ImgRad1

Monday 23 September 2013 - Friday 27 September 2013

Necsa's Visitor Centre

Book of abstracts

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Oral Presentation / 1

Imaging with neutrons and X-rays at Necsa- an overview

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Necsa's mandate to exploit the usage of radiation and its benefit to mankind is clearly demonstrated by the usage of penetrating radiation (neutrons, X-rays and Gamma rays) in the art of imaging - radiography and tomography. Imaging with neutron radiation at Necsa becomes digital in 1995 with a neutron tomography upgrade in 2003. X-ray tomography becomes available in 2005 but with 1mm focal spot size while micro-focus X-rays was introduced in 2011. Since then, many successes in the art of tomography imaging were recorded. This talk will highlight some successes, summarizes the current usage of the facilities and explain the future prospects to develop and expand the analytic service to the HEI's for post graduate students and researchers to experience the full benefit in utilizing the imaging analytic facilities at Necsa.

Oral Presentation / 2

Imaging experimental bone tool micro-structure: towards an understanding of archaeological bone tool function

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Many experiments have sought to recreate the types of damage that would be expected in ancient stone and bone weapon tips. This damage is usually presented as visible fractures or microscopic surface modification. Fatigue tests conducted on bovine bones, however, show the development of internal micro-cracks that result from stress, prior to actual breakage. In this paper I present the results of an experimental investigation of bone points subjected to a variety of activities. I assess the presence of microdamage using micro-focus computed tomography. The results show that two patterns of micro-cracks develop in bone and are best viewed in longitudinal section. Micro-cracks are a cumulative feature dependent on the amount of load applied and the duration of activity. When subjected to high enough loading rates, micro-cracks will merge together to eventually form a fracture. Although further tests are needed to confirm the exact point at which these fatigue fractures begin to form, micro-focus computed tomography has the potential to reveal whether an individual bone point underwent multiple or prolonged impacts and thus to elucidate the probable function/s of ancient pointed bone tools where no visible damage is apparent. Micro-focus computed tomography is a non-destructive and non-invasive procedure and therefore safe to use on archaeological artefacts.

Oral Presentation / 3

Intentional extraction of a third molar in early Homo species Telanthropus capensis

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Paleopathological findings amongst Australopithecinae and early Homo species at the Pleio-Pleistocene boundary are rare and confined to alveolar bone loss in adult individuals and to a suggested case of a pre-pubertal periodontitis in a juvenile Australopithecus africanus specimen. Assessment of the fossilized mandibular fragment SK 45 of the early Homo species Telanthropus capensis, confined on evolutionary and faunal ground to 1.5 – 1.2 million-years before the present, showed bone formation within the socket of the third molar (M3) or wisdom tooth, indicating that the individual lived after the tooth loss. As there is no evidence of maxillofacial trauma, and given the non-deciduous nature of M3, it is most likely that SK 45 was aided in the extraction by Telanthropus society members using a sharp osteodontokeratic tool. Post-mortem loss of M3 is ruled out by the evidence of bone formation within the socket of M3 supported by a density map of grey values, representative of atomic number of bone and breccia, reconstructed by μCT system housed at Necsa. Co-operation, shared responsibilities and prosocial acts that enhance the welfare of others are characteristics of human societies, and distinguish them from social structures in other species. Evolution of social behaviour in early Homo species is difficult to follow as it must be inferred from examination of archaeological evidence and paleobiological comparison. The most convincing, yet presumptive, diagnosis is the intentional extraction of the wisdom tooth. SK 45 thus provides paleopathological evidence for an early origin of prosocial behaviour to relieve pain in another and indicates a complex societal structure in early Homo at Swartkrans, South Africa.

Oral Presentation / 4

The Stellenbosch micro Computed Tomography facility

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This paper provides an overview of the Stellenbosch University micro Computed Tomography (micro-CT) facility. This includes a description and characterization of the system, using various examples of work completed in the last year for academic and commercial projects. The capabilities of the system are demonstrated and a focus on commercial applications in the manufacturing industry (castings) will be presented.

Posters, Exhibition and Necsa Visit / 5

The position of midline mandibular lingual canal in a sample of mandibles with relationship to the alveolar and cortical bone in the view of placing dental implants.

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The midline mandibular lingual canal (MMLC) contains a blood vessel that may haemorrhage if perforated leading to haematoma formation of the floor of the mouth and airway obstruction. The proximity of the implant site to the midline lingual canal is pivotal when dental implants are planned. This study sets out to decide whether a possible implant in the midline of the mandible is feasible in certain patient groups by determining the distance from the median lingual canal to the implant site.
Dried mandibles (31 black males; 28 black females; 32 white males; 31 white females) from the Pretoria Bone Collection were scanned using Cone Beam Computed Tomography (CBCT). Measurements were made on mid-sagittal or sagittal sections for edentulous and dentulous mandibles. Sections were inspected for the presence of MMLCs. A distance of 6mm across from cortex to cortex bucco-lingually was considered sufficient for placing an implant and was delineated with the caliper tool. If this distance was in excess of 6mm, the calliper was placed across the deepest part of the extraction cavity where a vertical line was dropped in the center of the canal to measure the superior distance to the median lingual canal (superior distance). An inferior distance was also taken from the lingual canal to the inferior border of the mandible.
Statistically significant differences (ANCOVA) were shown only for the superior distance among the sexes ($p = 0.0044$) and dentition patterns ($p = 0.0006$) where the former was significantly shorter in edentulous females (6.02mm ± 4.88). As 8mm is considered the minimum implant depth, edentulous female patients are at risk to injure the vessels of the MMLC during implants in that area. In conclusion the MMLC is a consistent feature within the anterior mandible and this area should be approached with caution by clinicians.

Posters, Exhibition and Necsa Visit / 6

X-ray micro computed tomography for whole maize characterisation

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Micro-structure of whole maize kernels were characterised using X-ray micro computed tomography (μCT). Kernels, differing in hardness, germinated for 0 h, 10 h and 22 h, followed by freeze drying, were scanned for 25 min. Results were depicted as two dimensional 2D slice images obtained from three dimensional (3D) volumes. Difference in endosperm texture of the 0 h kernels could be observed in the 2D slice images due to differences in endosperm density. Two types of endosperm (typical of a maize kernel) could be clearly identified. Floury endosperm is low in density and the vitreous endosperm is high in density. Attenuation differences were caused by a decrease in X-ray energy as it interacts with the vitreous endosperm. High attenuation indicated high density material (vitreous endosperm) and low attenuation indicated low density material (floury endosperm) or voids. Comparing 0h, 10 h and 22 h kernels the process of germination could be visualised. The onset and development of the germination process could clearly be seen as voids in the peripheral area of the kernel as well as between the germ and endosperm area. Pores in the germ of the 10 h and 22 h germination kernels confirmed that germination had taken place. Loss of endosperm integrity was also observed as decreased attenuation. X-ray micro computed tomography, if the speed of analysis can be decreased even more, can be a useful non-invasive method to determine endosperm integrity.

Oral Presentation / 7

Using multiple graphics processing units to register X-ray micro-CT and SEM/EDX images obtained from a copper ore

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X-ray microtomography provides three-dimensional information about the distribution of minerals within an ore sample and facilitates the three dimensional analysis of packed particle beds. A scanning electron microscope with energy-dispersive X-ray (SEM/EDX) attachment is capable of providing an extremely accurate mineral identification on a polished section of an ore sample. Combining these two imaging modalities offers the opportunity to enhance the analysis of X-ray micro-CT images of ore samples and verify the accuracy of such analyses. However, the non-trivial task of aligning, or registering, the SEM/EDX image to the X-ray micro-CT 3D image, or tomogram, requires significant computing power and time. Graphics processing units (GPUs) are massively parallel processors that have the potential to accelerate this registration algorithm as they provide substantial computing power and high-speed memory. Therefore, their use was studied in this work.

Registration of the images was achieved by maximising their Pearson product-moment correlation coefficient with respect to the 3D transform that maps 2D coordinates in the SEM/EDX image to 3D coordinates in the micro-CT tomogram. The algorithm used here is best described as a multi-scale registration algorithm that uses a brute force search at the lowest resolution, followed by a multi-start global optimisation algorithm, formed from the combination of a Genetic Algorithm and the Gradient Ascent Search algorithm, performed at each scale to locate the global maximum correlation coefficient. Multi-start global optimisation algorithms present substantial opportunities for parallelisation, making them a good fit for GPUs. Multiple levels of parallelism exist in this algorithm as individual correlation coefficients can be calculated using parallel reductions, while thousands of correlation coefficients can be calculated in parallel. Furthermore, portions of the algorithm can be run on multi-core central processing units (CPUs) to utilise all available computing power. This work focusses on the implementation of a parallel algorithm for determining the Pearson product-moment correlation coefficient of thousands of candidate registrations in parallel on a heterogeneous system consisting of multiple GPUs using the Open Computing Language (OpenCL) and the JavaCL library for the Java programming language.

Oral Presentation / 8

The implementation of MicroCT scanning technology to determine the presence and distribution of scheelite minerals in rock drill core samples

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The paper investigates the combination of micro Computed Tomography (CT) scan technology along with X-ray fluorescence (XRF) to determine the distribution of scheelite minerals in rock drill core samples. The aim is to aid mining industry to easily and efficiently identify scheelite and other ore minerals in rock drill core samples. These results could then be used to calculate the distribution of the minerals and the average grade of the core samples while keeping the drill core samples intact. This technique, if properly developed, has the potential to replace the traditional grade quantifying procedures.

Oral Presentation / 9

Application of microCT in geosciences: geochemistry

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Soils within the vicinity of Vaalputs radioactive waste disposal facility show complex system of chemical and morphological characteristics hosted within a thick dorbank (duricrust) horizon. Many regions within the dorbank horizon are dissected vertically and horizontally by highly laminated vein structures. These veins form between macro peds of the polygonally divided dorbank along possible desiccation cracks. Analyses of the laminated veins indicate alternating layers of calcite and amorphous silica. Adjacent to the laminated veins within the dorbank horizons are sporadic yet high barite ($BaSO_4$) concentrations. These barite concentrations were identified using x ray fluorescence (XRF) technique. The distribution and elemental associations were later confirmed using imaging techniques including micro CT, PIXE and SEM. The application of micro CT allowed a whole rock visualisation and the distribution of mineral barite within the rock which then revealed interconnected micro vein structures of barite. This indicates that the accumulation of Ba may have occurred under high sulphide soil climates and later the crystallisation of mineral barite appears to have occurred under progressive drying and sulphate enriched soil climates.

Oral Presentation / 10

Automatic segmentation of 3D high-resolution image by deformable models

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"Image segmentation" which consists in delineating a Region of Interest is in general a requirement before any analysis of image data. This step is all the more critical as its accuracy may impact the validity of the entire processing pipeline. However, commercial image processing software proposes few tools and most of them are based on quite basic principles as thresholding, region growing or mathematical morphology. Accordingly, segmentation is often performed interactively with much manual intervention. This process is long and overall user-dependent.

In the case of micro-CT data where the size of the image becomes huge (e.g. 2000 slices of 2000 x 2000 pixels), manual segmentation can take days which prevents from analyzing large sets of data. Moreover, at a resolution of 10 to 100 microns, so many details are visible that it may be difficult to follow a boundary of Region of Interest along the slices. Automatic segmentation methods are then required to be able to process the ever-increasing number of high-resolution 3D images acquired for biomedical, geoscience or palaeoscience applications.

One of the most efficient methods is called "deformable model". Deformable models are surfaces (or curves) which are plunged in the 3D image and deform under the influence of internal forces, which are defined within the surface itself, and external forces, which are based on features which are extracted in the image. The internal forces are designed to keep the model smooth or near a given reference shape during deformation. The external forces are in general defied to attract the model toward image discontinuities. By integrating a-priori information about the shape and global image data in a consistent mathematical description, deformable models offer robustness to image noise, low contrasted boundaries or partial volume artifact.

We will show some examples in medical and paleo-anthropological applications as automatic segmentation of endocast or musculoskeletal structures.

This work was supported by the HOPE ("Human Origins and Past Environments") French-South African Research Programme and by the INLOO ("3D information and engineering technologies for analysis of the Homo genus in South Africa") International Project for Scientific Cooperation of the French Center for Scientific Research (CNRS).

Posters, Exhibition and Necsa Visit / 11

Application of MRI and X-ray CT for the study of the solid and liquid phases during the leaching of low grade ores

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Heap bioleaching is gaining importance as a technique for the recovery of valuable metals (such as copper) from low grade ores. In this process iron and/or sulfur oxidising microorganisms are used to aid the oxidation of base metal sulfides in the ore, thereby liberating the metal ions into solution. The heaps are highly heterogeneous systems, both with respect to heap structure and the ore particle size and composition. This has a significant effect on the liquid distribution because the flow is variably dominated by gravitational and capillary forces, making it highly non-uniform. Therefore typical 'black-box' type experiments are non-ideal for the accurate description of the leaching processes. It is therefore desirable to use non-invasive tomographic techniques to study these systems.

The mineral particles within the solid ore can be identified using X-ray CT as their absorption of the X-rays is greater than that of the surrounding gangue rock. X-ray CT may therefore be used to study the selective leaching of minerals as a function of their position in the ore (proximity to the surface) and potentially their composition.

The liquid distribution within representative leaching systems is better examined using magnetic resonance imaging (MRI). Specialist acquisition protocols have been developed for this as the para- and ferromagnetic species within the ore have the potential to cause significant magnetic susceptibility distortions in the images (Fagan et al 2012). The accuracy of the MRI method is confirmed through comparison of the MRI acquisition of a saturated ore sample with an equivalent X-ray CT acquisition.

Through the eventual combination of the information from the two imaging techniques, the effect of liquid flow and degree of wetting on the mineral leaching can be quantified. This is critical new information which may be used to further optimise the operating conditions of a heap leach.

References

Fagan, M.A., Sederman, A.J., Johns, M.L. (2012) 'MR imaging of ore for heap bioleaching studies using pure phase encode acquisition methods', J. Magn. Reson. 216, 121-127

Posters, Exhibition and Necsa Visit / 12

3D image watermarking for protecting micro-CT data exchange

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In the context of microfocus X-ray imaging of fossils that constitutes an important part of the heritage in a country, more and more digital 3D images are being sent over computer networks. Institutions curating fossil collections attribute legal and ethical weight to these data; acknowledging their own rights and thereby willing to ensure the protection of data in their possession. From a practical and technical point of view, it is often important to achieve : (1) the confidentiality of the data, by restricting access to the rightful owners ; (2) the integrity of the data, ensuring that the information has not been, and will not be, modified by anyone; (3) the availability, which guarantees access to the data within standard procedure
to persons in agreed conditions.

An important issue is then to trace digital 3D images along the chain from their acquisition to their scientific investigation. Watermarking algorithms provide traceability by embedding a message directly into the 3D image in a quasi-invisible way. The very small difference between the original image and its watermarked version corresponds to the watermark signal associated with the embedded message. Of course, care must be taken to ensure that the watermarked 3D image has the same value as the original one.

Watermarking involves in general the insertion of a code identifying the owner but it is also possible to insert a trace linked to the user. Several cases making use of watermarking can be identified :
- the authenticity of images with the insertion of data confirming the origin and the fact that a certain 3D image refers to a particular fossil and institution ;
- controlling the integrity of 3D images, by putting control information, such as a digital signature, within data ;
- the addition of meta-data, allowing the content of images to be enriched by attaching a semantic description of the content.

Watermarking techniques are numerous and but they share some characteristics which, depending on the application, should be kept in mind when choosing the appropriate technique: robustness, capacity, complexity and invisibility.

We will present preliminary experiments on micro-CT images of anatomical structures and fossils.

Oral Presentation / 13

Investigating the effect of thermal shock on coal

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Thermal cracking occurs easily in processes that entail a steep temperature gradient and high pressure (like blast furnaces and gasifiers) and merits further investigation since the alteration of the coal structure during these conditions will consequently affect the behavior of the resulting char. The fractures that develop during these initial phases of reaction open up pathways to reaction sites and consequently affect the reactivity of the coal. This investigation deals with establishing the mechanism of development and spread of fractures associated with thermal shock through the coal structure as well as to make conclusions regarding the reactivity of the resulting char. More specifically, conclusions regarding the effect of the bedding plane (direction), specific macerals involved in crack propagation and size and distribution of minerals with respect to crack origin will be made. Micro-focus X-ray tomography is a very attractive method to investigate these processes in a quasi dynamic manner since the non-destructive nature of this analytical technique permits using the same sample during numerous stages of a process. Investigating the process of thermal shock requires developing a suitable experimental method to induce and track the induced fractures and consequently an experimental setup and procedure is proposed by utilizing a RF coil to induce a very steep temperature gradient within a graphite cylinder which encapsulates the sample under investigation, whilst micro-focus X-ray tomography will be utilized to quantify the associated alter

Posters, Exhibition and Necsa Visit / 14

Digital X-ray Tomography as an alternative method for Invertebrate Taxonomy and dissecting valuable Invertebrate specimens.

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Macroderes Westwood (Scarabaeidae: Scarabaeinae) is a flightless dung beetle genus that is endemic to Namaqualand in the arid South-West of South-Africa. All species are strongly convex in shape and show uniform morphology. This makes it difficult to separate them even with the use of a conventional light microscope. Furthermore, some species are known only from single up to very few specimens.

3D Tomography as opposed to conventional 2D photography allows for the accurate placement of landmarks on homologous structures of different specimens. These 3D co-ordinates can be imported into morphometric and statistical software that makes between-species delineation possible. The main advantage of this technique is its non-invasive and non-destructive nature - that once a specimen is scanned it does not have to be touched again. Thus, there is no further risk to specimens that are often fragile, nor is there any necessity to conduct dissections to view obscured or internal structures.

Here we present preliminary results in a novel and alternative application in zoology to distinguish between the species in the dung beetle genus *Macroderes*.

Oral Presentation / 15

Dental age estimations in a prenatal cadaveric population

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The state of development and emergence of the deciduous dentition is fundamental to the accurate estimation of age in paediatric and juvenile individuals. However little is understood about the growth of the immature mandible relative to the development of the deciduous dentition. The aim of the study is to investigate the configuration of the dental crypts relative to the developing deciduous dentition in individuals aged between 20 gestational weeks and 4 years. 30 mandibles were sourced from the Johannesburg Forensic Paediatric Collection, Division of Forensic Medicine and Pathology, University of the Witwatersrand. Micro-CT analysis was conducted using a Nikon Microfocus X-ray machine and reconstructions were completed using volume rendering software VG studio max v2.2. The anterior dental crypts were found to differentiate relative to the completion of the deciduous dental development. However the premolar dental crypts were defined before full dental developmental was complete. The dentition was also noted to commence its development from the buccal side of the tooth moving in a lingual direction. Thus the mandible develops in response to biomechanical forces placed on the developing dentition.

Oral Presentation / 16

Application of X-Ray CT and QEMSCAN in Geometallurgical study of gold: A Case study of the Witwatersrand gold ore

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A quartz-pebble auriferous conglomerate from the Witwatersrand gold Province (Carletonville, South Africa) prepared by high pressure grind rolls (HPGR) have been investigated by using three different Micro-focus X-ray tomography systems located in three geographically different places (i.e. NECSA: Radiation Science MIXRAD laboratory, SUN: Central Analytical Facilities CT Scan laboratory and Technikon University of Munich (TUM): Physics department, Germany) and QEMSCAN. Application of X-Ray Micro-CT technology combined with QEMSCAN to the field of geometallurgy is being explored for ore characterisation and generation of geostatistical data. Using these two analytical tools, as well as appropriate reconstruction algorithms, a palpable amount of information concerning gold morphology, liberation characteristics, degree of mineralisation, association with other minerals and quantitative HPGR induced crack network data were obtained. The reconstructed sequential slices show much minutiae of the gold in both two and three-dimensional representation which brands X-Ray Micro-CT an appropriate useful tool for geometallurgical studies. Assimilated X-Ray CT data was validated by comparing the findings with data obtained using QEMSCAN. Ability of X-Rays to permit rapid evaluation of gold mineral brings an innovative technology to the gold mining industry which minimise ore characterisation time, cost and assist in geostatistical distribution of gold interpretation.

Keywords: HPGR, X-Ray CT and Gold deportment

Posters, Exhibition and Necsa Visit / 17

Using micro-focus X-ray scans to document inner ear morphology in different species of horseshoe bats, Rhinolophus (Mammalia: Rhinolophidae), occurring in Southern Africa

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Horseshoe bats use an adapted auditory and echolocation system to navigate and hunt fluttering prey while flying in the dark amongst vegetation. To overcome the challenge of distinguishing prey from echoes produced by the vegetation, horseshoe bats have developed an intricate coupling of the auditory and vocalizing systems. They combine a long, constant frequency (CF) signal, that has short frequency modulated (FM) regions sweeping up and down at either end of the pure tone, together with Doppler-shift compensation, and an acoustic fovea in the cochlea. The latter being modifications associated with the cochlea, the coiled structure in the inner ear that usually detects a range of frequencies along its length, which focus instead on the specific frequency emitted in the constant frequency call particular to the species. Investigation of the inner ear structure of horseshoe bats has been limited, and has not included species from Southern Africa. The bat diversity in Southern Africa is relatively rich, with new species still being identified. In order to accommodate some geographic variation, as well as anticipated classification changes, micro-focus X-ray tomography scans were made at Necsa of cleaned skulls of 49 individuals, of what were ten different horseshoe bat species occurring in Southern Africa. Various linear and two-dimensional area measurements from a midsection of the horizontal view across the cochlea, showed some differences between species, albeit, these are less distinct between species of similar size. VGStudioMAX analytical software was used to create cochlea volumes from internal voids in the inner ear region of the reconstructed three-dimensional X-ray scans. More extensive analyses of these reconstructed volumes is still underway, however, overall area measures of these volumes also showed some distinctions between species, and, besides a few exceptions, cochlea area generally scaled negatively with skull length, zygomatic width and echolocation frequency.

Posters, Exhibition and Necsa Visit / 18

Applications of Cone Beam Computer Tomography in Anatomical studies

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Researchers and educationalists in the field of Anatomy constantly seek representations of structures that reflect the realm in which clinicians need to operate. Along with newer radiographic techniques creating new possibilities in diagnosis and treatment, the required anatomical knowledge to interpret these images also evolved. The high resolution images derived by Cone Beam computerized Tomography (CBCT) and the more advanced Micro-focus X-ray Radiography located at Necsa (Nuclear Energy Corporation of South Africa), render it appropriate for the three dimensional (3D) representation of anatomical structures for educational and research purposes. The ability to analyse the sample in sequence without destruction ensures successive assessment of the internal anatomy of a structure for example the ventricles of the brain; the pterygopalatine fossa; the inner and middle ear and the inner structures of the mandible and maxilla in dental studies. Outer structure may also be evaluated eg. the shape of the mandible which includes many morphological features associated with age, sex or population group identification of unknown individuals. The external appearances of the ventricles of the brain and the inner ear structures have also been reconstructed. To this purpose the Anatomy Department of the University of Pretoria in collaboration with Necsa are developing a digital database of skulls and mandibles called the Pretoria Pelindaba Skull Collection.

Oral Presentation / 19

AESOP: A new European and South African partnership - Imaging our past to promote our heritage.

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This presentation announces a new collaborative network called AESOP that strengthens the relationships between South African and European partners. The AESOP multidisciplinary and intersectorial Erasmus Mundus consortium co-ordinated by the University Paul Sabatier-Toulouse 3 (France) and co-coordinated the University of the Western Cape (South Africa) is composed of 11 European and 9 South African university partners, as well as four additional associate members. AESOP encourages the collaboration between different sectors to promote South African heritage inherited from past generations, maintained in the present and restored for the benefit of future generations. At the heart of this partnership are several visualization, quantification and other computer-based techniques which use images generated though non-destructive radiation techniques, and which offer additional insights into the records of our heritage, natural and cultural past.

This presentation provides cross-disciplinary examples illustrating techniques in a representative range of scientific cases in relation to the study and promotion of heritage. The AESOP consortium aims to contribute to the development of educational/academic networking and new skilled human resources, but also to the use of national symbols, cultural and natural heritage as vectors for sustainable partnership. In order to encourage newcomers at the interfaces of several fields including palaeontology, archaeological science, art conservation and material science, AESOP will organize 152 opportunities to contribute towards Master and PhD degrees, and to support academic staff, by encouraging double degree programmes between European and South African members. Such a partnership will also enhance the expertise and capability of AESOP teachers, students, engineers, researchers, and other professionals to assimilate new technical developments for improving research and curation process efficiency, as well as for developing a future European and South African joint training and research unit for the study and awareness of heritage.

Oral Presentation / 20

Evaluation Procedures for Spatial Resolution and Contrast Standards for Neutron Tomography

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Digital neutron imaging (radiography and tomography) is a powerful non-destructive analytical tool and has demonstrated its importance in industrial and research application worldwide. The standardization process, to certify digital neutron imaging as a standard practice in industry, entails standardized test phantoms to be evaluated. Through the evaluation of the phantoms the spatial resolution and contrast of a neutron digital imaging system can be determined in a controlled and standardized manner by accepting good practice in terms of scanning, data processing, data visualization and evaluation. Standard test phantoms are objects with physical features designed to test the capability of an imaging setup to reveal these features without any ambiguity. The good practice enables the acceptable assessment of different international digital neutron imaging facilities for spatial resolution and contrast abilities. The purpose of this contribution is to establish good practice for the experimental setup, acquiring of 2-D digital projections and the reconstruction process of the 3-D digital images of standard test phantoms for spatial resolution and contrast. Results obtained from applying this suggested good practice on contrast standard test phantom will be discussed.

Oral Presentation / 21

Evolutionary shifts in the dentitions of the extinct Bond's springbok, Antidorcas bondi

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During the Middle and Late Pleistocene the extinct Bond’s springbok, Antidorcas bondi, occurred in abundance throughout central southern Africa, from the north-eastern Karoo in the south to southern Zimbabwe in the north. It was unusually adapted to a highly specialised grazing niche, co-existing with other larger-bodied specialised grazers in a facilitating grazing system in highly productive grasslands. Unlike the semi-arid adapted modern springbok, it was associated with wetland indicators, such as hippos, waterbuck and lechwe, which today occur in the Okavango area of Botswana and in southern Zambia as a relict fauna. We record here by means of non-destructive micro-focus X-ray Tomography (μXCT), located at Necsa, a marked morphological shift in the dentitions of A. bondi from the end-Early Pleistocene to the Middle and Late Pleistocene, reflecting its adaptation to a specialised grazing niche. A distal shift in the emphasis of mastication caused a reduction of the premolar row and an increase in hypsodonty and enamel volume of the third molar.

Oral Presentation / 22

The first detailed cranial description of Massospondylus carinatus using a CT scan and 3D digital reconstruction

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Massospondylus carinatus Owen, 1854 is a basal sauropodomorph dinosaur from the Late Triassic to Early Jurassic. It was one of the first dinosaurs ever described and is emblematic of the importance of South African palaeontology to the study of dinosaur evolution. Massospondylus was the dominant large herbivore of its time and is represented by an array of well-preserved specimens. Surprisingly, there is a lack of detailed cranial descriptions for this taxon, and this has hampered comparisons with other sauropodomorph taxa. For example, the braincase and vertebrae were described as of 1854, whereas the skull was only briefly described in 2004. In fact, there are no cranial autapomorphies which have been set to clearly differentiate Massospondylus from its sister taxa. Most Massospondylus specimens are preserved in a mudstone matrix that makes preparation of fine-scale skull features difficult, therefore understanding its cranial anatomy requires advanced imaging techniques. The aims of this project were to produce a 3D representation of the skull and braincase of Massospondylus, describe its cranial anatomy (including internal structures) and compare this to the skull of other sauropodomorphs. These data are then used to establish cranial autapomorphies of Massospondylus, test its phylogenetic position by comparing it to related taxa, and form a strong basis for future studies of the growth and development of this important dinosaur taxon. Massospondylus is the only sauropodomorph for which a complete size series is known, therefore using these new data in conjunction with scans of the other skulls could allow for the understanding of brain development and how the skull bones change during growth.

Oral Presentation / 23

Does 1st metatarsal cortical thickness distribution in the Dmanisi hominin differ from that of modern humans?

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Two first metatarsals from Dmanisi (D2671, D3442) are analyzed. Early work demonstrated that the Dmanisi lower limb and ankle morphology are similar to modern humans. Less-derived metatarsal morphology, on the other hand, demonstrates similarity to earlier hominins. Here, we analyzed cortical thickness patterns in first metatarsal shafts of African apes and fossil hominins. We ask whether Dmanisi hominin 1st metatarsals are more similar to modern humans than extant apes, and whether they are more derived (human-like) relative to other hominin first metatarsals.

First metatarsals of chimpanzees, gorillas, modern humans, and fossils were CT scanned. For each metatarsal, we measured 17 cross sections from 25% to 65% of diaphyseal mechanical length. In each cross section, we measured thickness of the cortical wall radially at one degree increments. Cortical thicknesses were size standardized, after which they were used in a penalised discriminant analysis (PDA) to assess extant species-specific and fossil patterns.

Dmanisi metatarsals patterns of thickness distribution are not similar to modern humans. This indicates that at 1.8 my some aspects of foot anatomy have yet to be fully transformed into the modern human condition. Variability in shaft stiffness of Dmanisi metatarsals from various orientations could imply that these elements did not behave as a relatively unidirectional rigid propulsive lever and shock absorption mechanism, to the same extent as observed in modern humans, during bipedal gait. However, the degree to which the observed differences in metatarsal cortical thicknesses express a functional signal requires continued investigation.

Oral Presentation / 24

The qualification of coal degradation with the aid of micro-focus computed tomography

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The production of unwanted fines and ultra-fines during the handling and utilization of coal is a serious problem in processes that rely on large or closely sized particles. Degradation of coal occurs at a number of different places within the beneficiation or utilization processes and through a number of different mechanisms, none of which is thoroughly understood. In an effort to gain a better understanding of the degradation mechanisms, micro-focus computed tomography (μ-CT) was used to track the changes within a number of coal particles. The observed changes were caused by impact- and compression loading as well as rapid temperature increases. The resolution of the μ-CT tomograms allowed that the micro-structure within the coal particles could be identified and the influence of these structures on the degradation qualified. A comparison of the tomograms taken before and after breakage and fracture showed that the micro-structure of coal had an influence on the breakage characteristics. For compressive and impact loading, the biggest structural contributor was shown to be the network of existing cracks and cleats within a particle and the direction of the load application is the biggest contributor to the directionality of the newly formed cracks. For rapid temperature increases, an increase in new crack formation occurred with an increase in final temperature as well as heating rate; there is also increased crack formation in the lower density macerals.

Oral Presentation / 25

Morphological studies in forerunners of mammals enhanced by the use of CT-scanning imagery.

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South Africa is world renowned for its rich palaeontological record, which documents in great detail the evolution of mammals. The lineage closest related to mammals is known as non-mammalian cynodonts and first appears in the period known as the Late Permian, at about 255 Millions years ago. Cynosaurus suppostus is a Late Permian species of cynodont, known only from the Karoo Basin of South Africa. Specimens of this species were last scientifically described 48 years ago, and the collection of additional specimens previously not published, makes this taxon due for a formal scientific redescription. The use of X-ray computer assisted tomography (CT-scanning) is becoming fundamental to undertaking detailed morphology studies in fossil animals. We are employing this technique to illustrate the external views of the fossils as the 3D rendering is able to highlight features that is not always clearly depicted in traditional photography of the material, particularly when studying relatively small fossils. An important and unique additional use of this technology, is the possibility to study internal structures that are hidden, without damaging the material, such as dental replacement, as it is possible to recognize new teeth that will replace the functional ones. This technique also allows for the reconstruction of internal cranial cavities, (i.e. brain and nasal cavities). Landmark based study (geometric morphometrics) on the 3D rendering of the ontogenetic series of specimens, allows us to study the ontogenetic trajectory of Cynosaurus suppostus.

Oral Presentation / 26

Radiographic Flaw Detection of a Friction Stir Welded Ti-6Al-4V plate

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Abstract
A Friction Stir Welded Ti-6Al-4V alloy plate is non-destructively evaluated for flaws using the radiographic technique. Friction Stir Welding (FSW) of Aluminium alloys has been extensively studied over the past decade;
the inspections thereof, using a variety of non-destructive testing techniques is well documented. The choice of
the radiographic testing technique for this study is primarily because of its ability to easily distinguish between
the different types of flaws. The technique also allows for variation of the testing parameters so as to optimise the density, contrast, definition and geometric un-sharpness of the radiograph. Heat input and other factors involved during FSW of the plates are believed to introduce certain types of flaws. The initial results of this study indicate that FSW of this high strength-high temperature 5 mm thick titanium alloy plate generates no observable flaws.

Keywords: Radiographic testing, Friction Stir Welding, titanium alloy.

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Oral Presentation / 27

Maize endosperm density measurement with X-ray micro computed tomography (µCT)

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The staple food of Southern African is milled maize (Zea mays L.). Hard maize is favoured by the milling industry for improved end-product quality and milling yield. Two types of endosperm, vitreous and floury, are present in maize kernel and the predominant type present determines the hardness and milling performance of the maize. A relatively fast and non-destructive method for hardness determination is required. X-ray micro computed tomography (µCT) was used as a non-invasive technique to determine the average densities of the total kernels of maize samples differing in hardness, as well as that of the floury and vitreous endosperm. A linear calibration function was produced using a range of calibration polymers in the range of 0.9 to 2.2 g.cm-3. Different regions of interest (ROI) could be segmented and the average density of each ROI was calculated (total kernel = 1.46 g.cm-3; floury endosperm = 1.28 g.cm-3; vitreous endosperm = 1.51 g.cm-3). These average density values and volumes (mm3) of the whole kernels were subsequently used to calculate the mass of the individual maize kernels; these were within a range of 4.7 to 9.3% of the true masses.
This initial study, using X-ray µCT to determine densities of ROI and whole maize kernels, shows potential of using this technique to distinguish between hard and soft maize kernels. The average densities (1.4 – 1.48 g.cm-3) of the respective kernels ranked them in the same order of increasing kernel hardness as determined earlier by means of a milling index method (34.3 to 21.6% chop).

Oral Presentation / 28

Virtual prepartion of fossil bones from cave deposits in the Cradle of Humankind.

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The UNESCO World Heritage Site of the Cradle of Humankind, located 50 km northwest of Johannesburg in the Gauteng Province, is one of the most fossiliferous areas in the world. The dolomitic caves of this region have yielded several hundreds of hominin specimens, as well as several hundreds of thousands of fossilized bones of various extant and extinct mammals, birds, reptiles and fish. These fossils have been recovered from 15 different excavated localities and are dated as old as 4 to 4.5 million years ago (Way Point 160 in Bolt's Farm). The majority of these fossils are encased in calcified clastic sediments or so-called breccias, a very hard rock, which requires extremely meticulous manual preparation, and represents a heavy investment both in terms of time and money.
Virtual exploration of blocks of breccias, followed by virtual extraction of fossils from the calcified sediment (and possibly 3D printing), using 3D rendering software such as Avizo, constitutes innovative and efficient alternative methods. Here I present a few examples illustrating the potential offered by 3D imaging in the preparation of fossils encased in hard sediment. First, I describe virtual exploration of blocks of calcified clastic sediment using simple CT-scanner images in order to locate fossils and to conduct preliminary bone identifications. Secondly, I present the results of virtual extraction and successive bone identification of a small mammal fossil using micro-CT scanning data. The material presented in this study comes from the Malapa cave site, a recently discovered fossil locality in the Cradle of Humankind.

Posters, Exhibition and Necsa Visit / 29

Comparative study of the fore-limb of the Early Triassic cynodont Thrinaxodon liorhinus. Exploring burrowing anatomy.

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Therapsids were severely affected by the Permian-Triassic mass extinction event and only a few lineages were able to survive. One of the main behavioural responses that most likely aided in Therapsid survival across the extinction event was burrowing. Several fossils of the therapsid, Thrinaxodon were found in curled up position and assumed to have died in a burrow, leading to the idea that this taxon was perhaps a digger. To date, limb structure of Thrinaxodon has not been systematically compared to extant burrowing specialists. Besides exhibiting potential burrowing adaptations, the limbs of Thrinaxodon have been described as exhibiting a transitional phase between classic sprawled limbs of reptiles and mammalian parasagittal postures. The forelimb (humerus, radius and ulna) of Thrinaxodon liorhinus is compared with cursorial forms such as the reptile Varanus, and mammals Felis domesticus and Thylacinus cynocephalus, as well as with digging mammals, Vombatus and Lasiorhinus. This series of nested comparisons permits interpretation of the functional morphology of the fossil Thrinaxodon as being more similar to a cursorial or digger animal. New insights into the behaviour of the fossil Thrinaxodon are discussed by describing and completing morphometric analyses on forelimb skeletal elements. These results advance present understanding of Thrinaxodon limb structure, mobility, habitat and ecological preference.

Oral Presentation / 30

Ontogeny and cranial morphology of the basal carnivorous dinocephalian, Anteosaurus magnificus from the Tapinocephalus Assemblage Zone of the South African Karoo

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The rocks of the Karoo Supergroup of South Africa preserve a vast array of tetrapod fauna, and eight bio zones have been defined after these fauna. The Tapinocephalus Assemblage Zone of the Beaufort Group accounts for many tetrapod fauna, amongst the highest, the Dinocephalia. Recently a well-preserved juvenile Anteosaurus skull was recovered in the Tapinocephalus Assemblage Zone, near Merweville. Although one other specimen of a juvenile Anteosaurus has been discovered, this specimen only preserves the anterior portion of the snout. Therefore, a full cranial description and reconstruction of a juvenile Anteosaurus has not been possible up until the present study. In 1954 Boonstra synonymized most of the South African anteosaurids with Anteosaurus magnificus but could not include a description of a juvenile. In contrast to the specimen of Boonstra the recently discovered juvenile anteosaurid BP/1/7074 is a well preserved and complete skull that offers possibilities for understanding not only the potential differences between juveniles and their adult counterparts, but also the dentition and tooth replacement strategies of Anteosaurus magnificus, which are currently unknown. This specimen, which is preserved in approximately forty-five separate elements, has been scanned using Microfocus X-ray Computer Tomography (CT) and will be digitally reconstructed in order to produce a 3D model that can be utilised for comparison. Understanding dentition and tooth replacement strategies of Anteosaurus magnificus may also assist in understanding tooth replacement in related groups such as the Titanosuchids, work which was last done by Boonstra in 1962.

Oral Presentation / 31

Characterization of ~248 million years old vertebrate burrows using a non-penetrating imaging technique: photogrammetry

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Ichnology is the study of traces made by organisms in sediments. Among others, trace fossils may indicate the environmental conditions that influenced the behaviour of the organisms that created the traces. For this reason, some ichnofossils are useful in understanding the survival strategies of organisms after global biological crises such as the mass extinction event that occurred ~252 million years ago.

Accurate description of trace fossil characteristics (e.g., 3D morphology) is crucial in the identification of the potential trace makers. 3D imaging techniques of ichnofossils allow for more quantitative morphological descriptions unhindered by the limitations of conventional measurement techniques and vocabulary. Due to the lack of penetrating radiation facilities at the time of the study, the morphology of some Early Triassic (~248 Ma old) vertebrate burrows was digitized and analysed using photogrammetry, which is a non-penetrative, low-cost, unspecialised and ubiquitous imaging technique. Photogrammetry also assisted in generating 3D digital copies of the burrows that have been subsequently utilized for ichnotaxonomic analysis and comparative ichnological studies of these biogenic 3D objects.

Oral Presentation / 32

Characterization of the structure of the retromolar canal using MicroCT - a preliminary report.

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The retromolar foramen and its associated canal represent a largely under-reported anatomical variation of clinical significance in dentistry. The contents of this canal consist of nerves and blood vessels, which may be exposed during surgical access. Reported clinical consequences of this variation are usually three - local anaesthetic failure, intra-operative haemorrhage and loss of sensation over areas of distribution if the bundle is cut.

Along with poorly reported prevalence, its internal structure, source of contents and its association with hard and soft tissue structures have been poorly defined. Preliminary results of Microfocus CT scan analysis reveal various branching patterns. The most common pattern shows a single canal communicating between retromolar foramen and the inferior alveolar canal. Owing to the trajectory of the retromolar canal, it seems to contain nerve fibres branching off the inferior alveolar nerve rather than neurovascular structures entering the inferior alveolar canal. As such, the contribution of this anomaly to local anaesthetic failure seems doubtful.

Further study and clinical correlation is required to clearly determine clinical application based on results. This study serves to create awareness of the structure of a relatively unknown anatomical anomaly, to guide future investigation and to introduce a relatively under-utilised imaging modality to the field of dental research.

Posters, Exhibition and Necsa Visit / 33

Towards Automatic Detection of Infested Oranges using Computed Tomography Imaging

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The South African Radiography and Tomography Centre (SANCRAT) hosts a Microfocus X-ray tomography system (µCT) which is extensively being utilized in non-destructive examination research projects originating from higher educational institutes and research councils. In the biosciences field of application, oranges for export have to be free of infestation (larvae from moths and fruit flies); thus, µCT has been utilized in a research project by the citrus industry in South Africa in a pilot project to automatically identify infested oranges before export. It has been proven successfully, using µCT, that infested oranges can be identified using human vision; future research is focussed to detect infested oranges without human intervention where computer algorithms and codes will be applied for automatic detection of infested oranges.

Posters, Exhibition and Necsa Visit / 34

Imaging of Dense Minerals in Rocks Using Micro-CT

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High contrast visualization and thus correct identification of high density materials within rocks and drill cores without line, ring and other artifacts is a challenge – e.g. high quality visualization and quantification of gold particles embedded within the rock matrix is important in the mining industry to enhance processes for higher yield in gold extraction. Micro CT was successfully used to visualize and identify gold particles according to its morphology and attenuation coefficient. The associated minerals with gold were studied to get a better understanding of gold deposition, distribution and associations. Due to high density of gold special parameters of a Micro-CT system were optimized to minimize beam hardening to obtain better image quality and contrast. Different filter materials with varying thicknesses were used to increase transmission to aid to the successful reconstruction and higher quality results.

Oral Presentation / 35

“Investigating hominin tool-making capabilities using micro CT scanning of metacarpal bones”

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The discovery of hand bones stratigraphically associated with stone tools at Olduvai Gorge in the 1960 ignited debate about morphological correlates of hominin tool making and tool using. Retention of robust metacarpals was then argued to represent tool-making capabilities. Though stone tools dating as early as 2.6 million years have been discovered, robust hominin metacarpals only appear in fossil record after 1.8 million years. The debate then has been about which hominin was responsible for making the earliest stone tools and whether robusticity of metacarpals is a prerequisite for a stone-tool maker. The paucity of a full complement of hand bones dating prior to 600,000 years has limited inferences on stone-tool making. The recent discovery of a near complete hand of Australopithecus sediba has provided an opportunity to test the presumed link between metarcapal robusticity and tool making. The novel approach used in this paper consists of testing for metacarpal robusticity by comparing cross-sectional geometric properties of metacarpals across hominoid species (both human and non-human). Insights gleaned from the results can be used to make inferences into hominin tool making repertoires.

Posters, Exhibition and Necsa Visit / 36

Investigation into the application of Computed 3D Tomography in particle shape analysis of iron ore samples

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The possibility of using 3D neutron tomography to determine the geometrical properties of iron ore particles is explored in this study. Neutron tomography is a non-destructive technique enabling observation of the surface and interior of solid material and is an ideal tool for 3D geometrical analysis of irregularly shaped particles. Shape and size analysis is done using “Octopus”, “VGStudio MAX”, “Image-Pro Plus” and “Image J” software packages for the visualization and analysis of volume element (voxel) data.

The quality of 3D tomography data depends on the quality of the acquired tomogram and reconstruction of 3D images. Rock samples vary in composition, resulting in neutron images with a wide range of grey levels, which proves challenging during thresholding of images. The partial voxel problem, i.e., grey levels at the edge of particles, vary and could influence the values obtained for areas and perimeters depending on whether grey levels were added or subtracted from the particle.
Separation of connected particles or particles in close proximity proved to be difficult, as automatic separation techniques cannot handle irregular-shaped particles. Manual separation of particles was done in this investigation, which proved to be time-consuming.

Results show that 3D neutron tomography along with advanced image processing packages could be used in quantitative 3D particle shape determination. This could aid the understanding of particle separation techniques.

Oral Presentation / 37

Analysis of voxel data sets with VGStudio MAX

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VGStudio MAX is well-known for the quality of images, especially for 3D renderings. While this talk will show images of variousobjects which have been segmented, quantified, compared, or otherwise analyzed with VGStudio MAX, the focus will be on the analyses and the reliability of the results: How does the software support accuracy and reproducibility of results, and what influence does the user have?

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(5 posters on Neutron Imaging) as Complementary tool to (4 posters on X-ray imaging)

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A couple of posters from Necsa:

NEUTRONS:
2 x posters: Geoscience
1 x poster: Reverse Engineering
1 x poster: Civil Engineering
1 x poster: complementary - neutron and X-rays
1 x New upgrade Neutron Imaging facility

X-RAYS:
1 x poster: Anatomy
2 x posters: Archaeology
1 x Poster: Palaeontology

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Opening

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NIKON

Dr. RUDOLF, Carsten [1]

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CONCLUSION

Papers to SAJS
"Imaging with Radiation" interest group
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WITS

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Microfocus X-ray Computed Tomography (CT) Facility at WITS

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The Microfocus X-ray Computed Tomography (CT) Facility in the Palaeosciences Centre at the University of the Witwatersrand has been in operation since May, 2012. Details on the facility can be found on its website (www.wits.ac.za/microCT). It is unique amongst microfocus CT facilities in South Africa because of its combination of 320 kV, 225kV rotating, and 225 kV static targets. Each of these has certain strengths in optimizing images acquired from a range of fossilized materials, while collectively they leave the facility well-suited for serving a wide range of palaeoscience needs. The facility is linked to the Virtual Imaging in Palaeosciences (VIP) lab at Wits, which houses high end visualization equipment such as servers and software programs that are necessary for working with and analyzing image data. Scanning requests go through a scientific peer-review process in order to ensure scientific integrity and proper application of the technology. Within the partial year 2012, 29 proposals were approved for scanning. From these projects, there have been so far at least six publications in peer-reviewed international journals, such as Science, Journal of Vertebrate Paleontology, Journal of Human Evolution, and Journal of Archaeological Science. Scanning requests have accelerated thus far in 2013.