrently milled 2 mm and scanned each slide with a commercial scanning system. 78 slides of the ammonite block with a distance of 2 mm between each slice could be produced. The polyline-tool of the drawing program Corel Draw was used to digitize the individual 2D objects (mostly ammonites). The next step will be to create a 3D volume object from the 2D sections by combining matching line features to a surface object using the software package GOCAD. Statistical analysis of the orientation and relative position (e.g. imbrication) of the fossils, but also calcite cement distribution (representing geopetal structures) and post-diagenetic calcite veins displacing several ammonites will complete the geometrical reconstruction. 3D volume modelling from classified grid data (scan-/ foto-) via IDL (MARSCHALLINGER 1998 a, b, c; MARSCHALLINGER 2001) would be an additional detailed possibility. By using a software-package for outline accordance, for example CorresGrow (HERBERT & JONES 2001), complex structures could be detected and computed to a 3D model. A very low contrast of greyscales (not filled living chamber vs. sediment) will cause problems. SPIERSalign (Serial Palaeontological Image Editing and Rendering System), a software programm for reconstructing and analysing tomographic data sets, written by Russell Garwood, would be another possibility to align slice images. Otherwise Corel Draw will be used for manual alignment.

4.1.2 GOCAD

GOCAD (Geological Objects Computer Aided Design) is a software for modelling and interpretation of geological structures and objects. The geometry of a research object is characterised by a set of nodal points in three-dimensional, modelling space (uclidean geometry). Physical characteristics can then be modelled by combining the nodal points (discret smooth interpolation), and after that be shown as 3D models. 3D structural modelling and visualisation of natural datasets and the integration of these datasets, from small scale digitized hand specimen, terrestrial laser scanning, or reflection seismic data into comprehensive 3D-models is an essential part of the current research activity. The proposed research integrates well established 3D visualisation and geometrical modelling techniques in an exciting palaeontological task of reconstructing the distribution and alignment of ammonoids in a Triassic mass-occurrence from Turkey. The 3D reconstruction of ammonoids, calcite cement and calcite veins from digitized polished sections will be performed by using the commercial software package GOCAD. 3D surface laser scan data will be visualized in GOCAD, and by further processing size, orientation and distribution can be extracted.

4.2 3D Modelling Using 3D Laser Scans

By using laser surface scans, individual statistical information (e.g. imbrication or length of fossils) can be measured very fast and accurately. Statistical analysis can be made much quicker. Furthermore surface scans of single ammonites of the species *Orthoceltites* sp.(which is to 99 % the only ammonite species within the mass occurrence) can be used for reconstructing the individual ammonites of the 3D model (from the block of the ammonite mass occurrence) as close as possible to nature.

4.2.1 3D David Laser Scanner

The David Laser scanning tool is an efficient and cheap 3D scanning system. It works with the principle of triangulation from light-slices. Three-dimensional surfaces can be scanned very precisely. A calibration area behind the objects, together with the automatic or hand-held laser-scanner and a synchronised camera, yields very detailed three dimensional pictures.

4.2.2 Faro Laser Scanner

The new FARO® Laser Scanner Photon 120/20 with a new software-version FARO Scene 4.6, possesses the fastest Phase Shift Laser Scanner (976.000 points / second), with the biggest range, currently available on the free market. New technical features of the Photon 120/20 make the scanner a useful system for performing high-speed 3D scans with reduced random-noise obtained by efficient hyper-modulation. Surfaces of ammonites can therefore be reconstructed digitally without loss of information and digital-slices can be created.

Figure 2: 3D calculation from 3 polished slices of the ammonite bed. Distance between single slices is 2 mm. Reconstructed ammonites in grey and calcite veins in green.

5 Conclusions and Aims

The proposed research integrates well established 3D visualisation and geometrical modelling techniques in an exciting palaeontological task of reconstructing the distribution and alignment of ammonites in a Triassic mass-occurrence from Turkey. The 3D reconstruction of ammonites, calcite cement and calcite veins from digitized polished sections will be performed, using the commercial software package GOCAD. Statistical analysis of the orientation and relative position (e.g. imbrication) of the fossils, the calcite cement distribution (representing geopetal structures) and post-diagenetic calcite veins displacing several ammonites, will complete the geometrical reconstruction. Moreover, 3D surface laser scan data will be visualized in GOCAD. Abundant ammonites will be counted in detail and sedimentation processes such as post-mortem transport (e.g. Turbiditic ammonite layers) versus bottom current orientation will be explored. Expected 3D modelling results will be essential to reach geodynamic, palaeooceanographic and palaeobiological conclusions.

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References

Ager, D.V., GUTNIC, M., JUTEAU, Th.,MONDO, O. (1978): New Early Mesozoic Brachiopods from Southern Turkey. Bulletin Mineral Research and Exploration Institute of Turkey, Foreign edition, 91, pp. 59-75.

ANDREW, T., ROBERTSON A. (2002):The Beysehir-Hoyran-Hadim nappes: genesis and emplacement of Mesozoic marginal and oceanic units of the northern Neotethys in southern Turkey. Journal of the Geological Society (London), 159, pp. 529-543.

BRETT, C.E., BAIRD, G.C. (eds) (1996): Paleontolgoical Events: Stratigraphic, Ecological and Evolutionary Implications. Columbia University Press, New York, 604 pp.

BRETT, C.E., BAIRD, G.C., SPEYER, S.E. (1996): Fossil Lagerstätten: stratigraphic record of paleontolgical and taphonomic events. 3-40. In BRETT, C.E., G.C. BAIRD (eds). Paleontolgical Events: Stratigraphic, Ecological and Evolutionary Implications. Columbia University Press, New York.

DERCOURT, J., RICOU, L.E., VRIELYNCK, B. (eds) (1993): Atlas Tethys palaeoenvironments maps, 14 maps, 1 pl. Gauthier-Villars, Paris, 307 pp.

DERCOURT, J., GAETANI, M., VRIELYNCK, B., BARRIER, E., BIJU DUVAL, B., BRUNET, M.F., CADET, J.P., CRASQUIN, S., SANDULESCU, M. (eds) (2000): Atlas Peri-Tethys, Palaeogeographical maps, 24 maps and explanatory notes: I-XX. CCGM/CGMW, Paris, 269 pp.

DEYNOUX, M., CINER, A., MONOD, O., KARABIYIKOGLU, M., MANATSCHAL, G., TUZCU, S. (2005): Facies architecture and depositional evolution of alluvial fan to fan-delta complexes in the tectonically active Miocene Köprücay Basin, Isparta Angle, Turkey. In: KELLING, G., ROBERTSON, A.H.F, VAN BUCHEM F.H.P. (eds). Cenozoic Sedimentary Basins of South Turkey. Sedimentary Geology, 173, pp. 315-343.

ERNST, G., SCHMID, F., SEIBERTZ, E. (1983): Event-Stratigraphie im Cenoman und Turon von NW-Deutschland. Zitteliana, 10, pp. 531-554.

GALLET, Y., KRYSTYN, L., MARCOUX J., BESSE, J. (2007): New constraints on the End-Triassic (Upper Norian-Rhaetian) magnetostratigraphy. Earth and Planetary Science Letters, 255, pp. 458-470.

GARWOOD, R. J., RAHMAN, I. A., SUTTON, M. D. (2010): From clergymen to computers-the advent of virtual palaeontology. Geology Today, 26/3, pp. 96-100.

GRADSTEIN F. M., OGG J.G., SMITH A.G. et al. (2004): A Geologic Time Scale. Cambridge University Press 2004, pp. 1-589.

GUTNIC, M., MONOD, O., POISSON, A., DUMONT, J.F. (1979): Géologie des Taurides Occidentales (Turquie). Mémoires de la Société Géologique de France, 137, pp. 1-112.

HERBERT, M. J., JONES C. B. (2001): Contour correspondence for serial section reconstruction: complex scenarios in palaeontology. Computer & Geosciences, 27/4, pp. 427-440.

HORNING, T. (2008): The Carnian Crisis in the Tethys Realm. Multistratigraphic studies and palaeoclimate constraints. VDM Verlag Dr. Müller, Saarbrücken, 235 pp.

KELLING, G., ROBERTSON, A.H.F, VAN BUCHEM F.H.P. (eds) (2005): Cenozoic Sedimentary Basins of South Turkey. Sedimentary Geology, 173, Elsevier B.V., 436 pp.

KETCHAM, R. A., CARLSON, W. D. (2001): Acquisition, optimization and interpretation of X-ray computed tomographic imagery: applications to the geosciences. Computer & Geosciences, 27/4, pp. 381-400.

KETCHAM, R. A. (2005): Three-dimensional textural measurements using high-resolution X-ray computed tomography. Journal of Structural Geology, 27, pp. 1217-1228.

KIDWELL, S.M., FÜRSICH, F.T., AIGNER, T. (1986): Conceptual framework for the analysis and classification of fossil concentrations. Palaios, 1, pp. 228-238.

KRUTA, I., LANDMAN, N., ROUGET, I., CECCA, F., TAFFOREAU, P. (2011): The Role of Ammonites in the Mesozoic Marine Food Web Revealed by Jaw Preservation. Science, 331/6013, pp. 70-72.

KRYSTYN, L., GALLET, Y., BESSE, J., MARCOUX, J. (2002): Integrated Uppercarnian to Lower Norian biochronology and implications for the Upper Triassic magnetic polarity time scale. Earth and Planetary Science Letters, 203, pp. 343-351.

LOHR, T., KRAWCZYK, C., ONCKEN, O., TANNER, D. (2008): Evolution of a fault surface from 3D attribute analysis and displacement measurements. Journal of Structural Geology, 30, pp. 690-700.

LUKENEDER, A. (2001): Palaeoecological and palaeooceanographical significance of two ammonite mass-occurrences in the Alpine Early Cretaceous. PhD-thesis, University of Vienna, pp. 1-316, Vienna.

LUKENEDER, A. (2003a): Ammonoid stratigraphy of Lower Cretaceous successions within the Vienna Woods (Kaltenleutgeben section, Lunz Nappe, Northern Calcareous Alps, Lower Austria). In Piller W.E. (ed.). Stratigraphia Austriaca. Austrian Acadademy of Sciences Series, "Schriftenreihe der Erdwissenschaftlichen Kommissionen", 16, pp. 165-191, Wien.

LUKENEDER, A. (2003b): The *Karsteniceras* Level: Dysoxic ammonoid beds within the Early Cretaceous (Barremian, Northern Calcareous Alps, Austria). Facies, 49, pp. 87-100.

LUKENEDER, A. (2004a): The *Olcostephanus* Level: An Upper Valanginian ammonoid mass-occurrence (Lower Cretaceous, Northern Calcareous Alps, Austria). Acta Geologica Polonica, 54, 1, pp. 23-33, Warschau.

LUKENEDER, A. (2004b): Late Valanginian ammonoida: Mediterranean and Boreal elements – implications on sea-level controlled migration (Ebenforst Syncline; Northern Calcareous Alps; Upper Austria). Austrian Journal of Earth Sciences, 95/96: pp. 46-59, Wien.

LUKENEDER, A. (2004c): A Barremian ammonoid association from the Schneeberg Syncline (Early Cretaceus, Northern Calcareous Alps, Upper Austria). Annalen des Naturhistorischen Museums Wien, 106A: pp. 213-225.

LUKENEDER, A. (2004d): Ein Ammoniten-Massenvorkommen aus der Unterkreide – Der Olcostephanus Leithorizont (Nördliche Kalkalpen, Oberösterreich). Oberösterreichische Geonachrichten, 19: pp. 25-41.

LUKENEDER, A. (2005): An equivalent of the Karsteniceras Level within the Vienna Woods (Sparbach section, Lunz Nappe, Northern Calcareous Alps, Lower Austria). Geologica Carpathica, 56, 4, pp. 307-315, Bratislava.

LUKENEDER, A. (2007): Cephalopod Evolution: A new perspective. Implications from two Early Cretaceous ammonoids (Northern Calcareous Alps, Upper Austria). Denisia, 20, pp. 395-404.

LUKENEDER, A., SMRECKOVÁ, M. (2006): An Early Cretaceous radiolarian assemblage: palaeoenvironmental and palaeoecological implications for the Northern Calcareous Alps (Barremian, Lunz Nappe, Lower Austria). Annalen des Naturhistorischen Museums Wien, 107A, pp. 23-57.

MALOOF, A.C., ROSE, C.V., BEACH, R., SAMUELS, B.M., CALMET, C.C., ERWIN, D.H., POIRIER, G.R., YAO, N. and SIMONS, F.J. (2010): Possible animal-body fossils in pre-Marinoan limestones from South Australia, Nature Geoscience, 3, pp. 653-659.

MARSCHALLINGER, R. (2001): Three-dimensional reconstruction and visualization of geological materials with IDL – examples and source code. Computer & Geosciences, 27/4, pp. 419-426.

RATH, A., EXNER, U., TSCHEGG, C., GRASEMANN, B., LANER, R. & DRAGANIS, E. (in press): Diagenetic control of deformation mechanisms in deformation bands in a carbonate Grainstone, AAPG Bulletin.

ROBERTSON, A.H.F. (1993): Mesozoic-Tertiary sedimentary and tectonic evolution of Neotethyan carbonate platforms, margins and small ocean basins in the Antalya Complex, Southwest Turkey. In: FROSTICK, L. E., STEEL, R. J. (eds.). Tectonic controls and signatures in sedimentary successions.: Special Publication of the International Association of Sedimentologists, 20, Oxford, International, Blackwell, pp. 415-465.

SCOTESE, C.R., GAHAGAN, L.M., LARSON, R.L. (1989): Plate tectonic reconstructions of the Cretaceous and Cenozoic ocean basins. In: SCOTESE, C.R., SAGER, W.W. (eds.). Mesozoic and Cenozoic plate reconstructions. Elsevier, Amsterdam. pp. 27-48.

SCOTESE. C.R. (1998): Quicktime Computer Animations. PALEOMAP Project Department of Geology. University of Texas at Arlington, Arlington, Texas.

SCOTESE, C.R. (2001): Atlas of Earth History. Paleomap project, 52 pp., Arlington, Texas.

SEILACHER, A., REIF, W. E., WESTPHAL, F. (1985): Sedimentological, ecological and temporal patterns of fossil Lagerstätten. Philosophical Transactions of the Royal Society of London, B 311, pp. 5-23.

SENEL, M. (1997): Türkiye Jeoloji Haritalari, Nr. 4, Isparta Paftasi, Jeoloji Etütleri Dairesi, Ankara, 23.

SIMMS, M.J., RUFFEL, A.H. (1989): Synchroneity of climate change and extinctions in the Late Triassic. Geology, 17, pp. 265-268.

STAMPFLI, G.M., BOREL, G.D. (2002): A plate tectonic model for the Paleozoic and Mesozoic constrained by dynamic plate boundaries and restored synthetic oceanic isochrones. Earth and Planetary Science Letters, 196, pp. 17-33.

STAMPFLI, G.M., BOREL, G.D., MARCHANT, R, MOSAR J. (2002): Western Alps geological constraints on western Tethyan reconstructions. In: ROSENBAUM, G., LISTER, G.S. 2002. Reconstruction of the evolution of the Alpine-Himalayan Orogen. – J. Virt. Expl., 8, pp. 77-106.

WESTERMANN, G.E.G. (1990): New developments in ecology of Jurassic-Cretaceous ammonoids. In: PALLINI, G., CELLA, F. CRESTA, S., SANTANTONIO, M. (eds.), Fossili, Evoluzione, Ambiente. Com. Cent. Raff. Piccinini, Pergola, pp. 459-478.

WESTERMANN, G.E.G. (1996): Ammonoid Life and Habitat. In: LANDMAN, N.H., TANABE, K., DAVIS, R.A. (eds.). Ammonoid Paleobiology. Topics in Geobiology 13, Plenum Press, New York, pp. 607-707.

WYCISK, P., HUBERT, T., GOSSEL, W. & NEUMANN, C. (2008): High-resolution 3D spatial modelling of complex geological structures for an environmental risk assessment of abundant mining and industrial mega sites. Computers & Geosciences, 35/1, pp. 164-182, Elsevier..