

***Appendix VII: JPEG2000 Artifacts at 10:1 Compression***

JPEG2000 set to compress at a rate of 10:1 is not lossless. Data is thrown away and replaced with substitute pixels according to the compression algorithm implemented. In the data that is left it is possible to see what are called compression artifacts. Compression artifacts may include:

- Blurring
- Ringing
- Colour distortion
- Blocking

Based on descriptions and examples by Jakulin (24) and Punchihewa et al. (45), Appendix VII attempts to demonstrate the artifacts shown in JPEG2000 images compressed using a 10:1 compression ratio.

The image corruption demonstrated requires further investigation to determine precisely the type of compression artifact exhibited. The examples shown could be interpreted as demonstrating the same type of artifact. With further study it may be possible to confirm this, however for the purpose of this study it shall be noted that the compression artifacts here are believed to be ringing and global blurring. The destruction of the image in both cases is quite visible.

Although the concept is straightforward, Jakulin describes that blurring is where an image looks smoother than it did originally. Global blurring is evident in JPEG2000 images compressed at 10:1, although it could be argued that this is only a subtle distinction.

Ringing artifacts, according to Jakulin, are caused by JPEG2000 operating in the spectral domain where it tries to represent an image as a sum of smooth oscillating waves. This is appropriate for smooth colour gradients but not for capturing edges; instead of capturing the edge the compression method attempts to fit a wave function to it.

The following images show the effect of lossy compression:

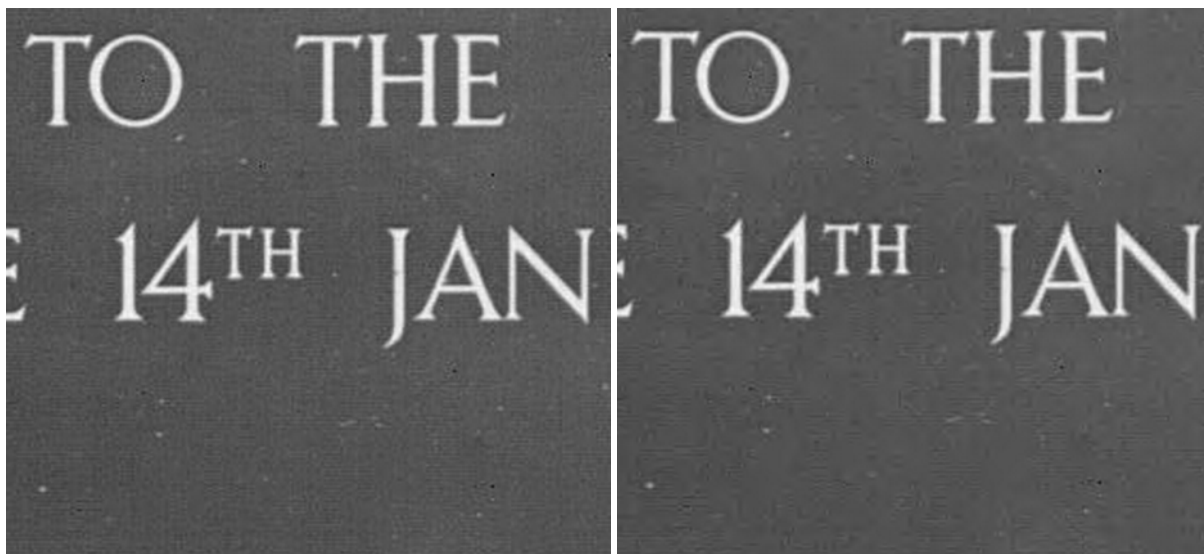


Image 1 and Image 2 show a section of the original TIFF and JP2 respectively, zoomed in by 166%. The ringing artifacts show up in the background of the JP2, however as the term 'visually lossless compression' might suggest, it is difficult to see, although not impossible.

To demonstrate the loss of fidelity in the background, both images have had a histogram equalization run on them to increase the global contrast of the images to help draw out additional detail.

The blurring in Image 4 correlates with the artifacts shown in the first JP2. The image has clearly been destroyed in comparison to the smoother variations in the original TIFF (Image 3), with the same equalization algorithm run on it.

Further:

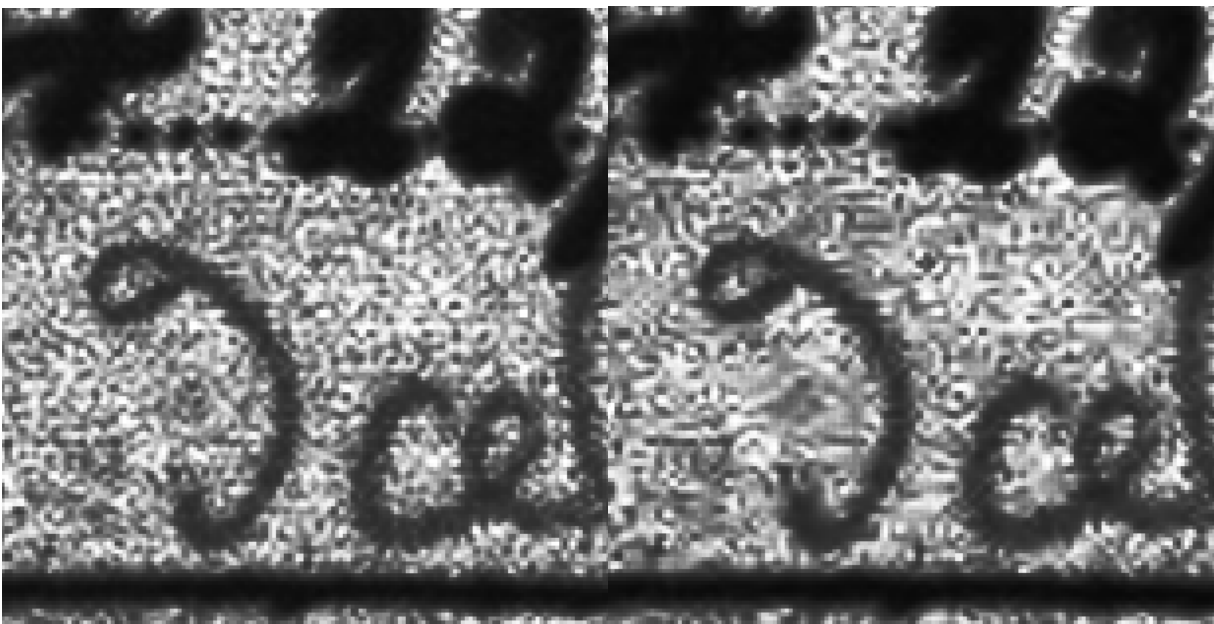
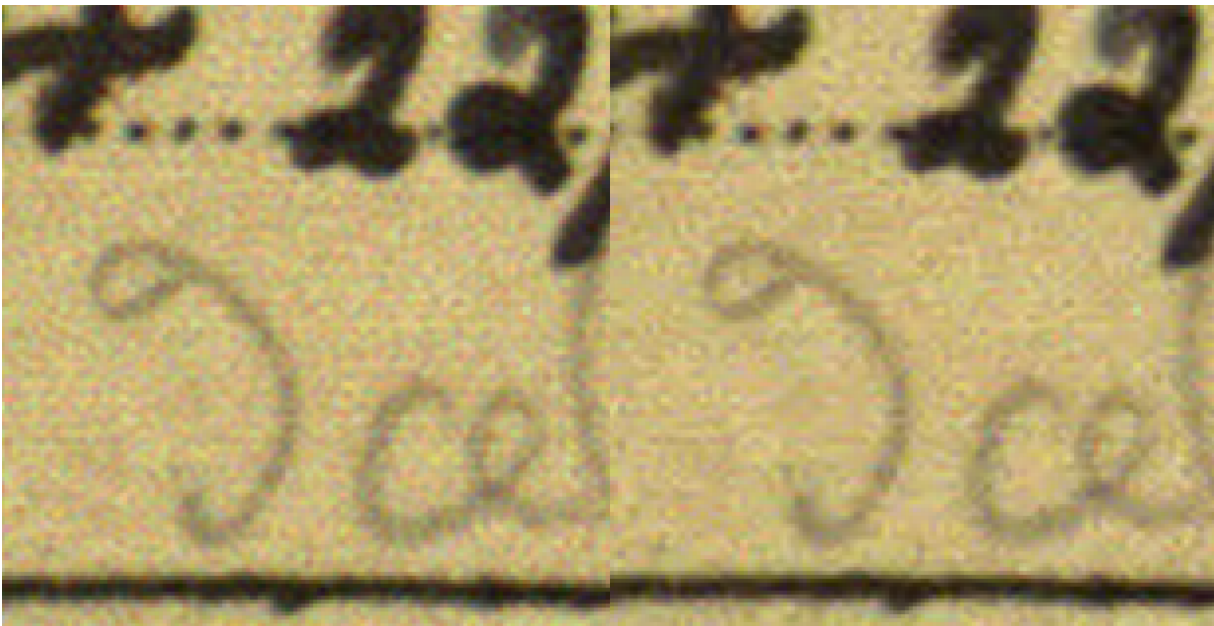
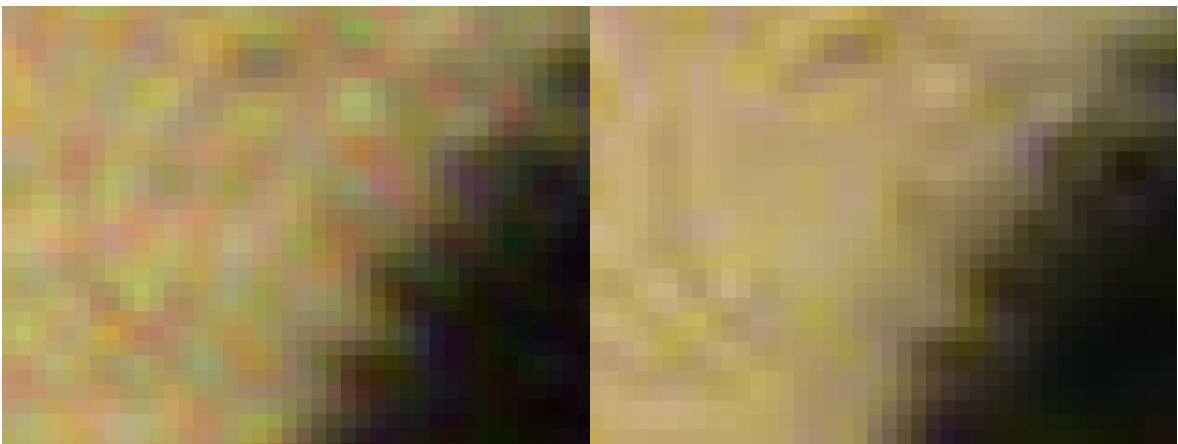
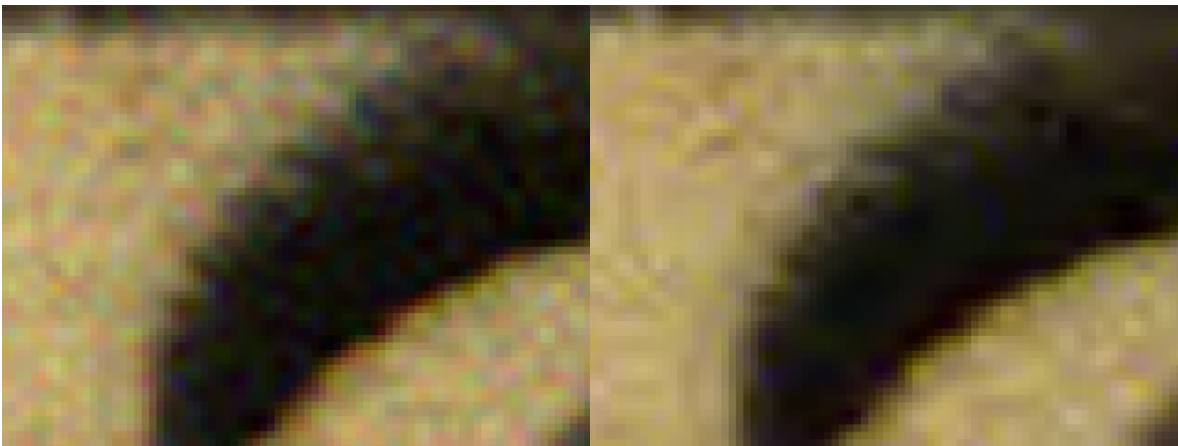


Image 5 and Image 6 shows the comparison between the TIFF and JPEG2000 files. These two images represent the original color version. Ringing Artifacts are visible. The subtlety of the artifact is also evident. Image 7 and Image 8 represent the images in greyscale, to show only the intensity of pixel values, and to reduce the number of perceivable gradations in between pixels; this has the effect of highlighting the corruption of the image. Artifacts here are demonstrated again by blurring, this time around the curves of the letters in the signature.

**NOTE:** The above image is zoomed to 152%.

Finally, in a slightly less obvious example:



This example aims to demonstrate global blurring and ringing artifacts together. It certainly demonstrates the insidious nature of the term “visually lossless”, when talking about the type of compression JPEG2000 provides. In Image 10, ringing is shown between the lower curve of the “3” and the lower loop of the “8”. Furthermore the reduction in noise around the top left of the figure “8” shows blurring.

Images 11 and 12 are zoomed into the left hand side of the number three. Images 13 and 14 are further zoomed into this section. In each of these images blurring is present. Comparing Image 12 to 11 shows blurring towards the middle of the image on the left and continues down to the far left of the edge of the number 3. In 14 this is amplified by the level of zoom but clearly shows patches of color compared to Image 13 where the natural color variations of the paper are shown.

In addition, a reduction in noise across Image 10 suggests global blurring. Perhaps further evidence of global blurring is the reduction in colors between the two portions of image, Image 9 contains 55,182 colors; Image 10, 44,069 colors.

Although our ability to perceive these particular artifacts at low zoom levels is minimal, it must be understood that the term “visually lossless” only applies to current display technology, without the use of image analysis techniques. The destruction of these images must raise questions over authenticity at high zoom levels (46), and with no way guaranteeing where data is lost in an image, there is also no way we know what information will be useful to users in the future. We must also question whether we are capable of preventing the future destruction of these images by maintaining a record that these images have been compressed using current lossy compression techniques.