<table>
<tr><td>ESRF</td><td>Experiment title:
X-ray study of twisted natural quartz (gwindels)</td><td>Experiment number:
MA-507</td></tr>
<tr><td>Beamline:</td><td>BM05
Date of experiment:
from: 28 april 2008 to: 29 april 2008
and 04 july 2008 to 07 july 2008</td><td>Date of report:
10 july 2009</td></tr>
<tr><td>Shifts: 12</td><td>Local contact(s): Jurgen Haertwig</td><td>Received at ESRF:</td></tr>
<tr><td colspan="3">Names and affiliations of applicants (* indicates experimentalists):
Gérard Dolino*, Pierre Bastie*, Laboratoire de Spectrometrie, Université Grenoble I
Beda Hofmann, Bern Museum (Switzerland)</td></tr>
</table>

Report: Aims of the experiment and scientific background

Although the properties of quartz have been studied for a long time, many questions remain in particular about the growth rate and shapes of natural quartz crystals [1]. The aim of our research is to study the puzzling structure of twisted Alpine quartz crystals, also known as gwindels in Switzerland. Gwindel is a moderately rare but spectacular crystal structure which is found mostly in two mountain ranges of the earth, the central granitic Alps and polar Ural. Gwindels are formed by an aggregation along a common X axis of bipyramidal prismatic quartz crystals elongated, as usual, along their Z axis ; however the successive crystals rotate by a few degrees around their common X axis. For a typical gwindel of 10 cm length along the X axis, the total rotation is between 20 and 50°.

Although they have been investigated by several European mineralogist during the 19 and 20th centuries, their structure and condition of growth has never been understood. In 1937, the Russian mineralogist Laemmlein [2], working on twisted crystals from the Alps and Urals, understood that gwindel formation occurs in two successive stages : there is first the puzzling formation of an helicoïdal plate with a continuous twist along the X axis ; then in a second stage, mosaic prismatic crystals grow around the already twisted initial crystal. The existence of these two structures was confirmed in 1987 by the work of Kuzmina et al. [3]: they observed by x-ray diffraction on a plate cut in a gwindel, that the central part had a continuous twist while the external part had a mosaic structure.

Experimental methods and results

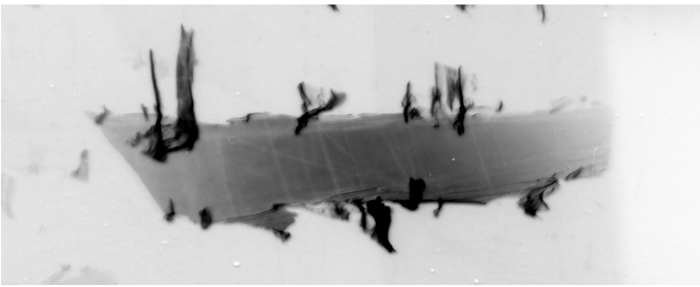
We have started a few years ago, structural studies of these crystal using the hard x-ray set-up of ILL, which indeed gave interesting results [4]; we have also performed on October 11, 2006 some exploratory x-ray topography on gwindels. (ESRF report, MA-206). We performed classical x-ray topography on several samples (gwindels and macromosaic quartz) with the Laue method, using x-ray with an energy of a few tens of keV, in order to be transmitted through natural crystals with a thickness of a few cm.

We used mostly classical Laue topography, with photographic recording, well adapted to get simultaneously several high resolution pictures of large objects. The study is completed by using fine beams to obtain structural details, in particular at the boundary between the twisted region and the mosaic grains. An x-ray camera is also used to reduce acquisition time during spatial scans.

We have investigated 3 gwindel samples :

- a « closed » gwindel from a private collector : this is a rare occurrence of the first stage of growth, reduced to a nearly perfect helicoidal plate.
- two "open" gwindels from the Bern museum:
    - a plate cut in the YZ plane, giving a 2D section of a gwindle.
    - a whole gwindel of 8 cm length with its complex 3D structure.

The various diffraction spots from the closed gwindel show mostly an internal continuously twisted structure. However a few thin mosaic grains were already observed on the external surfaces of this sample, revealing the initial occurrence the mosaic structure. (Fig)



The most revealing results were obtained in the YZ plate cut in a gwindel : with a x-ray beam incident close to the X axis, in the sample center, diffracted spots shows again the broaden bands corresponding to the homogeneous continuous twist of the crystal, already observed in the closed gwindels. On the other hand, in the two lateral sides of the sample, we observed deformed mosaic grains with discrete disorientation of about one degree. The crossover between the two structures (continuous twist and discrete mosaic grains) occurs abruptly at a well defined boundary.

Finally in the whole open gwindel similar crossover between continuous twist and mosaic grains are observed, but giving more complex pictures due to a full 3D geometry.

Although this is classical x-ray topography, a high energy source is needed to observe (without cutting) massive crystals of a few cm thickness. The use of fine beams is also often useful to analyse structural details.

CONCLUSION Clearly the existence of large crystal twist in quartz gwindels is a surprising features, which in the past was noted in several mineralogy and crystallography books. The present study confirms clearly the 2 stages growth model of Laemmlein [2] : There is first the initial growth of a small continuously twisted crystal, followed by the secondary growth of mosaic grains around this twisted seed. However the origin of the initial twisted structure is not understood.

References

[1] Frondel C, Silica Minerals, John Wiley and Sons, NY (1962).
[2] Laemmlein G, Bull. Ac. Sci. USSR. p. 937 (1937).
[3] Kuzmina MA, Punin, Yu O, Kamenev IE, Proc. Russ. Mineral. Soc. 116, 445 (1987)
[4] Bastie P, Dolino G, Hamelin B, Meisser N, J. de Phys; IV, 118, 259 (2004).