	Experiment title: High resolution tomography of the skull of "Toumaï" (*Sahelanthropus tchadensis*) and associated fossils, for a better knowledge of our direct origins.	**Experiment number**: Sc-1213
Beamline: ID17	**Date of experiment**: from: 30/04/2003 to: 06/05/2003 from: 04/08/2003 to: 07/08/2003	**Date of report**: 01/10/2005
Shifts: 18 + 9	**Local contact(s)**: Nemoz Christian	*Received at ESRF:*

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Report:

The original aim of this proposal was to image with the best resolution and image quality the internal structures of the skull of *Sahelanthropus tchadensis* (nicknamed Toumaï), and of some associated fragments of mandibles. We asked for beamtime on the ID17 beamline at the ESRF, since it is the only location that associates a high beam quality for tomography on fossils (brightness, monochromaticity and coherence), a high energy (to be able to image large fossils), and a large field of view with a good resolution (up to 18 cm of field of view for a pixel size of 45.5 microns in half-acquisition mode). All these properties designed logically ID17 as the best tool for a high quality microtomographic imaging of the *Sahelanthropus* fossils, particularly of the Toumaï cranium.

Despite an intensive preparation of the experiment with the ID17 staff, the principal aim of a complete imaging of the Toumaï cranium had to be abandoned very rapidly due to a lot of technical problems. Indeed, this experiment was the first one performed on ID17 that involved real 3D imaging on large objects with the microtomographic set-up. It revealed many technical limitations that were not highlighted during all the previous biological experiments performed on ID17 with this set-up. The major technical problems were :

- **The strong distortions of the pictures due to the fibre optic taper**. This aspect prevented us to use the complete width of the FreLoN camera, that drastically decreased the picture quality; moreover, as these distortions led to bad alignments of the different motors and to non precise pictures, it was impossible to perform half acquisition.

- **The insufficient memory for data acquisition**. This aspect limited the number of slices to four for each rotation. After a rapid evaluation of the time per stage, we concluded that the allocated beamtime was too short for a complete imaging of the cranium, even if there was no other limitation.
- **The exposure of the detector during the readout of the data**. It led to rapid saturation of the detector, that limited to only one quarter of the total dynamic of the detector.
- **The strong darkening of the optic fibre taper during the scans due to the long exposure to high energy X-rays (85 keV)**. It led to a progressive degradation of the data quality with time.

Another limitation that would have prevented to image the complete cranium is the mineralisation pattern of this fossil. Indeed, it appeared more mineralised than our initial estimations. Then the transmission of X-rays through its largest part did not reach more than one percent even at an energy of 85 keV. As presented above, the maximum available dynamic was limited, then through the cranium we obtained a dynamic just a little higher than the level of the dark noise of the detector. In such conditions, it becomes impossible to perform microtomography.

Regarding all these technical problems and limitations, we decided to image only the maxillary part of the cranium without the half-acquisition set-up. As the size of the imaged part did not exceed 9 cm, the X-ray transmission was sufficient to perform microtomography. Nevertheless, due to all the limitations presented above, the quality of these data was clearly less good than what we expected. Despite all these negative points, this scan remains today the only high resolution imaging of the maxillary of the Toumaï cranium. After a lot of data processing it would be possible to extract the roots of the teeth, but all the small structures in bones and teeth remain invisible due to a very strong noise. At the present day, no data about the cranium maxillary has been published, principally because the quality of the pictures implies a lot of processing to be able to obtain good results. It would be far more rapid and efficient to perform a new scan after the solving of the different problems.

The second experiment performed on the associated mandibles was far better than the first one. Indeed, as these fossils were smaller than the skull (the average size was around 5-6 cm), the transmission of X-rays was higher and then the signal/noise ratio better. The distorsions of the taper were still present, but as we were aware of them, we used the best part of the taper to perform the scans in order to reduce the problems on the reconstructed slices.

The data obtained on these fossils are currently the best ones ever made of them since they were performed using a monochromatic, partially coherent and nearly parallel beam.

These data about the mandibles fragments were used to illustrate the internal disposition of the teeth roots in two publications:

- Brunet, M., Guy, F., Boisserie, J.-R., Ibaye, A.D., Lehmann, T., Lihoreau, F., Louchart, A., Schuster, M., Tafforeau, P., Likius, A., Mackaye, H.T., Blondel, C., Bocherens, H., De Bonis, L., Coppens, Y., Denis, C., Duringer, P., Eisenmann, V., Flisch, A., Geraads, D., Lopez-Martinez, N., Otero, O., Campomanes, P.P., Pilbeam, D., Ponce de Leon, M., Vignaud, P., Viriot, L. and Zollikofer, C., 2004. "Toumaï", Miocène supérieur du Tchad, le nouveau doyen du rameau humain. **Comptes rendus Palevol,** 3: 275-283.

- Brunet, M., Guy, F., Pilbeam, D., Lieberman, D.E., Likius, A., Mackaye, H.T., Ponce de Leon, M., Zollikofer, C.P.E. and Vignaud, P., 2005. New material of the earliest hominid from the Upper Miocene of Chad. **Nature**, 434(7034): 755-759.

Following these experiments and others mainly devoted to paleontology, the different kinds of technical problems have been solved:

- A real time two-dimensional correction of the taper distortion was implemented. Thanks to it, a specific alignment protocol was developed that allows high quality half-acquisition scans and no displacement of the centre of rotation with the vertical position.
- It is now possible to acquire 64 slices per rotation, and probably soon, up to 128 slices.
- A chopper synchronized with the FreLoN camera avoids the exposure of the detector during the readout of the data.

- Thanks to the 2D distortion correction, the complete surface of the detector can be used which leads to a less strong influence of the darkening of the taper.

Finally, a specific attenuation protocol has been recently tested that allows to scan large fossils at an energy of 85 keV without saturation of the detector. It leads to very good dynamics even for a theoretical transmission lower than one percent, and then a quality of the reconstructed slices far better than with a classical scan protocol.

From these two experiments and the recent developments of the ID17 beamline, a new scan of the Toumaï cranium could now be achieved successfully with a very high picture quality.